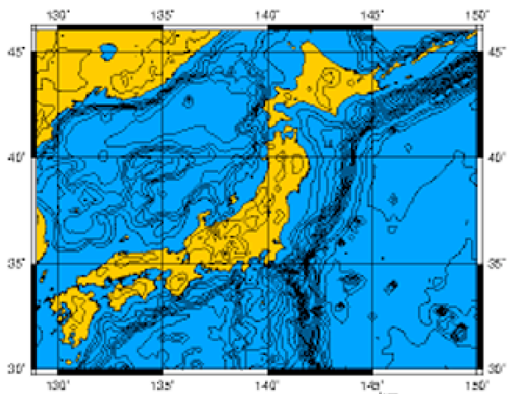
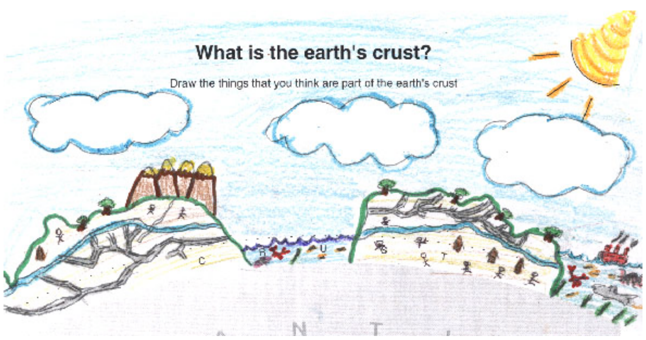
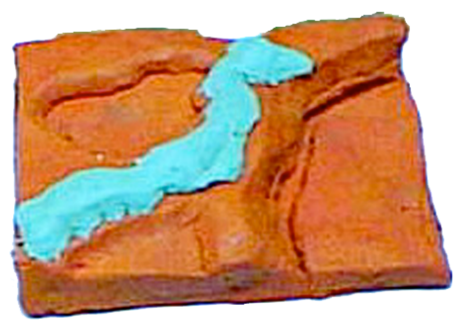
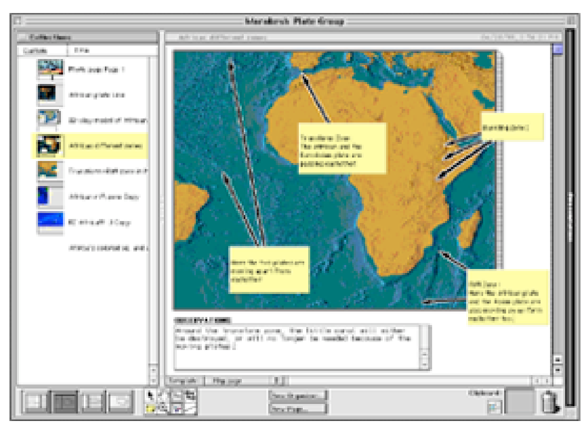
Earth Structures and Processes

Exploring Earth's Crust with Models and Data









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Developed by the Geographic Data in Education (GEODE) Initiative and the Center for Learning Technologies in Urban Schools (LeTUS) at Northwestern University

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Table of Contents

Unit Overview

The crust of the Earth is constantly changing. The side of a mountain slides into a valley, a volcano blasts its top off, and a mountain range grows out of the plains. These changes happen so slowly that they often go undetected. Yet, there is opportunity every day to observe and measure these changes somewhere. Each earthquake is evidence that the Earth's crust is changing and moving. And each time a volcano erupts, you get a glimpse of the power under the crust.

In this unit, students will look at earthquake and volcano data to explain the process that is changing the Earth's crust. To analyze this real data, students first spend some time getting acquainted with some places where there is evidence that the crust is changing: volcanoes, rifts, mountains, and trenches. Students begin by looking at the topography (shape) of these places by building 3-D models.

In the second part of this unit, students analyze earthquake and volcano data. Both sets of data are represented as points on a data map. To help students analyze and experience the data, students explore how the data is collected, reported, and experienced. Students first look at earthquake patterns to find the plate boundaries of the Earth. They then look at how the volcano data patterns relate to the plate boundaries.

Once students have looked for patterns in each of these data sets, students characterize these patterns to explain the processes changing the crust. Patterns in the earthquake and volcano data indicate ways the plates of the crust are moving. These movements lead to different kinds of changes to the crust: earthquakes happen in different places, volcanoes are shaped in different ways, and the topography of the land is different. These characterizations then lead students to draw models of the processes changing the crust.

Content and Process Goals

Earth Structures and Processes was created to help students

- Experience the community of science by using similar tools and engaging in similar experiences. In this case, they develop explanations from evidence in data.
- Use the tools of the science community, a Geographic Information System (GIS).
- Understand that the Earth's crust is changing all the time through a slow process.
- Understand that earthquake activity, volcano activity, and topography are all evidence of those changes.
- Explain the process that is changing the Earth's crust.
- Explain that the hot core of the Earth is driving the process by creating convection currents in the mantle.
- Decide if there is "enough" data to generalize patterns in data plotted on a data map.
- Search for patterns in data plotted on a data map.
- Characterize those patterns to develop an explanation of the process changing the Earth's crust.
- Use anecdotal data to support patterns found in data plotted on a map.
- Understand the experiences behind the data through descriptions of earthquake and volcanic events.
- Create models to explain how the Earth is structured: cool crust, hot mantle, and very hot core.
- Create models to explain the processes changing the crust.
- Support explanations and models with evidence.

Unit Summary

The main goal of this unit is to ask students to create explanations from their analysis and characterization of earthquake and volcano data. This is done in a simulated context of a group organizing to find patterns in earthquake and volcano activity in response to the effects these events having populations.

Lesson 1: This Just In
Students read myths, newspaper articles, and letters from "pen pals" to be introduced to a variety of places on the earth. In the unit, these places are called earth structures, structures built by the changing crust. Students begin to compare these places and more importantly drop anecdotal information (e.g. the Himalayas range is growing three centimeters per year) into the collective conversation of the class. This information will help students develop explanations from the data. Examples can often help include or eliminate ideas. There are also multiple opportunities for students to share their preconceptions.

Lesson 2: Topography of Earth Structures
Topography is the first piece of evidence students explore to begin to explain the process changing the crust. Students compare the topography of the earth structures and predict why they may be the same or may be different. Students are introduced to a Geographic Information System (GIS) while they are comparing the topography of the earth structures. Students also compare topographic maps of these places to the GIS representation. Students then build 3-D models of each earth structure to help with these comparisons.

Lesson 3: Journey to the Center of the Earth
Students read about and explore different models of the Earth to compare the layers of the Earth. Students focus on drawing models of the crust and the plates of the crust. Students describe the strengths and weaknesses of the models presented and create their own models of the Earth to represent the differences in the layers of the Earth.

Lesson 4: Earthquake! Observations from Data
Students are looking for patterns in the earthquake data to find the plate boundaries of the crust. Students are first introduced to earthquake data through real-time observations on the internet and plotting this data the "old-fashioned" way, with latitude and longitude. To put some meaning behind a map full of dots, students are introduced to descriptions of some of these earthquake events. Students also explore how scientists observe and measure these earthquakes.

Lesson 5: Assembling Earth's Puzzle
Students use lots of data to refine their initial predication maps of the plate boundaries of the crust. Students are introduced to the idea of "enough" data here to help them find reliable patterns in lots of data plotted on a map. They start by using one year of data on large paper maps and then use *MyWorld*, a GIS. The class then participates in small group meetings to debate the plate boundaries. Finally, the class comes to a consensus about those plate boundaries.

Lesson 6: Escaping Heat
The hot inner core of the earth drives slow-moving convection currents in the mantle. These currents move the plates of the crust. Students explore models of this process, examining what happens if there is a crack in the crust (resulting in volcanoes). Students are introduced to volcanic events in order to compare volcanoes. Students then begin to characterize the patterns they see in this volcano data. These characterizations help the students explain the process changing the crust of the Earth.

Lesson 7: Plates on the Move
Students begin this lesson by characterizing the patterns in the earthquake and volcano data to help them explain the process changing the crust. These characterizations are indications of different kinds of movement of the plates. From these characterizations students predict how the plates are moving. Students also have opportunities to look more closely at earthquake depth and volcano types to refine their explanations. Students will create models to explain the changes happening in the crust at their earth structures.

What technology will you need?

MyWorld Software

Install the ***MyWorld*** software and make sure that all the necessary map views are available: "**EarthStructuresIntro.mpz**" and "**ESInquiry.mpz**." The software and the map views will be used by the students and for whole class discussions using a computer projection system. Students will need to screen capture and save these files into a word processor.

Organizing for Computer Usage

Whole class discussions

You will need to have a computer hooked up to a multi-media projector for some of the activities. If one is not available, the computer screen could be projected using a TV. Another alternative is to have small groups gather around a computer. The computer used for these whole class discussions will need to have an internet hook-up and the *MyWorld* software already installed.

Student Usage

Students will need to use computers at several points during the unit. Students are working in teams of two or three during this unit, depending on the number of students in your class. Students will be using a word processor (i.e. Word or Apple Works) to screen capture and save data maps. The most efficient set-up would be one computer per team. Students can also take turns using fewer computers.

At the end of the unit, students will need to share the data maps that they have captured. This can be done by printing the data map captured or by having students use the computers to share the data. Color printing is suggested for the maps later in the unit so you can see the patterns.

For assistance with the software and screen capture directions, you should provide copies of the ***MyWorld* Tool Box** and the appropriate **screen capture directions** at each computer station. These can be found in the Appendix of the teacher's edition.

Saving Student Computer Work

You will need to decide the most efficient and effective way for your students to save their data maps. Students will look at data maps in *MyWorld* and screen capture them. Students will then save these screen captures in a word processor document. There is a template on your *MyWorld* installation disk.

Setting up a network: There are many advantages to this set-up. Students do not have to use the same computer each day, you have easy access to their work, and student files have a place to go and are easy to manage.

- Network the computer if possible.

- Create a shared drive (with guest access –no passwords required) on the teacher's computer to serve as a drop box for student work. Students can copy their files to this folder. Students then have access to their work from any computer station. Teachers can also have easy access to the files for comments and monitoring.
- Create aliases on this shared drive on each computer Desktop so that students can just double-click to open the connection/shared folder.

Alternatives

- Save work to a Zip disk, the computer's desktop, to a directory you specify on the hard drive or to a directory you specify on the network.
- Students could also screen capture and print their work after each computer session. This can mean a lot of paper. In addition, maps will need to be printed in color later in the unit. However, you can change the size or shape of the volcano data at that point in the unit if color printing is not an option.

What materials will you need?

For students (students are often working in teams of two or three):
MyWorld Tool Box and screen capture directions at each computer station
science journal or corresponding worksheets
Breaking News worksheets for each student
Pen Pal Reflections worksheets for each team
Cutout Topographic Map worksheets for each student
The Cool Crust worksheets for each student plus extras if students need another
Small World Map worksheets, 6 per student
Small World Map Pacific worksheet, a few for those teams that need it
Three Page Map worksheets, 1 set per team
Big Data Maps, 1 set for each group of 4-6 students plus one more
drawing paper for each student
large sheets of construction paper for each student
colored pencils, crayons, or markers for each student
index cards, large and small
modeling material (craft foam, cardboard, foam core, felt) for each team
hardboiled egg for each group of 4 students
plastic knife for each group of 4 students
craft foam (or other building material) for 3-D models of earth structures
glue stick
scissors
overhead pens in two or three different colors for each team
sentence strips
chart paper and markers
large box of crayons (64 count) for each group of 4
large sticker dots in a variety of colors
small sticker dots in a variety of colors
several rolls of clear tape
box of transparency sheets for the overhead and/or large sheets of transparent overlay
overhead pens in two or three different colors
maps and globes (see material preparation)
display board (optional)

For the teacher:
unit transparencies, blank transparencies, and transparency markers
overhead projector and/or chalkboard
computer projecting system (see *What technology do you need?)*
television and VCR
Restless Earth Video produced by Kurtis Productions
Rivers of Fire Video produced by Kurtis Productions
permanent marker
several opaque boxes with a variety of objects inside (see Lesson 3 set-up)

Preparation of Materials and Resources:

Big World Map
For this unit a Big World Map is provided. This map should be displayed throughout the unit. It will be used for several activities, so you may want to have it laminated so you can reuse it. Students will also tape models to this map.

Maps and Globes
Students will be using several maps and globes to talk about the Earth. Borrow maps and globes from other teachers in the building. For Lesson 4, students will need world maps to plot earthquakes using latitude and longitude. Borrow several political maps for this activity. They should be large enough for groups of students to gather around. A physical map of the world that also shows the topography of the ocean floor is helpful and should be displayed throughout the unit. Remove any plate tectonics or plate maps of Earth from the classroom. These will interfere with student predictions. There is not a right answer to this task, just a well supported one.

Big Data Map
These data maps are provided but will need some assembly. Students use and assemble these data maps in Lesson 5. Each data map consists of 28 pages. You will need to copy the map for your classes. Two or three teams of students can work around one map. So for a class of 30, six or seven copies of the map should be made. Why the extra? This is a world map centered on the Atlantic Ocean. Some of the student teams will need to look at the world centered on the Pacific Ocean. So for those extra copies, add on the extra columns needed to see the entire Pacific Ocean. There will probably be at least two maps centered on the Pacific Ocean. Students can also move the columns to see the entire Pacific Ocean. Just be sure that the other groups don't need those pieces. If you have multiple classes, the set of maps can be shared across classes.

***MyWorld Tool Box* and screen capture directions**
This tool box is a guide to the basic functions of the software that the students will use in this unit; the directions can be found in the Appendix. You will need to decide which screen capture directions your students are going to use. These directions should be copied (or printed in color from the project web site (http://www.geode.northwestern.edu/pbi)) and put in plastic sleeves and placed at each computer station. Thin binders are excellent to place by the computer with this kind of information. The sleeves encourage students to leave them at the stations rather than scooping them up in their paper work.

Latitude and Longitude
In Lesson 4 students will use latitude and longitude to plot real-time earthquake data on maps. You will need to determine if your students need help with this concept prior to doing the plotting activity. Activity 4.3 is a quick review of latitude and longitude, but you may want to ask the social studies teacher to review these concepts before you get to that part of the unit so the class can stay focused on the task.

Organizing Student Work

Data Maps on the Computer Files
As discussed above, if you choose, students will have computer files – data maps with notes – for you to respond to and assess how students are finding patterns in a large data set. If you choose not to have students screen capture and annotate their data maps, be sure you are talking to students while they are working at the computers. These conversations will provide guidance about students' progress in analyzing and explaining the data they are seeing. Without that conversation, the activity can become a connect-the-dots task.

Science Journals
In the student text, students are asked many times to write responses to questions or tasks. Students can write their responses in science journals or use the worksheets provided. There are several places where specific worksheets are used rather than the science journal (worksheets with maps, labeling diagrams, organizing a discussion, etc.) These are indicated in the materials list at the front of each lesson. Students using science journals can staple or tape these worksheets into their science journals.

Team Folder
Students will be working in teams during this unit, so each team should have a folder to collect their collective work. These folders should be kept in class in case of a teammate's absence. Prediction maps should be collected here, along with explanations. The folders are also a good way to collect student reflections about what they did that day and for you to give the groups direction about what they should be doing.

Reports with supporting evidence
There are several places where students are asked to integrate their written work with their computer work, especially at the end of the unit. Students can print data maps from screen captures, or use the computer to integrate these. The computer-only method can be time-consuming if your class does not have enough computers available. We suggest printing the data maps for these types of activities. Color printing is preferred if available.

3-D Models of earth structures
These will be used several times during the unit. Once the models are completed, they should be hung on the Big World Map. If you have multiple classes, you only need to display one map and one set of models. However, for the activities where teams organize into larger groups, students should use their own models. Store each class set of 3-D models in a large plastic bag to be pulled out during these activities.

Plate Maps
One of the activities asks students to make prediction maps on transparent overlays of large data maps. Students will use these maps and overlays starting in Lesson 5. These maps and overlays can be folded between classes or all the overlays from one class can be stacked and rolled if you

have multiple classes. These overlays can also be attached to a data map and the whole map hung on hooks in the room.

Picture Dictionaries
Starting in Lesson 3 students create a picture dictionary of terms that they are learning. Students will refine these definitions throughout the unit. There is a variety of ways to have students do this:

- index cards
- on notebook paper stapled together
- in the back of their science journal
- on the Picture Dictionary Page provided

Organizing Students

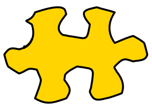
For much of this unit, students will be working on a team of two or three students. In the scenario, each team of students is assigned a different earth structure to study and explain. There are 15 different earth structures that need to be assigned. If you have a small class, students will work alone, but if you have 30 students, they will work in pairs. If you have over 30 students, the groups will need to be a little bigger.

Since students will be working on the same team through the entire unit, these pairings require some thought. There is a table at the beginning of Lesson 1 to help you assign the earth structures. The table gives you some hints about the difficulty of the data interpretation and characterization. The challenge of the task should be considered as well as the goals for each student. Students should be put in pairings that will help them, challenge their ideas, and balance the workload. High-achieving students with low-achieving students may not always be the best choice; think about which students are going to challenge the ideas of other students.

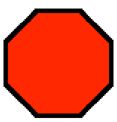
Icons for Earth Structures

Throughout the student and teacher text there are several icons:

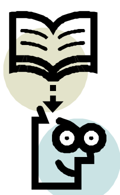
The Science Journal icon marks a place in the student and teacher text where there are reflection questions. Reflection questions ask students to reflect on what they've just read and synthesize information.



The puzzle piece icon marks "Figure It Out" questions, which follow readings or large data analysis. These questions ask students to comprehend and analyze information, data, or concepts.



The Stop sign icon marks "Stop and Think" questions in the Student Text. This may come in the middle of instructions or of a reading. Sometimes the directions call for students to write down their answers in their journal or on their worksheet, but often students should just stop to consider the question. These questions are often questions that ask the student to make a prediction or to compare ideas.



"What's the Point?" questions come at the end of each lesson. These are overview discussions and questions that address the lesson as a whole; they ask students to think about the purpose of the activities within a lesson. What's the Point? guidelines also appear within the teacher text.

Lesson 1

This Just In

To tackle a problem, you first need to figure out how to think about that problem. Students will identify what they know and experience models of the kinds of thinking that they will encounter throughout the rest of the unit: making observations and explaining those observations with what they understand (developing theory).

Why is it important for students to develop skills of observation and explanations?

In this first lesson, students spend some time collecting observation and information about a variety of places. This anecdotal data will help students develop explanations of the processes that change the Earth's crust. This unit is about observing and analyzing data and developing explanations from that analysis and from what we know. This is what scientists do, and this is how understanding is developed. If some core idea in science were to change, how we perceive data and explain the events around us would change too.

Lesson Overview:

In this first lesson, students are responding to myths, news articles, and pen pal letters while developing the kinds of thinking that they will use in this unit: observing patterns in data and then formulating explanations based on these data. This lesson gives you the opportunity to activate prior knowledge and identify students' conceptual understanding of the processes of the Earth.

Activity 1.1: Myths and Science

In this first activity, students will read stories told by ancient peoples to explain natural phenomena like volcanoes, earthquakes, or how mountains come to be. These stories or myths give examples of explanations supported by observations.

Activity 1.2: Breaking News

Students respond to descriptions of seismic events as described in newspaper articles. Later these events will simply be represented as dots on a map. The newspaper articles are used to help engage students and to start to generate questions and identify preconceptions the students might have about the Earth's crust and seismic activity.

Activity 1.3: Mission and Team Orientation

Students are introduced to the mission of the unit and to a fictitious support team by pen pal letters. These "pen pals" will introduce the students to the earth structures they will study throughout the unit. The pen pal letters also provide some content for students to respond to and which you can then include in the collective conversation of the classroom. Students are also introduced to the software used in the unit, *MyWorld*, through a teacher-led discussion about making predictions.

Learning Objectives:

Content

- Earthquakes and volcanoes are places where movement and change are happening.
- Students will acknowledge a preconception about the processes of Earth's changing crust.

Process

- Develop skills in identifying and using observations and explanations.
- Write "fat" and "skinny" questions.
- Begin to support explanations using anecdotal data and prior knowledge.

*Assessment Criteria***:**

Students have many opportunities to share their pre-conceptions and questions about the processes changing the Earth's crust. Students should be sharing their explanations of earthquakes and volcanoes. Students should also be able to distinguish between an explanation and an observation by responding to text and descriptions and by making their own.

Vocabulary:

earthquake – a sudden movement of the Earth's crust caused by the release of stress accumulated along geologic faults or by volcanic activity

explanation – a statement that makes something (a structure or operation or circumstance) understandable by describing it; making sense and inferences from observations

observation – the examination of something; the noting of a fact or occurrence; often involves a measurement

seismic – vibrations of the earth caused by the moving of the Earth's crust; earthquake

volcano – an opening in the Earth's crust through which molten lava, ash, and gases are ejected; a mountain formed by the materials ejected from a volcano

Activity	Suggested Pacing	Student Resources	Teacher Resources
1.1: Myths and Science	80- 90 minutes	o Student text, p.1-18 o Science Journals or 1.1 Worksheets o Drawing paper, colored pencils or crayons (optional)	o Prepared illustration as example (optional)
1.2: Breaking News	40-50 minutes	o Student text, p. 19-27 o Science Journal or 1.2 Worksheets o Breaking News Expert Group/Home Group Worksheets, each student o Sentence strips for each group	o Chart paper and markers o Overhead projector, pens, and transparencies o Artist spray adhesive (optional)
1.3: Mission and Team Orientation	80 to 90 minutes plus presentations (a few each day as the class moves forward)	o Student text, p. 28-64 o Science Journal or 1.3 Worksheets o Pen Pal Letter Reflections o Index cards, colored pencils, markers or crayons o Sentence strips	o Transparency 1: Mission o Computer with *MyWorld* installed o Multi-media projector or TV with computer connected

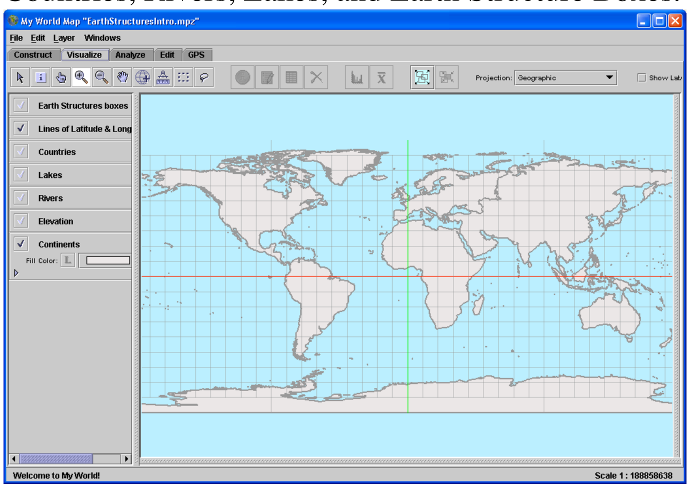
Teacher Tip: *Pacing*
Try not to spend more than 5 or 6 days on these activities. All ideas will be visited again.

Activity Set-Up:

Activity 1.1: Myths and Science

- Review "Reader's Theater" Teaching Strategy if you are not familiar with this technique.
- Create a bulletin board space for groups to display myth illustrations.
- **Activity 1.2: Breaking News**
- Read each of the four news articles prior to class.
- Prepare to divide your class into groups of four and have each group count off by four; each number will read a different article.
- Gather sentence strips in three different colors for the closing discussion: one color for questions, one color for observations, and one color for explanations.
- Prepare a place to hang the sentence strips. Hang sheets of chart paper and spray them lightly with a low tack artist's adhesive. This will allow the sentence strips to be hung and later removed. This should be done the day before. The tack will remain for several weeks. WARNING: Do not spray when students are in the room. Fumes can be irritating.
- **Activity 1.3: Mission and Team Orientation**
- Read the pen pal letters and familiarize yourself with each earth structure location.
- Prepare your own example of what the students do –see the activity for details.

- For this activity, group students into pairs. Pairs of students will be focusing their study on one of the locations. Some locations are harder than others; give careful consideration to which structure you assign to which students. Use the *Teacher Assignment Sheet* to help guide your assignments.
- Create display space for the *Big World Map* and some small flags (index card size) that will be created by each earth structure team.
- Collect stars to mark earth structure locations.
- Set up a computer to project or display for the whole class.
- Set up student computers to capture maps from *MyWorld* and write observations.
- Prepare to use the *MyWorld* map view "**EarthStructuresIntro.mpz**." This is a map view that has the following layers: Lat/Long, Elevation and Bathymetry, Continents, Countries, Rivers, Lakes, and Earth Structure Boxes.



See activity specifics for directions on how to lead this activity.

Team Assignments

Use the notes to help you assign the earth structures. It is important that most of these are assigned so students have the opportunity to compare patterns and see how the crust is moving in differently at different regions.

Earth Structures	Notes to Teacher	Students Assigned
Andes Mountains	Easy	
Baja California	Fairly easy but zone models can be confusing here later in the unit	
The Hawaiian Islands	Easy but location behaves differently than the others (hot spot)	
The Himalayas	Easy but the surrounding regions are messy	
Iceland	Data interpretation can be complex because of location on the globe but fairly straightforward, moderately difficult.	
Japan	Easy	
The Java Trench	Data interpretation easy but obscure place	
The Mariana Trench	Data interpretation easy but obscure place	
Mount Etna	Data is messy – Difficult to interpret plate motion	
Mount Popo	Data is messy	
Mount St. Helens	Common location but data interpretation can get sticky	
Mount Vesuvius	Data is messy	
New Zealand	Fairly straightforward	
Mount Kilimanjaro	Difficult data interpretation and model to understand	
St. Helena Island	Easy data interpretation but obscure location	
The Aleutian Islands	Included in TE and student discussion for modeling purposes	TEACHER

**These earth structures will cover most of the major plates of world and include all the continents except for Antarctica. Antarctica was omitted because though the basic data interpretation is straightforward, the map view manipulations are difficult.

Enacting the Lesson

Activity 1.1: Myths and Science

Students read myths from around the world to stimulate a discussion about observations and how we explain things around us: *in terms of what we know*. This is true of myths, and it is also true of science.

Engaging Your Students

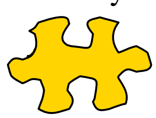
Read and discuss the stories in *Think About This* in the *Student Text*. Students are introduced to two ancient stories. Read these two stories aloud and then have a class discussion using the following questions as a guide.

- What is a myth?
- What is each myth trying to explain?
- What observations did these ancient cultures make about the Earth?
- How did they explain their observations?
- How do you think scientists explain these observations?

A question to ask after reading the Peruvian myth: *Why did the people go outside during the earthquake? Would you go outside?*

Explain the reader's theater activity. In this activity, each group will:

a) Read a different myth.
b) Have a discussion about the myth using the Figure It Out questions as a guide.

Figure It Out 

A. What is each myth trying to explain?
B. What observations did the characters in the myth make about the Earth?
C. How did they explain their observations?
D. How do you think scientists explain these observations?

c) Produce a short (1-2 minutes) reader's theater of the group's myth.
d) Produce an illustration to accompany the myth.

Teacher Note: *Reader's Theater*
What is a reader's theater? Students use parts of the text to act out the story. Members of the cast are props, like trees or the sun, as well as main characters. A narrator can "tell" the story. This is a great way to share the stories of the myths with the other class members. You could demonstrate the reader's theater with the short myths in *Think About This!*

Guiding Student Activity

Divide the class into small groups, one group of 4 to 6 students for each myth.

Have the groups read their myths and work on the task. As students are working, clarify the task and ask what they think. Ask students: *How do you think we currently explain this event? What evidence would we look for to support our explanations?*

> **Teacher Tip**: *Reading Names*
> These myths are packed with names that students might have trouble pronouncing. Encourage students to try sounding them out or saying the names together. If students are still having trouble, they can read over or replace the name with a simpler name so the meaning can be the focus. For example, if students are reading Tijus-keha, the letter T could be substituted when the name is read.

> **Teacher Tip:** *Assessment*
> As you are circulating, take note of any unusual preconceptions and interesting explanations. Gather these for your own use, and if there are ones that you might want the class to refer back to, have the student write that idea on a sentence strip and post it.

> **Teacher Note:** *Pacing*
> Allow the students one class period to read, discuss, and produce their reader's theater. Group presentations and class discussion should take place the next class period. If possible, do the first part of the lesson during reading class and the presentations during science class.

Develop a quality check. As a class, develop a list of things that should be in students' reader's theater or myth presentations. Discuss what makes a good presentation and what kinds of explanations should be made in the presentations. Create a rubric or scoring guide to assist in giving students feedback.

Making Meaning of the Activity

Groups present their reader's theater and illustration of the myth. In addition to reenacting the story, the group should share the highlights of its discussion about observations and explanations about natural phenomenon that occur on Earth.

Wrap up by having student answer and then discuss Reflection Question A. In the class discussion, students should bring up ideas about the kinds of observations and explanations that the ancient cultures made: ground shaking, turtle swimming, etc. They observed the world with the tools they had and explained the world around them with what they knew. In Reflection Question B, students should focus on phenomena that relate to the Earth's crust. A few of the myths talk about the sun or moon as well as the Earth.

Reflection Questions

A. What kinds of observations about Earth did the myths explain? Give examples.
B. **It's Your Turn:** Choose one of the natural phenomena explained in the stories shared in class today. Explain this phenomenon in your own words. What observations would you want to make to support your explanation?

> **Teacher Note:** *Setting Expectations*
> The idea here is for students to reveal their preconceptions about possible explanations for seismic and volcanic activity and to gain an awareness of what they know and what they don't know. It is important that ideas get out in the class conversation and not be "right" or "wrong." Students should feel free to express their existing beliefs.

Homework

Assign Reflection Question B for homework.

Assessment

What work is assessed?	What are you looking for?
The class' summary of the kinds of explanations for these seismic and volcanic events. Individual explanations for and questions about where earthquakes and volcanoes happen (Reflection Questions and teacher notes).	• General ideas about what the class thinks. You should also look for examples of students' individual ideas that may help stimulate discussion.

Additional Extension Activity

- Have students choose and read another myth from the selection in their Student Text. They should compare and contrast this myth to the one they read in class. How would they explain these observations? What information would they want to help support their explanation?
- Have students write an original "myth" or "legend" to explain some earth structure or process. These could be illustrated or dramatized.
- Have students do independent research to find current scientific explanations for the observations that are explained in their original myths.

Activity 1.2: Breaking News

Like the people of ancient cultures, we still watch our world and try to explain what is happening. We can watch more of our world than the people of the ancient cultures could because of more sophisticated science equipment, newspapers, and internet communication. In this activity, the class will use newspaper articles to observe four different events that shook the ground.

> **Teacher Note**: *Observations*
> We use the word "observation" in this unit for secondhand descriptions as well as firsthand descriptions. We cannot always observe these events firsthand, so we must depend on others' observations.

Engaging your students

To kick off the lesson, read the headlines of each of the four articles in the Student Text. For convenience, they are listed below.

A. *Quake flattens ancient Iran city; At least 5,000 killed, mud-brick medieval fortress crumbles* (from the Chicago Sun Times on December 27, 2003)

B. *KILLER QUAKE HITS MEXICO Capital in chaos; death reports rise (*from the Chicago Sun-Times on September 19, 1985)

C. '*They said there was no danger'/Volcano survivors recall a night of horror, heroes and death* (from the Houston Chronicle on November 20, 1985)

D. *At Least 8 Dead As Peak Erupts; Worst Blast Yet: Mt. St. Helens Throws Mud and Column of Ash* (from the New York Times on May 19, 1980)

Ask pre-reading questions to help engage the students in the activity.

Ask and discuss:

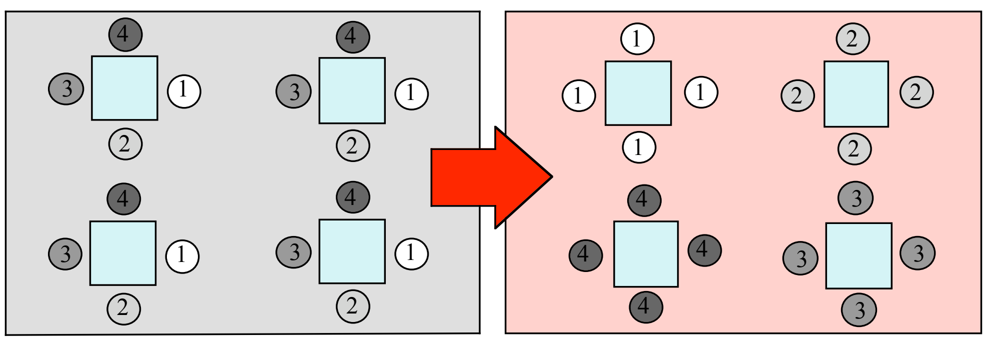
- *What do you think the articles are about?*
- *Where are these places?*
- *What do the titles make you think about?*
- *Have you ever experienced a volcano or an earthquake? Do you know someone who has? What was that experience like? What do you think was happening?*
- *Have you ever experienced any other natural event like a tornado, hurricane or monsoon? What was that experience like?*

Explain the Jigsaw.

Each student in a HOME group of four will be assigned a different one of the four articles to read. After the students have been assigned their articles, they break up into EXPERT groups. For example, all of the 1's go to a table and read the first article; all of the 2's go to another table and read the second article, and so on.

After each expert group has finish reading the assigned article, its members will fill out the reading guide (*Breaking News! Expert Group Worksheet*) together. Once each expert group is finished, each member will return to his or her home group, where everyone will share what is observed in each article, questions that might have arisen, and explanations of each expert group. The goal here is to get ideas from everyone.

Teacher Note: *Jigsaw*
Why Jigsaw? By making the groups smaller, more people can talk and more ideas can be shared. The jigsaw format also helps engage students because they need to become experts in order to share with the other members of their home group. Each member of the group is held accountable for reading, extracting main ideas, writing down observations, questions, and explanations, and communicating these back to the home group. Students have the support of the expert group before they return to share with the home group.



This illustration represents four groups of four. For a class of 32, you would have eight groups of four, two expert groups for each article.

Guiding Student Activity

Assign articles to each member of a Home Group. Article distribution can be random within a group. However, you may want to think ahead about which students will be grouped with which in the expert groups.

Teacher Tip: *Keeping students on track*
Give students a specific amount of time for each task. This helps keep them focused and use time wisely. An **overhead timer** is a great investment.

Direct students to move into Expert Groups to read and share ideas about the article assigned to each group. Students break up into their expert groups and read the seismic event article and generate questions, ideas and reactions to the article. To help facilitate the discussion, select one member of each group to lead the session. Students will need the article and their notebooks to record ideas and questions. All students should fill out the student worksheet titled *Breaking News! Expert Group*; they will need it when they return to their home groups.

Share Jigsaw discussions. Students return to home groups and share their information. In these discussion groups, article experts share a brief description of the seismic event and the group's questions and ideas about why, where, and how often earthquakes and volcanoes occur. Each student should log any additional questions, observations, and explanations brought up by other members that the expert group might not have thought of. Students should use student worksheet *Breaking News! Home Group* to help facilitate this discussion.

Prepare the Jigsaw product. Before ending the Jigsaw sessions, have each group come up with a short list of observations, explanations, and questions to share during the class discussion. Have the home jigsaw group put these on sentence strips to post in the categories observations, explanations, and questions.

Alternative
Rather than doing the jigsaw, simply read one earthquake article and one volcano article with the class and have a class discussion about why, where, and how often seismic events occur.

Making Meaning of the Activity

Have the groups share. Each group facilitator should share the group's short list of observations, explanations, and questions to display in the classroom using the sentence strips.

Teacher Note: *"Fat and Skinny" Questions*
If you are interested in developing students' questioning skills, you might want to use the idea of "fat" and "skinny" questions. A "skinny" question is one that is generally factual and can be answered by looking up facts or by answering "yes" or "no." For example: *When was the last time Mt. Saint Helens erupted?*

A "fat" question is one that encourages students to measure, observe, or compare something. For example: *I wonder if there are more small earthquakes or more large earthquakes around the Java Trench?*

Throughout this unit and especially in the early lessons, there are many opportunities to develop students' skills with questioning. It is important to get students to ask "fat" questions so we figure out what we need to observe in order to explain what is happening during these seismic events.

Conduct the closing discussion. After all groups have shared their ideas, have a class discussion highlighting interesting conceptions and interesting observations. Allow groups to react and ask questions of each other. The questions below should help guide you through the discussion.

- What do you think is going on? Why did these events happen? How often do you think these events occur? What information are you using to guess how often they occur?
- What are some things that were observed by people in the articles?
- Were any of these events predicted? How? By whom? How accurate were the predictions?

Teacher Note: *What's expected?*
These seismic and volcanic events indicate that something is happening or changing. Things are moving! Be sure this idea comes up in the closing discussion.

The idea here is for students to reveal their preconceptions about patterns in seismic and volcanic activity and to gain an awareness of what they know and what they don't know. It is important that ideas get out in the class conversation and not be considered "right" or "wrong." Students should feel free to express their existing beliefs.

Homework

Students should answer the reflection questions for homework.

Reflection Questions

A. Why do you think earthquakes and volcanoes happen?
B. How often do you think earthquakes and volcanoes happen?
C. Where do earthquakes and volcanoes happen?
D. Do you think there is a predictable pattern? Explain your ideas.
E. What questions do you have about earthquakes and volcanoes? Write one "fat" question and one "skinny" question. "Fat" questions are the ones that will help you figure out what observations you need to make to explain earthquakes and volcanoes.

Assessment

What work is assessed?	What are you looking for?
The class's summary of why, where, and how often they think earthquakes and volcanoes happen. Individual ideas about how often, why, and where earthquakes and volcanoes happen (Reflection Questions and teacher notes).	Students can distinguish between observation and explanation. General ideas about what the class thinks. You should also look for examples of students' individual ideas that may help stimulate discussion. For example: o Earthquakes happen only once in a while and volcanoes erupt rarely (misconception). o Earthquakes never happen in Illinois (misconception). o Volcanoes only happen on islands (misconception).

Additional Extension Activity:

Have students find their own description of seismic events. This activity can be an opportunity to help students develop search skills on the Internet or in a library periodical database.

Activity 1.3: Mission and Team Introductions

Students are introduced to their mission of finding patterns in the earthquake and volcano data. Students are also introduced to the earth structure that they will be studying through a pen pal letter from a fictitious team member who lives near the earth structure.

Engaging your students

Read and discuss the mission. Launch this activity by reading the mission or having a student read the mission aloud. Discuss any questions students might have about the mission. Be sure to clarify vocabulary like "seismic" and "earth structure" with the students.

> **Teacher Tip:** *Vocabulary*
> The word seismic comes up in the mission letter. You will need to explore this word with your students after you read the letter. Seismic means moving or vibrating earth.
>
> Earth structure is another term that may need clarification. You may need to ask students: *What is a structure?* Something built. *So what is an earth structure?* A structure built by the earth. Though earth structure is not a widely used term in science, it makes sense in this unit. For our purposes, an earth structure is a place where the crust of the earth is being shaped and molded by the movement of Earth's plates. For student purposes, use examples from the list to help students define earth structure. Students will develop a more robust definition of earth structure throughout the unit.

Assign student pairs/groups to earth structures. Students will be following this earth structure through the rest of the unit. Use the *Teacher Assignment Sheet* to help you assign teams to earth structures.

Use a *MyWorld* map view to have a broad prediction discussion about where students think earthquakes and volcanoes happen. To start the discussion, have students answer the Stop and Think question. Display the *Big World Map*.

> **Stop and Think**
>
> Looking at the *Big World Map*, where do you think earthquakes and volcanoes happen? What do you already know that helps you make that prediction?
> *Accept any answers. Use student responses to guide the discussion using My World.*

**** Goals for this teacher-led class discussion:**

- Students explore possible patterns in earthquake and volcano data by looking at elevation and depth, continents, and topography under the ocean.
- Students locate the earth structures and look for patterns.
- Students are introduced to some of the basic functions of the software (kinds of data, map views, layers, turning layers on and off, the information tool, the navigation tools, the re-centering tool, and the zoom in and zoom out tools.

Teacher Note: *Vocabulary*
It is essential at this point in the discussion that you highlight the difference between **elevation** and **depth** so that students can use these words correctly throughout the rest of the unit. "Elevation" is used when referring to heights above sea level, while "depth" refers to the height of the land below sea level, though in some fields a "negative elevation" is used to talk about depth. Both terms are used in this curriculum.

Whole-class discussion: Intro to *MyWorld*

Questions | **Maps** | **Concepts**

1. Launch *MyWorld*

Open the MapView called **"EarthStructuresIntro.mpz"** This is a Map View with Earth Structure Boxes, Lat/Long Lines, Counties, Lakes, Rivers, Elevation and Depth, and Continents layers available.

Where do you think the earthquakes and volcanoes happen? Any predictions?

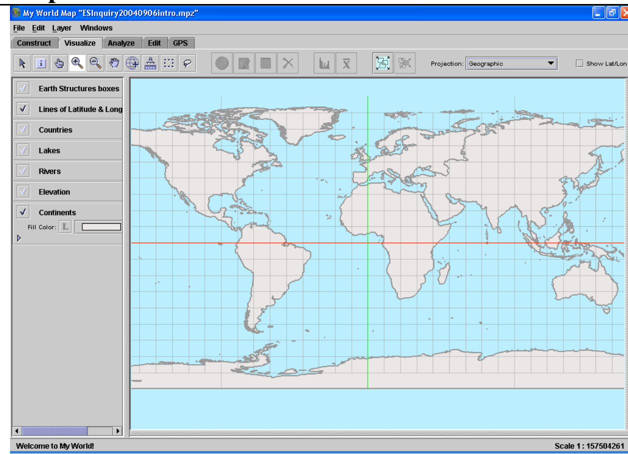
What do you see on this map?

What do you recognize?

What information is there?

What are Lat/Long lines for?

What observations about the world can you make?



Continents
Oceans
Equator
Prime Meridian
Latitude
Longitude

Observation

Activating prior knowledge about where earthquakes and volcanoes might occur.

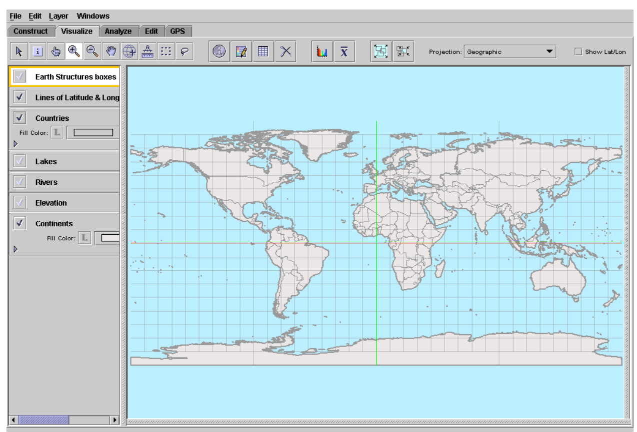
2. Describe *MyWorld*

MyWorld is a GIS – an information system. How is it like a wall map?
It shows information and places.

How is it different?
You can change the map to make different observations and you look at multiple data maps at the same time to compare them.

Show/Hide Countries, Lat/Long Lines, and Elevation (Move-Map, Show lat/long).

Any predictions now?



Definition of GIS

Map window
Layers
Show/hide layers
Zoom in & out tools
Move Map tool
Zoom to All tool

Predicting earthquake and volcano patterns
Activating prior knowledge

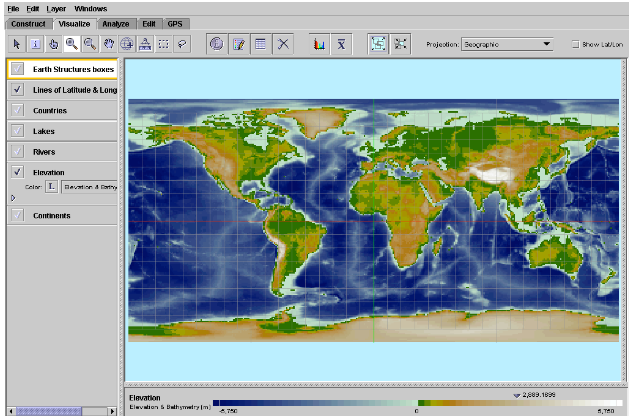
3. Show Elevation layer

What does this view tell you? (Use the Arrow tool to pick a value on the legend and see how that relates to color.) It tells you elevation and depth.

Where are some high-elevation places? How high?

Where are some low-elevation places? How low?

Where is sea level?



Elevation
Sea level
Meters + and -

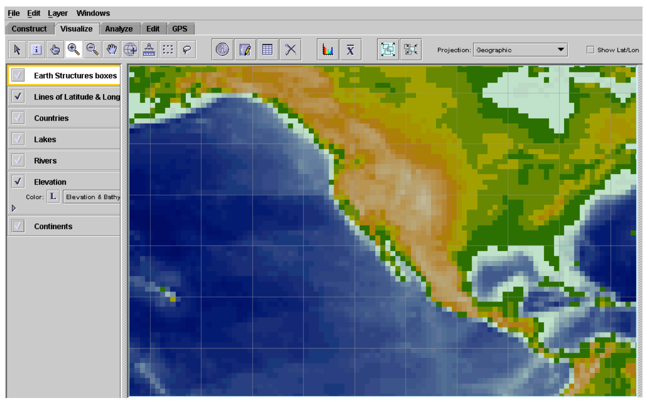
Represent data using colors
Map legend

Analyzing data

4. Closer Look

Choose a place that you think has lots of earthquakes. Choose a place you think has few earthquakes. Why did you choose these places? (Show Zoom in & out, Move-Map, Zoom-to-All, Re-Center Projection.)

What kinds of earthquake and volcano activity happen at your earth structure?



More about elevation and depth representation

Zoom in & out tools
Move-Map tool
Zoom-to-all tool
Re-center projection

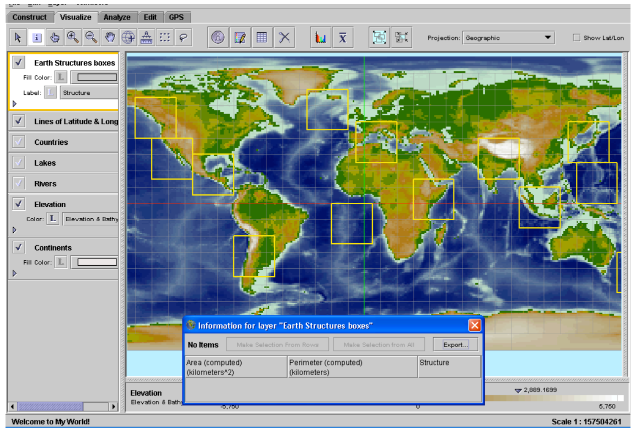
Justifying Predictions
Activating Prior Knowledge

5. Show “Earth Structures Boxes” layer

Each of these boxes contains an interesting structure of the earth’s crust. (Select the Boxes layer, then select the information tool to show students the names of the earth structures in each box.)

We will be studying them.

What observations can you make about these 14 places (similarities, differences)? Do you have any earthquake and volcano predictions?



Earth structure
Crust

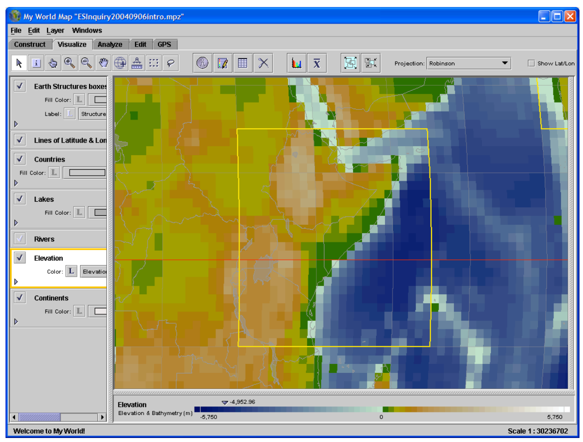
Show/Hide layers
Info. Tool

Similarities
Differences

6. Student observations

Have students come up front one at a time to describe observations of any earth structure.

Students arrange the Map window (zoom, show layers) to show an example of what they observed. *Ex: It is shallow by the land (-45.9 m) and then it gets deeper far away from the land (-5,268.3 m).*



Practice with tools

Finding and describing similarities and differences

Reflect on <u>where</u> and <u>why</u> students think earthquakes and volcanoes happen. Students should answer and discuss the Stop and Think question.

Stop and Think

Why do you think earthquakes and volcanoes happen?

Students should understand that earthquakes and volcanoes tell us that the earth is moving.

Guiding Student Activity

Describe the task of reading, reflecting on, and sharing the pen pal letters. Explain to students what will happen to encourage students to reflect on and share the information in the pen pal letters.

- In pairs, students will read and reflect on their pen pal letters from the Junior Science Assistants mentioned in the mission letter.
- As students are reading, they should make note of important or interesting ideas and try to explain what is happening in this region. After reading, students will respond to reflection questions and create a flag for their earth structure.
- Pairs will then be asked to introduce the earth structure to the class. Interesting ideas or questions should be written on sentence strips and posted in the class.

Teaching Tip: *Modeling with the Aleutian Islands*
You will notice that there is one earth structure that we have left for you the teacher so you can model the kinds of thinking and tasks that students do with the different earth structures. See the student annotated pages for reflections about the Aleutian Islands. You will also want to prepare sentence strips with observations, explanations, and questions.

Possible observations: A new island was created. There are volcanoes around the edges of the Pacific Ocean. *Possible Explanations*: The Aleutian Islands are created by volcanic eruptions. *Possible* Q*uestions*: I wonder if the deep trench has anything to do with the volcanoes?

Ask student pairs to **read and reflect on their letters from the Junior Science Assistants.** Encourage students to make a note of important or interesting ideas from their letters. Students should use the student worksheet *Pen Pal Letter Reflection* as a guide to capture important ideas. This is a good opportunity to distribute sentence strips. Students should write observations, explanations, and "fat" questions on sentence strips.

Teacher Tip: *Anecdotal Information*
Help students identify important and interesting ideas. This is key. Students will need this anecdotal information later to help them make sense of the earthquake and volcano data. These interesting ideas (e.g. the Himalayas grow 3 centimeters per year) form a context for understanding the data. Use the *Earth Structures Teacher Notes* to help guide the extraction of this information.

Ask students to **prepare an introduction of their location and create an earth structure flag.** Have index cards and drawing materials available for the students to create earth structure flags. Circulate among the students, checking to see that students have captured key observations about each region and have written explanations for the changes happening in that region.

Teacher Note: *Why do it this way?*
The goal of this unit is for students to explain a process from clues given in data. To better be able to analyze data students need to recognize differences and places first. This is sort of like name dropping. In this first lesson we are dropping names and bits of information about places around the world that become part of the collective conversation. These places and bits of knowledge can then be used as examples when students are interpreting the data. The data is no longer just a set of dots on a map but rather a changing moving piece of the earth and these dots are events of change.

Making Sense of the Activity

Groups introduce their earth structures. Each group introduces its earth structure and shares interesting observations of and explanations for what is happening in this region. Post students' sentence strips on chart paper and hang the flags around the large class map.

Students can show the class where the earth structure is located by placing a star on the *Big World Map* or by using the Earth Structure boxes in *MyWorld*. After each group presents, highlight interesting pieces of information in a short discussion.

Teacher Tip: *Pacing*
Spend one class period having pairs read and discuss the letters. Don't present all the structures the next day. Have a couple of groups present each day while you move forward in the unit rather than all at once. Interesting ideas will surface and discussions will be richer because the class can focus on fewer ideas.

Explain and prepare students for the homework assignment. There are two sets of Reflection Questions. Students should do the first Reflection Question for homework after this activity and the second set of the Reflection Questions only after all the earth structures have been presented.

Reflection Question

It's Your Turn: Write a letter to your Junior Science Assistant. In your letter you should introduce yourself, introduce where you live, and share with your pen pal things you found interesting about that region of the world.

To help students with this question, ask them to brainstorm a list of things that they could tell their Junior Science Assistants about where you live. Are there any earth structures nearby that could be interesting? What about bodies of water? What do people do? What kinds of seismic and volcanic activity are there in your region?

After several presentations and again when all of the groups have shared, ask students to answer the following Reflection Questions.

Reflection Questions 

A. From what you have heard from your classmates, is the seismic activity at each earth structure similar? Explain.
B. What interesting observations stood out for you? Which observations from the pen pal letters do you think will help you figure out why, where, and when earthquakes and volcanoes happen?
C. **<u>It's Your Turn</u>:** Write another letter to your Junior Science Assistant. In this letter **explain** what you think is going on at that earth structure and in that region. For example, you should explain how things are moving in your region and why you think they are moving that way.

Homework
This activity will take place over several days, so there is homework for after the first day and homework for after all groups have presented. After the first day, assign Reflection Question: Part 1. Students are asked to write a letter introducing themselves and where they live to their pen pal. After all the earth structure teams have presented, assign Reflection Question: Part 2. Students are asked to explain why earthquakes and volcanoes happen.

Assessment

What work is assessed?	What are you looking for?
Pen Pal Letter Reflections worksheet Student introduction of earth structure	<u>Content</u>: Earthquake and volcano data are evidence of change and things are moving (e) and (b). There are qualitative observations that show change too (for example, Hawaii adding land) (c).
Question (g) of the *Pen Pal Letter Reflections* worksheet asks for questions students have – these should be shared on sentence strips. Explanations on sentence strips. Observations on sentence strips.	<u>Process</u>: Distinguish between observation and explanation. Ask "fat" and "skinny" questions. Identify explanations and begin to support with observations. Identify observations and begin to explain what is happening.

Additional Extension Activity:
Students can go to the library or use the Internet to find out other interesting things about each Earth structure. Students can also be challenged to find a picture, diagram, or image of each earth structure.

WHAT'S THE POINT?

Students have now collected observations about earth quakes and volcanoes and been introduced to the earth structures you will study as part of the class mission.

Ask students to answer the questions. Be sure to emphasize that when earthquakes and volcanoes happen, the earth is moving and changing at that place.

- When an earthquake shakes the ground or a volcano blasts, what is happening? *The ground is moving and changing.*

- Why? Where do you think the ground is moving to? What changes are those movements causing? *Students might use examples from their region. Earthquakes happen because the volcano is preparing to blast. Or, earthquakes happen because the ground is moving and shifting. The island grew because the middle of the earth is trying to get out.*

- How would explain why those changes are happening? What would you do or want to observe to support your explanation? *Students will have a variety of answers here.*

Teacher Reflection

What do your students know about why, where, and how often earthquakes and volcanoes happen?

Are there any preconceptions that stand out? How do think you will address them or use these ideas to help with other student misconceptions?

Are students trying to connect explanations with the observations they have made so far?

Name ______________________________

Activity 1.1: Myths and Science

Title of Myth ____

Figure It Out: *Myths and Science*

A. Where did this myth take place?

____

B. What natural events on the Earth were the people (in the myth or who developed the myth) living through?

Answers will vary.

C. How did they explain these natural events in the myth?

Answers will vary.

D. How would YOU explain these natural events?

Answers will vary.

Name ___________________________________

Activity 1.1: Myths and Science

Reflection Questions

A. What kinds of observations about Earth did the myths explain? Give examples.

Answers will vary.

B. **It's Your Turn:** Choose one of the natural phenomena explained in the stories shared in class today. Explain this phenomenon in your own words. What observations would you want to make to support your explanation?

Answers will vary.

Name ________________________________

Breaking News!
Expert Group

Directions: Read the news article assigned to your expert group. In your group, discuss and complete the table below.

Article Title ______________________________ Article Date ______________

Publication ______________________________

EXPERT GROUP
Describe the Event *What was the event? Where did it occur? When did it occur? How long did it last? What warning signs, if any, had there been that it was going to happen? What were things people saw or reported?* Answers will vary. A bulleted list would be a good way to list information.
Explain the Event *Why do you think this event is happening? Does it occur often?* Answers will vary.
Questions about the Event *What questions do you have about the event? Were there any terms/explanations that you didn't understand? Is there something else you would like to know about the event that wasn't talked about in the article?* Answers will vary.

Name ______________________________________

Breaking News!
Home Group

Directions: After you have returned back to your Home Group, take turns reporting back to the others the information gathered from each article. Write down any questions the group has about the event.

HOME GROUP	
Article 1 Circle One: Volcano Earthquake Location: ______________________ **Main Ideas:** Answers will vary.	**Article 2** Circle One: Volcano Earthquake Location: ______________________ **Main Ideas:** Answers will vary.
Explanations: Answers will vary.	**Explanations:** Answers will vary.
Questions: Answers will vary.	**Questions:** Answers will vary.

Name ____________________________________

HOME GROUP	
Article 3 Circle One: Volcano Earthquake Location: ______________________________ **Main Ideas:** Answers will vary.	**Article 4** Circle One: Volcano Earthquake Location: ______________________________ **Main Ideas:** Answers will vary.
Explanations Answers will vary.	**Explanations** Answers will vary.
Questions: Answers will vary.	**Questions:** Answers will vary.

Name ______________________________

Activity 1.2: Breaking News!

Reflection Questions

A. Why do you think earthquakes and volcanoes happen?

Answers will vary.

B. How often do you think earthquakes and volcanoes happen?

Answers will vary.

C. Where do earthquakes and volcanoes happen?

Answers will vary.

D. Do you think there is a predictable pattern? Explain your idea.

Answers will vary.

E. What questions do you have about earthquakes and volcanoes? Write one fat question and one skinny question. "Fat" questions are the ones that will help you figure out what observations you need to make to explain earthquakes and volcanoes.

Answers will vary.

Name ___________________________________

Activity 1.3: Mission and Team Introduction

Stop and Think

Looking at the *Big World Map,* where do you think earthquakes and volcanoes happen? What do you already know that helps you make that prediction?

Answers will vary.

Stop and Think

Answer this question after you've made your predictions.

Why do you think earthquakes and volcanoes happen?

Answers will vary.

Name ______________________________

Pen Pal Letter Reflections

Directions: Using the information found in your pen pal letter, complete the following table.

Earth Structure ____

<table>
<tr><th>Observations</th><th>Explanation</th></tr>
<tr><td rowspan="3">Describe where your earth structure is located.

Give a brief physical description of your earth structure.

Describe any changes happening in the region of your earth structure.

What are some other interesting observations about your earth structure?

Does your Earth structure have a lot of seismic activity (volcanoes or earthquakes)? How do you know?</td><td>How would you explain the changes happening in the region of your earth structure?</td></tr>
<tr><th>Questions</th></tr>
<tr><td>What questions do you have about your earth structure?</td></tr>
</table>

flection Questions: Part 1

<u>It's Your Turn:</u> Write a letter to your Junior Science Assistant. In your letter you should introduce yourself, introduce where you live, and share with your pen pal things you found interesting about his or her home region of the world.

Dear ________________________________,

Sincerely,

Reflection Questions: Part 2

A. From what you have heard, is the seismic activity at each earth structure or in each region similar? Explain.

Students should answer "no" and support their answer with evidence from the groups' reports.

B. What interesting observations stood out for you? Which observations from the pen pal letters do you think will help you figure out where, when, and why earthquakes and volcanoes happen?

Answers will vary.

C. **<u>It's Your Turn</u>:** Write another letter to your Junior Science Assistant. In this letter, **explain** what you think is going on at that earth structure and in that region. For example, you should explain how things are moving in your region and why you think they are moving in that way.

Answers will vary.

Lesson 2

Topography of Earth Structures

In this lesson, students will use topographic maps to build three-dimensional models of earth structures. Students will then use these models, along with elevation and depth data, to compare the earth structures.

What have students learned so far?

In Lesson 1, students observed and tried to explain earthquakes and volcanic eruptions. The class has been invited to be part of a mission to look for patterns in earthquakes and volcanoes. The class has also decided that earthquakes and volcanoes indicate that the ground is moving and changing. Students have also been introduced to some of the different earth structures that they will be studying throughout this unit.

Why is it important for students to study the topography of their region?

The Earth's crust is constantly moving and shifting. This shifting changes the shape of the land and ocean floor over time. Earthquakes indicate shifting within the crust, changes in the land that can also be observed in the form of mountains, volcanoes, rifts, and trenches. So the shape of the land is one indicator of the kinds of movement and changes that are happening in the crust. Students will eventually characterize these movements and make sense of the patterns in the earthquake and volcano data. Recognizing and characterizing the structures of the crust will help students interpret the patterns of earthquake and volcano data distributed around the world.

Lesson Overview:

Activity 2.1: How High and How Low

Students will look at maps of earth structures. Students will learn how the map represents three things: 1) elevation (how high above sea level), 2) depth (how far below sea level), and 3) the shape of the structure.

Activity 2.2: Building 3-D Models

Students will build a three-dimensional model of earth structures from topographic maps. Students will then compare earth structure models.

Activity 2.3: Comparing Earth Structures

Students will use *MyWorld* to compare two earth structures and show any similarities and differences between the two. Students will also capture maps and write observations in a word processor.

Learning Objectives:

Content

- o Identify differences in elevation, depth, and sea level on a Geographic Information System (GIS), *MyWorld*.
- o Identify on a topo map: different elevations, different depths, sea level, and slope (steepness) of the land.
- o Describe how topo maps and GIS maps show elevation and depth.
- o Describe the shape of the land using GIS maps, topographic maps, and the 3-D models.
- o Compare the topography of different earth structures.

Process

- o Support ideas with evidence.
- o Find similarities and differences.
- o Capture observations and note observations and explanations.

*Assessment Criteria***:** Students should understand and be able to interpret both GIS and topographical maps. They should also be able to construct an accurate topo map, including an accurate representation of sea level. Finally, students should be able to compare earth structures on both types of maps and use their observations to support their ideas.

Vocabulary:

contour lines – A line connecting points of equal elevation and representing this level in relief on a map

depth -- level of land below sea level

elevation – level of land above sea level

GIS (Geographic Information System) – computer software that enables users to construct interactive maps and perform analyses using database and geospatial queries

slope – The change in elevation (rise) over a distance (run), measured either in a percent gradient or in an angle of the slope; closely spaced contour lines represent a steeper slope than contour lines that are spaced farther apart, assuming the same contour interval

sea level – The location where the ocean water meets the land, with an elevation of zero (0); mean sea level would be the average height of all stages of tide

topographic Map – A map representing natural features located on the ground and containing contour lines that show the elevation of the land

Activity	Suggested Pacing	Student Resources	Teacher Resources
2.1: **How High and How Low**	40-50 minutes	o Students text p. 65-67 o Science Journal or 2.1 Worksheets o Cutout Topographical Map, 1 each student o Large box of crayons or colored pencils for each group	o Computer projection system o MyWorld with map view "EarthStructureIntro" o Overhead projector o Lesson 2 Transparency 1 o *MyWorld* Tool Box
2.2: **Building 3-D Models**	40-50 minutes	o Student text p. 68-76 o Science Journal or 2.2 Worksheets o Colored Topo Maps from Activity 2.1 o Modeling material: craft foam, cardboard, or foam core o Scissors o Glue stick	o 3-D Model of the Aleutian Islands (see set-up) o Glue stick o Scissors o Tape o *Big World Map* posted
2.3: **Comparing Earth Structures**	40-50 minutes	o Student text p. 77-93 o Science Journal or 2.3 Worksheets o Computers with MyWorld and map view "EarthStructureIntro" available o Copies of *MyWorld* Tool Box and Screen capture directions for each computer station	o Computer projection system o MyWorld with map view "EarthStructureIntro" o Overhead projector

Teacher Note: *Pacing and Pen Pal Letters*
At the end of Lesson 1, students read and prepared introductions of their earth structures through the pen pal letters. It is suggested that you spread out these introductions over several days. During each activity in this lesson, allow about 10 minutes at the beginning or end of the class for teams to share their introductions of their earth structures.

Activity Set-Up:

Activity 2.1: How High and How Low

- Set up computer projection system.
- Practice the teacher-led discussion using *MyWorld* that takes place in this activity.
- Color in the Aleutian Islands Map using a color scheme similar to the one used in *MyWorld* for elevation and depth. See suggested colors in the activity.
- Each student will need a topographic map for his or her earth structure. In the next activity, teams will make 3-D models from one topo map. Each group will need two topo maps for the activity, one to cut apart and one to use as a reference.

Activity 2.2: Building 3-D Models

- Build a 3-D model of the Aleutian Islands to show students the end product.
- Prepare the *Big World Map,* on which the 3-D models will be displayed. Both the map and topo maps use the same scale, so place the topo maps using latitude and longitude.

Activity 2.3: Comparing Earth Structures

- Set up computer projection system and student computers so students have access to *MyWorld* and the Map View "**EarthStructureIntro.mpz**."
- Set up computer projection system and student computers so students have a way of capturing maps and writing observations and explanations. See description in the Front Matter.
- Choose which set of instructions for the *MyWorld* Tool Box and screen capture directions is appropriate for your classroom computer set-up. (These can be found in the appendix). Make copies of the instructions for each computer station. Go through these directions so that you are familiar with the process before having students try it.

Enacting the Lesson

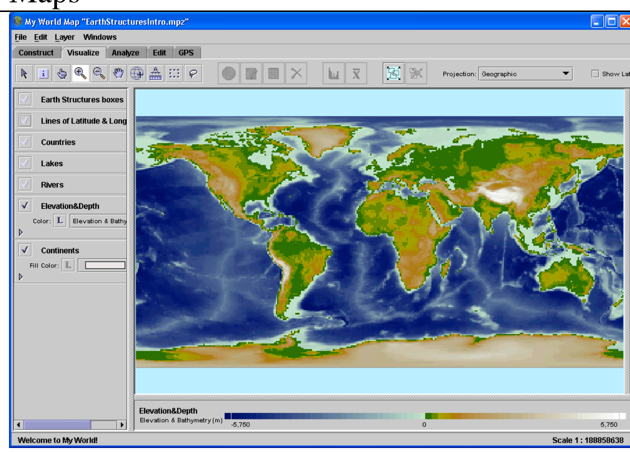
Activity 2.1: How High and How Low

In this activity, students will look at maps of earth structures. Students will learn how the map represents three things: 1) elevation (how high above sea level, 2) depth (how far below sea level, and 3) the shape of the structure.

Engaging your students

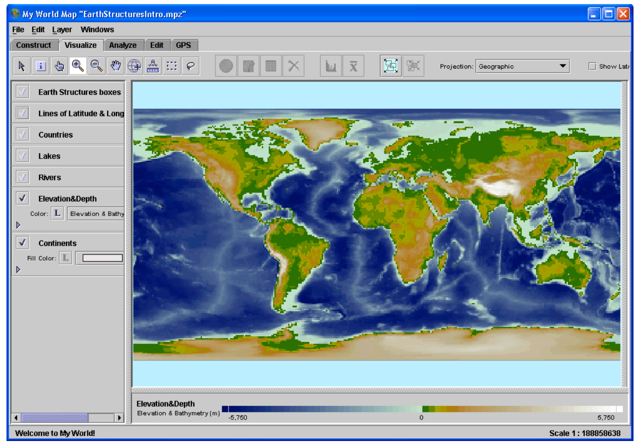
Use *MyWorld* and the following guide to help students read elevation and depth information from a GIS (Geographic Information System) map. You will use the same Map View from Lesson 1 but focus on elevation and depth. Ask students to demonstrate how they know how to read these maps. Most answers have been provided in the following discussion.

Whole-class discussion: Using *MyWorld* to talk about topography maps

Questions	Maps	Concepts
Launch *MyWorld* Open the MapView called **"EarthStructuresIntro.mpz"** This is a Map View with Earth Structure Boxes, Lat/Long, Countries, Lakes, Rivers, Elevation & Depth and Continents available. *How are elevation and depth represented on this world map?* Using color: land above water is colored in greens, browns, and grey to white to show different elevations. Land below water is colored different shades of blue to show depth. Show students the legend at the bottom of the screen, which shows different colors representing different elevations.		Elevation Depth Legend (color scheme) Observation Activating prior knowledge about elevation and depth

A closer look at elevation and depth.

Where on the map are the high peaks? How do you know?
The legend at the bottom of the map shows you that the highest peaks are white, e.g. the Himalayas or Andes.



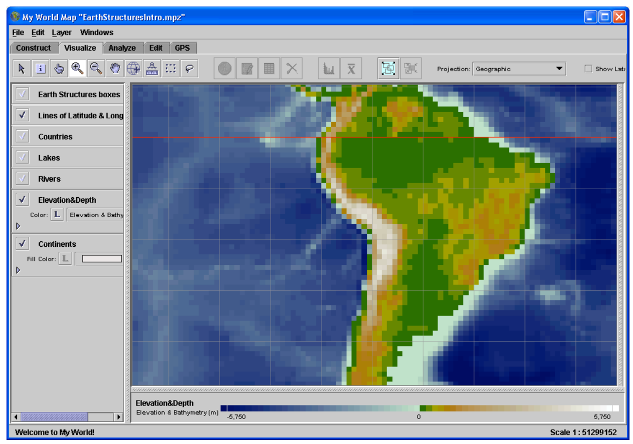
Highest peaks
Elevation

Zoom in & out
Move Map tool
Zoom to All tool
Pointer tool
Legend (color scheme)

Activating prior knowledge

What does a mountain range look like on the map?
Show examples. To the right is the west coast of South America, where the main range is the Andes. Students should notice the gradual change in color to show the increase in height.

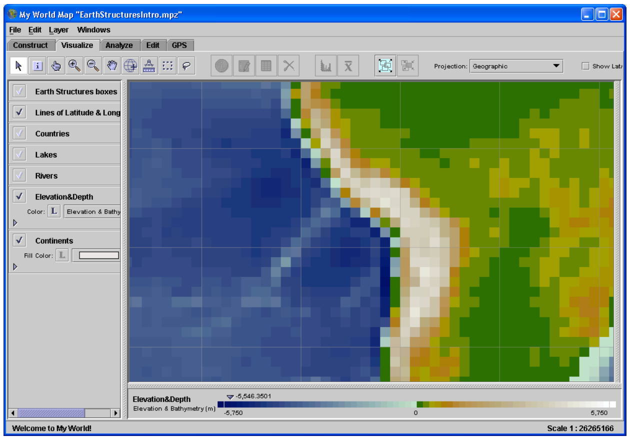
Where are the highest peaks on these mountains?
Students should see that the highest peaks are white, but you may need actual data to determine the highest of these. Find some high peaks by using the pointer tool to click on the map. The different elevations will display above the legend.



Mountain range
Shape of mountains represented in GIS

Where on the map are the deepest parts of the ocean? How do you know?

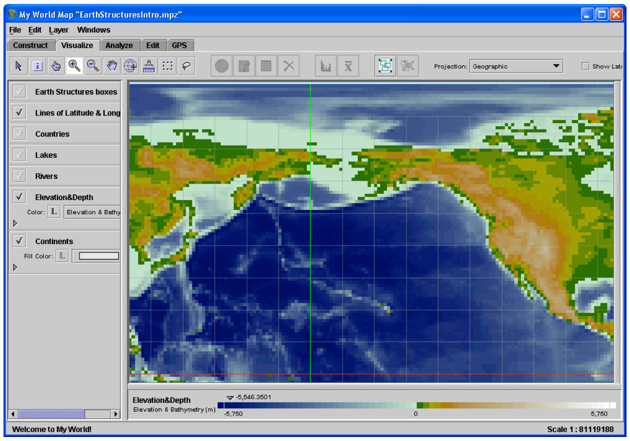
Depth is shown with the color blue. The darkest blues are the deepest parts of the ocean. Zoom in on the coast of South America. Students should notice the deep ocean depths near here. Be sure to point out to students that the high peaks of the Andes are located right next to the deepest parts of the ocean – a trench.



Elevation
Sea level
Meters + and -

Where is the water shallow?

Show students how to use the Zoom To All tool in order to see the entire world again. Show students the shallow water (light blue) near the Aleutian Islands. Show students how to re-center the map around the Pacific Ocean.



Zoom To All tool
Re-Center Map tool

How is sea level represented?

Sea level is where the ocean water meets the land; it is shown on the map by a color change from light blue to dark green.

Where is the dry land close to sea level?

Students should notice the change in the colors as land gets closer to sea level; dark green shows the lowest elevations.

Closer Look at a Region

How are elevation and depth represented on this region map?

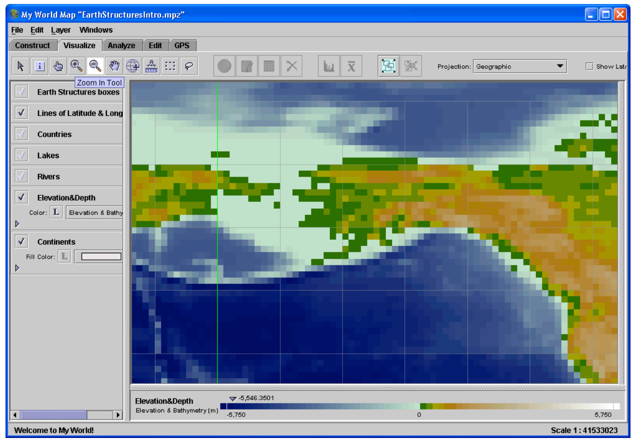
The same color scheme is used in the regional map as in the world map.

Describe Alaska and the Aleutian Islands.

Where are the highest peaks for this region?

Where are the deepest parts in the ocean?

Where is sea level on the map?



More about elevation and depth representation

Zoom in & out
Move Map,
Zoom to all, Re-center
Projection

Justifying predictions
Activating prior knowledge

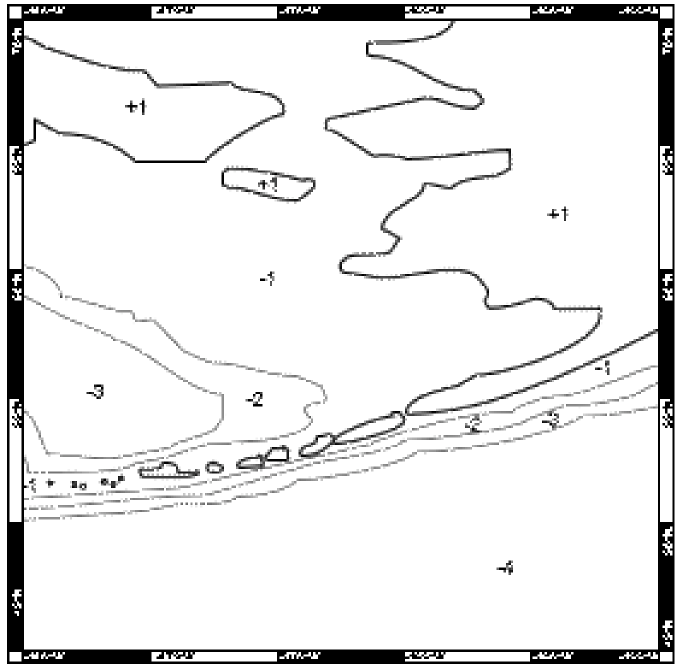
Guiding Student Activity

Compare the description in the pen pal letter to the map of the Aleutian Islands. This is a Stop and Think question in the Student Text. Read that section of the pen pal letter aloud to the class and ask students, *How did Kirima describe the Aleutian Islands? How is her description represented on the map?*

> "The islands are all in a curved line, stretching towards the southwest from the Alaskan peninsula and then curving towards the northwest as it slowly becomes Russian territory.
>
> There is a volcano called Mount Makushin, which is 1,735 m (5,690 ft) tall…
>
> If you ever want to visit, you'll have to come on an airplane because there's no other way to get here.☐You could use ships and boats but you have to be an expert navigator since the coasts here are very jagged and rocky. Most of the coastlines around our islands are lined with steep cliffs and mountains.
>
> One of the coolest geological features of the area is the formation of new landforms."

Review a topographic map of the Aleutian Islands with the class. This map is on a transparency and is also in the Student Text at the end of Lesson 2. A topographic (topo) map uses lines to describe the shape of the land rather than color.

Aleutian Islands Cutout Topographic Map



Ask: ***How are elevation and depth represented on this map? What does the key tell us?*** Elevation is represented with positive and negative numbers and lines. The number +1 on the map means that everything in the section marked +1 is between 0 and 1500 meters above sea level. The number -3 on the map means everything that is marked -3 is -3000 to -4500 meters below sea level.

Ask students to show the class a high elevation, a low elevation, and a low ocean depth on the topo map.

Ask: ***How is sea level represented on the map?*** It is line where the numbers change from positive to negative. Help students recall that sea level is where the ocean water meets the land.

Elevation Key: Color in each number

STRUCTIONS

Pick a color for each elevation

Color each number box →

Color the map by number

Use map for making a model

+4	=	More than +4,500 m above sea level
+3	=	+3,000 to +4,500 m above sea level
+2	=	+1,500 to +3,000 m above sea level
+1	=	0 to +1,500 m above sea level
_	=	Sea Level
-1	=	0 to -1,500 m below sea level
-2	=	-1,500 to -3,000 m below sea level
-3	=	-3,000 to -4,500 m below sea level
-4	=	-4,500 to -6,000 m below sea level
-5	=	More than -6,000 m below sea level

a

Ask: ***How is a change in elevation shown on the topographic map?*** Direct the students to look at the lines and the spaces between the lines. Each contour line represents a different elevation. On this map, different contour lines show a difference of 1500 m. Sometimes the lines are close together and sometimes the lines are far apart. You can think of the lines on the map as steps. When the lines are close together, the elevation of the land is changing rapidly in a short distance. This is like getting to second floor of a building with a ladder; it is a steep climb in a short distance. When the lines are farther apart, the elevation of the land is changing more gradually over a longer distance. It is more like taking a ramp to the second floor of a building. Help students understand how to read the lines on the topo map by asking the following questions:

- *According to this map, where might you have a difficult time climbing?* (Where the lines are close to together)
- *According to this map, where on this map might you have an easy time climbing?* (Where the lines are farther apart)
- *How did you determine the answer to these two questions?*

Teacher Note: *Content*
On this topographic map and on the other maps in this unit, the contour lines are spaced at a constant interval – 1500 m. For future reference, some topo maps have contour lines that do not represent the same interval. Be sure to read the legend.

Making Meaning of the Activity

Ask the students to color the topo map using similar colors to *MyWorld*.
Students should use greens, yellows, and browns and grays for land above sea level and blues for the land below sea level. Be sure students notice how the colors help them see the shape of the land.

Teacher Tip: *Science Crayons*
Use large boxes of 64 crayons for science class only. Students will keep the colors in order and organized so students have all the colors needed for an activity like this. For this activity, here are the suggested colors from a Crayola box of 64 crayons.
+4 gray
+3 tan
+2 olive
+1 forest
-1 sky blue
-2 periwinkle
-3 corn flower
-4 blue
-5 midnight blue

Reflection Question

Both the GIS and topo map show elevation and depth. Describe how each map shows elevation and depth.

Teacher Tip: *Optional Challenge*
If there is time, ask students the following challenge question. Display the *MyWorld* map view you have been using in this lesson. The Elevation and Depth Layers should be showing. Zoom in so the United States fills the window. *Where is Lake Michigan?*

Students should notice that there aren't any lakes or rivers on the map. Where are they? We know they are the middle of the U.S., so why don't they show up with colors in the blues? Is it because the land is under water?

Answer: the Great Lakes are above sea level. They formed when water filled in the hole after the glacier melted. Without the Lake layer turned on, you can see a part of the land lower than the surrounding land. Lake Michigan has the lowest depth of all of the Great Lakes.

Homework
Assign the Reflection Question for homework.

Assessment

What work is assessed?	What are you looking for?
Reflection Question	A GIS map uses different colors to represent different elevations and depths. A topo map uses lines (contour lines) to show elevation and depth: higher numbers show high elevations and lower numbers show deep oceans.

Additional Extension Activity
If you are interested in doing more with topo maps . . . .

Activity 2.2: Building 3-D Models

In this activity, students will build a three-dimensional model of their earth structure from the topographic map. Students will then compare earth structure models.

Engaging your students

Show students the model of the Aleutian Islands that you built. Ask them what the two different colors mean. (They show above sea level and below sea level.)

Alternative
If you think this activity is more than your students can do in a day or two, skip the activity and do the comparisons at the end of the activity with the colored topo maps. You could send the materials and directions home for students to do with their parents also. The point of the lesson is to get students to think about the similarities and differences in the shape of the different earth structures.

Guiding Student Activity

Distribute materials and direct students to the instructions in the Student Text for building these models. Students will need to work with their teammates on this activity. It is easier to build these models in pairs than individually.

Students should build a three-dimensional model of their earth structure using the topo map from the previous activity. The example they are given is the Aleutian Islands, where the deepest elevation is –4.
The main steps in creating the model are:

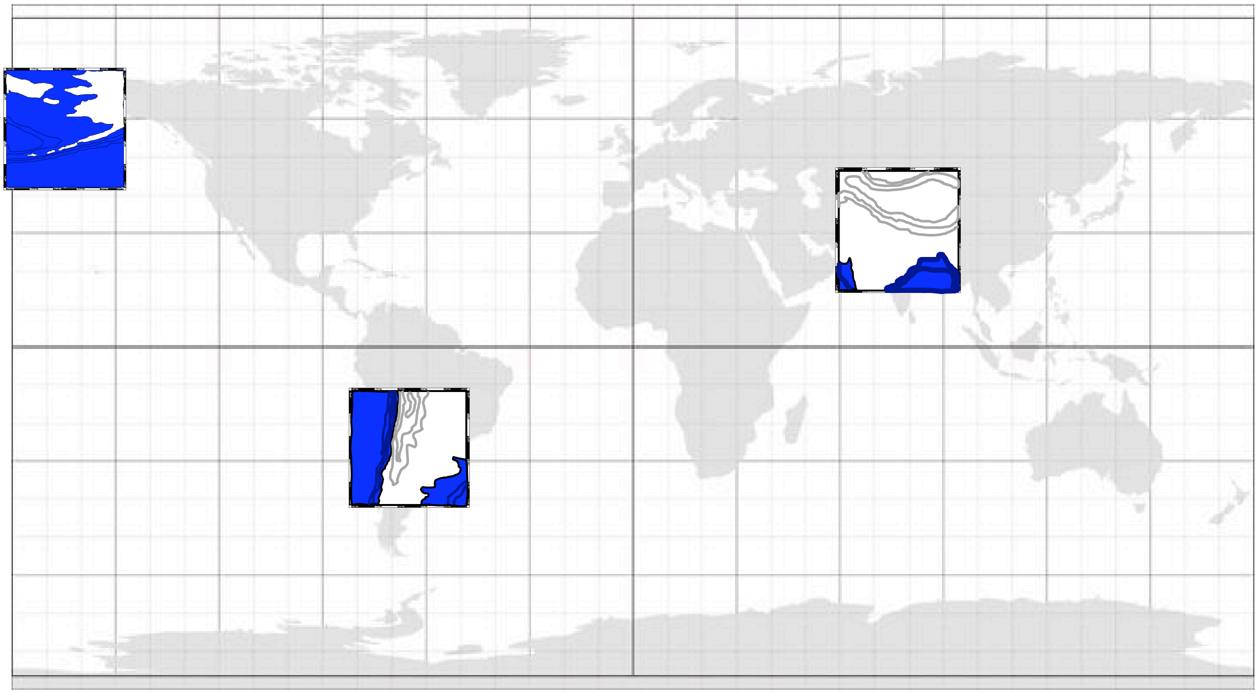
1. coloring the maps by elevation
2. cutting out foam for each level
3. cutting out map areas one by one
4. stacking and gluing the layers until all are done

Teacher Tip: *Cutting the Lowest Part*
How do you help students who are having trouble? There is a routine to the directions: cut foam, cut lowest part of map away, cut foam, cut lowest part of map away. Some students struggle with the fine motor skill of trimming the foam; the cutting also does not need to be perfect.

Making Meaning of the Activity

Direct students to the Figure It Out questions after they have completed their models. Some of these questions need to be done in class because students are asked to compare their 3-D earth structures to another team's. All the topo maps are in the Student Text so that students can easily compare earth structures.

After students have completed the comparisons of their earth structures, **tape all the models on the *Big World Map***. The latitude and longitude for each model are on the topo map. Students should notice how some of the topo maps line up next to each other on the Big World Map.



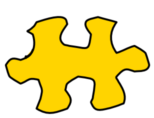
Teacher Tip: *Setting Expectations*
The models are a great place to anchor observation and discussion about the earth structures. Students should be able to describe their earth structure and compare it to other earth structures. Students might confuse some of the vocabulary at this stage, but pay attention to what they are observing.

Teacher Tip: *Sea Level Model*
If students are having trouble with "sea level," tape a few foam earth structure models to the bottom of a clear, flat container (shoe box). This represents the earth without water. Slowly add water to the container until sea level is reached. Notice the shape of the land below the water. Notice that the water stops at the same place on each model- where the color changes. Some earth structures have lots of land above the water and others have lots of land below the water.

Homework

Students should complete any Figure It Out questions they have not completed in class, as well as the Reflection Questions.

Figure it Out



Looking at your three dimensional model of your earth structure, answer the following questions.

1. What parts would be hard to climb? Which would be the steepest slopes? Show a classmate.
2. What parts would be easy to climb? Which would be the least steep slopes? Show a classmate.
3. What differences do you notice in the shape of the land below sea level and above sea level?

4. What observations can you make about your earth structure? Using your model and your topo map, describe your earth structure. Be sure to include the elevation, depth, steepness of the slopes, and shape of your earth structure.
5. Look back at the letter the Junior Science Assistant sent you. How did your pen pal describe the topography of the earth structure? Compare your description to your pen pal's description.
6. Look at the other earth structure topo maps. Find a map that you think has a shape similar to your earth structure. Describe what is similar about the two structures.
7. Look at the other earth structure topo maps. Find a map that you think has a shape different from your earth structure. Describe what is different about the two structures.

Reflection Questions

Why so you think some earth structures are different from your earth structure? Do you think these other places have the same patterns of earthquakes and volcanoes?

Assessment

What work is assessed?	What are you looking for?
3-D Model	Complete an accurate model.
Figure It Out Questions	Identify and describe changes in elevation of the models. Notice land above sea level and below sea level are the same. Some might notice land under the ocean is at a more constant depth than the land above water. General descriptions of the shape of earth structures. Example: "steep mountains next to deep ocean (trench)" or " high level mountains."

Additional Extension Activity

- Build a 3-D model of the topography of the world…
- Build a topographic map of Mt. St. Helen before the 1980 eruption and after the eruption. The change is quite dramatic.

<u>Activity 2.3: Comparing Earth Structures</u>

In this activity, students use *MyWorld* to compare two earth structures and show any similarities and differences between the two. Students will also capture these maps and write their observations in a word processor.

Engaging your Students

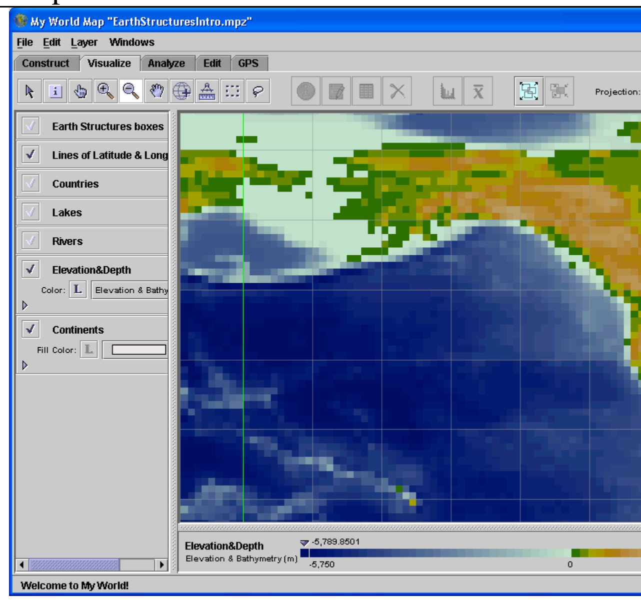
Questions | Maps | Concepts

Launch *MyWorld*

Open the MapView called **"EarthStructuresIntro.mpz"** This is a Map View with Earth Structure Boxes, Lat/Long, Countries, Lakes, Rivers, Elevation & Depth and Continents available.

Show Elevation & Depth and Zoom in to show the Aleutian Islands**.**

How did we describe the Aleutian Islands the other day?
Show students how to capture this map and write observations about the Aleutian Islands.

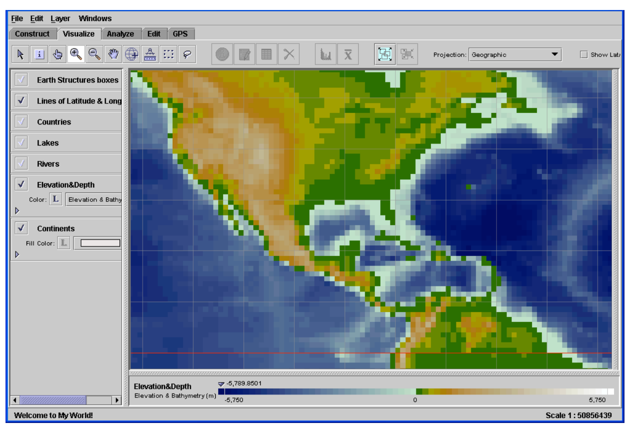


Screen capture

Writing observations

Compare to the Caribbean Islands

How are the Caribbean Islands similar to the Aleutian Islands? How are they different?
Show the students a map of the Caribbean Islands**.** Compare the two earth structures. Show any similarities and differences.



Finding and describing similarities and differences

Show students how to save their work. Demonstrate how to open and close a session at the computer.

Guiding Student Activity

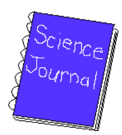
Students will choose two earth structures to compare and capture Students will work at the computers in pairs. . Student will also write their observations in the word processor. You should be guiding students and helping them get started with the file management. Once they learn the routine, the class will run smoothly.

Making Meaning of the Activity

After all small groups have been to the computer to make comparisons, **summarize by asking students if they found an earth structure similar to theirs.** Why do they think it is similar? Do you think these two places have similar earthquake and volcano activity?

Ask the class to sort the earth structures by similar shape. Ask one member of each earth structure team to hold the 3-D model of their earth structure. Ask these students to then group themselves by earth structures that they think are similar in shape. For example: islands could go together, the trenches, etc. There is no right or wrong answer at this point, but let the students discuss why they think certain earth structures are similar. Once all 15 earth structures are grouped, ask the students to discuss in that group why they think their group of earth structures is different from other earth structures. This should bring out some more questions about earth structures and what is happening at each location.

Reflection Question



Do you think the two earth structures you compared have similar patterns of earthquakes and volcanoes? What makes you think that?

Homework

Assign the Reflection Question for homework.

Assessment

What work is assessed?	What are you looking for?
Captured maps with written observations	When capturing, students can compare anything. The main point of the activity is to familiarize students with the routines of capturing, writing observations, and saving their files. This activity does provide opportunity for students to begin to support their ideas with evidence. The maps and observations they capture in this activity can be assessed for <u>supporting ideas with evidence</u> and communicating those ideas.

WHAT'S THE POINT?

Why do you think the earth structures are shaped differently?
Students should still be making predictions about why the earth structures are shaped differently. Students might say, there is different movement happening, or the ground is different at each earth structure. These are all acceptable answers at this stage in the unit. Students will be expected to articulate the role of shape in analyzing the data later in the unit.

Do you think there are differences in patterns of earthquakes and volcanic eruptions? Why or why not?
Students should still be making predictions about how the shape of the land relates to earthquakes and volcanoes. Students might say, Japan is an island and has a lot of earthquakes and volcanoes so all islands must have similar patterns of earthquakes and volcanoes. Another example is: The Andes and the Himalayas have different patterns because they are shaped differently. One is steep and has a trench next to it and the other is a large mountain without the deep ocean next to it.

At this point students are trying to make explanations but they do not have any supporting evidence. The supporting evidence will be expected later in the unit.

What patterns do you predict for earthquakes and volcanoes in your region? What helps you make these predictions?
All student responses should be accepted. Students should be using anecdotal information from the pen pal letters or from their own experiences to predict patterns. Encourage students to describe that supporting evidence.

For your information, different earth structures are the result of the different ways the crust moves. The shape of the land is evidence that the crust is moving. The shape of the land changes with each movement, whether earthquake or volcanic eruption. Later students will use these differences in the shape of the land to find patterns in earthquake and volcano data.

Teacher Reflection

What interesting relationships are students making between the shape of the land and earthquakes and volcanoes?

Are there any preconceptions that stand out? How do you think you will address them or use these ideas to help with other student misconceptions?

Are students trying to connect explanations with observations they have made so far? What are students using as supporting evidence of these explanations?

What do students think is moving during an earthquake?

What do students think is happening during a volcanic eruption?

Name____________________________

Activity 2.1: How High and How Low

Stop and Think Question

Look back at the letter from Kirima Chiqua, the Junior Scientist who lives on one of the Aleutian Islands. How did Kirima describe the Aleutian Islands? How is her description represented on the map?

"The islands are all in a curved line, stretching towards the southwest from the Alaskan peninsula and then curving towards the northwest as it slowly becomes Russian territory.□ There is a volcano called Mount Makushin, which is 1,735 m (5,690 ft) tall… If you ever want to visit, you'll have to come on an airplane because there's no other way to get here.□You could use ships and boats but you have to be an expert navigator since the coasts here are very jagged and rocky. Most of the coastlines around our islands are lined with steep cliffs and mountains.One of the coolest geological features of the area is the formation of new landforms." *These are Kirima's Words*

Reflection Question

Both the GIS and the topo maps show elevation and depth. Describe *how* each map shows elevation and depth.

The GIS uses different colors to represent elevation and depth. A topo map uses lines. Each line on a topo map represents an elevation or a depth. The view of the map is a birds eye view. If there is little space between two lines then the change in elevation was great (steep slopes). If there is a lot of space between the lines then the change in elevation was not so great (slow slopes)

Name___________________________

Activity 2.2: Building 3-D Models

Figure It Out

Looking at your three-dimensional model of your earth structure, answer the following questions.

1. What parts would be hard to climb? Which would be the steepest slopes? Show a classmate.

Answers will vary. *Be sure students are noticing the spacing between the lines to determine how steep the land is.*

2. What parts would be easy to climb? Which would be the least steep slopes? Show a classmate.

Answers will vary. *Be sure students are noticing the spacing between the lines to determine how steep the land is.*

3. What differences do you notice in the shape of the land below sea level and above sea level?

The land above sea level is very similar to the land below. It has hills, valleys, etc. The land under the water is a more flat than the land above water.

4. What observations can you make about your earth structure? Using your model and your topo map, describe your earth structure. Be sure to include the elevation, depth, steepness of the slopes, and shape of your earth structure.

Answers will vary based on the earth structure. The Aleutian Islands would be described as a string of islands off the coast of Alaska. There is a deep trench right next to the string of islands. The topography of Alaska is fairly flat though.

Name___________________________

Activity 2.2: Building 3-D Models

5. Look back at the letter the Junior Science Assistant sent you. How did your pen pal describe the topography of the earth structure? Compare your description to your pen pal's description.

> Answers will vary based on the earth structure. The Aleutian Islands are described as a string of islands that are jagged and rocky. The coast is lined with steep cliffs.

6. Look at other earth structure topo maps. Find a map that you think has a shape similar to your earth structure. Describe what is similar about the two structures.

> Answers will vary based on the earth structure. The Aleutian Islands are similar to Japan is some ways and even Hawaii in some ways. A string of islands. The Aleutian Islands is also similar to the Island chains in Indonesia (Mariana Trench and the Java Trench)

7. Look at the other earth structure topo maps. Find a map that you think has a shape different from your earth structure. Describe what is different about the two structures.

> Answers will vary based on the earth structure. The Aleutian Islands are very different from the Himalayas. The Himalayas is a large mountain range not a little island chain. I am not sure there if there are any volcanoes at the Himalayas either though there are many at the Aleutian Islands.

Name___________________________

Activity 2.2: Building 3-D Models

Reflection Questions

Why do you think some earth structures are different from your earth structure? Do you think these other places have the same patterns of earthquakes and volcanoes?

Answers will vary based on the earth structure. Students should say something about how there might be different earthquakes or volcanoes at different places. Some students may even try to guess which earth structures have more earthquakes.

Name___________________________

Activity 2.3: Comparing Earth Structures

Reflection Question

Do you think the two earth structures you compared have similar patterns of earthquakes and volcanoes? What makes you think that?

Answers will vary based on the earth structure.

Lesson 3
Journey to the Center of the Earth

Students look at models from one of the Junior Scientists to figure out what is moving during an earthquake. Students look closely at the outermost layer of the Earth, the crust, and learn about some of the differences in the interior layers. Students create their own models of the layers of the Earth.

What have students learned so far?
In Lesson 1, students gathered observations about earthquakes and volcanoes, and they learned about earth structures from their pen pals. In Lesson 2, students constructed three-dimensional models of their earth structures and compared them to other students' earth structures. The class also decided that earthquakes and volcanoes tell us that the ground is moving and changing.

Why is it important for students to learn about the Earth's crust?
Earth structures result from things happening in and under the crust. Earthquakes and volcanoes happen as a result of movements in the Earth's crust and changes in the Earth's layers. This information will help students begin to look for patterns in earthquakes and later help them explain how and why the crust moves

Lesson Overview:
Activity 3.1: The Cool Crust
Students explore models of the Earth's crust and interior. Students then focus on drawing a model of the Earth's crust. This model will help students understand what is moving and changing when they observe earthquakes and volcano data.

Activity 3.2: Moving Forward
Students have made observations and explanations thus far in the unit. Now it is time to support those explanations with data. The data will help students improve and justify their explanations of the changes happening at their earth structures. In this activity, students re-cap and review ideas generated by the class and decide what data would support their explanations.

Learning Objectives:

<u>Content</u>

- Earthquakes release energy in the form of seismic waves, which vibrate through the Earth.
- Scientists use these waves to indirectly observe the layers of the Earth.
- The crust of the Earth is cool, but the rest is very hot, hot enough to mold and melt rock.
- The crust is divided into pieces called plates.
- There are two kinds of crust: oceanic (thin) and continental (thick).
- Earthquakes happen where these plates meet and when these plates move.
- The movement causes the crust to change shape (creating earth structures).
- The crust moves when the layers below the crust move and shift.
- The mantle is the layer just below the crust; it is plastic and moldable, like asphalt or putty.
- The Earth also has an outer core, which is fluid, and an inner core, which is solid.

<u>Process</u>

- Draw models to represent conceptual understanding.
- Identify strengths and weaknesses of a model.

Assessment Criteria:

Students will have opportunities to demonstrate misconceptions and preconceptions for these content ideas. Students will be expected to create models that accurately demonstrate the layers, the differences in the layers, and the parts of the crust.

Vocabulary:

crust – the outermost layer of the Earth

geologist – A scientist who studies of the origin, history, and structure of the earth

inner core – a dense ball of solid metal; extreme pressure squeezes the atoms of iron and nickel so tight that they have no room to spread out and become liquid

mantle – the part of the Earth's interior lying beneath the crust and above the core

outer core – the layer of molten (melted) metal that surrounds the inner core

plate boundary – the area where two of the Earth's plates meet

plates – sections of the Earth's crust

seismic wave – a vibration that travels through Earth carrying the energy released during an earthquake

Activity	Suggested Pacing	Student Resources	Teacher Resources
3.1: The Cool Crust	80-100 minutes	o Student Text, pp. 94-99 o Science Journal or 3.1 Worksheets o The Cool Crust Worksheet o Hardboiled egg and plastic knife, per group o Colored pencils or crayons for each student o Large sheet of construction paper for each student	o Lesson 3 Transparency 1 & 2 o Opaque boxes with different objects (see set-up) o Chart paper o Wedge template (optional) o Unpeeled orange (optional)
3.2: Moving Forward	40-50 minutes	o Student Text, pp. 100-101 o Science Journal or 3.2 Worksheets o Sentence strips from previous lesson o Three sticker dots of the same color for each student o Five different colored sticker dots per student	o

Activity Set-Up:

Activity 3.1: The Cool Crust

- Make one hardboiled egg for each group.

Safety Note
Students should be warned not to eat the egg and instructed to wash their hands after the activity.

- Put together opaque containers (i.e. film canisters or shoe boxes) containing different objects that make different sounds (e.g. pencils, ball, penny and a washer, paper clip, nail, ball of paper, water, rubber band, honey, etc.). You will need to decide if you will lead this activity or if students will form small groups to do the activity. This will determine the number of opaque containers needed.
- Make some extra copies of *The Cool Crust* handout for students to improve their models of Earth's crust for homework.
- On the Earth Structures website(http://www.geode.northwestern.edu/pbi/), browse some student samples of drawings of the crust prior to doing the activity.
- You may want to have an orange available to demonstrate the plates of the Earth.
- Decide how students are going to organize their picture dictionaries. See activity for organization ideas.
- If you decide to use the handout, make multiple copies of the Picture Dictionary Page for each student as they will probably have more words than will fit on the page. You will find the Picture Dictionary Page among the handouts for the whole unit.

Activity 3.2: Moving Forward

- Be sure to have the observations and explanations from the other lessons clearly displayed.
- Create two groups of colored sticker dots. The first group should contain enough sticker dots of the same color for all students to have three. The second group of sticker dots should have five different colors, enough for each student to have one of each color. Each color represents a different earth structure: mountain, trench, rift, volcano, and island.

Enacting the Lesson

Activity 3.1: The Cool Crust

Students use an egg to model the interior layers and crust of the Earth. Students then draw and label their own models of the Earth's crust. This model will help students understand what is moving and changing when they observe earthquake and volcano data.

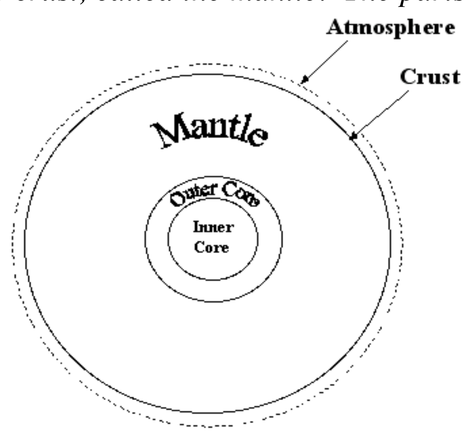
Engaging your students

Brainstorm with the class by asking, *What do you think is moving or changing during an earthquake or volcanic eruption? How can you explain or illustrate what is moving and changing?*

Read Benny's letter together as a class and explore Benny's model of the Earth. After you have read the beginning of the letter, distribute a hard boiled egg to each group of students and introduce the layers of the earth. Use Benny's description but also explain the model by leading a discussion. Below is one teacher's introduction of the layers of the Earth using the model.

Teacher Note: *Sample Introduction*
This is one teacher's introduction of the layers of the Earth using the model.

- **Draw a large circle on the board or overhead. Refer to the egg and the circle simultaneously.** Say*: This egg represents the Earth. On the outside of the Earth is a hard, cool shell called the crust. The inside of the Earth is hot, very hot.*
- **Have the students gently crack the egg without losing any shell.** Say: *These sections or pieces of the shell of the Earth are called plates.*
- **Have the students carefully peel off some of the shell while trying to keep the section whole.**
- **Have the students look at the hardboiled egg inside.** Say**:** *Though not a perfect model, the white of the egg represents the Earth under the crust, called the mantle. The parts of the Earth that are under the crust are very hot, so hot that the rock melts.*
- **Draw a circle inside the circle to represent the mantle.** Your drawing could be similar to the drawing from the *Cool Crust* student worksheet, but it should show the whole Earth.



- **Slice one of the eggs in half and draw a smaller circle inside the circles that you have already drawn.** Say: *Though not a perfect model, the yolk of the egg is similar to the core of the Earth. The core is divided into an inner core and an outer core. The core of the Earth has a solid part and a liquid part, while the mantle is plastic and fluid, like silly putty or hot asphalt.*

Teacher Tip: *More Models*
If students are having trouble seeing the plates of the crust with the egg model, a thick orange peel can be used. Peel the orange in large sections. Like the egg, there are problems with the model. The crust of the Earth is very thin, like that of the eggshell – not like the thick peel of an orange – and the interior of the orange has no correlation to the interior of the Earth.

Teacher Note: *Why do it this way?*
Looking at Benny's model will help students visualize the plates of the Earth. You should also model the drawings for the next part of this activity. Some students have trouble visualizing a cross section of the Earth like the one on *The Cool Crust* handout. The teacher's drawings are to help students transition into drawing their own models of the Earth's crust.

After the class has explored and discussed Benny's model, **students should answer the Stop and Think Questions: The Egg: The Earth** in their science journals or on the handout provided. When students are done, have a brief discussion.

A. How did Benny describe the crust of the Earth? How did he describe what is under the crust?
B. According to Benny's letter, what does he think is moving? What is making it move? Do you agree with Benny? Why or why not?
C. Most models have strengths (things they help explain well) and weaknesses (things they don't explain very well or problems where the model isn't quite right for what it is supposed to show). What do you think about the egg model of the Earth's layers? What are some strengths of the model? What are some of the weaknesses of this model?

Guiding Student Activity

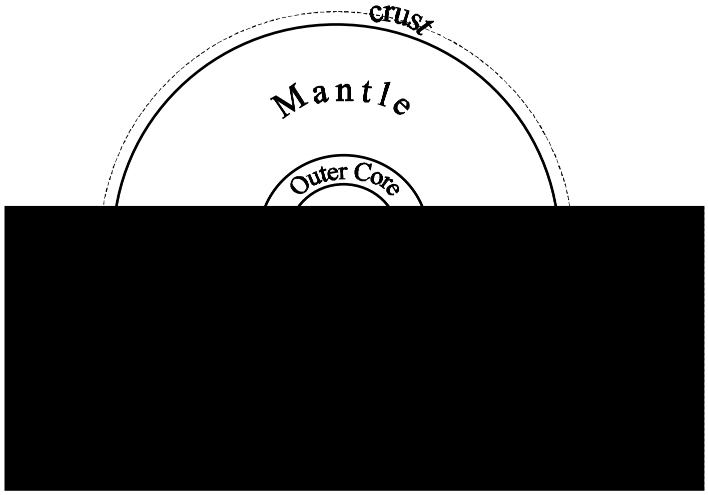
As a class, make a list of the things that students think are in the Earth's crust. Direct the students' attention back to the crust of the *Earth* and ask: *What do you think is part of this thin outer crust of the Earth?*

Collect students' ideas on chart paper or on the overhead. Your list might include: mountains, canyons, valleys, continents, oceans, lakes, trees, dirt, volcanoes, plants, rocks, clouds, and air. Have students record this list in their science journals for later reference.

Help students keep trying to think of more things for the list, using questions like, "What's between the mountains?" Once you have your list, you may want to sort it a little to make it more manageable. Some of the things on the list are part of the crust (mountains), and others are on top of the crust (houses and plants).

Draw the Earth's crust. Distribute the student handout titled *The Cool Crust*. Have students draw and label the structures of the Earth's crust. Students should label their diagrams.

Teacher Tip: *Visualizing the Model*
Some students have trouble with the side view representation of the Earth's layers. They may know what structures are in the crust but have trouble representing them in this view. Since you have the drawing on the board, cover most of the Earth so your drawing looks like the one on the worksheet. Once the class has generated a list of structures in the Earth's crust, choose one or two to draw in order to model how to draw a side view.



Making Meaning of the Activity

Ask students to share their drawings of the crust with another student. Ask: *what do the drawings have in common? Did you both include the same components? Do you notice anything on your partner's drawing that does not make sense to you? Did you notice anything you would want to add to your own drawing?*

Review student drawings. Use the following questions to help students reflect on and improve their drawings. Use student work and ideas to help lead this discussion.

- What happens to the land under the water?
- Where should you put the water on your drawing? Oceans? Rivers? Lakes?
- Is the land all connected?
- Are most of the earth structures we've talked about in class represented on your drawings?
- Is the crust on your drawing broken into pieces (plates)?

Student Misconceptions

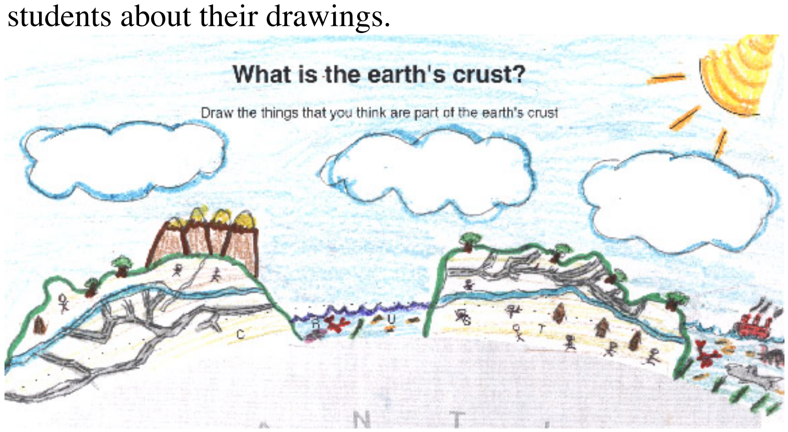
This activity may reveal other student preconceptions or misconceptions. As you circulate, take note of any that would be interesting ideas to highlight for the class. Find ideas that are accurate as well as ones that are inaccurate. Here are a few ideas that may come up:

Misconceptions	Correct Conceptions
• Islands float on water. • There are bodies of water under the land. • The land under the water is all the same depth. • The crust is the same thickness everywhere. • There isn't any land under the water.	• The crust of the Earth changes at the edges of the pieces (plates), so that is where the mountains, volcanoes, and trenches are located. • The land under the water is similar to the land above the water. • The land under the water is connected to the land above water.

One way to address the land/water misconceptions is to discuss what would happen if you poured all the water off the Earth. There would still be land underneath where the water had been. There are valleys and mountains down there too.

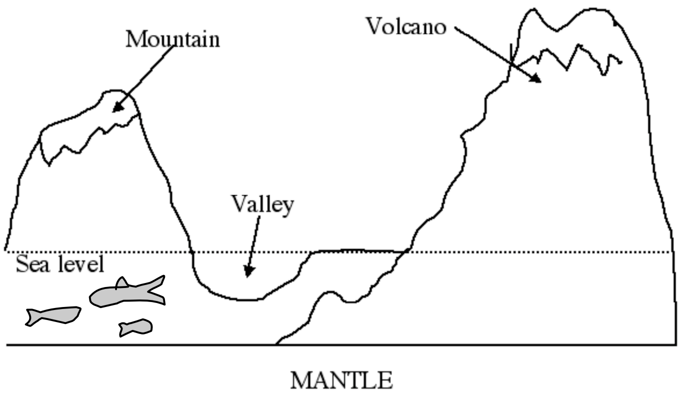
Student Work

Look at some examples of students' crust drawings on the Earth Structures web site (http://www.geode.northwestern.edu/pbi/) to get ideas about what kinds of discussions you might want to have with students about their drawings.



This student's drawing represents many of the earth structures talked about in class, including roads and rivers. It also raises questions: What happens to the land when it goes under the water? What is sea level? What would it be like below sea level, if you could walk under the ocean?

One group of students was having trouble with this activity. The students were all drawing the land floating on water; they were not representing the connectivity of the land. They were also having trouble with the curve of the Earth in the drawing. In response, the teacher gave this group of students the drawing below, some clay, and a clear plastic shoe box and asked the students to build what the drawing represented.



The students quickly figured out what was wrong with the representation. They fixed it and built their models. This stimulated a discussion about water level as well as sea level. Students were then ready to fix their own representations of the Earth's crust.

Summarize the crust drawings by asking students to answer Question A of the *Reflection Questions.*

Ask students to answer **Question A** of the Reflection Questions. After students have had a chance to write their responses in their science journals or on the handout, ask a few students to share their descriptions.

Students should describe the crust as the cool, thin layer of the earth that moves. The crust is divided into plates, and when these pieces move, we have earthquakes. Mountains, valleys, lakes, etc. are all part of the crust; houses, lakes, oceans, plants, etc. are all on top of the crust.

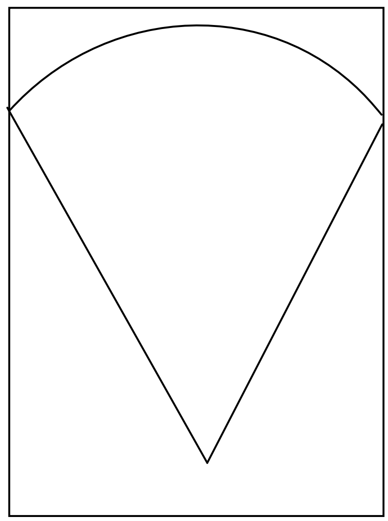
Question B of the ***Reflection Questions*** should be assigned for homework. Have pairs share and respond to each other's letters at the beginning of the next class.

Reflection Questions

A. How would you describe the Earth's crust to your pen pal?

B. **<u>It's Your Turn</u>:** Write a letter back to Benny telling him what you think about his ideas about the moving plates. Your letter should also describe the strengths and weaknesses of his egg model. Draw your own model of the layers of the Earth. Be sure you include labels so that Benny will be able to understand your drawing clearly.

Teacher Tip: *More Structure*
If your students need more structure to create their models, it might help to have all students use the same template. Use a wedge template for the students' drawings. The wedge represents a portion of a cross section of the earth. The curved part is the crust and pointed end of the wedge is a portion of the inner core. Cut out a pattern of a wedge that would fit on the paper and have students trace the pattern. See example below.



Introduce the reading *It's All Cracked Up.* Tell the students that they will read more about the layers of the Earth and then create a model of the Earth similar to Benny's. Introduce the reading by **shaking the prepared opaque boxes** and asking students to write down what they think is in the boxes. Do not reveal the contents of the boxes.

Discuss techniques that students used to figure out what was in each container. Students might say: *It sounded like a pencil rolling. It sounded light and small.* Respond with a question (e.g., How can you measure small and light with sound only?) that will lead to the answer, **indirect observation**. We take what we think we know and make assumptions to come up with explanations. This is what scientists must do to study the forces that shape Earth because they cannot directly observe what takes place in the Earth. You can reveal what is really in the boxes, but point out that scientists cannot open the Earth to directly observe what is happening inside. They can only make assumptions based on the data they collect.

In pairs, ask **students to read *It's All Cracked Up* and answer the *Figure It Out* questions 1-3** that follow. **Question 2** asks students to improve the models of the Earth's layers they drew in their letters to Benny. They are also asked to describe the strengths and weaknesses of their models now.

Teacher Tip: *Model of the Mantle*
The consistency of the mantle is difficult to visualize. How can a rock be fluid and move? A pretty good model is cornstarch and water. Mix equal parts of water and cornstarch. A tablespoon of each for a group of students would be enough, but you could also make one large container. When you push slowly, the mixture is fluid and moves. When you push sharply, the mixture goes hard. This model of the mantle can be visited again later when students talk about the different kinds of movement of the crust, so you might want to keep the mixer in a covered container.

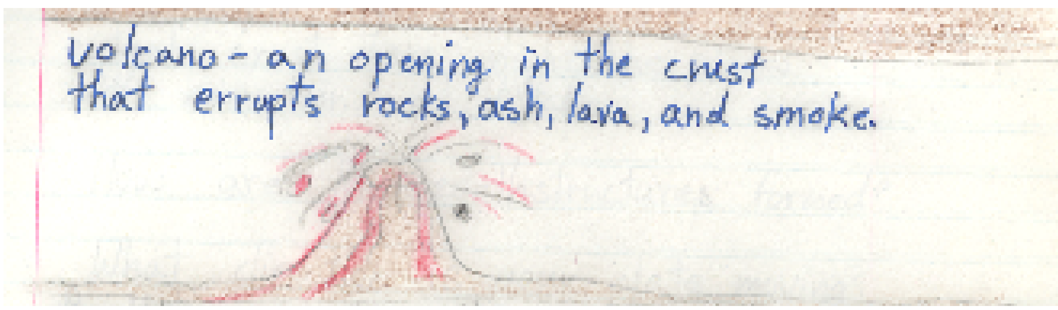
Question 4 asks the students to create a picture dictionary, so a class discussion about what terms should be represented in the dictionary should take place before students do **Question 4**.

Teacher Tip: *Picture Dictionary Organization*
Students will be building these picture dictionaries throughout the unit. There are many ways to organize this collection:

- index cards on a ring
- notebook paper books
- the back of their science journals (turn the notebook over so students are not writing on the spiral and the paper will be set-up the right way to)
- list in their science journals.

Figure It Out

1. What kind of indirect evidence do geologists use to study the structure of the Earth? Why can't they use direct evidence?
2. You learned some new facts about the layers of the Earth. Add these new ideas to the model you drew for Benny. Describe the weaknesses and strengths of the model you have now created.
3. Why do you think we can't feel the Earth's plates moving over a long period of time? Is there ever a time when we can fell the Earth's plates moving for a short period of time?
4. You have heard a lot of terms so far in this lesson. Create a picture dictionary for these terms: earthquake, volcano, plate, plate boundaries, crust, mantle, inner core, outer core, oceanic crust, continental crust, seismic wave. (The class should add any other terms that have come up in class discussion and are important to figuring out what changes are happening in the crust and why.)
   Here is an example of one student's picture dictionary entry for **volcano**:



Reflection Questions

A. What do you think is moving and changing during an earthquake or volcanic eruption?
B. One of the other Junior Scientists described the Earth in terms of a peach. Draw a picture of what this model might look like. What are the strengths and weaknesses of this model?

Homework

This is a two-day activity, so there is homework for each day.

Day 1:

- If student drawings of the Earth's crust need improvement based on the reflection at the end of the activity, have students improve these drawings for homework. Be sure they keep both copies for reflection later.
- Reflection Question: The Egg: The Earth Question B

Day 2:

- Students should complete the *Figure It Out* and *Reflection Questions* that follow the *It's All Cracked Up* reading.

Assessment

What work is assessed?	What are you looking for?
Cool Crust Drawings	Misconceptions and preconceptions Accurate identification and attempted representation of the natural structures of the Earth's crust.
Cool Crust Drawings, improved	Accurate representation of: o Connected land o Water's location and changes in the thickness of the crust o Crust, in pieces
Picture Dictionary	This is the students' first opportunity to draw pictures and define terms in their picture dictionary. Feedback will be needed. Ideas and representations may not be accurate – that is expected. Students will develop these definitions throughout the unit.
Earth Models Drawn for Benny Reflection Question #2 Figure It out question #2 Reflection Question B Letter to Benny Reflection Question B	Content Accurate representation in model of: o cool crust o plates o thin and thick crust o layers of the Earth o description of the layers Process Strengths and weaknesses of model Draw models to represent conc. understanding

Additional Activities

- Read aloud or as a class the classic novel *Journey to the Center of the Earth* by Jules Verne. You could even read just parts of the story, especially the descriptions of the world beneath the surface. After they have read it, students can write their own adventure for the characters in the story. Encourage students to use their imagination. There is also a 1959 movie of the same name that is great substitute if reading the entire book is not an option.

- To find out how geologists know what is in the center of the Earth, students read about the use of indirect evidence. You may choose to have your students do an additional activity demonstrating the process of making inferences based on the use of indirect evidence. A good activity can be found in the AIMS unit *Down to Earth* (ISBN 1-881431-00-2), called

"Submerged Island." Students use a "Mark Twain" method of probing to discover the shape of a submerged island. They use a skewer (sonar stick) and poke it through intersecting points on a piece of grid paper that is placed on the top lid of a box. The island is inside the box. They record the depth each skewer descends and then create a contour map of the island without seeing it. This activity is also a good extension lesson to use as a bridge with the earlier activity of creating topographic maps of students' earth structures.

Activity 3.2: Moving Forward

Students have made many observations and explanations thus far in the unit. Now it is time to support those explanations with data. The data will help the students justify and improve their explanations. In this activity, students recap and review ideas generated by the class and decide what data would support their explanations.

Engaging the Students

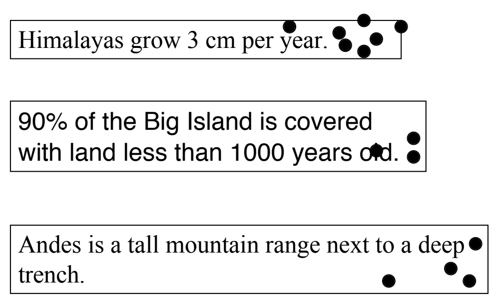
Revisit the mission and ask the class to briefly recap some of the big ideas that they have covered so far. Use the overhead or a piece of chart paper to help students recap some of the big ideas that they have studied so far. Students have read about earthquake and volcano events, made models of the Earth's crust and interior, been introduced to their earth structures through the pen pal letters, and created three-dimensional models of their earth structures. You may want to review some of these terms: earthquake, plate, volcano, crust, mantle, and seismic wave.

> **Teacher Tip:** *Preparation*
> Be sure to have all of the observations and explanations that students have collected and generated so far in this unit posted in the room. These should have been posted on sentence strips or written on chart paper during previous activities.

Guiding Student Activity

Briefly review the student observations that students have posted on sentence strips. Keep all or most of the observations. Duplicates can be weeded out and observations that do not relate directly to the dynamics of the Earth's crust can be eliminated or moved to the side. If there are explanations in this list of observations, move them to the collection of explanations. Spend just a few minutes on this task.

Ask students to quickly identify three observations that they think will be particularly helpful or that they found particularly interesting. Give each student three dots of the same color. Students should then take a few minutes to review the observations posted and when they are ready, place their sticker dots next to the observations on the sentence strips.



Re-visit the earth structures. Say: *Several earth structures have been introduced to us. We have been introduced to mountains, islands, trenches, volcanoes and rifts (or areas that are pulling apart). Do you think these are all changing in the same way? We have several explanations from student introductions of the earth structures.*

Ask students to choose the best explanation for each kind of earth structures. All students should mark what they think the best explanation for a mountain is with a color you have selected, the best explanation for trenches with a different color you have selected, and so on. If a student does not like any of the explanations given, ask him or her to add his or her own explanation to the collection using a sentence strip. Each color sticker represents a different earth structure: mountain, trench, rift, volcano, and island.

Teacher Tip: *Questions*
If you have been collecting and posting questions, you might want to sort through the questions at this time and only keep posted those questions that relate directly to understanding the changes in the Earth's crust.

Making Sense of the Activity

Help the class develop a plan to support their explanations.
Say: *We have observations of the changes in the Earth's crust, and we have possible explanations. What do we do next? What do you need to support your explanations? What data do you think you would need? Where are we going to find these data?*

Teacher Tip: *Setting Expectations*
This plan is simple. We want students to simply ask for earthquake data. In the next lesson, students will be introduced to earthquake data on the Internet. Guide them there.

Teacher Tip: *Why Do It This Way?*
Using *data* is how our observations are different from those in myths of ancient cultures. Data help us support our claims. You should spend a little time here giving examples of claims people make with NO data and why those claims aren't believable without data. Present an example of a claim made without data. Why aren't these claims believable without data? What kinds of data would be needed to support them?

Ex. It is too cold to vacation in South America right now.
Ex. It snows in July in Australia.
Ex. It is warmer at the North Pole than it is at the South Pole.

Reflection Question 

What kinds of patterns do you expect to see in these data?

Assessment

What work is assessed?	What are you looking for?
Class Plan	Collectively, students know that earthquakes happen where the plates meet and when plates move.

WHAT'S THE POINT?

Students have now focused on developing explanations and observations. Students have decided which data they want to support their explanations of the changes happening at the earth structures. Now they need to look at some data to support their explanations.

What changes are happening at the earth structures? *Mountains are growing, the crust is spreading, new land from volcanoes, land shifting*.

What helps you to know these movement and changes are happening? *Earthquakes and volcanoes: earthquakes are movements of the earth. These movements cause changes in the crust*.

Where do you think these changes are happening? *There are a few exceptions, but for our purposes at this point, earthquakes happen at the plate boundaries. Exceptions can be explored later.*

What data do you need to support your explanations? *Earthquake and volcano data will support the explanations. You might also want students to talk about how much data they will need: over what period of time will data be collected? Most students will not have a clear vision of how much data is needed. In the activities that follow, students will first look at one week of current earthquake data and then one year of data and then will use a Geographical Information System called MyWorld to look at up to ten years of earthquake data.*

Teacher Reflection

What do your students understand about Earth's crust?

What kinds of misconceptions do you see in students' work?

What is your plan to deal with those misconceptions?

How are the earth structure teams working? What things are going well? What kinds of problems are they having? What is your plan to deal with these issues?

Describe a time when students were working well together.

Describe a time when students were having trouble. What do you think the root of the problem is? What do you think the solution is?

Name____________________________

Activity 3.1: The Cool Crust

Stop and Think Questions: The Egg: A Model of the Earth

A. According to the notes you read in your student book:
- How did Benny describe the crust of the Earth?

Benny compared the Earth to an egg. The crust was analogous to the shell of the egg.

- How did he describe what is under the crust?

The Mantle: Hot rock that moves like putty or hot asphalt

B. According to Benny's letter, what does he think is moving? What is making it move? Do you agree with Benny? Why or why not?

The plates (giant puzzle pieces of the thin crust)

C. Most models have strengths (things they explain well) and weaknesses (things they don't explain well or problems where the model isn't quite right for what it's supposed to show). What do you think about the egg model of the Earth's layers? What are some strengths of the model? What are some of the weaknesses of this model?

Strengths: model has 3 layers, the layers are approximately the same proportions
Weaknesses: egg is an oval not a sphere, in a hardboiled egg all layers are solid, this is not true with the Earth.

Name____________________________

Activity 3.1: The Cool Crust

Reflection Questions

A. How would you describe the Earth's crust to your pen pal?

Answers will vary.

B. **It's Your Turn:** Write a letter back to Benny telling him what you think about his ideas about the moving plates. Your letter should also describe the strengths and weaknesses of his egg model. Draw your own model of the layers of the Earth. Be sure to include labels so that Benny will be able to understand your drawing clearly.

Answers will vary.

Name____________________________

It’s All Cracked Up

Figure It Out

8. What kind of indirect evidence do geologists use to study the structure of the Earth? Why can’t they use direct evidence?

Geologists study seismic waves to study the inside of the Earth. They can not directly study the inside of the Earth because conditions are too extreme for humans to travel very deep into the Earth.

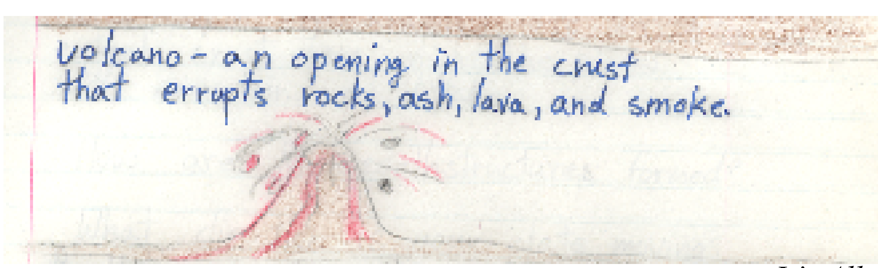
9. You learned some new facts about the layers of the Earth. Add these new ideas to the model you drew for Benny. Describe the strengths and weaknesses of the model you have now created.

Answers will vary.

10. Why do you think we can’t feel the Earth’s plates moving over a long period of time? Is there ever a time when we can feel the Earth’s plates moving for a short period of time?

We can’t feel the plates moving because they move very, very slowly. We can feel them move when there is an earthquake or a volcanic eruption.

11. You have heard a lot of terms so far in this lesson. Create a picture dictionary for these terms: earthquake, volcano, plate, plate boundaries, crust, mantle, inner core, outer core, continental crust, seismic wave. (The class should add any other terms that have come up in class discussion and are important to figuring out what changes are happening in the crust and why.) Here is an example of one student’s picture dictionary entry for volcano:



Name____________________________

It's All Cracked Up

Reflection Questions

A. What do you think is moving and changing during an earthquake or volcanic eruption?

The plates are moving and as a result the crust is changing.

B. One of the other Junior Scientists described the Earth in terms of a peach. Draw a picture of what this model might look like. What are the strengths and weaknesses of this model?

The peach skin is the crust, the flesh of the peach the mantle, and the pit is the core.
Strengths: three layers
Weaknesses: the pit is much bigger than the core really is.

Name ______________________________

Activity3.2: Moving Forward

Reflection Question

A. What kinds of patterns do you expect to see in these data?

Answers will vary.

Lesson 4

Earthquake! Observations from Data

In this lesson students will look at some real-time earthquake data. Real-time earthquake data is posted within minutes of an earthquake, each time one takes place anywhere in the world. Students will draw a plate boundary prediction for their earth structure and look to this real-time data to support or challenge their predictions. The class will then plot one week of data and look for patterns in the data.

What have students learned so far?

In Lesson 3 students learned about the cool crust and the hot layers of the Earth. The cool crust moves because of changes that happen in the hot layers. Students learned that the cool crust is divided into giant puzzle pieces called plates and earthquakes happen where these plates meet (plate boundaries). In the last activity students also decided that earthquake data would be good data to use to look for these plate boundaries.

Why is it important for students to explore earthquake data?

In this lesson students are introduced to the source of the data they will eventually see in the database *MyWorld*. Introducing the students to only one week of data helps them better understand how an earthquake happens and what changes occur in the crust during an earthquake. When students plot one week of data, they also get a glimpse of what it was like to explore data prior to the computer and communications technology we take for granted today. Before these technologies existed, work with seismic data was labor-intensive and data was often incomplete and therefore difficult to analyze.

Lesson Overview:

Activity 4.1: Real-Time Observations of Data
Students explore earthquakes by looking at live earthquake data from the USGS website. Students view the most recent earthquakes, within the last hour, day, and week, and learn how earthquake data is collected and recorded. Students will then read about two famous earthquakes and learn more about what happens during an earthquake and how earthquakes are observed and reported.
Activity 4.2: Plate Boundary Prediction
Students make a blind prediction on a world map of where they think the plate boundaries are located for their earth structure.
Activity 4.3: Plotting Latitude and Longitude (OPTIONAL)
Students review plotting of latitude and longitude to prepare for the next activity.
Activity 4.4: Plotting and Analyzing Earthquake Data
Students download current earthquake data from the USGS website and plot the data on a class map. Students then look for patterns in the data and identify places where they need more data.

Activity 4.5: "The Restless Earth" Video
Students watch a video to confirm some of the patterns that they might have seen in the data.

Learning Objectives:

Content

- Earthquakes happen every day somewhere but not everywhere.
- Earthquakes are relatively short events that happen in groups at locations where the plates are moving or where volcanoes occur.
- Earthquakes tell us the plates are moving
- Earthquakes happen at plate boundaries.
- Earthquakes are measured using magnitude and intensity.
- Geological conditions and depth can affect the results of the earthquake.
- Earthquakes, especially large ones, lead to more quakes and aftershocks.

Process

- Students continue to develop observations and explanations.
- Students begin to develop support for their explanations.
- Students look for patterns in point data on map.

Assessment Criteria:
Students understand that earthquakes are indicators of movement and that earthquakes happen at plate boundaries. Other content ideas are added to the class conversation. Students will look for and describe patterns in point data plotted on maps. Students should be encouraged to make explanations be all explanations should be accepted. Students should also be asked to support explanations with data though this may be a new skill that will require your feedback.

Vocabulary:

aftershocks – smaller earthquakes that occur near the epicenter after a large earthquake, caused by adjustments in the rocks after the major earthquake

equator – the imaginary circle around the earth's surface at equal distance from the poles; divides the Earth into the Northern Hemisphere and the Southern Hemisphere

epicenter – the point of the Earth's surface directly above the focus of an earthquake

focus – the point of origin of an earthquake

intensity – the effects of an earthquake as measured by the amount of damage it produces for people, buildings, and the Earth's surface

latitude – the distance north or south of the Earth's equator

longitude – the distance on the Earth's surface, measured east or west from the Prime Meridian at Greenwich, England

magnitude – a measure of the amount of energy released by an earthquake, as indicated on the Richter Scale

prime meridian – the zero meridian (0°), used as a reference line from which longitude east and west is measured; passes through Greenwich, England

Ring of Fire – an extensive zone of volcanic and seismic activity that coincides roughly with the borders of the Pacific Ocean

seismic waves – energy that radiates outward from the focus; there are two types of seismic waves: surface waves and body waves

surface waves – seismic waves that travel along the outer layer of the Earth

body waves – seismic waves that travel through the Earth's interior

Activity	Suggested Pacing	Student Resources	Teacher Resources
4.1: Real-time Observations of Data	40-50 minutes	o Student Text, pp. 102-113 o Science Journal or 4.1 Worksheets	o Computer o Internet connection o Computer projecting capabilities o
4.2: Plate Boundary Prediction	15 minutes	o Student Text pp. 114 o Small World Map Worksheet, each student o Science Journal or 4.2 Worksheets	o Globes o Transparency of Small World Map
4.3: Plotting Latitude and Longitude (OPTIONAL)	30 minutes	o Student Text pp. 115-116 o Science Journal or 4.3 Worksheets Atlas/world map o Small World Map Worksheet, each student	o Maps
4.4 Plotting and Analyzing Earthquake Data	60 minutes	o Student Text, pp. 117-118 o Small World Map Worksheet, each student o Science Journal or 4.4 Worksheest o Picture Dictionary	o *Big World Map* o Map of the world, one per group o Small dot stickers o Computer o Internet Connection o Projecting Capabilities o Lesson 4 Transparency 1
4.5 Restless Earth Video	40 minutes	o Student Text, pp. 119-120 o Science Journal or 4.5 Worksheet	o Video, *The Restless Earth*, o TV and VCR

Activity Set-Up:

Activity 4.1: Real-Time Observations of Data

- The USGS website has great background information, such as the FAQ. Surf around prior to class to become familiar with the site and perhaps find other areas you'd like to visit if time permits.
- You will need to project from a computer connected to the internet or gather groups of students around one computer. If using small groups, you can have some students gather around the computer while others read *Ground Shaking* and answer the related questions. Have the USGS website set up to display a real-time map in a region that would most likely have an earthquake today. The USGS real-time data can be accessed from the Earth Structures and Processes website (www.geode.northwestern.edu/pbi) or by doing a search.
- Decide if you are going to download earthquake data before class or if students will download the earthquake data during class in Activity 4.4. If you are going to have it done before the class does Activity 4.4, you could instruct students how to download this data at the end of Activity 4.1.
- There are a lot of terms introduced in this lesson. Be prepared to add these words to your word wall: fault, focus, epicenter, seismic waves, seismograph, magnitude, intensity, depth, and aftershocks.
- Locate San Francisco, California; New Madrid, Missouri (near St. Louis); and the Fiji Islands. Students will read about these three places in the reading, *Ground Shaking*. In the pre-reading discussion, these places are identified. Use the *Big World Map* to share these locations with students.

Activity 4.2: Plate Boundary Prediction

Gather a few globes from other classrooms. The globe in the best representation of the Earth.

Activity 4.3: Plotting Latitude and Longitude (OPTIONAL)

Decide if students need to practice finding places using latitude and longitude. This skill could be reviewed in another class, such as social studies. If you decide not to do this activity, you can use the techniques listed in Activity 4.4 to help quickly review the skill within the task of plotting earthquake data.

Activity 4.4: Plotting and Analyzing Earthquake Data

- Decide if you are going to have students print their own earthquake data or if you will print the data before class. Printing the data before class can be less time consuming and you can better control the data distribution. See the Student Text for directions on printing the data from the USGS website.
- Display the *Big World Map*. Students will need to plot data on this map.
- You will need several copies of world maps. These can be political maps but should be large enough for a group of students to gather around. Ask a social studies or geography teacher for assistance.
- Students will need small dot stickers for plotting earthquakes on group maps and then on the large class map. On the class map, plot all the earthquakes in one color. A different colored dot will be used later for volcanoes.

Activity 4.5: Restless Earth Video

- Preview the student questions and the video prior to class to familiarize yourself with where you might want to stop the film and what key ideas you wish to stress to your students. You might even want to prepare a video viewing guide to help the students focus.
- The video recommended here is called the *The Restless Earth*, by Bill Kurtis Productions. You can use any video that reinforces the ideas of looking for patterns in earthquake data. Be sure to preview the video so plate boundaries are not given.

Enacting the Lesson

Activity 4.1: Real-Time Observations of Data

You will guide students through the United States Geological Survey (USGS) website while addressing students' understanding of earthquakes. USGS is an organization that watches and reports changes in Earth's crust, atmosphere, living organisms, and resources.

Engaging your students

Read *Think About This* in the Student Text to encourage students to think about an earthquake experience. Ask: *Has anyone experienced an earthquake? What is it like?* Especially if you live an area that does not usually have earthquakes, use the descriptions in the *Think About This* section to help students imagine what experiencing an earthquake might be like. Is the experience the same for everyone? Can we think of examples that we have experienced that we can use a reference (e.g. a truck moving outside, a building being demolished)?

Teacher Note: *Simulating an Earthquake*
To simulate an earthquake, you will need a very large rock and a piece of cardboard to protect the floor. Send a few students to different parts of the school, for example, down the hall or right outside the doorway. When everyone is in place, drop the large rock. Ask students to describe what they experienced. Ask students who were farther away if they knew when the earthquake happened. Ask students who were close by if they knew when the earthquake happened. Have them describe their experiences. What did they observe? Did they observe vibrations or shaking?

This can be especially helpful if your students have never experienced an earthquake.

Get students thinking about earthquakes. Say: *Today in class we will look at earthquake data in real-time. Real-time earthquake data is posted within minutes of an earthquake happening each time one occurs in the world.* Begin a class discussion by asking some questions. You want to get the students thinking about the following:

a. Where do most earthquakes happen in the world?
b. When and where was the last earthquake in the US?
c. How many earthquakes happened in your home state this week?
d. How many earthquakes happened in California this week?
e. How big are most earthquakes? How deep are they?

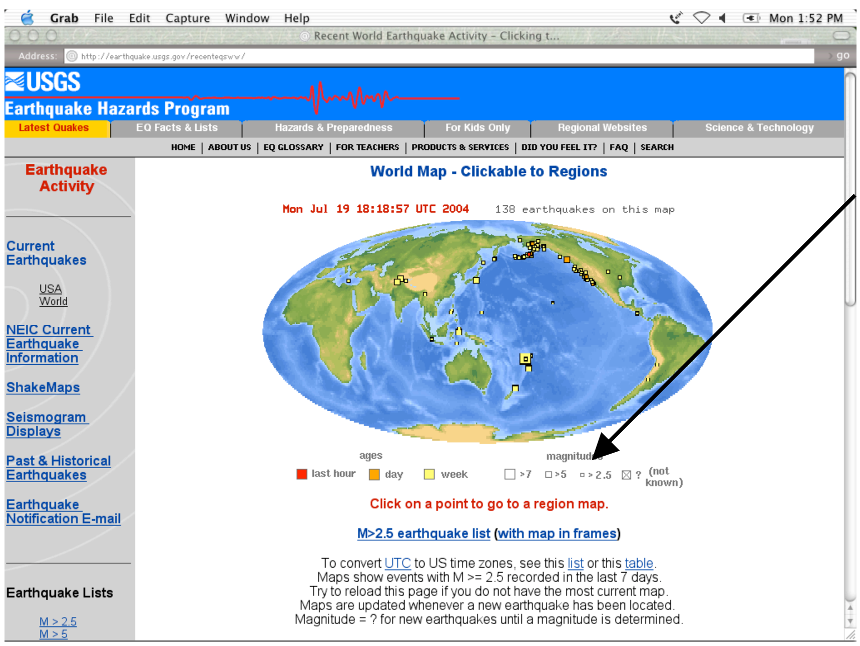
Teacher Note: *Student Text*
The discussion questions above and the ones that follow are also found in the Student Text. They may be used if a student is absent and you want him or her to complete the activity. Otherwise students should not be looking at the questions as you lead the discussion.

Explore some real-time data on the USGS web-site. Display the real-time data on the USGS web-site. The USGS website shows the most current earthquake data available in the world. It is refreshed every time a new earthquake is located and/or every hour. Explain that earthquakes happen all the time in many places, both in water and on land.

f. *Why don't we hear about earthquakes everyday?* They may be very small earthquakes, the area may not be heavily populated, so the quake isn't "newsworthy", etc.

> **Teacher Note:** *Resources*
> If you do not have the ability to project a computer screen to the whole class, have the students in groups at desktop or laptop computers navigate the site at your direction. If you do not have enough computers for the students to view the monitors comfortably, have half the class begin the *Ground Shaking* reading in their student books and complete the review questions, then switch groups.

g. *Where was the last recorded earthquake? How large was it? Do you think it made the news? Why or why not?* Answers will vary depending on data.



Here the color of the box tells you if the quake was within the last hour, day, or week. The size of the box tells you the magnitude of the quake.

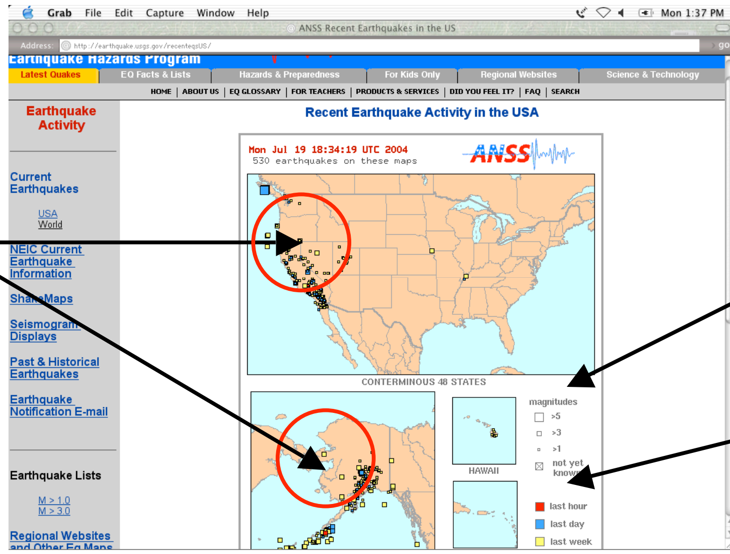
Look at recent earthquake data in the United States.
More than likely there has been some recent earthquake activity in the US over the last week. Click above "World" and select "USA".

Here the students will probably be amazed at how many earthquakes have taken place within the last few days or even the past hour. Most will probably be less than a magnitude of 3.

h. *Where in the United States was the last recorded earthquake? How large was it? Do you think it made the news? Why or why not?* Answers will vary depending on data.

If you are lucky, an earthquake might pop up while you are displaying the image to the class.

Click on an area with the most recent earthquake. California and Alaska are usually safe bets.



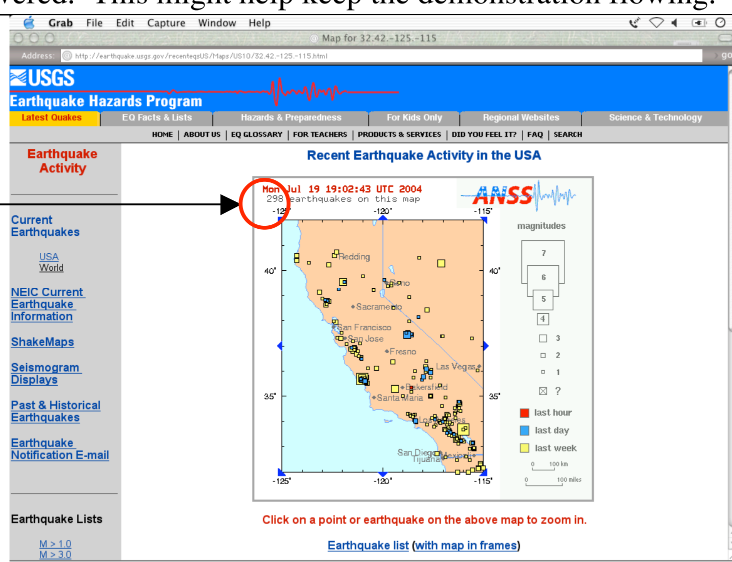
Magnitude

Time

You will get a magnified image of that area. The sizes of the boxes are drawn to show the magnitude of the earthquake. The color indicates when it occurred.

Teacher Tip:
During the whole class discussion, give kids sticky notes to write down questions they have that are not answered. This might help keep the demonstration flowing.

This tells you how many earthquakes had been recorded during that week on this map.



i. *Does the number of recorded earthquakes surprise you? Did you hear of any of them on the news recently? What makes the reporting of earthquakes* *nationally newsworthy?* Students will probably say how big the earthquake is and if it causes any damage or injures people.

Continue the discussion about earthquake data.

j. *How are earthquake data recorded?*

Show students a list of earthquakes. Orient them to the different headings: Magnitude, Date, Local Time, Latitude and Longitude, Depth, and Location.

	MAG	DATE y/m/d	LOCAL-TIME h:m:s	LAT deg	LON deg	DEPTH km	LOCATION
map	1.0	2004/08/26	10:20:28	37.507N	118.826W	2.4	14 km (9 mi) WSW of Toms Place, CA
map	1.8	2004/08/26	09:24:27	35.282N	117.098W	0.8	21 km (13 mi) WSW of Goldstone Lake, CA
map	2.3	2004/08/26	09:04:17	34.800N	116.264W	6.2	13 km (8 mi) NW of Ludlow, CA
map	2.0	2004/08/26	08:33:10	35.149N	118.667W	9.4	3 km (2 mi) SW of Bear Valley Springs

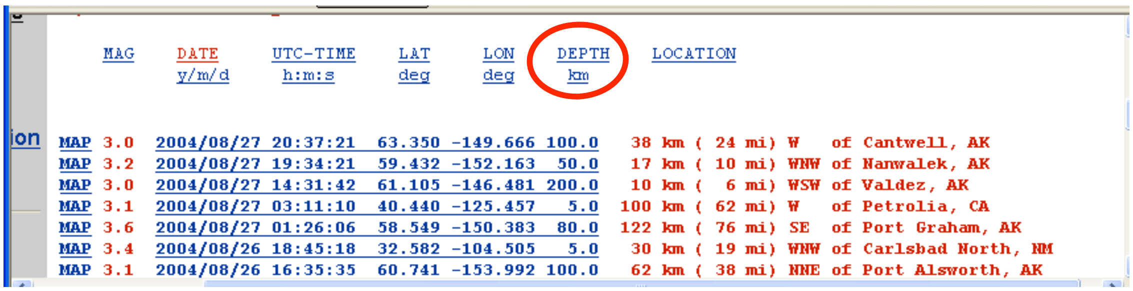
Explore differences in magnitude. On most of the maps, differences in the magnitude of earthquakes is displayed using different size boxes.

k. *What does the magnitude of an earthquake mean?* Magnitude is the "strength" of the earthquake. It is a number that characterizes the relative size of an earthquake. Magnitude is based on measurement of the maximum motion recorded by a seismograph. We generally use the Richter Scale to measure magnitude. Earthquakes with magnitudes 1 or 2 are not felt, 3 to 4 are sometimes felt but there is little or no damage, 4 to 6 are always felt and there is often minor damage, and larger than 6 are always felt and there is much damage and devastation.

l. *How does magnitude vary?* Show students a map and/or a list of earthquakes. Students should notice the differences in the magnitude numbers. Below many of these real-time maps, there is an option for M>3 or M>1. Students should see that most earthquakes are small, not felt, and cause little or no damage.

Continue on to discuss depth.

m. *What does the depth of an earthquake mean? How does depth vary?* Show students an example of a list of earthquakes. Students should notice that the depth number varies. The depth shows the place where the earthquake happens. As a reference, the crust of the earth varies in thickness between 5 km and 70 km. Notice that earthquakes happen at varying depths and some happen below the crust in the mantle. On the list shown below, there are two such earthquakes: 100 km and 122 km below the surface of the earth.



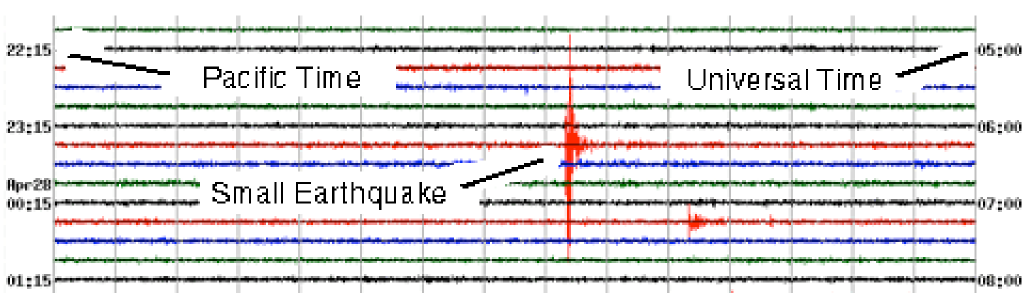
	MAG	DATE y/m/d	UTC-TIME h:m:s	LAT deg	LON deg	DEPTH km	LOCATION
MAP	3.0	2004/08/27	20:37:21	63.350	-149.666	100.0	38 km (24 mi) W of Cantwell, AK
MAP	3.2	2004/08/27	19:34:21	59.432	-152.163	50.0	17 km (10 mi) WNW of Nanwalek, AK
MAP	3.0	2004/08/27	14:31:42	61.105	-146.481	200.0	10 km (6 mi) WSW of Valdez, AK
MAP	3.1	2004/08/27	03:11:10	40.440	-125.457	5.0	100 km (62 mi) W of Petrolia, CA
MAP	3.6	2004/08/27	01:26:06	58.549	-150.383	80.0	122 km (76 mi) SE of Port Graham, AK
MAP	3.4	2004/08/26	18:45:18	32.582	-104.505	5.0	30 km (19 mi) WNW of Carlsbad North, NM
MAP	3.1	2004/08/26	16:35:35	60.741	-153.992	100.0	62 km (38 mi) NNE of Port Alsworth, AK

Content Note: *Estimating Depth: Kilometers and Miles*
The depth of earthquakes is measured in kilometers. One kilometer is a little more than 1/2 of a mile or 1 mile is a little less than 2 kilometers (1 mile = 1.609344 km).

Wrap up the discussion.

n. *How is this earthquake data collected?* Explain to students that earthquake data is recorded all over the world. If there is an earthquake in California a seismograph in China can record that earthquake. Seismographs are also recording the movement locally.

Show students samples of seismograms for recent earthquakes. Explain that earthquakes send out waves when they happen. Scientists record and analyze these waves. Time is recorded in the local time (i.e. Pacific Time) and Coordinated Universal Time (UTC).



Content Note: ***Measuring and Comparing Time***

Earthquakes are reported using Coordinated Universal Time (UTC). Scientists do this so data can be compared around the world. When the sun is at high noon in Greenwich, England, it is 12:00 UTC.

Here is an example.
If an earthquake happens at 12:00 UTC on December 31 (high noon in Greenwich, England), what is happening in the rest of the world?

Location	Local Time Zone	UTC conversion	Local Time
Greenwich, England	Greenwich Mean Time		12:00 hours or 12:00 pm (high noon)
New York, New York	Eastern Standard	-5 hours	07:00 hours or 7:00 am (mid-morning)
Chicago, Illinois	Central Standard	-6 hours	06:00 hours or 6:00 am
San Francisco, California	Pacific Standard	-8 hours	04:00 hours or 4:00 am
Hawaiian Standard	Hawaiian Standard	-10 hours	02:00 hours or 2:00 am (very early morning)
Baghdad, Iraq	USSR, Zone 2	+3 hours	15:00 hours or 3:00 pm (mid-afternoon)
Hong Kong, China	China Coastal	+8 hours	20:00 hours or 8:00 pm (mid-evening)

Teacher Tip

If you are interested in exploring UTC more with your students, display a 24-hour clock set to UTC time in your classroom.

Making Meaning of the Activity

What will this data tell you? Tell the students that over the next few days they will be plotting recent earthquakes on world maps and looking for patterns in that data. Remind students that earthquakes happen at plate boundaries. Every time there is an earthquake, scientists use that as one piece of data. The students will be collecting this data to predict where these plate boundaries are.

- *How much data do you think we will have to plot in order to predict plate boundaries? How many earthquakes do you think it will take to see some patterns?* Answers will vary. Most students will really have no idea. Some might base their answers on the data they observed in this activity.

Teacher Note: ***Science Content***
Some plate boundary patterns will be evident with data from a few days to a month to a year; a strong pattern can be evident in that short a time. Other plate boundary patterns will need several years of data for a weak pattern to emerge. Still other plate boundaries are still debated between scientists because there is little data to make predictions.

Show students what data the class is going to plot the next few days. You can use the data below the World Map to print up lists of M>2.5 earthquake data for the world. This will be one week of earthquake data not including the very small earthquakes. You could at this point ask a student volunteer to download this data prior to the next class so you will have time to divide up the data and make appropriate copies for Activity 4.4.

Reflection Questions

Ask students to reflect on the activities of today using the reflection questions for this activity. The reflection questions students will answer are:

A. What one place that recently experienced an earthquake surprised you? Why was that surprising to you?
B. What questions did you ask yourself about earthquakes and where they happen as you looked at the USGS website?

Conclude by introducing the homework reading, *Ground Shaking*. Introduce the reading by telling students that they will be reading about two historic earthquakes, one that destroyed a city and one that changed the direction of the Mississippi River. Using a map, ask students to locate San Francisco, California and New Madrid Missouri on the *Big World Map*. These two historical earthquakes happened in these two places. Ask students which city was destroyed. Tell students that they will also read about a more recent earthquake that happened in Fiji. Locate Fiji on the *Big World Map*. Ask*: What is it like to experience an earthquake?* Have the students brainstorm ideas or share experiences to help introduce the reading.

Teacher Tip: *Explore USGS more*
If your students have the opportunity, the USGS web-site is a great place for students to explore independently. Encourage students to explore this site during library/media center time or computer time. Inform the other teachers that this is site that students will be working with.

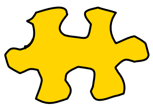
Teacher Tip: *Vocabulary*
There is a lot of new vocabulary in this lesson. Add the new words to the class word wall. Some possibilities are: seismograph, magnitude, intensity, depth, epicenter, focus, aftershocks, fault, and seismic waves.

Teacher Note: *Reading Vocabulary*
Some words in the *Ground Shaking* reading may be unfamiliar to or problematic for students. You may want to either review these with the students or do a pre-reading activity. These words include concussion, tremblor, imperceptible, sediment, and glaciation.

Homework

Students should read the *Ground Shaking* article in their student books and answer the *Figure It Out* Questions that follow.

<u>Figure It Out</u>



The *Figure It Out* questions that students answer are the following:

1. Describe what happens during an earthquake.
2. Describing the tremors after the great San Francisco Earthquake of 1906, U.S. Weather Service forecaster Alexander McAdie wrote, "They will come at greater intervals and grow weaker until they become absolutely imperceptible." Write this sentence in your own words.
3. Reread this part of the the first 9-1-1 recording from the Lom Prieta earthquake:

   Caller: It's tore up! Everything's tore up, should I take my kids outside?

   Dispatcher: Yeah, that would be a good idea because here comes another one!

   Do you think the dispatcher gave the caller good advice? Explain.
4. How are earthquake data collected?
5. What factors might affect how destructive an earthquake is?
6. Why is it easier to predict **where** an earthquake will occur than **when** it will occur?

Assessment

What work is assessed?	What are you looking for?
Student Reactions during discussion	**<u>Content</u>** Students have sense about where and how often earthquakes happen. Earthquakes are indicators of movement. Earthquakes happen at plate boundaries.
Figure It Out Questions	Geological conditions and depth affect earthquake results. Earthquakes are short events that have aftershocks that follow.

Activity 4.2: Plate Boundary Prediction

After reviewing their descriptions of an earthquake event as a class, students will make predictions of where the plate boundaries for their earth structures are located.

Engaging Student Activity

Review the *Figure it Out* questions from the *Ground Shaking* reading. Question 2 and Question 3 may be difficult for the students but are getting at important ideas. **Question 2** describes the aftershocks of an earthquake; they become farther and farther apart until the quakes are so small that people cannot feel them anymore. Depending on the earthquake, these aftershocks can go on for minutes, hours, days or months. **Question 3** asks students to think about what to do during an earthquake especially if they have never experienced one. In the Midwest, where tornadoes are common, people are told to stay inside or go to the basement. This way they will not be hit by flying debris. In contrast, during earthquakes, the advised strategy is to move under a stable object like a table or doorway or go outside away from falling objects and collapsing walls. Look at *Think About This* box at the start of this lesson for more descriptions that talk about what to do in an earthquake.

Help students connect earthquakes with plate boundaries. Remind students that earthquakes occur at plate boundaries. Tell the students that they are now going to predict the plate their earth structure sits on. After they have made their predictions, students will look up earthquake data to refine them.

Guiding Student Activity

Label the world map. Distribute a copy of a world map to each student. Have the students label the following on their maps:

- North, South, East, West
- All of the oceans and continents
- The Equator and Prime Meridian
- The lines of latitude (90 S – 90 N)
- The lines of longitude (180 W – 180 E)

Teacher Tip: *Time Saver*
If time is an issue, and your students are familiar with these labels, label the latitude and longitude on the maps before you photocopy them.

Students should label the coordinates of their earth structure.

Students predict the plate boundaries. Instruct students to draw where they believe the plate boundaries are for the plate on which their earth structures sit. Remind them that plates are complete pieces, like the piece of shell from the hardboiled egg in Activity 3.1. Each piece may be irregularly shaped, but it has no beginning or end.

Student Misconceptions
Students' first predictions might be based on the continent outlines; they might be very small circles around their earth structures or the region of their earth structures; or they might be very big boxes or circles. Don't discuss whether these predictions are wrong or right, but have students explain how they came up with their predictions.

Making Meaning of the Activity

Ask students to explain their predictions. On the reverse side of their prediction maps, ask students to explain what supported their predictions.

Wrap up the activity. Ask students if any questions came up while they were making their predictions. Tell students that in the next activity they will collect and plot more earthquake data to support their predictions. Students will then revise their predictions after reviewing some more data.

Teaher Hint: *Save Maps*
Save the plate boundary predictions for the end of the unit for the students to refer back to throughout the rest of the unit. Students should date them as they will make several predictions throughout the unit.

Students Conceptions: ***Plates***
Students might wonder how big a plate is? How many plates there are in the world or in their region? Are there plates under water? These are all great questions. Do not answer them but add them to your collection of questions. Encourage students to share their ideas but do not settle on an answer. Let the data answer the questions. If these questions do not come up you may want to bring them up.

Reflection Questions

Answer the reflection questions. Ask students to reflect on the activities of today using the reflection questions for this activity. The questions they will answer are the following:

A. Were there any places you were pretty sure about? Why were you pretty confident that was a boundary? Are there any places you were unsure about?
B. What information is missing that might help you be more sure?

Teacher Tip: *Finding Maps*
If some students find a picture showing the plate boundaries, ask them to put it away for now and not look at it for the next few days. Plate mapping will be more interesting that way, and they can check their predictions later against the picture in the book. Point out that each diagram of plate boundaries that you find has some different lines – even the experts disagree!

Homework
Students should complete the reflection questions for Activity 4.2.
(Optional) If your students need the review, assign Activity 4.3: Plotting Latitude and Longitude (Optional).

Assessment

What work is assessed?	What are you looking for?
Plate boundary prediction	Encourage students to describe he evidence they are using. There is not a right or wrong answer here, but an opportunity to find out students preconceptions.

Activity 4.3: Plotting Latitude and Longitude (OPTIONAL)

Students are given either the names of locations or the coordinates of the location on the student worksheets. They need to find either the latitude or longitude of the location or the name of the location with given coordinates using a world map.

Alternatives

- Have each student write down a "secret location" using latitude and longitude coordinates only. Have students trade with a partner, who then tries to figure out what the location is.
- Ask the Social Studies teacher to review latitude and longitude with the students using this activity or others.
- Just jump into Activity 4.4: Plotting Earthquake Data and have the students plot the data; then address student needs on the spot.

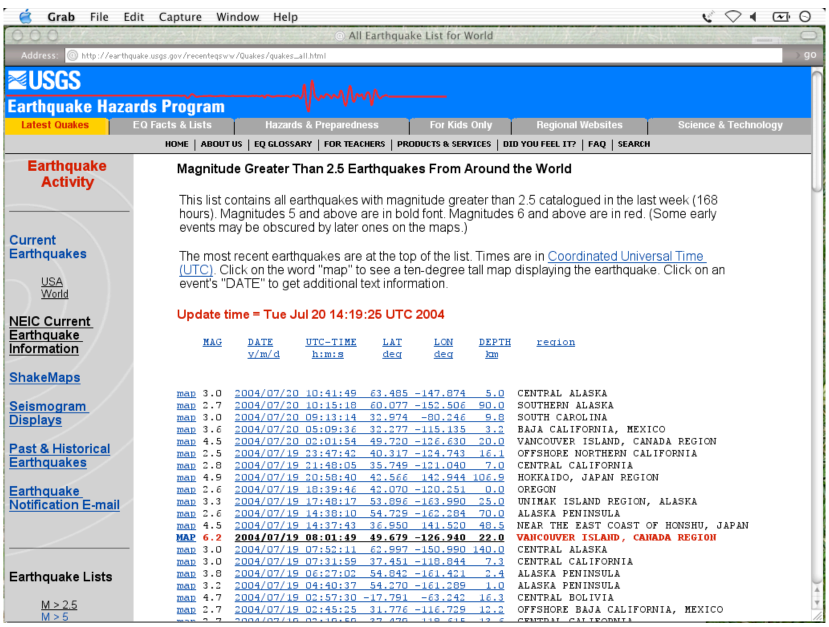
<u>Activity 4.4: Plotting and Analyzing Earthquake Data</u>

The class plots one week of current earthquake data downloaded from the USGS web site. Students will then look for patterns in the plotted data to support their plate boundaries predictions.

Engaging Student Activity

Orient the class to the Big World Map and the ways that lines of latitude and longitude are represented in the earthquake data. Show the class a sample of earthquake data using the overhead projector. Students should notice that the latitude and longitude are numbered with positive and negative numbers.

- ***Positive numbers of latitude are north of the <u>Equator</u> and negative numbers of latitude are south of the Equator.***
- ***Positive numbers of longitude are east of the <u>Prime Meridian</u> and negative numbers are west of the Prime Meridian.***



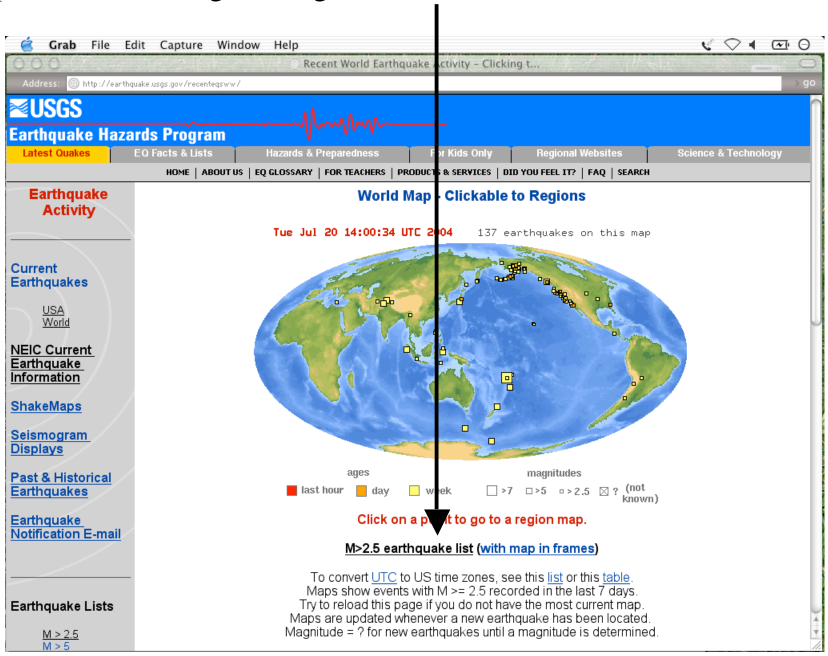
Notice the longitude lines to the West are labeled with a negative number.

Mark the latitude and longitude of the Big World Map. Using a marker, number the lines of latitude on the **Big World Map**. (Note: They should be numbered already in a small font. Write larger numbers so students can see the numbering.)

> **Important! Teacher Tip**: *Downloading Earthquake Data*
> To save class time, download the earthquake data from the USGS website before class. Photocopy the data and divide it up into manageable chunks for each group in your class. Distribute the data to the groups rather than having them download the data themselves. You shared the source of these data in Activity 4.1.

Download global earthquake data. Direct students to go the website they previously visited that shows a world view of the most recent earthquakes:

Click on the "M>2.5 earthquake" list under the world map. This will list all the earthquakes with a magnitude greater than 2.5 recorded in the last week.



Guiding Student Activity

Print/Distribute the list of earthquakes and world maps to each group of students. Each piece of data represents an earthquake. Depending on how active the Earth has been in the past week, the list of earthquakes could end up being several pages long. Divide up the data among each group of students so all the earthquakes for the past week get plotted.

Distribute a world map and some small dot stickers to each group of students. These maps can be political maps of the world. Eventually all the class data will be plotted on the *Big World Map*. Having students plot their groups data on smaller maps at their tables helps ease congestion around the *Big World Map*.

Teacher Tip: *Latitude and Longitude*
If you wish to review latitude and longitude and check student understanding and ability, have all groups plot the first few earthquakes on the list. As students are working ask individual students to plot earthquake data to check their ability to plot using latitude and longitude.

Have groups plot earthquake data on maps. Students should begin to plot the data on their small blank maps. The USGS list also provides the region so students know where to start looking. This also helps you scan quickly to see if they are on the right track.

Once each group has plotted the data assigned to it, students can go up to the large class map and plot the same data. They should place a sticker over the coordinates that match the data. By the end of class, you should have all earthquakes consolidated on the large class world map, and all students should have their portion of the list plotted on their map.

> **Alternative**
> In terms of logistics, you may want the students to go in pairs up to the class map and plot a few earthquakes from their list. You can assign the data by region so each pair goes to a different area on the map. While students are cycling through this, those at their seats can work on the small maps.

Making Meaning of the Activity

Lead a class discussion to **help the class analyze the one week (168 hours) of earthquake data** plotted on the *Big World Map*. Use the following questions and possible responses to help students describe patterns in the plotted earthquake data. These questions are in the Student Text also.

What patterns do you see in the data?
- Clusters of earthquakes around Northern California (or someplace else)
- Lines of earthquakes near the continent borders
- A wiggly line of earthquakes down the middle of the Atlantic Ocean
- A ring pattern of earthquakes surrounding the Pacific Ocean
- *Encourage students to come up and show the patterns they are seeing. Watch for students that use too few earthquakes for a pattern.*

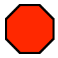
What do you think these patterns tell you?
- Where the plate boundaries are
- Where future earthquakes will probably happen

Where is there a lot of earthquake data plotted?
- It depends on the data. For one week of data, there should be clusters of data around the map because when one earthquake happens in a region others follow shortly after. So there will be areas without any earthquakes and others with many earthquakes.

Where are there few earthquakes plotted?
- The middle of the ocean
- In Antarctica or the Artic Circle
  These regions can be deceiving due to the map projection. There are earthquakes in both places, but the map projection spreads the data points out. This idea is better addressed when using the data visualizer *MyWorld*.
- In Africa, in Russia, in Colorado
  It depends on the data, but some regions are just not very active, or there aren't any fault lines there so there won't be earthquakes.

Where did earthquakes occur that surprised you?
Where did you expect to see earthquakes but did not?
Is there any data plotted in the ocean? Why or why not?
- Depending on the data set, few earthquakes are plotted in the middle of the ocean. Why? No one lives there, so the data may not be reported.

Ask students to **find supporting evidence for their plate boundaries**. Direct earth structure groups to answer the Stop and Think questions together.

Review the  **Stop and Think questions with the class**. These are:

A. How does the data support your plate boundary prediction?
B. What areas still need support?
C. What data would help you support your plate boundary prediction? Why?

With the whole class, highlight ideas that came up in some groups. Students should see some patterns but realize that more data is needed. In the next lesson, students will analyze one year of data. Be sure the class comes to some conclusion on question C.

Homework

Students should complete the Reflection Questions for Activity 4.4.

Reflection Questions

A. Describe the patterns you saw.
B. Is one week of data enough to predict your plate boundaries? Explain.
C. Describe the patterns you would expect to see in one year of earthquake data.
D. Do you think one year of data enough data to predict your plate boundaries? Explain.
E. The San Francisco Earthquake of 1906 sparked much study of the Earth and the changes that happen in the Earth's crust. Telephones did not exist, computers were not yet invented, and communication on a global scale was left to the mail. After plotting earthquake data the "old fashioned" way, what do you think are the challenges of trying to understand the changes in the crust? What advantages does technology bring?
F. Add new words from this lesson to students' picture dictionaries and improve the definitions for those they already have done.

Assessment

What work is assessed?	What are you looking for?
Plotted earthquake data on small map	Students should have correctly plotted the earthquakes assigned to them.
Class map with earthquake pattern plotted	Students should be describing the patterns they are seeing in the data (clusters of earthquakes)

Activity 4.5: "The Restless Earth" Video

Students watch a video that features scientists studying earthquakes and finding patterns in earthquake data. Students will see how scientist measure and observe earthquakes and will focus on some patterns in earthquakes and volcanoes.

Engaging Student Activity

Introduce the video by asking students what it might feel like if an earthquake were to strike right now. What might they observe happening around them? Tell students that this video shows real earthquakes, as well as how scientists study them and try to predict future earthquakes.

To prepare for viewing the video, direct students to **briefly review the Stop and Think questions** in their Student Text.

Guiding Student Activity

Watch the video. The video is 30 minutes in length. Prompt the students to write down any notes that may aid them in answering the Stop and Think questions in their student booklet.

Stop and Think questions

A. Describe some of the ways seismologists measure and predict earthquakes. What are some of the tools that they use and what do these measure?
B. Why is it important to study earthquakes that happened over 300 years ago?
C. Eighty percent of all Earth's earthquakes have happened along an area around the Pacific Rim. What is this area called? What type of earth structure do you think is found along this area?

Making Meaning of Activity

After watching the video, ask students to answer the Stop and Think Questions. After students have had a few minutes to answer the questions, engage the class in a discussion. Students should share what they were able to extract from the video along with answers to the questions. The last question refers to the Ring of Fire, a subduction zone. Along the Ring of Fire are many volcanoes, which are common along subduction zones. Students will look at these patterns later in the unit. This discussion should foreshadow activities coming up concerning volcanoes.

Assessment

What work is assessed?	What are you looking for?
Discussion about earthquake patterns	Students should be confirming some of the patterns that are in the earthquake data and starting to ask questions about the relationship between earthquake and volcano patterns.

WHAT'S THE POINT?

Students have now had an opportunity to see some of this data they've been talking about. After seeing all of the data for just one week they should begin to develop an appreciation for just how much data are available. After plotting some of the data, they should be able to tell you that if they plotted more they might be able to see patterns where the plate boundaries might be. Talk about how much data they might need.

- How do these data support or challenge your plate boundary prediction?
- Has your prediction changed? If so, how?
- What data would you like now to support your prediction?

Teacher Reflections

What do your students understand about earthquakes?

What kinds of misconceptions do you see in students' work?

What is your plan to deal with those misconceptions?

How are the earth structure teams working? What things are going well? What kinds of problems are they having? What is your plan to deal with these issues?

Describe students' comfort with analyzing earthquake data. Are they ready for more data? What types of problems are they having?

Name ______________________________

Activity 4.1: Real-Time Observations from Data

Reflection Questions

Today you learned that there are many earthquakes occurring every day all over the world.

A. What one place that recently experienced an earthquake surprised you? Why was that surprising to you?

Answers will vary.

B. What questions did you ask yourself about earthquakes and where they happen as you looked at the USGS website?

Answers will vary.

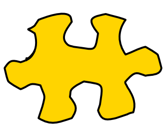


Figure It Out: *Ground Shaking*

1. Describe what happens during an earthquake.

There is a rapid shaking of the ground. Students might also mention more specific details as mentioned in the description of the San Francisco earthquake but this should be in addition to the first statement.

Name ______________________________

Activity 4.1: Real-Time Observations from Data

2. Describing the tremors after the great San Francisco Earthquake of 1906, U.S. Weather Service forecaster Alexander McAdie wrote, "They will come at greater intervals and grow weaker until they become absolutely imperceptible." Write this sentence in your own words.

Answers will vary.
Example: The time between when the ground shakes will be closer and closer together until eventually they will slow down so much we hardly feel them.

3. Reread this part of the first 9-1-1 recording from the Lom Prieta earthquake:

Caller: It's tore up! Everything's tore up, should I take my kids outside?

Dispatcher: Yeah, that would be a good idea because here comes another one!

Do you think the dispatcher gave the caller good advice? Explain.

Answers will vary.
Students should recognize that since the vibrations of the earthquake will make objects fall off walls and shelves in homes that can potentially harm someone that going outside to an open area is good advice. A frequent misconception reinforced by movies is that the ground will crack, open up and swallow them.

4. How are earthquake data collected?

Seismologists measure the seismic waves through the use of seismographs.

5. What factors might affect how destructive an earthquake is?

The size on the Richter scale—how much energy is released. Other factors are how populated an area is, how many buildings there are, how earthquake proof the buildings and bridges are constructed, the geological conditions of the ground, and the depth of the quake affect how destructive an earthquake is.

6. Why is it easier to predict where an earthquake will occur than when it will occur?

Scientists can only measure and keep track of movement along faults. They try to detect small changes in the land. They determine risk by monitoring active faults and faults where earthquakes have occurred in the past. Scientists don't collect data everywhere in the works so an earthquake can strike without warning.

Name ____________________________

Activity 4.2: Plate Boundary Predictions

Reflection Questions

A. Were there any places you were pretty sure about? Why were you pretty confident that was a boundary? Are there any places you were unsure about?

Answers will vary.

B. What information is missing that might help you be more sure?

Answers will vary but students should mention that they need more earthquake data.

105

Name ___________________________

Activity 4.3: Plotting Latitude and Longitude (OPTIONAL)

Using the blank map of the world your teacher gives you, complete the following activity.

Match the cities with the correct latitude and longitude.

_e_	1. San Francisco, California	a.	-35^{O} S, -56^{O} W
_d_	2. Perth, Australia	b.	7^{O} N, 80^{O} E
_c_	3. Moscow, Russia	c.	56^{O} N, 38^{O} E
_b_	4. Colombo, Sri Lanka	d.	32^{O} S, 116^{O} E
_a_	5. Montevideo, Uruguay	e.	38^{O} N, -122^{O} W

Find and mark the following locations on the world map. Write the problem number on the coordinates on the map.

Problem	Latitude	Longitude	Location Name
6.	42^{O} N	13^{O}E	Rome, Italy
7.	59^{O} N	18^{O} E	Stockholm, Sweden
8.	-22^{O} S	-48^{O} W	Rio de Janeiro, Brazil
9.	53^{O} N	-6^{O} W	Dublin, Ireland
10.	40^{O} N	116^{O} E	Beijing, China
11.	-26^{O} S	28^{O} E	Johannesburg, South Africa
12.	19^{O} N	-99^{O} W	Mexico City, Mexico
13.	41^{O} N	-87^{O} W	Chicago, Illinois

Name ___________________________

Activity 4.3: Plotting Latitude and Longitude (OPTIONAL)

Using your map, find the exact coordinates for these locations.

City	Latitude	Longitude
14. Anchorage, AK	61 N	149 W
15. Aberdeen, Scotland	57 N	2 W
16. Denver, CO	39 N	105 W
17. Honolulu, HI	21 N	157 W
18. Athens, Greece	37 N	23 E
19. Bangkok, Thailand	13 N	100 E
20. Belfast, Northern Ireland	54 N	5 W
21. Warsaw, Poland	52 N	21 E
22. Bombay, India	4 N	72 E
23. Hong Kong, China	22 N	114 E
24. Lisbon, Portugal	38 N	9 W
25. Munich, Germany	48 N	11 E

Name________________________________

Activity 4.4: Plotting and Analyzing Earthquake Data

Reflection Questions

A. Describe the patterns you saw.

Answers will vary.

B. Is one week of data enough to predict your plate boundaries? Explain.

One week of data is not enough to predict plate boundaries.

C. Describe the patterns you would expect to see in one year of earthquake data.

Answers will vary.

D. Do you think one year of data is enough data to predict your plate boundaries? Explain.

Answers will vary. Students should say no because there are many areas with only a few data points and many areas with none.

E. The San Francisco earthquake of 1906 sparked much study of the Earth and the changes that happen in the Earth's crust. Telephones did not exist, computers were not yet invented, and communication on a global scale was left to the mail. After experiencing plotting earthquake data the "old fashioned" way, what do you think are the challenges of trying to understand the changes in the crust? What advantages does technology bring?

Answers will vary.
Accept all reasonable responses.

F. Add any new words from this lesson to your picture dictionary and improve the definitions for those you have already done.

Name ___________________________

Activity 4.5: "The Restless Earth" Video

A. Describe some of the ways seismologists measure and predict earthquakes. What are some of the tools that they use and what do these measure?

Seismologists use instruments such as seismographs to measure seismic waves. They use tilt and creep meters to measure changes in the earth's surface. They also use satellites to measure changes in land elevation.

B. Why is it important to study earthquakes that happened over 300 years ago?

They give us clues to what happened in the past and help us predict what might happen in the future.

C. Eighty percent of all Earth's earthquakes have happened along an area around the Pacific Rim. What is this area called? What type of earth structure do you think is found along this area?

This is called the Ring of Fire. There are many volcanoes located along this area.

Lesson 5
<u>Assembling Earth's Puzzle</u>

In this lesson, students begin to refine their plate boundary predictions with real earthquake data. They first saw one year on large paper maps and then up to ten years using a GIS, *MyWorld*. At the conclusion of the lesson, students participate in a series of group and class meetings to agree upon the plate boundaries for the world.

What have the students learned so far?
In Lesson 4, students plotted 1 week of earthquake data and looked for patterns to determine where the plate boundaries are for each earth structure. Students also learned how earthquakes happen and how the data is collected and reported.

Why is it important for students to learn how to support predictions with data?
Supporting ideas with data is what makes science different from the ancient myths students read in the first lesson. The data helps us reason and talk about ideas and explanations. For example: Pam decided to wear a winter coat to school today because the news said it was going to be cold. That does sound reasonable. But we may need more data. For example: Where does Pam live? What time of year is it? What was the temperature yesterday? What if Pam decided to wear a winter coat in Florida in May where it was 80 degrees Fahrenheit the day before? Data helps us better interpret our explanations and construct understanding.

Lesson Overview
Activity 5.1: Refining Predictions
Students receive and review a memo from NESS (National Earth Structure Survey) and refine plate boundary predictions. Students also assemble data maps for the next activity.

Activity 5.2: Looking for Patterns in One Year of Data
Students will look at one year of earthquake data plotted on a large map in order to improve their plate boundary predictions. You will also introduce the class to criteria for "enough" data.

Activity 5.3: *MyWorld* Data
Using *MyWorld,* students will consult more data to improve their plate boundary predictions. Students also gather supporting evidence to justify their plate boundaries.

Activity 5.4: Neighbor Plate Meeting
Students meet with other earth structure teams to share and debate the plate boundary predictions. Teams will be asked to justify their predictions and groups will look for places where they disagree, where plates overlap, or where there are large gaps in the plate boundaries. This is a preparation meeting for mapping the plates of the whole earth.

Activity 5.5: Neighbor Plate Meeting Reports
Students will make final revisions to plate boundary predictions and combine all teams' predictions to make a plate map that covers the entire Earth.

Activity 5.6: A Closer Look at Earthquakes
Students will plot earthquake data on their 3-D models in order to describe and compare data patterns across earth structures.

Learning Objectives:

Content

- The crust is divided into plates. Students will find the boundaries of these plates.
- Earthquake patterns are not the same everywhere. Students will begin to see that different earth structures have different patterns of earthquake data.

Process

- Justify predictions with enough data.
- Participate in a debate of observations and explanations
- Analyze and compare data.
- Create explanations form evidence.

Assessment Criteria: Students should be able to explain that the crust is divided into giant puzzle pieces called plates. They should notice that earthquakes mainly happen where plates meet. Additionally, they should notice that earthquakes happen in different patterns at different earth structures. Students can identify "enough" data when analyzing data points on a map. They'll begin to support and create explanations with the data they are analyzing.

Activity	Suggested Pacing	Student Resources	Teacher Resources
5.1: Refining Prediction	30 minutes	o Students text p. 121-122 o Science Journal or 5.1 Worksheets o *Small World Map* worksheet (*Small Pacific Map* worksheet for a few groups) o 1 set of Big Data Map pages per group of 4-6 students o Clear tape	o Lesson 5 Transparency 1 o Small World Map Transparency o Extra copies of Big Data Map pages (to extend the map for some groups) o Clear tape
5.2: Looking for Patterns in One Year of Data	30-40 minutes	o Students text p. 123-125 o Science Journal or 5.2 Worksheets o Big Data Map assembled for each group of 4-6 students o Several clear transparencies o Clear tape o 2 colors of markers for transparencies, each team	o Lesson 5 Transparency 2-4 o Extra copies of Big Data Map pages (to extend the map for some groups) o Globes with small stickers (optional)
5.3: *MyWorld* Data	80-90 minutes**	o Students text p. 126 o Science Journal or 5.3 Worksheets o *Small World Map* worksheet, each team (*Small Pacific Map* worksheet for a few groups) o Big Data Map assembled for each group of 4-6 students o Overlays from Activity 5.2 o 2 colors of markers for transparencies o *MyWorld* with map view "ESInquiry" o Saved map file from Lesson 2 o *MyWorld* Tool Box and screen capture directions for each computer station	o Globes
5.4 Neighbor Plate Meeting	40-50 minutes	o Students text p. 127-128 o Science Journal or 5.4 Worksheets o Big Data Maps o Overlay of plate boundary predictions from Activity 5.2 & 5.3. o *MyWorld* with map view "ESInquiry" o Chart Paper and markers	o

5.5: Neighbor Plate Meeting Reports	80-90 minutes	o Students text p. 129-130 o Science Journal or 5.5 Worksheets o Three Page Map Worksheet, each student o Clear tape o Big Data Maps o Overlay of plate boundary predictions from Activity 5.2 & 5.3. o Neighbor Plate Meeting Report from Activity 5.4. Big Data Map and plate boundary predictions from Activity 5.4.	o Large roll of acetate or enough clear transparency film to cover the *Big World Map* o Permanent marker o Lesson 5 Transparencies 5 - 9
5.6 A Closer Look at Earthquakes	30 minutes	o Students text p. 131-132 o Science Journal or 5.6 Worksheets o 3-D model of earth structure from Lesson 2 o One color of small dot sticker for each team. o *MyWorld* with map view "ESInquiry" o Pen Pal Letters from Lesson 1	o Computer Projection System (optional) o *MyWorld* with map view "ESInquiry" (optional)

Teacher Note: *Pacing***
Time spent on Activity 5.3 and 5.6 and any future computer activity depends on how many computers students have access to and how you decide to organize them. Each team of students will need about 30 minutes on the computer to complete the tasks in Activity 5.3. Each team will need about 15 minutes on the computer to complete the tasks in Activity 5.6.

Activity Set-Up:

Activity 5.1: Refining Predictions

- o Make several class sets of the *Small World Map* worksheet. Students will use this worksheet several times during this lesson.
- o Copy sets of the Big Data Map pages. Two or three earth structure teams will work around one map. In a class of 30 students where two students are working on each of the earth structures, you will need 5 or 6 sets of the Big Data Map. Make one or two extra copies of the Big Data Maps so you can re-center the map around the Pacific Ocean.

Activity 5.2: Looking for Patterns in One Year of Data

- o Each earth structure team will need several sheets or one larger sheet of transparency film to overlay the large data map. If smaller sheets are used, clear tape will be needed to tape them together.
- o You will need to decide which earth structure teams will work together on one data map. Teams should be able to reasonably stay out of each other's way while working on the Big Data Map.

Activity 5.3: *MyWorld* Data

- *MyWorld* Tool Box and screen capture directions should be at each computer station.
- Student computer files from previous lessons and *MyWorld* map view "ESInquiry.mpz" need to be set up at each computer.
- Determine where and how students will have the opportunity to use computers to analyze and capture data from the computer.
- Gather globes from other classrooms. Gather small dot stickers to mark patterns on the globe.

Activity 5.4: Neighbor Plate Meeting

- Look at a couple of world maps showing the plate boundaries on the Earth Structures Web page, www.geode.northwestern.edu/pbi, and/or the "Expert Map" transparencies. By knowing where scientists believe boundaries are, you can help students make decisions about their own plate boundaries, although they do not have to match.

Activity 5.5: Neighbor Plate Meeting Reports

- Set up the computer projection system with the *MyWorld* map view for this lesson. If the class conversation insists on revisiting the data again, you can use the projector.
- Copy the Three Page Map for each student.

Activity 5.6: A Closer Look at Earthquakes

- Set up the computer projection system with the *MyWorld* map view "ESInquiry.mpz" for this lesson. If the class conversation insists on revisiting the data again, you can use the projector.
- Students will need their 3-D models of their earth structures and the *Big World Map* to display them on when the task is complete.
- Be sure all the sticker dots are the same color. In a later activity, students will plot volcanoes on their models using a different color sticker dot.
- Plot earthquake data on the 3-D model of the Aleutian Islands.

Enacting the Lesson

Activity 5.1: Refining Predictions

The team has received a memo from NESS. The class will review the memo, and then students will refine their plate boundary predictions.

Engaging Your Students

Read and discuss the letter from NESS. This memo should help reframe the plate boundary task for the students. Be sure students notice that NESS would like students to use data to support their findings.

Guiding Student Activity

Students refine plate boundary predictions. In Lesson 4, students made a rather blind prediction about where they thought the plate boundaries for their earth structure were located. Now they have had experience with some data, so in this activity students will refine their predictions.

Distribute copies of the *Small World Map* handout. Students should then **label the location of their earth structure on the map.**

Teacher Tip: *Re-centering the small map*
Teams that have earth structures along the Pacific Ocean will need to use a different map to map their plate boundaries, one centered on the Pacific Ocean. Simply take an extra *Small World Map* and cut it in half down the Prime Meridian. Retape the pieces so the Pacific Ocean is attached. We have also included a *Small Pacific Map* worksheet that is centered on the Pacific Ocean.

Students should then draw where they think the plate boundaries are located, using any new ideas they have from data they've seen so far.

Making Meaning of the Activity

On the reverse side of their prediction maps, ask students to **explain how they decided where to draw the plate boundaries** of your earth structure. Ask: *What supporting evidence did you use?* Encourage students to use data from Lesson 4 as well as anecdotal data from pen pal letters and prior knowledge to support their predictions. Ask students to share their supporting evidence. Discuss what kinds of data students used and if they are enough. Also ask students to share how their predictions have changed and why they have changed.

Teacher Tip: *Organization*
Students will be using the *Small World Map* worksheet to record predictions and identify data several times in this unit. Be sure students put the date and a description of the task on each *Small World Map* worksheet. Each *Small World Map* worksheet should be kept in a folder to collect the work from the unit or stapled into their science journals for future reference.

Say: ***Now we will look at more data****, to help you improve yourr plate boundary predictions. In teams you will put together world data maps that have one year of earthquake data plotted*. Students will need to put desks together for the big maps, or lay their maps out on the floor. Six desks together, or a large table, will hold one map.

Assemble the Big Data Maps for Activity 5.2. Distribute Big Data Maps for students to tape together. Groups of students will work around large data maps. Two or three earth structure teams can work around one data map. One stack of 28 papers makes up one complete data map – give one stack to each group of students. The map has latitude and longitude on it to help students assemble the map. Each team will also need a roll of tape. They should line up their map pages, and tape the paper together at the edges to make one large world map with one year of earthquake data already plotted.

Teacher Tip: *Multiple Classes*
If you teach several classes, they can all share the same set of data maps. The maps can be folded along the seams and stacked up between classes so they don't take up too much room. Or, punch holes along the top of the map. Reinforce the holes with tape or circles and hang the maps on hooks when not in use.

Teacher Tip: *Finding Maps*
If some students find a picture showing the plate boundaries, ask them to put it away for now, and don't look at it for the next few days. Plate mapping will be more interesting that way, and they can check their predictions later against the picture they found. Point out that each diagram of plate boundaries that you find has some different lines – even the experts disagree!

Assessment

What work is assessed?	What are you looking for?
Prediction Map #2	Students should have drawn a new plate boundary prediction. Students should also be supporting that prediction with some data patterns they saw in Lesson 4. Students might also be supporting predictions with anecdotal data. For example: "Earthquakes happen in Hawaii, so there must be a plate boundary there."

Activity 5.2: Looking for Patterns in One Year of Data

In this activity, students will look at one year of earthquake data plotted on a large map to improve their plate boundary predictions. You will also introduce the class to criteria for "enough" data.

Engaging Your Students

Review the big data maps with one year of earthquake data plotted. Ask groups to gather around the large maps that the class has already assembled. In the upper left corner of the assembled map is information about the data that is plotted on this map. To acquaint the students with the data map, ask:

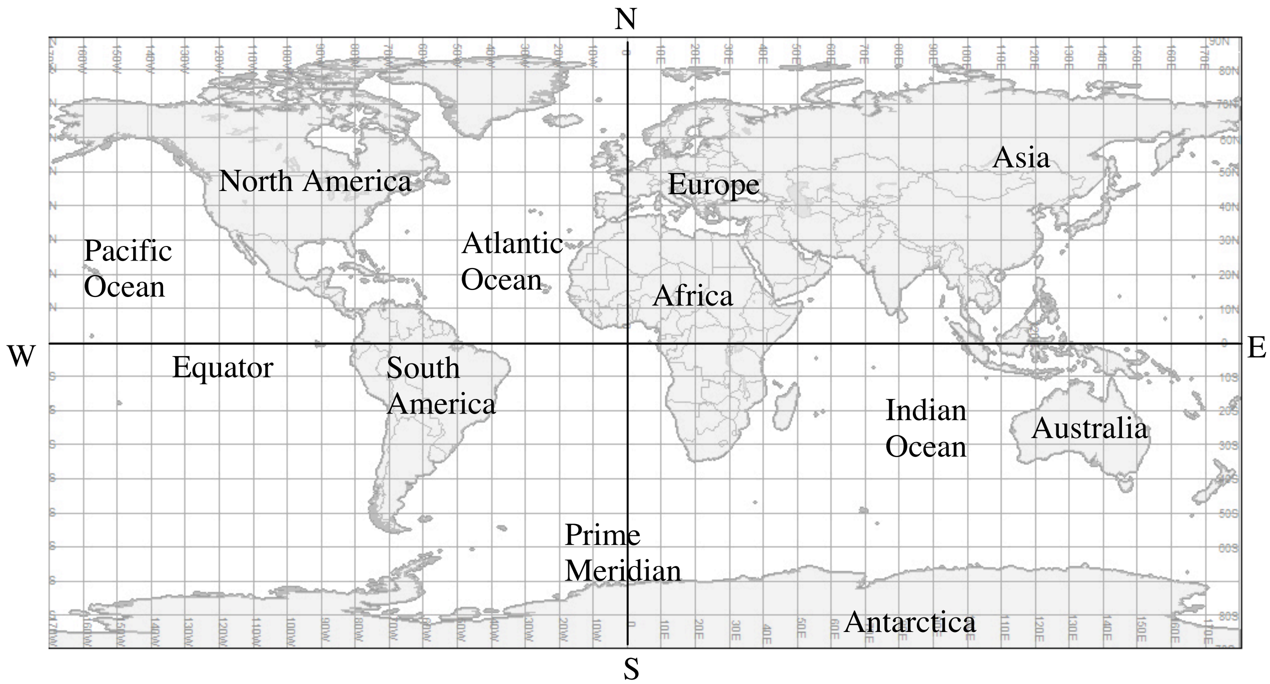
- Over what period of time did these earthquakes happen? *One year – 2002*
- Does this map show all the earthquakes that took place? If not, which earthquakes are shown? *No; only earthquakes with magnitudes 4.5 and larger are shown.*
- What would the map look like if ALL the earthquakes for the year were plotted? *Students might have a variety of answers. Students might say that the earth would be covered with dots or there would be large blobs of earthquakes in places that there were large earthquakes because of the aftershocks. Accept all answers. Encourage others to respond. Some of these questions will be dealt with when students use GIS data.*
- What information does this map give us about each earthquake? *The location of each earthquake and a general idea of the magnitude – 4.5 or higher.*

Teacher Tip: *Grouping Students*
Group students around the data maps so that groups will not get in each other's way. For example, Mt. Etna and Mt. Vesuvius should not be working on the same data map. Japan and St. Helena can work on the same data map**.**

Teacher Note: *Why do it this way?*

- Making students deal with the actual complex data gives them a taste of being scientists, debating data instead of just memorizing answers.
- We give the students one year of data to help students see how much data is "enough."
- The large paper map provides opportunities for teachers and kids to talk and justify their ideas with the data. Once the map is on the computer screen, it can be difficult to see what students are using as supporting data.

Ask students to label the map with: N, S, E, W, the Equator, the Prime Meridian, the names of the continents, and the names of the oceans. These labels will help you talk about locations on the map.



Use the Stop and Think questions to help students do some initial analysis of the data.

A. Look at the one week of data your class plotted on a map and the one year of data plotted on this new data map. What do you notice about patterns in the data? Do you see the same patterns? Do you see different patterns? Describe what you see.
B. Compare your plate boundary prediction from Activity 5.1 to this new data map. Where would your prediction lines be on the data map? How well does your prediction line up with earthquake data?

Guiding Student Activity

Prepare to analyze data and find plate boundaries. Each team should place a transparency over the part of the map where its earth structure is located. Students should trace some latitude and longitude numbers from the Big Data Map onto the transparency so they can put the transparency back in the same spot each time.

Students will need to decide here how much transparency to put down to find their plate boundaries. Some might use one 8 1/2” x 11” sheet, while others will decide to cover the entire Pacific Ocean. At this point, students might be making this decision based on prior conceptions rather than data. Let the data guide them. Students using multiple sheets should tape them together.

Ask: ***How do you find boundaries among all these dots****?* The data on the map looks like a scattered mess of dots. In some places there are clumps of dots, in other places there is one dot. Look for a general direction in the dots. Too many and the pattern is too difficult to see. Too few and you cannot tell where the pattern is between the dots. Can the dots be connected? No! You need enough data to see a clear pattern

Introduce the idea of "enough" data. Use the "Too Many, Too Few, Just Right" transparencies to discuss how much data are enough. The actual number of years or magnitude ranges needed to have enough data varies by region. Students will need to decide if they have enough data to support their plate boundary predictions.

Teacher Note: *Why do it this way?*
Generalizing from a scatter of information is the way this kind of data is used by professionals. Connecting the dots only works for certain kinds of time series plots. Scatter plot analysis is a common kind of work with data.

Direct students to use the one year of earthquake data to improve their plate boundary predictions. Students will mark plate boundaries on a transparent overlay of the data map. Students should use one color marker for places where they have "enough data" to support plate boundary lines and another color marker for places where they need different data or are unsure of their plate boundary lines. Students should make a key that shows what their different colored lines represent.

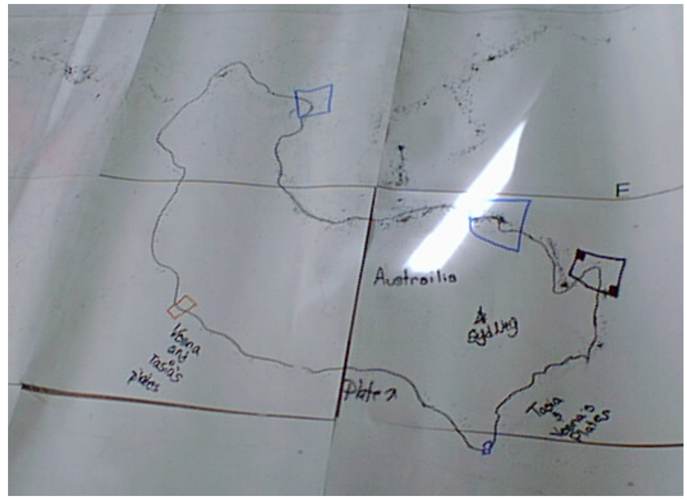
While teams are working, circulate through the room asking students to show you the evidence they have to support their plate boundary lines. Assist students who are simply connecting the dots or are not using the data to find their plate boundaries.

Teacher Tip: *Re-centering the Big Data Map*
Groups whose earth structures that are located along the Pacific Ocean may have some trouble with the map projection; the plate boundaries are on opposite ends of the map. This is easily fixed by adding pieces on to the map. Make an extra copy or two of the Big Data Map. Add on a row or two of map pages so the entire Pacific Ocean can be seen. You now have a map of the entire world and a little extra. Taking the map pages off one side of the map and taping them to the other side could also do this.

Teacher Tip: *Top and Bottom of the Globe*
Teams with earth structures that have plate boundaries near the north and south poles may have problems seeing "enough" data in the geographic projection of this due to the distortion of the projection. Encourage these groups to use a globe to look at their data. Students will have an easier time dealing with the top and bottom of the world in the next activity. *MyWorld* has an easy to see globe projection to see the data without the distortion.

These are examples of students' first plate boundary predictions:

Los Angeles plate



Sidney plate

Making Meaning of the Activity

Ask: ***How have your predictions changed today? Why did they change?*** This is Reflection Question A. Students should share how they improved their plate boundary predictions and how the data supported those changes.

Ask students if they had enough data to support their predictions and if not, what data would they like now. In the next activity, students will have the opportunity to use a GIS, *MyWorld*, to improve their predictions.

Homework

Assign Reflection Questions B and C for homework.

Reflection Questions

A. How have your predictions changed today? Why did they change?
B. How did you predict your plate boundaries? How did your group work on this problem together?
C. Did you have "enough" data to support your plate boundary predictions? How did you decide?

Assessment

What Work Is Assessed?	What are you looking for?
Earth structure team data maps	Students should have drawn a continuous shape for their plate. Students should be using data to support their plate boundary predictions. Students have identified places where they are sure and places where they are unsure of their plate boundaries.
Reflection Question C	Students should be asking for more earthquake data here. Students may not have a sense of how much time or what magnitudes they should be asking for. Accept all other suggestions also.

Activity 5.3: *MyWorld* Data

In this activity, students will consult more data to improve their plate boundary predictions. Students will also gather supporting evidence to justify plate boundary predictions.

Engaging Your Students

Identify areas where more information is needed to improve plate boundary predictions. Distribute Small World Map Worksheets. Students should look at the plate boundary predictions they made in Activity 5.2 to identify areas where they are not sure of the plate boundaries. Students should draw boxes on the map to highlight the areas they would like to get a closer look at in *MyWorld*.

Guiding Student Activity

Improve plate boundary predictions with data in *MyWorld*. Teams will bring their small maps to the computer. Students should use the *MyWorld* Tool Box as a guide to the software. Students should be using a *MyWorld* map view, called "**ESInquiry.mpz**" that has information about elevation and depth, earthquakes, and volcanoes.

Ask students to capture supporting evidence. Students can gather that supporting evidence using screen capture as they did in Lesson 1. This screen capturing can be time consuming now but will make discussions easier later. This screen capturing can also help you see what the students are using as supporting evidence and how they are interpreting scatter plots.

Teacher Note: *Why do it this way?*
With the software's database, students can get immediate answers to their questions. They can ask more specific questions, and find LOTS of data quickly. Students are using the computer as a data gathering tool, not just sitting back and watching.

Revise plate boundary predictions. Using the information that students gathered from *MyWorld*, they can revise their prediction lines. Students should use a different color pen to make revisions.

Teacher Tip: *Top and Bottom of the Globe*
Teams with earth structures that have plate boundaries near the north and south poles may have problems seeing "enough" data in the geographic projection due to the distortion of the projection. Encourage these groups to use the globe (orthographic) projection in *MyWorld*. It might also be helpful to have a few globes around the class so students can map their plate boundaries on the globe using stickers in those areas rather than on the map, especially across the top of the globe.

Ask students to name their plate. Students should be prepared to tell the class how they came up with the name of the plate.

Making Meaning of the Activity

Ask: ***How have your predictions changed today? Why did they change***? These are Reflection **Questions A and B**. Students should feel surer of their predictions, though there are many places that they will still have questions about – this is okay. The experts have questions too.

Explain that during the next class students will meet with other earth structure teams to debate the plate boundary predictions.

Homework

Students should answer the Reflection Questions in their science journal or using the handout. The previous class discussion will help set expectations for students' individual answers to these questions.

Reflection Question

You have made a series of predictions so far. You made predictions in Activity 4.2, and again Activity 5.1 and 5.2.

A. How have your predictions changed?
B. Why have your predictions changed?
C. How certain do you feel now of your plate boundary lines?

Assessment

What work is assessed?	What are you looking for?
Plate Boundary Map with Supporting Evidence	1. Students analysis of data 2. "Enough" data 3. Places they have questions

Teacher Note: *Assessment and Communication*
Write comments on student computer files so students can improve their communication and analysis of supporting evidence.

Additional Extension Activities

If you are cycling your students through a small number of computers you will need activities for the students that are not at the computers. Look in the Appendix for possible readings or activities.

Activity 5.4: Neighbor Plate Meeting

Students will meet with other earth structure teams to share and debate their plate boundary predictions. Teams will be asked to justify their predictions, and groups will look for places where they disagree, where plate boundaries overlap, or where there are large gaps in the plate boundaries. The goal is to agree on where the plate boundaries are located for that region in preparation for the class' mapping of the plates for the whole world.

Engaging Your Students

Review the task: figuring out where the Earth's plates are. Students will meet with a group of "neighbor plates" to debate the patterns each group found in the data and come to a consensus about where the plate boundaries are located. Explain to students that they should use the *Neighbor Plate Meeting Agenda* to guide the discussion. During the discussion, students should keep track of changes they make to the plate boundary lines. To close the meeting and prepare for the next activity, the meeting group needs to prepare a short report about what happened at their meeting. A Meeting Agenda is found in the Student Text.

Organize the Neighbor Plate Meeting. For this activity the class will be divided into 4 groups. Each group will consist of three or four earth structure teams that are neighbors. Each meeting group should have a Big Data Map and each earth structure team should bring their plate boundary predictions on the transparency pieces. Each group should stack up the transparencies from each team on one map. Tape them to the top of the map so you can easily lift the layers.

Teacher Tip: *Hints for Guiding a DEBATE*
You may need to give students tips about how to debate in a courteous manner. For example: students should wait until a group has finished sharing before they question or challenge the ideas of that group. Students should always go back to the data to ground the discussion. Before someone can challenge another person's idea, he or she must first describe the differences and similarities in the two ideas.

Teacher Tip: *Neighbor Plate Meeting Organization*
Earth structures that are neighbors should be meeting together. Here is a suggested grouping:

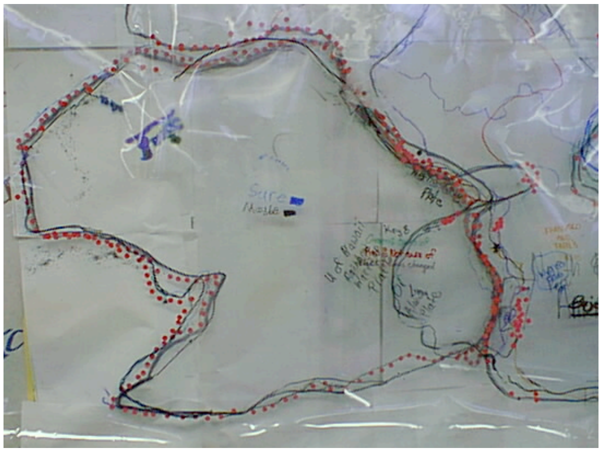
#1 Andes, New Zealand, and St. Helena
#2 Mt. Popo, Baja, Hawaii, and Mt. St. Helen
#3 Mt. Vesuvius, Mt. Etna, Iceland, and Mt. Kilimanjaro
#4 Himalayas, Java Trench, Mariana Trench, and Japan

Guiding Student Activity

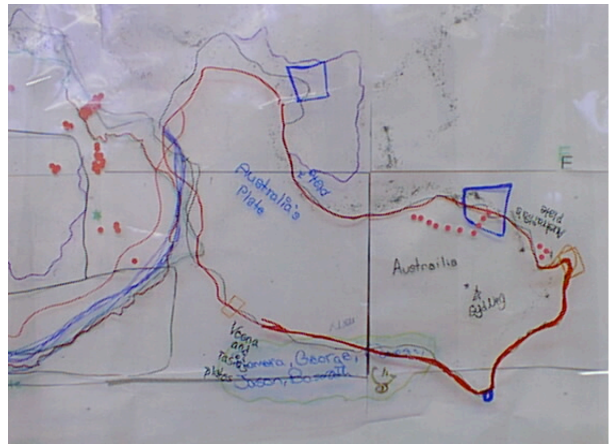
Convene Neighbor Plate Meeting. Students should use the agenda in their Student Text to guide their meeting.

While groups of students are meeting, ask students for supporting evidence and if there is debate about the patterns in the data, encourage students to go back to the computer to find and capture supporting data.

Here are some sample student plate maps:



Pacific Ocean plate



Australia plate

Teacher Hint: *Why do it this way?*
Having students JUSTIFY their ideas is powerful. It evokes depth of understanding. Students are also wonderful at holding their peers responsible, especially if they have ownership of the problem/task. Students can give each other feedback on supporting their ideas with evidence.

Teacher Tip: *Re-center the Map*
The groups that have Hawaii, Japan, and the Mariana Trench may get confused because their plate goes off the edge of the map. You can make extra copies of the four map pages from the other side of the map, and extend the map out, to make the Pacific Ocean whole for their plate mapping.

Making Meaning of the Activity

Use Reflection Question A for a closing discussion with class. Briefly discuss what happened in the Neighbor Plate Meeting Groups.

Reflection Questions

A. What region did you disagree on most? How did you work it out?
B. Did any of your plate boundary prediction lines change during the meeting today? Why did you change them?

Homework

Students should answer the Reflection Questions in their science journal or using the handout.

Assessment

What work is assessed?	What are you looking for?
Neighbor Plate Groups	Groups of students going back to the data to support their predictions Students asking questions about data Groups agreeing on plate boundaries
Reflection Question B	Student able to reflect and articulate the process they are going through to determine plate boundaries.

Activity 5.5: Neighbor Plate Meeting Reports

Students will make final revisions to their plate boundary predictions and combine all teams' predictions to make a plate map that covers the entire earth.

Engaging Your Students

Announce that today is the day the class will assemble Earth's Puzzle. Neighbor Plate Meeting Groups will meet briefly to prepare, and then each of those groups will be asked to report to the class.

Allow the Neighbor Plate Meeting Groups a short time to prepare. Meeting groups share a brief report. The report should include:

- What were each earth structure team's predictions at the start of the meeting?
- Where did you agree?
- Where did you disagree?
- Who changed their prediction lines? Why did you change them?
- How did the plate lines change during the meeting?
- Where are the plate boundary lines now?
- What are the names of the plates you discovered?

Guiding Student Activity

Each Neighbor Plate Group will report. Remind students that while each group is reporting, they should watch for plate boundary predictions that are similar to their own. They should also consider what supporting evidence was used, whether there was "enough" supporting evidence, and share any questions that they now had\ve about the plate boundaries. If students disagree with a group that is presenting, the group should be allowed to report before a debate of the data begins.

Teacher Tip: *Guiding a Debate*
If differences or similarities in plate boundaries come up during the Neighbor Plate Meeting Report, let the presenting group finish, and then encourage other students to come up and DESCRIBE the similarities to or differences from their own plate lines. This is excellent practice at communicating about data, predictions, and explanations.

Making Meaning of Activity

After the groups have presented, lead a class discussion about the plate boundaries. The following questions can help guide the discussion.

- Where are the places you are least sure of our boundaries?
- Are there any gaps? Has the class found all of the plate boundaries?
- How can you explain earthquake data that is not at a plate boundary?
- What about the bottom and the top of the world? What plates are there?
- What is a plate?
- Are all the plates above water? Below water?
- What questions can be added to the list now?

At the end of class, ask a small group of students to **trace all the agreed-upon plate boundary lines** on a new set of transparency sheets so the class can see the plate boundary lines for the whole world. A large single sheet of acetate works best here but small transparencies can be taped together. This new transparency of all of the plate boundaries can be hung over the Big World Map or overlay one of the Big Data Maps. Ask the students to label the map with the names that the groups had given the plate. If two names were given for a plate, hyphenate the name.

Ask students to determine which plate their earth structure is part of. Which side of the boundary line is it on? Some earth structure teams might have trouble with this because it is not clear which side of the boundary it is on. For example, Iceland is in the middle of a rift so part of the island is on one plate and the other part of the island is on another plate. Ask students to decide. Students could use the largest city or the city their pen pal lives in to decide which side of the plate boundary they are going to focus on for the rest of the unit.

Students will need a *Three Page Map* worksheet to draw and shade a sketch of their plate and to identify their earth structure. Students will be focusing on this plate and how it moves through the rest of unit. Be sure students date these and keep them handy for future lessons.

Student generated Whole world map plate

Show students a variety of "Expert" Plate maps. Highlight how different they are. Scientists are still trying to figure out this complex system, and the students are going to contribute another map to this effort.

Ask students to answer Reflection Questions A-D in class.

Reflection Questions 

A. What is a plate? Write a description of the plate that you mapped.
B. Your class has been collecting questions about the Earth's crust, earthquakes, and volcanoes. Which of these questions have you answered?
C. In Lesson 1, you wrote explanations for how and why earthquakes and volcanoes were happening at your earth structure. Earthquakes and volcanoes are evidence that the crust is moving and changing. Explain how and why you think those changes are happening at your earth structure.
D. In Lesson 4, you read about three historically significant earthquakes: one in New Madrid, Missouri in 1812, the Great San Francisco Earthquake of 1906, and a deep earthquake near the Fiji Islands in 2002. Based on your class map of the plate boundaries, on what plates did these earthquakes take place? Did all of these earthquakes happen on a plate boundary? Why do you think they did or did not?
E. **It's Your Turn:** Write a letter to the lead researchers at NESS describing the plate boundaries you found for your earth structure, and include the supporting evidence you used to support your final prediction. NESS researchers would like to know where you feel sure about the data and where you are still unsure. And, if there are places that you still have questions about or where there was much debate during the conferences, tell NESS about these places as well.

Ask students to answer **Question A** and then have a brief class discussion to agree on a definition of a plate and to help define what should be included in students' descriptions of their plates. **Question B** asks the class to revisit the questions they have been collecting and see which ones they have answered. Any answered questions can be removed from the class list and new questions should be added. **Question C** asks students to write an explanation for the changes happening at their earth structure. New explanations should be added to the class list of explanations.

Question D should be worked through in class. This is a way of modeling the kinds of thinking and questioning that is needed. Some new questions will be probably arise from this question also. The San Francisco earthquake and the earthquake near the Fiji islands both happened on or near a plate boundary. The New Madrid earthquake did not. Ask the class for explanations. For your information, not all earthquakes happen at plate boundaries. There are fault lines throughout the plates, or places where there are minor shifts in the ground. There are also places in the middle of plates where volcanoes happen. Hawaii is a good example. Where there are volcanoes, there are earthquakes. Hawaii is on a hot spot, a weak spot in a plate that allows the hot mantle to be released in the form of a volcano. Students will learn more about hot spots in a later lesson.

Prepare students to answer Question E for homework. Ask students what should go into this letter to NESS. As a class, create a framework for the letter. This will help students write a better quality letter. Individual students should answer this question for homework to be sure everyone's ideas are shared. During the next class, ask student teams to write one letter together and include their annotated supporting evidence. Students can take turns printing the evidence they captured in Activity 5.3 or you could print all of them prior to class. This is an excellent place to assess students' ability to analyze and use supporting evidence.

Teacher Note: *Pacing*
During the next class, earth structure teams should work on their letters to NESS. In the same class period, students can also do Activity 5.6. This works nicely if you have to cycle students in and out of computer time.

Homework

Students should complete Reflection Question E.

Assessment

What work is assessed?	What are you looking for?
Reflection Question A	The crust is divided into pieces called plates.
Reflection Question B	Students begin to create explanations for Earth's crust processes.
Reflection Question E	Accurate analysis of point data.
Class Meeting Reports	Plate boundary lines are supported with enough data.

<u>Activity 5.6: A Closer Look at Earthquakes</u>

In this activity, students will plot earthquake data on their 3-D models and describe the pattern they see in the data. They will then find earth structures with similar and different earthquake patterns.

Engaging Your Students

Ask students: ***When you were analyzing the earthquake data, were the patterns the same everywhere?*** *Can you name a place that had a lot of earthquakes that seemed to occur in lines? Can you name a place where the earthquakes were scattered everywhere? What kinds of earthquake patterns are there at your earth structure?* Elicit student answers and encourage them to show these places on any of the map representations in the room.

> **Teacher Hint**: *Example*
> Students might describe the earthquake pattern in Japan as a lot of earthquakes in a straight line. In contrast, the Himalyas have a scattering of earthquakes. At Mt. Etna and Mt. Vesuvius earthquakes happen in scattered patterns also.

Guiding Student Activity

Describe the task. Students will use *MyWorld* to plot earthquake data on their 3-D models. Students should plot 3 years of medium earthquakes using sticker dots. Students should then capture their earth structure map and describe the pattern of earthquakes. Students will then find and capture earth structures that have similar and different patterns. More specific directions are found in the Student Text.

Making Meaning of the Activity

Direct students to answer the Reflection Questions in their science journal or on the handout provided.

Reflection Questions

A. Why do you think some earthquake patterns are similar?
B. Why do you think some earthquake patterns are different?
C. **<u>It's Your Turn:</u>** Look back at the letter your pen pal sent you. Compare the earthquake data you just plotted with the description of the earthquakes in the letter. Write a letter to your pen pal describing your comparison.

As a closing to the class, ask one team member of each earth structure team to take their 3-D models with the earthquake data plotted on it and organize themselves into groups that have similar earthquake patterns to their own. This is great check of student understanding of the patterns, especially if students are having trouble describing the patterns they are seeing.

Once students are in groups based on similarity, ask each group to describe this similar pattern. Then ask students to describe why their group's earthquake pattern is different from the other groups'.

> **Teacher Tip:** *Why do it this way?*
> In the next two lessons, students will add even more data and try to characterize the patterns in the data. This activity leads up to that comparison, which then leads to students determining motion at plates, a complicated data analysis. This is also a great way to find out what kinds of patterns students are seeing in the data, especially if they are having trouble describing patterns in data. The kinds of talk that happens during a grouping activity like this provides excellent examples for students who are struggling with communicating their ideas or using precise language in descriptions.

> **Teacher Note:** *Pacing*
> This activity could be done the same day that earth structure teams are working on their letters to NESS from Activity 5.5, especially if you are cycling students through a set of computers in the classroom. This activity can also be done during the same computer sessions in Activity 5.3.

Assessment:

What work is assessed?	What are you looking for?
Models with sticker dots	Model should show the pattern of the earthquakes on or near the earth structure.
Reflection Questions A and B	Students begin to see that different earth structures have different earthquake patterns.

WHAT'S THE POINT?

What is a plate boundary? What happens at plate boundaries? *A plate boundary is place that two plates meet. Earthquakes and volcanoes happen at these boundaries. Crust is added and crust is taken away at these boundaries.*

Where is your earth structure in relation your plate boundaries? *Most of the earth structures are near or on a plate boundary. Some are not. Hawaii, for example, is not. Encourage the students to think about why. Ask students if they think the changes happening at Hawaii and Japan, which is on the boundary, are happening in the same way. Students should be starting to see that there are different patterns of change at different earth structures.*

How do you think the earthquakes at your plate boundary relate to the changes happening at your earth structure? *Accept any insights here. In the next two lessons, students will start to categorize the different patterns in earthquakes and volcanoes that they are noticing at different earth structures and plate boundaries. Different kinds of movement result in different patterns of earthquakes and volcanoes and therefore different earth structures.*

Teacher Reflections

What was the process of finding the plate boundaries like for your students?

What was the process of student debate like for your students?

How are well are your students supporting their ideas with data?

How well are your students describing what they are seeing in the data?

Are students using enough data?

Name___________________________

Activity 5.2: Looking for Patterns in One Year of Data

Stop and Think Questions

A. Look at the one week of data your class plotted on a map and the one year of data plotted on this new data map. What do you notice about patterns in the data? Do you see the same patterns? Do you see different patterns? Describe what you see.

In the one week of data, the earthquake data will probably look like clusters at different places around the map. The Ring of Fire might be visible. In the one year of data, there will be earthquakes all over the world, with some clusters were there was a lot of activity. Plate boundaries should be more pronounced, yet some places there will not be "enough" data.

B. Compare your plate boundary prediction from Activity 5.1 to this new data map. Where would your prediction lines be on the data map? How well does your prediction line up with the earthquake data?

It depends on students previous predictions. Some students will still be struggling with how big a plate is? Where the patterns are? Etc.

Name________________________

Activity 5.2: Looking for Patterns in One Year of Data

Reflection Questions

A. How have your predictions changed today? Why did they change?

B. How did you predict your plate boundaries? How did your group work on this problem together?

C. Did you have "enough" data to support your plate boundary prediction? How did you decide?

Name___________________________

Activity 5.3: *MyWorld* Data

Reflection Questions

You have made a series of predictions so far. You made predictions in Activity 4.2, and again Activity 5.1 and 5.2.

D. How have your predictions changed?

Answers will vary.

E. Why have your predictions changed?

Answers will vary. Students be changing their predictions based on data.

F. How certain do you feel now of your plate boundary lines?

Answers will vary. Student should be more confident because they have more supporting evidence.

Name ______________________________

Activity 5.4: Neighbor Plate Meeting

Reflection Questions

A. What region did you disagree on most? How did you work it out?

Answers will vary.

B. Did any of your plate boundary prediction lines change during the meeting today? If so, why did you change them?

Answers will vary.

Name ______________________

Activity 5.5: Neighbor Plate Meeting Reports

Reflection Questions

A. What is a plate? Write a description of the plate that you mapped.

The crust is divided into giant puzzle pieces. These puzzles pieces are called plates. Some are very big, covering two continents and others much smaller but they all fit together like a puzzle. Student descriptions of their plate will vary but should include the size and location.

B. Your class has been collecting questions about the Earth's crust, earthquakes, and volcanoes. Which of these questions have you answered? Do you have any new questions?

Answers will vary.

C. In Lesson 1, you wrote explanations for how and why earthquakes and volcanoes were happening at your earth structure. Earthquakes and volcanoes are evidence that the crust is moving and changing. Explain how and why you think these changes are happening at your earth structure.

Student will have a variety of answers to this question. This question is seeding Lesson 6, where students explore why the crust moves.

Name ______________________________

Activity 5.5: Neighbor Plate Meeting Reports

D. In Lesson 4, you read about three historically significant earthquakes: one in New Madrid, Missouri in 1812, the Great San Francisco Earthquake of 1906, and a deep earthquake near the Fiji Islands in 2002. Based on your class map of the plate boundaries, on what plates did these earthquakes take place? Did all of these earthquakes happen on a plate boundary? Why do you think they did or did not?

> Which plate students say these earthquakes happened on depends on the class plate map. Students should use the names from the class map but here are the names from an "expert" map. New Madrid happened on the North American Plate, and Fiji Islands happened on the Pacific Plate. San Francisco is on the North American plate or the Pacific Plate depending on where the plate boundary is.

E. **<u>It's Your Turn:</u>** Write a letter to the lead researchers at the NESS describing the plate boundaries you found for your earth structure and include the supporting evidence you used to support your final prediction. NESS researchers would like to know where you feel sure about the data and where you are still unsure. And, if there are places that you still have questions about or where there was much debate during the conferences, tell NESS about these locations as well.

Name ______________________________

Activity 5.6: A Closer Look at Earthquakes

Reflection Questions

A. Why do you think some earthquake patterns are similar?

Answers will vary.

B. Why do you think some earthquake patterns are different?

Answers will vary.

C. **It's Your Turn:** Look back at the letter your pen pal sent you. Compare the earthquake data you plotted with the description of earthquakes in the letter. Write a letter to your pen pal describing your comparison.

Lesson 6

Escaping Heat

In this lesson, students look at explanations and evidence for how and why the plates of Earth's crust move. Students will start to explain the process that is changing Earth's crust. They will also begin to describe the processes that are causing changes at their earth structures. To do this, students will look at volcano data for their earth structure and begin to characterize the data patterns.

What have students learned so far?

Students know that earthquakes and volcanoes are indications that the crust is moving and changing. In Lesson 3, Junior Science Assistant Benny explained that the Earth's crust is divided into giant puzzle pieces called plates. In the Lesson 5, students successfully mapped the plate boundaries for the whole world using earthquake data. Students now know what plate their earth structure is part of. Students also discovered in Lesson 5 that earthquakes happen in different patterns at plate boundaries and earth structures.

Why is it important for students to know how and why the plates move?

In order to describe the process that is causing changes at an earth structure, students need to understand what drives the process. The changes that are happening at the earth structures are the results of convection currents moving the plates. Mountains grow, new islands born, volcanoes change shape all because the crust of the earth is moving. When the crust moves we have an earthquake. The crust may crumple and shift in different ways though and the differences in earthquake and volcano patters are evidence of these different kinds of movement. Students will describe these movements further in Lesson 7.

Lesson Overview:

Activity 6.1: Heating Soup

In this activity, students will predict how and why the Earth's crust moves. Students will then read some explanations about how and why the Earth's crust moves.

Activity 6.2: Comparing Volcanic Activity

Students will compare the volcanic activity at the different earth structures using the descriptions from their pen pal letters.

Activity 6.3: Oozing and Blasting Volcanoes

You will introduce students to some real-time volcano data using the internet. Students will then compare volcanoes in a reading.

Activity 6.4: Characterizing Volcano Data Patterns

In this activity, students will plot and analyze real volcano data. Students will then compare volcano data patterns across earth structures.

Activity 6.5: "Rivers of Fire" Video
Students will watch a video that describes the data being collected at the erupting volcanoes of Hawaii. This data is being collected to help predict future eruptions. Students are also introduced to the processes that are changing the crust at Hawaii, a hot spot.

Learning Objectives:

Content

- The heat of the inner core of the Earth drives plate motion.
- Uneven heat distribution in the mantle causes convection currents that move the mantle and therefore move the crust.
- Molten material under the crust is called magma. Above the crust, it is called lava.
- Magma rises through cracks in the crust at a rift, pushing the crust apart. This creates a ridge (narrow band of hills or mountains).
- A Volcano is a place at the Earth's surface where molten material escapes and creates new crust.
- Volcanoes erupt differently; the result is volcanoes of different shapes.
- Scientists are observing volcanoes to predict eruptions.

Process

- Support and create an explanation from evidence.
- Compare patterns in data.
- Characterize patterns in data.

Assessment Criteria:
Students can articulate content objectives yet may be using different terms in discussion. Students are using different kinds of supporting evidence for explanations of the processes shaping the crust. They have not yet built a complete explanation. Students are continuing to develop skills to characterize patterns in data and then compare those characterizations.

Vocabulary:

cinder cone- a short/small volcano with steep sides and symmetrical cone shape that generally has short explosive eruptions of cinder (hot rocks and ash)

convection currents – a process of heat transfer that occurs where heat energy is not distributed evenly: material is heated, expands, increases in density, and rises over the cooler material, moving away from the heat source. As it cools the material becomes denser again and sinks; common in liquids and gases, this also happens in the Earth's mantle (although very slowly)

lava – molten mantle material (melted rock) that is above the crust surface

magma – molten mantle material (melted rock) that is below the crust surface

ridge – a narrow band of hills or mountains

rift – a narrow opening at Earth's crust where magma comes up and the crust moves apart

shield volcano – volcano with gradually sloping sides that generally has quiet eruptions; lava that erupts is usually runny, thick, [contradictory? Should it be thin?] and makes fiery fountains

stratovolcano – tall, steep-sided, cone-shaped volcano; generally erupts explosively with ejected material that is often thick and slow and consists of hot rocks and ash

vent – a channel or tube through which magma escapes to the surface of the crust.

Activity	Suggested Pacing	Student Resources	Teacher Resources
6.1: Heating Soup	40-50 minutes	○ Student text pp. 133-137 ○ Science Journal or 6.1 Worksheets ○ Three Page Map from Lesson 5 ○ *Magma Convection* worksheet ○ *Picture Dictionary* worksheet ○ Sentence strips (optional)	○ Lesson 6 Transparency 1 - 3 ○ Materials for convection demonstration (optional)
6.2 Comparing Volcanic Activity	20 minutes	○ Student Text pp. 138-139 ○ Science Journal or 6.2 Worksheets ○ Pen Pal Letters from Lesson 1 ○ 3-D Models ○ Large index cards, each team	○
6.3: Oozing and Blasting Volcanoes	20 minutes	○ Students text p 140-144 ○ Science Journals or 6.3 Worksheets	○ Computer projection system set-up with an internet connection
6.4: Characterizing Volcano Data Patterns	40-50 minutes (each team will need about 15 minutes of computer time)	○ Students text p 145-146 ○ Science Journals or 6.4 Worksheets ○ 3-D Topographic Maps with earthquake data plotted ○ Index cards from Activity 6.2 ○ Small sticker dots in one color ○ Large sticker dots in a variety of colors ○ Chart paper ○ Tape ○ *MyWorld* map view "**ESInquiry**" ○ Saved map file from Lesson 5 ○ *MyWorld* Tool Box and screen capture directions at each computer station.	○ Prepared 3-D model of the Aleutian Islands (see set-up)
6.5: Rivers of Fire Video	40 minutes	○ Student Text pp. 147-148 ○ Science Journal or 6.5 Worksheets	○ TV/VCR system ○ Video, "Rivers of Fire ,"produced by Kurtis Productions

Activity Set-Up:

Activity 6.1: Heating Soup

Decide if you are going to do a demonstration of convection currents. Run through the teacher demonstration prior to class to see how much time is required to heat the amount of water you will use and to make sure that your flakes work. Alternatives are oatmeal or drops of food coloring.

Activity 6.2: Comparing Volcanic Activity

Prepare an index card with a description of the volcanic activity at the Aleutian Islands. (See the activity for details.)

Activity 6.3: Oozing and Blasting Volcanoes

- Locate and mark on a map the three volcanoes in the *Oozing and Blasting Volcanoes* reading. (See the activity for details.)
- Browse the Volcano World web site for interesting photos of volcanoes to share. Try to find two different kinds of volcanoes erupting.
- Browse some other volcano websites. There are some links and descriptions to some of these at the project website, http://www.geode.northwestern.edu/pbi/.
- Talk to the computer teacher or person in charge of the media center to make some of these volcano websites available for students to browse.

Activity 6.4: Characterizing Volcano Data Patterns

Using small sticker dots to plot volcano data on the 3-D map of the Aleutian Islands. The dots should be a different color from the earthquake dots already plotted.

Activity 6.5: "Rivers of Fire" Video

Watch the video to prepare yourself for the student viewing.

Enacting the Lesson

Activity 6.1: Heating Soup

In this activity, students will predict how and why Earth's crust moves. Students will then read some explanations about how and why it moves.

Engaging your students

Ask students to make a prediction. Say: *You have successfully mapped the plate boundaries for the world. Earthquakes gave clues to the plate boundaries. Earthquakes also indicate that these plates are moving. How are these plates moving? What makes them move?* Ask students to write their explanations in their science journals or on a piece of paper.

Share and discuss some of the student explanations. Use the explanations from *Think About This* to encourage students to offer more of their ideas, questions and explanations into the conversation. All ideas should be welcomed into the conversation. In the rest of this lesson and the next lesson, students will use evidence to support or dismiss explanations of how and why the crust moves.

Guiding Student Activity

Read some other explanations about how and why the crust is moving. Both of these explanations are in the form of letters to the Junior Science Team. One letter describes the convection currents in the mantle and the other describes how magma comes up through a rift at the Mid-Atlantic Ridge. Both letters should be read and discussed in class.

The letter describing convection currents will require some discussion and modeling for the students to understand this complex process. After reading and discussing the first letter, students should answer the **Stop and Think Questions** to help them make sense of convection currents and to make a prediction before the next letter.

Stop and Think

A. Using the Magma Convection worksheet, draw arrows to represent the convection currents in the Earth's mantle. *Students should draw arrows on the map in a circular pattern, rising to the crust in the hot areas and sinking in the cool areas.*

B. Make a prediction. What do you think happens to the magma if there is a crack in the crust? *Students will probably say that the magma gets out or erupts or something of that sort. Ask them what they think happens to the plates of the crust as the magma pushes its way out.*

Content Note: *Convection Currents*
Convection currents happen because there is uneven heat distribution. The material closer to the inner core is hotter than the material near the crust, so the material has different densities at different places. The hot material has a lower density and rises, while the cool material has a higher density and sinks. This causes a constant circulation of material as it heats or cools. This circulation pulls and pushes at the crust.

Teacher Tip: *Models of Convection Currents*
If you think you would like your students to have more models of convection currents, here are a few you can use in a demonstration:

Flakes in Water
Pour water into a large beaker until it is filled to about 5 cm from the top. Center the dish on a hot plate and heat it. Add a few pinches of dry parsley or oregano. Looking from the side of the dish, have the students observe what happens in the water. Students should see the flakes rising and falling. Point out that the water moving in convection currents carries the flakes up away from the heat source and then down the sides once the water is cool.

Food Coloring in Water
Take a clear, shallow, plastic dish, like a plant saucer. Set the dish on top of two cups so the cups are supporting it at either end. Fill the plastic dish with room temperature water. Fill another cup with hot water and place it under the center of the dish. Add food coloring to the center of the dish. Watch the pattern of the food coloring. Try adding the food color at the edge of the dish. How is the pattern different? (This activity is adapted from a GEMS unit called *Convection: A Current Event*, published by the Lawrence Hall of Science, University of California. ISBN # 0-912511-15-X)

The second letter, *What happens if there is a crack in the crust?*, is a description of how magma rises up through cracks in the ocean floor, pushing the crust apart. The place where this magma pushes its way out is called a rift. This rising magma creates a narrow band of mountains called a ridge. Students will probably get this idea fairly easily. Ask them what they think happens to the crust when this magma pushes its way out. The magma piles up, and the crust moves apart with the convection currents.

Teacher Tip: *Rift Demonstration*
To help students better understand the process of how the crust moves apart, put two chairs in the front of the room about a meter apart with the backs facing each other. The space between the two chairs represents the rift. Then have students form two lines. Have them move in pairs through the chairs turning away from each other once they pass through the rift (chairs). As the students move away from the chairs the crust is spreading. Students farther away from the chairs represent older crust. Students near the chairs represent new crust. The chairs and build up of "student" magma forms the ridge. The chairs are the ridges. Students should notice that crust at the rift is younger than crust far from the rift.

Teacher Tip: *Model for Magma Escaping*
A great model for mountain building at a rift is a cracked egg that is then hardboiled. You could do this as a demonstration for the students before class and share the result with the class. This "mountain building" of the egg white does not always happen so this may be difficult to do in front of the students.

Content Note: *Rifts and Ridges Background*
Not all rifts are under the oceans; for example, the African Rift Valley is one above water. The crust is added at both places – above and below water – in a similar manner. The magma that comes out at rifts is dense and rich in basalt. We call this basalt-rich crust oceanic crust, even though not all of it is under the ocean (most is). In the next lesson, students will look at differences in the crust.

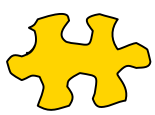
Making Meaning of the Activity

Use Figure It Out questions 1 and 2 for a closing discussion and summary with the class. In Question 2, students will need the *Magma Convection* worksheet to show how the crust moves in the direction of the convection current.

Ask students to answer and discuss question 3-5 if time permits.

Prepare students for Question 6 and 7 for homework. **Question 6** asks students to respond to the explanations given by the Junior Scientists at the start of the lesson. You should add any student explanations that came up in class too; especially those explanations that is especially interesting or will help eliminate misconceptions. For **question 7** you will need to help the class decide which words should be added to their picture dictionary (rift, ridge, convection current, and magma are possibilities).

Figure It Out



1. Why do the plates of the crust move?

2. How does the crust move? Draw arrows on the crust of your *Magma Convection* worksheet showing what happens to the crust.

3. Think back to the example of the pot of soup. If you take the soup off the heat, the bubbling stops after a few seconds. Imagine we could shut off the heat in the inner core of the Earth. What do you think would happen to the Earth?

4. Suna described how magma escapes through cracks in the crust, and crust is added as a result. Do you think crust is always added the same way? Why do you think this?

5. Do you think all volcanoes erupt the same way? What makes you think that?

6. Look back at the explanations in the *Think About This* box at the beginning of the lesson. Knowing what you do now about how and why the crust moves, what would you say to Cate

from New Zealand? To Keona from Hawaii? To Kazuo from Japan? To Consuela from Mexico?

7. You have learned some new terms in reading the explanations. Add these new terms to your picture dictionary.

Homework

Students should answer Figure It Out questions 6 and 7 and any unfinished questions for homework.

Assessment

What work is assessed?	What are you looking for?
Magma Convection worksheet	Students should have drawn arrows representing the convection currents and moving crust.
Figure It Out Question 1	Convection currents in the mantle move the plates of the crust. Heat from the inner core drives the currents.
Figure It Out Question 4 and 5	Students should be thinking abou differences that might occur in volcano patterns and explanations for those differences.
Figure It Out Question 6	Students should begin creating explanations from evidence.
Picture Dictionary (rift and ridge)	Crust is added at a rift, creating a ridge of mountains.

Additional Extension Activities

If you would like your students to explore convection further, there is a GEMS unit called "Convection: A Current Event," published by the Lawrence Hall of Science, University of California. ISBN # 0-912511-15-X. Students explore convection in water, the atmosphere, and Earth's mantle.

<u>Activity 6.2: Comparing Volcanic Activity</u>

In this activity, students will compare the volcanic activity at the different earth structures using the descriptions from their pen pal letters.

Engaging your students

Review and discuss student reactions to explanations of how and why the plates of the crust move (Figure It Out question 6 from Activity 6.1). Below are the original junior scientist explanations to help you guide this discussion. It is important for students to use evidence to support or dismiss explanations. Students should not feel like there are right answers; there are just better supported answers.

"I think the crust shakes back and forth, like gelatin does when you shake it. The plate is just floating on the wiggly molten mantle and when this wiggles the crust wiggles." - Cate Philips from New Zealand	Let students dismiss this explanation with what we now understand about convection and how crust is added at the ridges. Cate has the idea that when the mantle moves, the crust moves with it. The crust moves with the mantle and the mantle generally moves in one direction for long periods of time.
"I think with each earthquake, the crust is moving in the same direction. The plate has to be. I can see it in the way the Islands are lined up in a row. I think the reason they are moving has something to do with the hot center. Some of that heat escapes every time a volcano erupts around here." - Keona Kawena from Hawaii	Keona has the one direction part right. The way that the Hawaiian Islands and many other islands in the Pacific are strung like beads, was one of the first clues scientists used to explain plate tectonics. Students should also agree with Keona's "hot center" idea and that heat escapes.
"I don't understand how a solid rock can move without something pushing it." - Kazuo Matsuyama from Japan.	This can be a difficult idea to understand. How can solid rock be fluid and behave like gas and liquid? You may want to revisit the cornstarch model from Lesson 3. The force that is pushing this process is the heat rising from the center and pushing the plates apart. There are also places where plates are coming back together and crust is being destroyed (Lesson 7).
"I think the Earth's plates are moving apart, and volcanoes are places where the hot mantle is seeping out. Once my mother was boiling an egg that had a crack in it, but she didn't know. Well, the egg on the inside just pushed out and this white "mountain" of egg was just stuck on the outside of the egg along the crack. It was cool and it made me think about volcanoes." Consuela Sanchez from Mt. Popo	This is a great model of how the crust oozes out of rifts to form ridges of mountains.

Guiding Student Activity

Ask: ***What happens at a volcano anyway?*** Students should understand that crust is added each time a volcano erupts. If students do not get this idea, use the volcano descriptions from the pen pal letters as examples to get this point.

Ask: ***Are all volcanoes the same?*** Elicit student ideas. Again use the pen pal descriptions to compare volcanic activity.

Ask: ***What types of volcano activity happen at your earth structure?*** Direct students to go back to their pen pal letters to find descriptions of volcanic activity. Give each earth structure team an index card or small sheet of paper to summarize the volcanic activity for their earth structure. Students should use the questions in the Student Text to guide their summary.

Making Meaning of the Activity

Ask: ***Is crust being added the same way at each earth structure?*** Organize the class to compare the volcano activity at the earth structures much like you compared the earthquake activity in Activity 5.6. One student from each earth structure team should have in hand the 3-D model and the description of volcanic activity that the group just wrote on an index card. Students should organize themselves into groups that have similar types of volcano activity.

Once the groups have organized themselves according to volcanic activity, **lead a class discussion that gets students to compare the patterns across groups**. What is similar? What is different? Why are there differences in volcanic activity? Students should see that volcanoes happen in different kinds of patterns. Some students might predict that different kinds of movement lead to different kinds of volcano patterns.

Teacher Tip: *Setting Expectation and Pacing*
This organization and comparing activity should be quick. Let kids organize and generalize. Try not to scrutinize each and every earth structure pattern. This activity is really just a warm up to some more detailed comparisons. The important thing here is that students have described the volcanic activity at their earth structure clearly and accurately.

Direct students to answer the Reflection Question.

Reflection Question

Why are there differences in volcanic activity?

Assessment

What work is assessed?	What are you looking for?
Earth structure team descriptions of volcanic activity	Earth structure teams should tell how often volcanoes erupt, describe an eruption, and tell how many volcanoes are in the area of their earth structures.
Grouping by volcano activity	This is one of the students' early attempts at comparing and grouping data. Groupings should be supported with the analysis of the data.

Volcanic Activity from pen pal letters

Earth Structure	How often do volcanoes erupt?	Describe an eruption.	How many volcanoes are in the area?
Aleutian Islands	Unknown	Earthquakes become more frequent, larger before an eruption; violent eruptions	Many active volcanoes, most underwater lots of volcanic islands
Andes Mountains	Unknown	Ash clouds pour out of volcanoes; mudflows occur when volcanic debris mixes with water, and the mudflows come down the mountains at high speed – very destructive	30 active volcanoes
Baja California	Not often – Tres Virgenes hasn't erupted since the 1700s	Unknown	A few, including Tres Virgenes
Hawaiian Islands	Pretty frequently – the last violent eruption of Kilauea was in the late 1990s	Usually, lava comes out quietly or in a fountain, although it can flow very fast (35 mph). Occasionally eruptions can include dark ash clouds and flying sand and burning rock.	The island of Hawaii is made up of five volcanoes. There's also an underground volcano forming an island called Loihi.
Himalayas	Unknown	Unknown	Volcanoes scattered throughout the area
Iceland	Frequently. An underwater volcano	Most erupt under the ice. Rapidly	Many; Iceland's land comes from

	eruption in 1963 created a new island, Surtsey. Another eruption in 1973 forced an evacuation of 5,000 residents and caused massive damage – the dangerous volcanic activity continued for a year.	flowing mixtures of water, ice, and rocks result from volcanic eruptions; they are very dangerous and destructive.	lava flows
Japan	Not very often; Mt. Fuji hasn't erupted since 1707	Unknown	Over 200 volcanoes; over 40 active volcanoes
Java Trench	Frequent – most of the eruptions have occurred within the last 100 years	Volcanoes spit up ash and steam, then erupt explosively, shooting out rocks and lava. Tsunami waves may result from the eruptions.	76 active volcanoes
Mariana Trench	Unknown, but recent	Eruptions spew ash and lava.	12 volcanoes above the water, 40 submarine volcanoes
Mount Etna	Frequent – almost 200 times in the last 3,500 years	Small ash and steam eruptions occur all the time; eruptions only affect the area at the summit. Lava moves slowly down the mountain	1 – but close to Mount Vesuvius
Mount Popocatepetl	Volcanic activity infrequent – last major eruption more than 10,000 years ago; another in the 9th century, and 20 minor eruptions since then	Steam and volcanic gases come from crater; raining ashes, ashcloud, and series of earthquakes and minor eruptions occur with eruptions.	Unknown
Mount St. Helens	Some activity in the 1800's, violent	Bulge of magma in the side released in	Several volcanoes in the Cascades

	explosion in 1980, current volcanic activity: frequent recent activity	a large blast – downpour of rocks, eruption of pumice and ash; huge blast out of north side of volcano – rock and debris came out of the side. Rock, debris, and ash erupted. The powerful blast wiped out forests; mudflows destroyed houses.	
Mount Vesuvius	Last major eruption was 1,000 years ago, with more minor eruptions in the early 20^{th} century; still frequent volcano-related earthquakes	Clouds of rock and ash erupted high into the air. When these collapsed, hot gas, rock, and fast-moving lava, mud, and ash flows resulted.	None, but close to Mount Etna (2 of 4 active volcanoes in Italy)
New Zealand	Frequent small eruptions, major eruption in 1886	The three peaks of Mount Tarawera erupted at once, sending up ash and smoke clouds in a loud blast much more powerful than Mt. St. Helens' eruption.	Lots of volcanic activity – over 400 active volcanoes
African Rift Valley	Some volcanic activity, infrequent eruptions	Unknown, but eruption similar to Mt. St. Helens is feared.	20 volcanoes in the southern end
St. Helena Island	No eruption in 6 million years	Unknown – happened millions of years ago	Island is a volcano – most of the rock on the island came from two volcanoes on opposite sides of the island

Activity 6.3: Oozing and Blasting Volcanoes

You will lead a discussion about volcanoes while showing students some real-time volcano data at the Volcano World web site. This website is full of volcano data that is organized for the general public. It is packed with photos, real-time data, and links to other data sources.

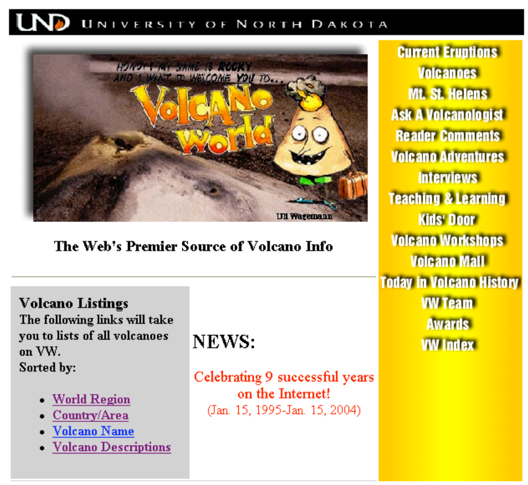
Engaging your students

Use the *Think About This* questions to help get students thinking about what it would be like to experience a volcanic eruption. Remind students of the descriptions they read in the newspaper articles in Lesson 1.

To get students thinking about volcano data, ask and discuss the following questions:

a. *Where do most volcanoes happen in the world?*
b. *When was the last volcanic eruption?*
c. *Where was that eruption?*
d. *How often do you think volcanoes erupt?*

Introduce the Volcano World web-site, which has volcano data organized for the general public. It includes photos, real-time volcano data, and links to other data sources. It is sponsored by the University of North Dakota and gets data from several science sites.



Guiding Student Activity

Continue discussion.

e. *When and where was the last recorded volcanic eruption?*

Go to current eruptions and look at the list that is recorded here. Eruptions are posted about once per month. Students should notice that the last eruption listed for some volcanoes is "ongoing."

Eruptions are sorted in order of the last update on VW (The most current updates are at the top of the list).

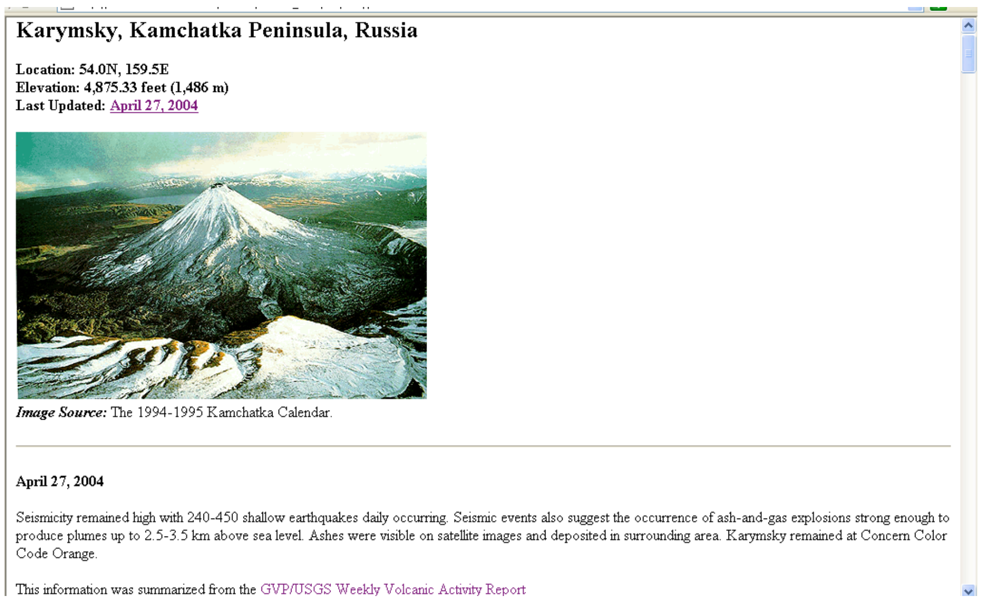
VOLCANO:	DATE OF MOST RECENT ERUPTION OR ACTIVITY:	LAST UPDATED	LOCATION
Asama, Honshu, Japan	September 14, 2004	September 14, 2004	36.4N, 138.53E
Egon, Indonesia	September 13, 2004	September 14, 2004	8.7S, 122.55E
Etna, Sicily, Italy	September 13, 2004	September 14, 2004	37.7N, 15.0E
Mauna Loa, Hawai'i	September 12, 2004	September 14, 2004	19.5N, 155.6W
Mayon, Philippines	September 12, 2004	September 14, 2004	13.3N, 123.7E
Fuego, Guatemala	ongoing	September 14, 2004	14.5N, 90.9W
Karymsky, Kamchatka, Russia	ongoing	September 14, 2004	54.0N, 159.5E
Kilauea, Hawai'i	ongoing	September 14, 2004	19.452N, 155.292W
Santa Maria, Guatemala	ongoing	September 14, 2004	32.88N, 131.1E
Sheveluch, Kamchatka, Russia	ongoing	September 14, 2004	56.65N, 161.36E

f. *What does "ongoing" mean?*

Find a volcano that is "ongoing" on the current eruption list and link to it to learn more about the volcano.

g. *How is volcano data reported?*

If you select any one of the volcanoes on the current activity list, you will usually find a picture of the volcano and a list of reports describing its volcanic activity. These reports are usually summary reports from USGS and the Global Volcanism Program.


Karymsky, Kamchatka Peninsula, Russia

Location: 54.0N, 159.5E
Elevation: 4,875.33 feet (1,486 m)
Last Updated: April 27, 2004

Image Source: The 1994-1995 Kamchatka Calendar.

April 27, 2004

Seismicity remained high with 240-450 shallow earthquakes daily occurring. Seismic events also suggest the occurrence of ash-and-gas explosions strong enough to produce plumes up to 2.5-3.5 km above sea level. Ashes were visible on satellite images and deposited in surrounding area. Karymsky remained at Concern Color Code Orange.

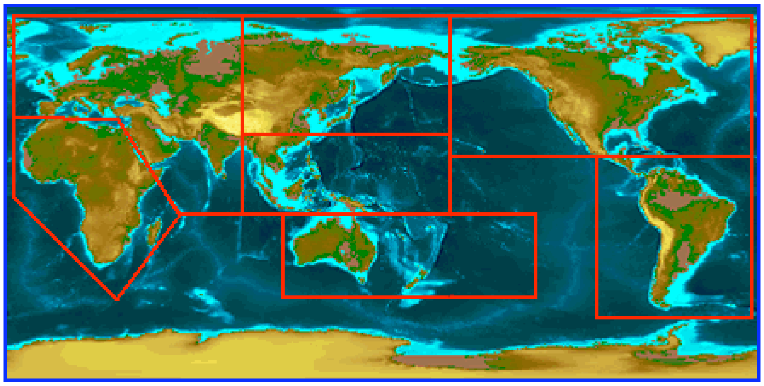
This information was summarized from the GVP/USGS Weekly Volcanic Activity Report

Teacher Note: *Global Volcanism Program*
The Global Volcanism Program is a very useful website for volcano information. This program seeks better understanding of all volcanoes through documenting their eruptions – small as well as large – during the past 10,000 years. This site has a very large database of volcanoes and regularly posts reports. The reports are not written for the general population but can be a very useful resource. Many other websites and data bases seem to get their data from the reports posted by this program.

h. *Where are most of the volcanoes?*

Go back to the home page of Volcano World and select Volcanoes. This will link you to a page like the one at the right.
You can find photos and movie clips of eruptions and volcanoes. You can even find a link to volcanic observatories here.

Select "Earth's Volcanoes" to link to a world map that organizes volcanoes by region. Spend some time browsing the different maps and lists of volcanoes that are available for each region. (This is not an all-inclusive list of volcanoes.) This list has photos, so you can get students to compare different types of volcanoes – and to notice that not all volcanoes are the same. Students might also notice that not all the earth structures have volcanoes listed in this data base.



You can also click on the name of the region you would like to see.

i. *What are some differences in the eruption patterns of different volcanoes?*

Select two different volcanoes that recently erupted or are currently erupting. There is usually a photo of the erupting volcanoes. Compare the photos. Below left is a picture of a tall volcano in Guatemala erupting smoke and ash. Compare the eruption to that of Kilauea, on Hawaii, at the right. These pictures may not be available at the time you are viewing the website, but browse a little to find some interesting photos.

Fuego (left) and Pacaya (right), November 10, 1994. ***Photograph copyrighte***

http://volcano.und.nodak.edu/vwdocs/volc_images/south_america/guat/fuego.html

http://hvo.wr.usgs.gov/kilauea/update/main.html#images

Making Meaning of the Activity

j. ***Do all volcanoes erupt in the same way? Is all crust added the same way?***

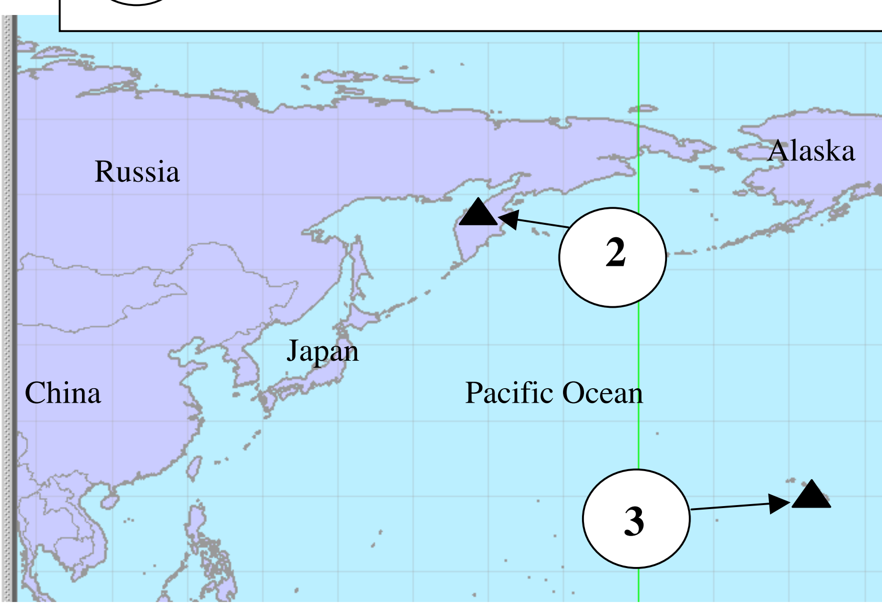
Students should notice from the website that there are different kinds of volcanoes and that volcanoes erupt in different ways.

Prepare students to read *Oozing and Blasting Volcanoes* for homework. In this reading, students will be introduced to three volcanoes: Paricutin in Mexico, Bezymianny on the Kamchatka Peninsula in Russia, and two of the volcanoes on Hawaii, Kilauea and Mauna Loa. You should show students where these places are located on a map. Use the maps below as a guide. In this reading, students will compare the shape, eruption patterns, and eruption debris of these volcanoes.

1 aricutin in Mexico

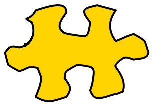
2 ezymianny in Russia

3 ilauea and Mauna Loa in Hawaii, U.S.A



Homework

Ask students to read *Oozing and Blasting Volcanoes,* and to answer the Figure It Out questions that follow. Students will need their science journal or additional picture dictionary worksheets for Figure It Out **Question 6**. Students should add these words: shield volcano, stratovolcano, cinder cone, lava, and magma.

Figure it Out 

1. What is a volcano?
2. How long does an eruption last?
3. Compare a shield volcano, stratovolcano, and a cinder cone volcano. A table might help you organize your ideas.
4. Where do most volcanic eruptions occur?
5. What types of volcanoes are at your earth structure? Explain.
6. You have learned some new terms in this reading. Add these new terms to your picture dictionary.

Assessment

What work is assessed?	What are you looking for?
	<u>**Content**</u>
Discussion and Figure It Out question 1	A volcano is a place at the Earth's surface where molten material escapes and creates new crust.
Figure It Out question 3	Volcanoes erupt differently
Picture Dictionary	Magma vs. Lava

Additional Extension Activities

If students have the opportunity in another class or when at the media center, they can browse several interesting websites to learn more about volcanoes. See the project website, www.geode.northwestern.edu/pbi/, for more links.

Activity 6.4: Characterizing Volcano Data Patterns

In this activity, students will plot and analyze real volcano data. Students will then compare volcano data patterns across earth structures.

Engaging your students

Say: ***You just read about different kinds of volcanoes. Let's compare the three kinds of volcanoes: shield, stratovolcano, and cinder cone***. Use the table below to help you lead a class discussion to compare volcanoes. Use descriptive examples from the reading to help with the comparison.

Shield	Strato	Cinder Cone
large	large	short/small
gradual sloping sides	steep, symmetrical cone	steep, symmetrical cone
quiet eruptions	explosive eruptions	explosive eruptions
runny, thin lava, fiery fountains	thick, slow lava, ash, rock	cinders, hot rocks

Content Note: *Comparing types of volcanoes*

Volcanoes do not always fit nicely into each type. They can display characteristics of one type at one time and then another type at a different time. There are more general characteristics to compare these types of volcanoes. These are marked below with **. Some of these characteristics will be explored in Lesson 7, some will not. This is just for your information.

Shield	Strato	Cinder Cone
large	large	short/small
gradual sloping sides	steep, symmetrical cone	steep, symmetrical cone
quiet eruptions	explosive eruptions	explosive eruptions
runny, thin lava, fiery fountains	thick, slow lava, ash, rock	cinders, hot rocks
*ejection is basaltic	*andesitic	*both
*common at hot spots and rifts	*common at subduction zones	*everywhere
dissolved gas releases easily	dissolved gas does not release easily	dissolved gas does not release easily

Guiding Student Activity

Students will now go to the computer to plot volcano data for their earth structure and compare the patterns to other earth structures. Students should use small sticker dots as they did in Activity 5.6 to plot volcanoes on their 3-D model. Be sure students use a different color from the earthquake dots. Students should use the *MyWorld* map view "**ESInquiry.mpz**." This map view has earthquake data, volcano data, earth structure boxes, and elevation and depth data available.

Students are also asked to compare the patterns they see at their earth structure to data patterns of other earth structures. Students should screen capture and annotate maps in the same document they used in previous activities. If time is an issue, Step 2 and 3, the comparisons students do at the computer, can be skipped. If you do this, you will not have the same opportunity to give students feedback on how they are analyzing data.

After all the groups have had a chance to collect volcano data on their 3-D models, ask, ***Are the patterns in the volcano data the same?*** One member of each earth structure team will now participate in grouping the earth structures with similar volcano data. Students might group together all the earth structures that have a volcano pattern that is a straight line. Another group might be earth structures that have volcanoes in a scattered pattern. Students should have in hand their 3-D models with their volcano data plotted and the index cards summarizing volcanic activity. To start you may want to have students return to the groups formed in Activity 6.2.

Once the class has settled on the grouping of the earth structures, these new **groups should work together to characterize the volcano patterns**. Each group will need a piece of chart paper to write down the characterization of their volcano data. The following questions can help you guide students to describe and characterize the patterns they see in the volcano data:

How can your group characterize the volcano patterns? Describe the data pattern. Some possible group characterizations could be: few, lots in clusters, line of volcanoes, or scattering of volcanoes. Let students decide how they are going to describe the pattern.

Using the volcanic activity descriptions from Activity 6.2, how would your group characterize the volcanic eruption patterns? What kinds of volcanoes do you think are represented in your group? Students should be encouraged to use their volcanic activity descriptions to help the group characterize the kinds of eruptions that happen at their earth structure. Question 5 from Figure It Out questions in Activity 6.3 should also help them see if the eruptions patterns are similar. On the same chart paper, groups should write a description of the kinds of eruptions that are represented in their group.

Groups should ***label the 3-D models to indicate which group each earth structure is in***. Large sticker dots in different colors should work. This is so when the 3-D models are returned to the Big World Map students can look to see if there are patterns.

Have **each group prepare to share the volcano data characterizations with the class**. Each group should have on the chart paper:

- a characterization of the data pattern,
- a description of the kinds of eruption activity
- the kinds of volcanoes students think are at their earth structure
- the earth structure volcanic activity index card taped to the chart paper

> ***Teacher Note:*** *Why do it this way?*
> In the next lesson, students will be asked to analyze and characterize several pieces of data. This type of activity prepares student for future analyses.

Making Meaning of the Activity

Have each group share their characterizations and descriptions with the class. Students should be looking for similarities to their group, and patterns in the data.

Look for more patterns in volcano data. Tape the 3-D models to the Big World Map. These models have earthquakes plotted in one color, volcanoes plotted in another, and sticker dots indicating the volcano group. Do you notice any patterns? Do certain volcano patterns happen in certain places?

<u>Reflection Questions</u>

A. Why do you think volcanoes happen in different patterns at different earth structures?
B. Why do you think earthquakes happen in different patterns at different earth structures?
C. **<u>It's Your Turn</u>**: Write a letter to your pen pal describing the pattern of volcanoes and the type of volcanoes you think are at your earth structure. Be sure to tell your pen pal how you figured these things out.

Homework

Assign Reflection Questions for homework.

Assessment

What work is assessed?	What are you looking for?
Group descriptions	<u>Process</u> Students' ability to compare patterns in data
Screen captures from Step 2 and 3 Characterizing patterns done by groups	Groups becoming more descriptive and precise with their characterizations of patterns. This is the first time students are writing characterizations, so students will need feedback. The descriptions should be general and include all of the earth structures in the group.
Reflection Questions A-C	Students should be using anecdotal data and volcano data to support/create explanations

Activity 6.5: "Rivers of Fire" Video

Students watch a video that features scientists studying volcanoes and finding patterns in earthquake data. Students will see how scientist measure and observe volcanoes in Hawaii. There is also some excellent footage of erupting volcanoes.

Engaging Student Activity

Introduce the video by asking students what it might feel like if they were standing at Kiluea in Hawaii right now**. What might they observe happening around them? Tell them that this video shows real scientists observing an erupting volcano.**

To prepare for viewing the video, direct students to briefly review the Figure It Out questions in their Student Text.

Guiding Student Activity

Watch the video. The video is 30 minutes in length**.** Prompt the students to write down any notes that may aid them in answering the Figure It Out questions in their student booklet.

Making Meaning of Activity

After watching the video, ask students to answer the Figure It Out questions. After students have had a few minutes to answer the questions, engage the class in a discussion. Ask: *can we predict a volcanic eruption?* Students should share what they were able to extract from the video, along with answers to the questions.

Figure It Out

A. Were the volcanoes described in the video "quiet" or "explosive" volcanoes?
B. What kinds of data are collected to help predict if a volcano is going to explode?
C. The video described Hawaii as a hot spot. What is a hot spot? How is crust added at Hawaii?
D. Why do new active volcanoes continue to pop up and old volcanoes go extinct at a hot spot?
E. Is your earth structure changing because of the same process that is happening in Hawaii? Explain.

Homework

You could select or find a volcano-related article from the Appendix. There are articles about the possible eruption of Mt. St. Helens and an article describing a volcanic eruption on Io, one of Jupiter's moons.

Assessment

What work is assessed?	What are you looking for?
Figure It Out question E	Process Comparison of patterns
Discussion	Content Students can articulate that we have the ability to predict where and generally when an eruption may occur if we are watching. Often we are not watching; in addition, we cannot know for sure *how* the volcano will erupt.

Additional Extension Activities

A video clip of stratovolcano erupting and a shield erupting would be nice to have in this lesson. . . .Students could then compare the eruptions rather than just descriptions of the eruptions.

WHAT'S THE POINT?

In this lesson, you have looked at how volcano data is collected and reported. You have also determined that volcanoes are not all the same. You have noticed these differences in the data patterns and in the descriptions of the volcanic eruptions.

Why do you think volcanoes erupt differently? *They are erupting in different places and as the result of different processes.*

How do you think volcano patterns relate to earthquake patterns? *Where there are earthquakes there are volcanoes. The earthquakes often release the crust so the magma can get out.*

Explain the process causing the changes happening at your earth structure. *Students will have a variety of answers here but their explanations should be supported with anecdotal data, earthquake data, and volcano data. Student explanations may not be complete, but students should attempt to make sense of the data. In the next lesson students will describe the process of the crust changing and use that additional information to describe the processes changing their earth structure.*

Teacher Reflection

How are your students doing with analyzing point data on maps?

How did the characterization activity go? How well did students characterize the data patterns?

Are students supporting explanations with data? What kinds of data?

What content is the class struggling with?

What processes are they having trouble developing?

Name ______________________________

Activity 6.1: Heating Soup

Stop and Think

A. Using the *Magma Convection* worksheet, draw arrows to represent the convection currents in the Earth's mantle.

B. Make a prediction. What do you think happens to the magma if there is a crack in the crust?

Students predictions will vary. Encourage students explain what is supporting their prediction.

8. Why do the plates of the crust move?

The very hot core heats the mantle. The uneven heat distribution in the mantle (hot near the center and cool near the surface) starts convection currents in the mantle. When the mantle moves, the crust on top moves with it.

9. … *onvection* worksheet showing what happens to the crust.

10. Think back to the example of the pot of soup. If you take the soup off the heat, the bubbling stops after a few seconds. Imagine we could shut off the heat in the inner core of the Earth. What do you think would happen to the Earth?

Eventually the crust would stop moving because the convection currents would stop in the mantel.

1… s added as … ink this?

Students responses will vary. Encourage students to justify their answers. Crust is added in a variety of ways. It escapes but in different ways at different places leading to different earth structures.

12. Do you think all volcanoes erupt the same way? What makes you think that?

Answers will vary, encourage students to justify their answers. Students will use what they know to justify and that is fine. This question is seeding future explorations of volcanoes.

Name ______________________________

Activity 6.1: Heating Soup

13. Look back at the explanations in the *Think About This* box at the beginning of the lesson. Knowing what you do now about how and why the crust moves, what would you say to Cate from New Zealand? To Keona from Hawaii? To Kazuo from Japan? To Consuela from Mexico?

Students answers will vary. Here are some possibilities.
Cate: The crust moves in the direction of the convection currents. If the pattern of the convection currents changes so does the plate movement. The crust seems to move in one direction.

Keona: I agree with you. The crust moves in one direction and the heat escapes. The hot center is what drives the whole process. If you look closely at the Islands of the Pacific they do look like chains.

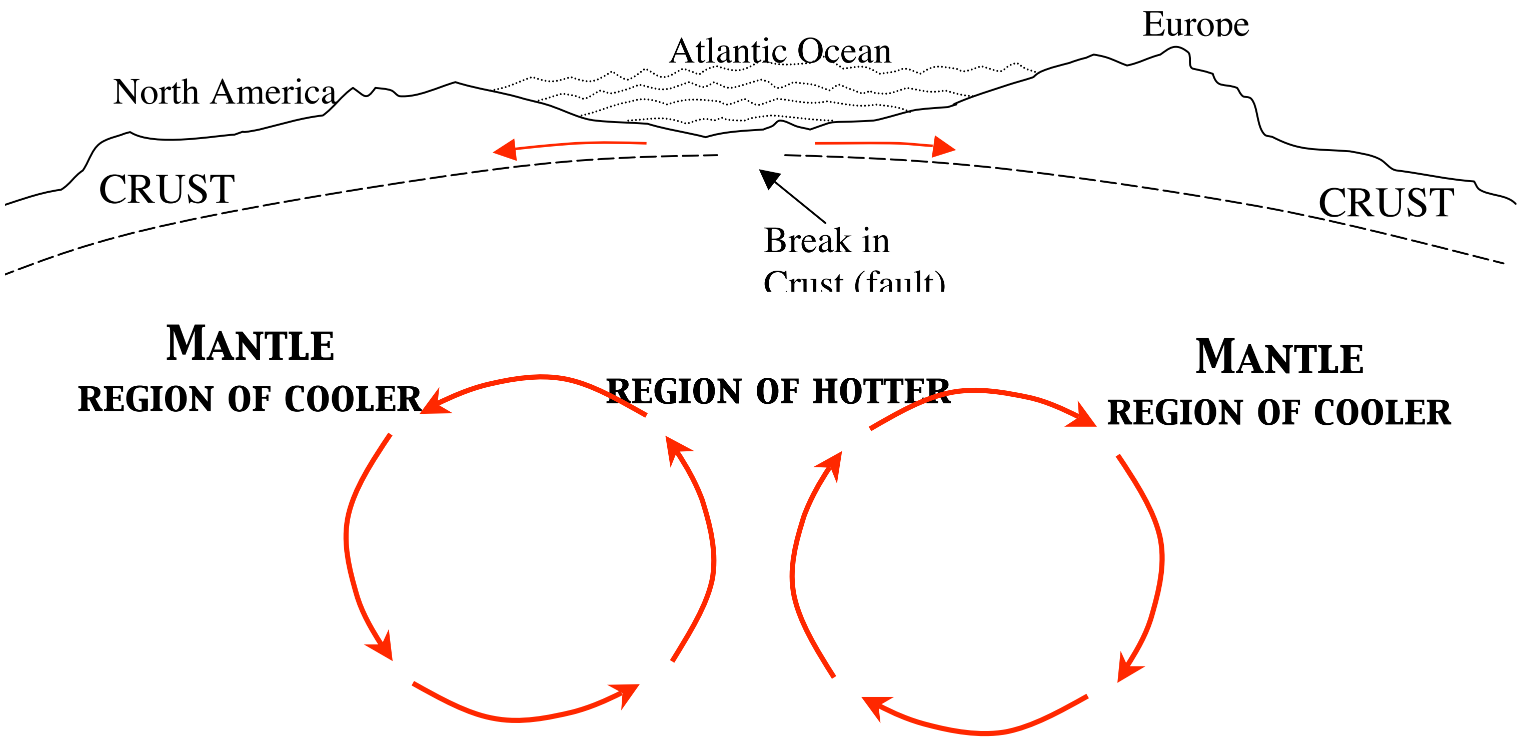
Kazuo: Heat is moving the rock. . .Just like the egg. . .the crust is pushed out of the way by the rising hot material.

Consuela: Great analogy. . .if all of the plates are moving apart is the Earth getting bigger? (No, somewhere they are moving together).

14. You have learned some new terms in reading the explanations. Add these new terms to your picture dictionary.

Name ______________________________

Magma Convection



172

Name ______________________________

Activity 6.2: Comparing Volcanic Activity

Reflection Question

Why are there differences in volcanic activity?

Students responses will vary. This is an opportunity to identify student preconceptions before they read more about volcano activity and how the process works.

Name ______________________________

Activity 6.3: Oozing and Blasting Volcanoes

Reflection Questions

What questions did you ask yourself about volcanoes as you looked at the real-time web-site?

Questions will vary.

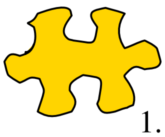


Figure it Out

1. What is a volcano?

Answers will vary.

2. How long does an eruption last?

Answers will vary.

3. Compare a shield volcano, a stratovolcano, and a cinder cone volcano. A table might help you organize your ideas.

4. Where do most volcanic eruptions occur?

Both answers are acceptable.
Around the Pacific Ocean – the Ring of Fire or under the ocean on the sea bottom

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Name ______________________________

Activity 6.3: Oozing and Blasting Volcanoes

5. What types of volcanoes are at your earth structure? Explain.

Answers will vary. Be sure students compare their volcano to those in the reading to justify their decision.

6. You have learned some new terms in this reading. Add these new terms to your picture dictionary.

Name________________________

Activity 6.4: Characterizing Volcano Data Patterns

Reflection Questions

D. Why do you think volcanoes happen in different patterns at different earth structures?

This is an opportunity to elicit preconceptions and to start getting students to think about the process of adding crust. Volcanoes happen in different patterns because the crust moves in different ways.

E. Why do you think earthquakes happen in different patterns at different earth structures?

This is an opportunity to elicit preconceptions and to start getting students to think about the process of adding crust. EArthquakes happen in different patterns because the crust moves in different ways.

F. **It's Your Turn:** Write a letter to your pen pal describing the pattern of volcanoes and the type of volcanoes you think are at your earth structure. Be sure to tell your pen pal how you figured these things out.

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Figure It Out

1. Were the volcanoes described in the video "quiet" or "explosive" volcanoes?

____

2. What kinds of data are collected to help predict if a volcano is going to explode?

____

Name______________________

Activity 6.4: Characterizing Volcano Data Patterns

3. The video described Hawaii as a hot spot. What is a hot spot? How is crust added at Hawaii?

____

4. Why do new active volcanoes continue to pop up and old volcanoes go extinct at a hot spot?

____

5. Is your earth structure changing because of the same process that is happening in Hawaii? Explain.

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Lesson 7

Plates on the Move

This is the lesson where students bring everything together. Students will characterize what they see in both earthquake and volcano data and refine their explanations of the changes happening at their earth structure with this data. Students will then use that analysis to determine the direction the plates are moving. At the end of this lesson, students will explain how that movement is changing their earth structure. They will also support those explanations with earthquake, volcano, topography, and anecdotal data.

What have students learned so far? Students know that earthquakes and volcanoes indicate that the crust is moving and cause changes at the earth structures. In Lesson 5, students mapped the plates of the world. In Lesson 6 students learned that the circulation of the convection currents causes the crust to move with the currents. Students also learned in Lesson 6 that volcanoes are places where crust is added and that different types of volcanoes add crust in different ways. These differences show up in different patterns of volcano data and differences in volcano behavior. Students have also begun to explain the processes that are causing change at their earth structures, using supporting evidence.

Why is it important for students? The point of the whole unit is for students to make explanations from data. This is what scientists do – try to explain the patterns they see in data. New ideas and explanations are discovered by this method. After conversation and debate in the scientific community, explanations evolve into collective knowledge. The questions and explanations in this field of science are changing and evolving all the time, so it is a natural discussion for students to participate in. There are really not any right or wrong answers, just better supported answers.

Lesson Overview:

Activity 7.1: Characterizing Both Data Patterns
In this lesson, students will look at both earthquake and volcano data to sort and characterize the patterns. This will help students describe and explain the processes causing changes at their earth structures and at the plate boundaries.

Activity 7.2: Identifying Zones
In this activity, students will identify the different kinds of movement zones at their earth structures and then around their plates. Students will also predict in which direction the plate is moving.

Activity 7.3: Depth of Earthquakes (Optional)
In Activity 7.1, students learned that deep earthquakes happen at subduction zones. In this lesson, students will look at some depth data of earthquakes to help them explain and identify subduction zones. They will also read about the differences between oceanic and continental crust.

Activity 7.4: Volcano Types Data (Optional)
Students will look at patterns in volcano data to help them explain what is happening at their earth structures and plate boundaries.

Activity 7.5: What is Happening at Your Earth Structure?
In this final activity, students will summarize their evidence and explain the changes that are happening at their earth structures.

Learning Objectives:

Content:

- Earthquakes and volcanoes happen in different patterns because plates move in different ways.
- Plates move in different ways: subduction, buckling; rifts; and transform
- At subduction zones, one plate dives under another plate, leading to deep earthquakes under the overriding plate.
- Stratovolcanoes are more common at subduction zones and shield volcanoes are more common at rift zones.

Process:

- Characterize and then identify data patterns with multiple variables.
- Make explanations (of a process) from data.
- Draw a model to help with an explanation of the data.

Assessment Criteria:
Students will create explanations from the data. There is not any right or wrong explanations of the data, just those that are well supported and poorly supported. Students should be able to explain the process that is causing the changes at their earth structure and at the plate boundaries. They should also be supporting these explanations with multiple pieces of data: earthquake, volcano, topographical, and anecdotal data from the pen pal letters. If you choose to do Activity 7.3 and 7.4, students should also be able to use earthquake depth and volcano type data in their explanations.

Vocabulary:

buckling zone – area where plates are moving together and the crust is pushing up into a mountain range

continental crust – thick and less dense crust, primarily makes up the continents

oceanic crust – thin and dense crust, primarily under the ocean

rift zone – area where plates are moving apart and crust is being added

subduction zone – area where plates are moving together and one is diving under the another

transform zone – area where plates are moving past each other

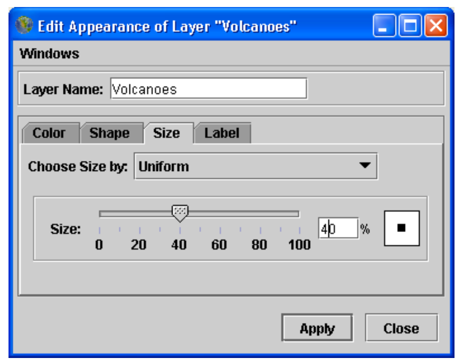
Activity	Suggested Pacing	Student Resources	Teacher Resources
Activity 7.1: Characterizing Both Data Patterns	40-50 minutes	○ Student Text pp. 149-159 ○ Science Journals or 7.1 worksheets ○ 3-D model with earthquake and volcano data plotted ○ Computers with *MyWorld* and map view "**ESInquiry**" ○ Chart paper and markers ○ Color printer (optional)	○ Computer projection system with *MyWorld* and map view "**ESInquiry**" ○ Lesson 7 Transparency 1
Activity 7.2: Identifying Zones	40-50 minutes **	○ Student Text pp. 160-161 ○ Science Journals or 7.2 worksheets ○ Pictures from 7.1 ○ Plate maps from Lesson 5 ○ Computers with *MyWorld* and map view "**ESInquiry**"	○ Lesson 7 Transparencies 1-8 ○ Computer projection system with *MyWorld* and map view "**ESInquiry**"
Activity 7.3: Depth of Earthquakes (Optional)	40-50 minutes**	○ Student Text pp.162-165 ○ Science Journals or 7.3 worksheets ○ *Small World Map* worksheet for each team ○ Computers with *MyWorld* and map view "**ESInquiry**"	○ Computer projection system with *MyWorld* and map view "**ESInquiry**"
Activity 7.4: Volcano Types Data (Optional)	40-50 minutes**	○ Student Text pp.166-167 ○ Science Journals or 7.4 worksheet ○ *Small World Map* worksheet for each team ○ Colored pencils, each team ○ Computers with *MyWorld* and map view "ESInquiry"	○ Computer projection system with *MyWorld* and map view "**ESInquiry**"
Activity 7.5: What is Happening at Your Earth Structure?	80 -90 minutes**	○ Student Text pp. 168-170 ○ Science Journals or 7.5 worksheet ○ Three Page Map from Activity 7.2 ○ Topo maps from Lesson 2 ○ Picture started in 7.1 ○ Display board (optional) ○ Computers with *MyWorld* and map view "**ESInquiry**" ○ Color printer (optional)	○ Computer projection system with *MyWorld* and map view "**ESInquiry**" ○ Lesson 7 Transparency 9

Teacher Note: Pacing*
In Activity 7.2, each team will need about 20 minutes to identify and note the zones for their plate. In Activities 7.3 and 7.4, students will need about 10 minutes on the computer to observe and capture the data pattern. The observations in these activities could also be done with a projector in front of the whole class. For Activity 7.5, students will just need to print the data they have collected throughout this unit. This can be done before class or during class; you can decide when. Be sure students have computers available to re-capture data they may need. If you have the computer time, students can also create reports on the computer using Power Point or Word.

Activity Set-Up:

Activity 7.1: Characterizing Both Data Patterns

- Students will need access to computers with *MyWorld* map view "**ESInquiry**."
- Decide how student groups are going to share examples of the different kinds of zones. See the activity for organization ideas. If you are not going to use a color printer, it is suggested that you change the size of the volcanoes so students can differentiate the earthquakes from the volcanoes. To do this, open the map view, and double-click on the Volcano Layer. A box will show with "Color" and "More" tabs. Select the "More" tab, then select the "Size" tab. Change the size of the volcanoes to 40%. Apply the changes and close the box. You should probably save this version of the Map View with a different name (e.g. "**ESInquirybigvolc.mpz**") so you do not change the original map view.



- At each computer station, there should be the *Icon Tool Box* and screen capture directions.

Activity 7.2: Identifying Zones

- Set up the computer projection system with *MyWorld* map view "**ESInquiry**" available.
- Students will need access to computers with *MyWorld* map view "**ESInquiry**."
- At each computer station, there should be the *Icon Tool Box* and screen capture directions.
- Be sure students have available the Three Page Plate map they drew in Lesson 5 and the drawing they did in Activity 7.1.
- Decide if students are going to do Activity 7.3 and 7.4. Question B of the Reflection Questions is a seeding question for these activities and should be skipped if you are not going to do these activities.

Activity 7.3: Depth of Earthquakes (Optional)

- Set up the computer projection system with *MyWorld* map view "**ESInquiry**" available.
- Students will need access to computers with *MyWorld* map view "**ESInquiry**."

Activity 7.4: Volcano Types Data (Optional)

- Set up the computer Projection System with *MyWorld* map view "**ESInquiry**" available.
- Students will need access to computers with *MyWorld* map view "**ESInquiry**."

Activity 7.5: What is Happening at Your Earth Structure?

- Set up the computer projection system with *MyWorld* map view "**ESInquiry**" available.
- Students will need access to computers with *MyWorld* map view "**ESInquiry**."
- Decide how students are going to share their explanations. What will the students' products look like? (There are some suggestions in the activity.) Students can print data maps if you have access to a color printer. If a color printer is not available, you could enlarge the volcanoes so students can differentiate between earthquakes and volcanoes (see Activity 7.1 set-up). Another option is having students use the computers to share their data. They can simply use the screen captures that they created to organize their report.
- Decide how students are going to share their reports. The lesson suggests that students share these reports in small groups much like they did in the Neighbor Plate Meeting. Each small group should have access to a computer with *MyWorld* and "**ESInquiry**." If you decide to organize the class in this way, set up these small groups.

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Enacting the Lesson

Activity 7.1: Characterizing Both Data Patterns

In this lesson, students will look at both earthquake and volcano data to sort and characterize the patterns. This will help students describe and explain the processes causing changes at their earth structure and at the plate boundaries.

Engaging the Students

Say: ***Describe the pattern you see in the earthquake and volcano data of the Aleutian Islands.*** Show students a transparency of the Aleutian Islands with earthquake and volcano data plotted. You can use either the *MyWorld* map view "**ESInquiry**" or the Lesson 7 Transparency 1. How do the patterns relate to each other? How would students characterize the data patterns?

Ask students to compare the earthquake and volcano data patterns for the Aleutian Islands to the patterns for their earth structure. Are the patterns similar? How are they similar? How are they different? Elicit answers from students to get them thinking before they start to characterize the patterns.

Lead the class to group earth structures with similar earthquake and volcano data patterns. One member of each team will participate in an all class sort of the earth structures like the class has done before. This time students are looking for common patterns in both the earthquake and volcano data. Students should bring use their 3-D models to share the data patterns for each earth structure.

Once groups have been established, **highlight some of the differences and similarities across the groups.** It may be helpful to have the "**ESInquiry**" map view available to share the data patterns with the entire class.

Guiding Student Activity

Groups should then be directed to **write a description of the patterns for their group of earth structures**. Students should write these descriptions on chart paper.

- Describe the pattern of earthquakes.
- Describe the pattern of volcanoes.
- Describe the topography of the land.
- Name the pattern.
- Describe the relationship of the earth structures to the plate boundaries.

Students are asked to choose some examples from their earth structures that characterize the patterns they see in both the earthquake and volcano data. They may want to look at the actual data in *MyWorld* map view "**ESInquiry**" to find examples.

Teacher Tip: *Organizing to Capture Examples*

- If your class has the time, it would be helpful if groups screen captured and printed examples of the data patterns. One or two examples would be sufficient. These data maps can be attached to the chart paper. Students will need to print to a color printer for the data patterns to be visible.
- Another option is to have groups identify examples by listing the places on their chart and when groups share their characterizations with the rest of the class the computer hooked up to the projector can be used to share the pattern examples.

Groups are also asked to draw a diagram to try to explain what they think is happening at their earth structure. All student explanations should be accepted. This is to foreshadow some of the diagrams and explanations they will be asked to interpret in the reading.

Making Meaning of the Activity

Each group should then share the pattern descriptions and explanation diagrams with the rest of the class. While groups are presenting, students should be directed to ask themselves:

- Does my earth structure belong with that group?
- Are there data pattern characteristics that are special to my earth structure?
- What is the reason for the differences in the data patterns between my earth structure and this group's earth structure?
- Does the group's explanation make sense with the data?

As groups share their characterizations, be sure to highlight any interesting explanations of the data. Be sure to get students thinking about reasons for differences in the data. The data is different because the plates are moving differently. In the *Zones* reading, students will learn more about these different kinds of movement.

Ask the students to answer the Reflection Questions and then have a class discussion about each one. In **Question A**, students should relate the different earthquake and volcano patterns to movement. Different patterns indicate that the crust is moving in different ways. In **Question B**, students should be questioning how volcanoes differ. They might guess that eruptive (strato or cinder cones) volcanoes happen in different places from quiet (shield) volcanoes. This pattern will be explored in more depth in Activity 7.4; this question sets the stage for thinking about that data.

Reflection Questions

A. Name one earth structure you think has the same kinds of earthquake and volcano patterns as your earth structure. Why do you think they are similar? Draw a diagram explaining the changes happening at your earth structure.

B. You know that each time a volcano erupts new crust is added to the surface. In the letters you read in Activity 6.1 you learned that the crust is added when magma rises and oozes through the cracks in the crust, forming narrow ridges of volcanic mountains and pushing the plates apart. Based on the data you have analyzed, do you think crust is added at your earth structure in that same way? Why do you think that? What might make it different? Is crust added at your earth structure? If so, how?

Prepare students for reading *Zones*. Say: *Today in class we characterized the earthquake and volcano patterns, named them, and tried to explain the patterns in the data. In the* Zones *reading, you learned about some of the patterns and descriptions that scientists have found in the earthquake, volcano, and topography data. See how their analyses compare with the analyses our class did.*

Homework

Assign students the reading *Zones* and the Figure It Out questions that follow. Students will need to be prepared to add descriptions of each of the zones to their picture dictionary. This will be the last opportunity for students to add terms to their picture dictionary. Prepare students for the evaluation of their picture dictionaries.

In **Question 3**, students should be able to explain that some crust is less dense than other crust. There is a reading in Activity 7.3 that discusses the reasons for some of these differences. At this point it is acceptable for students to simply articulate that the crust is different. **Question 4** sets the stage for Activity 7.3, where students will look for deep earthquakes. **Question 5** prepares students for Activity 7.4, where they'll look at the types of volcanoes that happen at subduction zones and rift zones. **Question 8**, asks students to draw a picture of what is happening. Look to see what types of supporting evidence students are using. They should be using earthquakes, volcanoes, anecdotal data, and topographical data to support their explanation.

Figure It Out

1. Which zones are places where crust is being added?
2. Which zones are destroying crust?
3. Why does one plate subside under another plate?
4. Most earthquakes happen near the surface, within the thin crust. At which zone do earthquakes happen deep in the upper mantle? Why?
5. What type of volcano eruption pattern do you expect to see at a subduction zone? What types of volcanoes are generally created at a subduction zone?
6. What type of volcano eruption pattern do you expect to see at a rift zone? What types of volcanoes are generally created at a rift zone?
7. You have learned some more terms in this lesson. Add these new terms to your picture dictionary. Improve the definitions and pictures you have already done.
8. **<u>Its Your Turn</u>:** Draw a picture of what you think is happening at your earth structure. Describe the evidence that you have to support this.

Assessment

What work is assessed?	What are you looking for?
Group characterization of data	Groups should be describing the data and discussing possible explanations of the data. This characterization should also be supported with data and examples. Groups should have drawn and labeled diagrams to explain the data. These diagrams may not be exact, but make sure students are using data to support what they are finding.
Reflection Question A	Students should be able to articulate that differences in data indicate different kinds of movement.
Figure It Out Question 8	Students are beginning to explain the processes of the Earth's crust. Be sure students are supporting their answers with multiple kinds of data: earthquake, volcano, topographical data, and anecdotal data. This is an opportunity to give students feedback on using supporting evidence.
Picture Dictionary	Students have added their last terms. Picture dictionaries should be assessed here.

Activity 7.2: Identifying Zones

In this activity, students will identify the different kinds of movement zones at their earth structures and then around their plate. Students will also predict which direction the plate is moving.

Engaging Students

Group the earth structures into different types of zones. **Say**: *You just read about the different kinds of zones and drew pictures of what you think is happening at your earth structure. Taking your earth structure pictures in hand, let's group the earth structures by zones. If you think your earth structure is at a rift. . . .* Some students may think their earth structure has more than one zone. They should choose the one that is most common at their earth structure.

> **Teacher Note:** *More Than One Zone*
> Some earth structures (i.e. New Zealand, Mt. Etna, Mt. Vesuvius, Mt. Saint Helens) have more than one type of movement. You will have to decide if you want the students to struggle with the multiple zones or focus on one. More often students should focus on one type of zone to explain and analyze the data.

Once the earth structures are sorted, **ask:** ***Is everyone in the same groups as in the last activity?*** *If teams moved, why did they move?* If a team has moved, help students articulate why that group moved by focusing on the supporting evidence. If none of the groups moved, have the groups share their supporting evidence.

Compare the names that the class came up with in Activity 7.1 to the names that were in the *Zones* reading. How are they similar? How are they different? Those in the *Zones* reading describe movement.

Ask students to compare the pictures they drew in Activity 7.1. Students should be encouraged to look carefully at each other's pictures and share strengths and weaknesses they see in the drawings. These conversations should help students struggling with drawing these models as they look at examples drawn by other students.

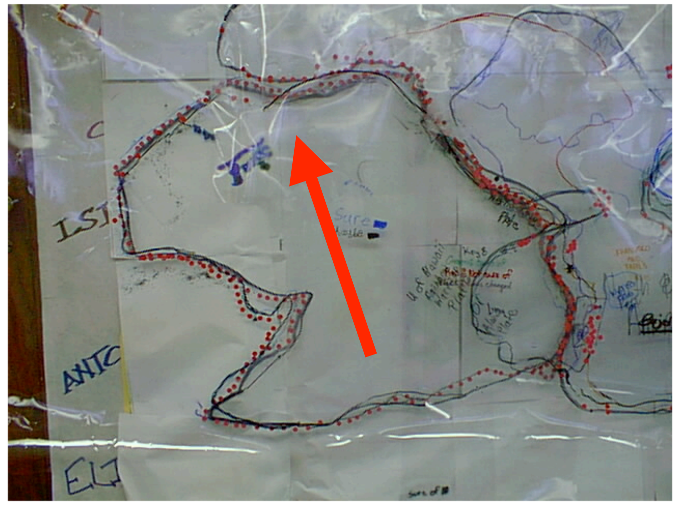
Review the types of zones using the transparencies of the *Zones* reading and the Data Transparencies. Be sure this review focuses on the movement and the data patterns that indicate that movement.

Guiding Student Activity

Have students identify the types of movement zones that are around their plate. Earth structure teams will use earthquake and volcano data in *MyWorld* to analyze earthquake and volcano data for the boundaries around their plate. Students should capture a map of their plate with both earthquake and volcano data plotted.

Next ask students to label the types of zones that are around their plate. Students should label their plate map drawn on the Three Page Map Worksheet in Lesson 5. Students should use the symbols recommended in the zone descriptions to identify the different types of zones around their plate.

Students should then be asked to look at all of the zones around their map and determine the direction their plate is moving. Students should draw arrows on their plate map to show the direction the whole plate is moving. Students should also draw this arrow on the Big World Map with the Plate Boundary Overlay. Students will then look at this information to determine if all these movements make sense together.



Making Meaning of the Activity

Discuss class analysis of plate movement. Look at all the movement arrows drawn on the class map. How are the plates moving? Do all the predicted movements work together? At some places the plates are pushing together, at other places they are pulling apart, and at others they are moving past each other. The class should come to a consensus if there are plate movements that do not seem to make sense together. It would be helpful to have a computer projection system set up with *MyWorld* if the class needs to review some data. The Orthographic (Globe) view will be especially helpful if you are looking at movement close to the poles or for plates that cross the pole. If you have not looked at the South Pole yet with the class, this is a good opportunity to do so. There is a plate there – it was left out of the unit due to map projection issues.

Prepare students to answer the Reflection Questions for homework. Students will need their pictures from Activity 7.1 for **question C**. In **question D,** students will need to describe the supporting data they found to explain the process that is changing their earth structure. Encourage students to use a variety of data to explain what is happening. Question B is seeding ideas for Activity 7.3.

Teacher Tip: *Activity 7.3 and 7.4*
Students have a sufficient amount of data to explain the changes happening at their earth structure. Activity 7.3 and 7.4 provide opportunities to look at volcano and depth data closer. This data will help students explain some of the differences they are seeing in the data patterns.

Homework

Assign the Reflection Questions for homework.

Reflection Questions

A. How did you determine what direction your plate was moving?
B. Why do some plates subside and other buckle up when the plates collide?
C. In the Figure It Out questions after the *Zones* reading, you drew a picture that explains the process changing your earth structure. After today's discussion and a closer look at the data, make any changes or additions to your picture to better represent this process.
D. Describe the evidence you have to support your explanation. Earthquakes? Volcanoes? Topography? Anecdotes from your pen pal?

Assessment

What work is assessed?	What are you looking for?
Three Page Map with zones identified	Students should have labeled the zones based on the data patterns they see.
Direction arrows on the large class map	The class should come to some consensus about the direction of the plates.
Reflection Questions B and C	Students should be using a variety of evidence to explain the process that is changing the crust and their earth structures.

Activity 7.3: Depth of Earthquakes (Optional)

In Activity 7.1, students learned that deep earthquakes happen at subduction zones. In this lesson, students will look at some depth data of earthquakes to help them explain and identify subduction zones. They will also read about the differences between oceanic and continental crust.

Engaging your students

Make a prediction. At subduction zones, one plate dives under another. At buckling zones, both colliding plates push up a mountain range. Why the difference? Why does some crust "sink" and other crust not "sink"?

Have students read *Is All Crust the Same?* and answer the Figure It Out questions that follow. This should help students explain why some crust subsides and other crust bends when the plates collide. Ask students to create a comparison chart for **question 1** as they read.

Oceanic Crust	Continental Crust
Thin (6-11 km)	Thick (30-40 km)
Young rocks	Old rocks
Dense rock	Less dense rock
Magma comes from the mantle	Magma comes from the crumbling crust
Rock that is low in silica, basalt	Rock that is high in silica, granite

Content Note: *Crust Models*
There are many different ways to think about the differences in the crust. You can describe the continental crust as styrofoam (thick and brittle). Oceanic crust is more like clay, dense and smooth. In reality these two types of crust are very close in density but enough that one "floats" on the other.

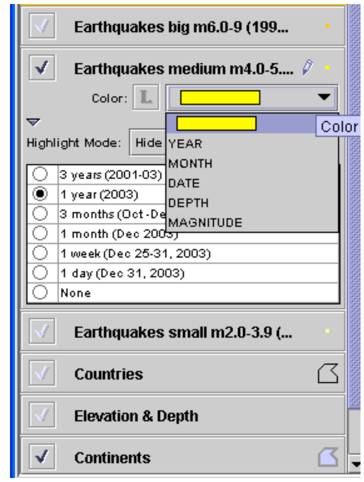
Figure It Out

1. Compare oceanic crust to continental crust.
2. Is the plate your earth structure is part of primarily oceanic crust or continental crust?
3. Why might you expect to see deep earthquakes at a subduction zone?
4. **<u>It's Your Turn:</u>** Go back to the picture you drew in Activity 7.1 and improved in 7.2. How did you represent oceanic and continental crust in your diagram? Label oceanic and continental crust on your drawing.

Ask students where they would expect to find deep earthquakes. Students should mark these places on a *Small World Map* worksheet. Gather a class list of these places as well. Be sure the Aleutian Islands and Japan are on the list. As students give you the place names, ask them to explain why they think they would find deep earthquakes there. This is great practice for supporting their ideas with evidence.

Ask students to compare the depths of earthquakes using *MyWorld*. The class can look at this data together or each team can take its *Small World Map* worksheet to the computer. Use the directions below to look at the depth of the earthquakes.

a. **Open the *MyWorld* map view "ESInquiry."**
b. **Show 3 years of medium earthquake data**. The map displays a colored dot for the location of each earthquake in the data set.



c. **Change the attribute being displayed on the map to depth.** Select the Color Attribute pull down menu for this layer. Here you will see all things in the data for each earthquake. This data set has the following information for each earthquake: year, month, date, depth and magnitude. **Select DEPTH**.

d. **Review the changed map view**. You should notice a new legend on the bottom of the map. Earthquake depth is represented by different colors. Earthquakes that are shallow or near the surface are displayed in very light grey. The deepest earthquakes are black and the medium earthquakes are shades of medium grey.

e. **Change the Projection of the Map to Orthographic (Globe)**. Data is distorted at the north and south poles when using most flat map projections. The globe shape is also the best representation of what the data really looks like. When using this projection, the best way to navigate the map is with the Re-Center Tool. The point you click will become the center of the view.

Making Meaning of the Activity

Check the places where the class expected to see deep earthquakes. Does this data support the idea that these places are subduction zones? Have students mark the places where they found deep earthquakes. If they are having trouble seeing the data, they may want to hide the Continents Layer.

Teacher Note: *What's in the Data?*
Students should be able to describe the gradual color pattern in the data. The deepest earthquakes are under the "floating" plate and away from the plate boundary. The shallow quakes are at the plate boundary. The color scheme should show a gradual trend toward the deep earthquakes.

As a closing discussion, talk about Figure It Out Question 2. Show the students the earthquake depth data for the Aleutian Islands and Japan using a computer projection system and *MyWorld*. Students should notice that at Japan the earthquakes are deeper than at the Aleutian Islands. Ask students to explain why they think there is this difference if they are both subduction zones. At Japan, an oceanic crust is subsiding under a continental crust. At the Aleutian Islands an oceanic crust is subsiding under an oceanic crust. The crust is not as thick so the earthquakes are not so deep.

Figure It Out

1. Where do the deep earthquakes happen? Where do they happen in relationship to the plate boundary? How can you explain this pattern?
2. The earthquake and volcano data indicate that the Aleutian Islands and Japan are subduction zones. Compare them. How are they same? How are they different? How do you explain the differences?
3. Name another place where there is a subduction zone. Explain how the data supports that location.

Homework

Assign Figure It Out questions 1 and 2 for homework if there is not time in class for students to do them, as well as the Reflection Question. For the Reflection Question, students should add any new ideas to their picture from Activity 7.1 and describe any new supporting evidence.

Reflection Questions

What types of movement zones are happening at your earth structure? Describe the data you have to support that idea.

Assessment

What work is assessed?	What are you looking for?
Figure It Out question 1	Comparison of oceanic crust to continental crust. The most important idea is that one type is less dense than the other because they're made of different rock.
Question 3	Students have labeled oceanic and continental crust on their model pictures.
Figure It Out questions 1 and 3	Description of the data pattern and how depth indicates subduction zones.
Reflection Question	Students have identified movement happening at their earth structures and supported it with data, including deep earthquakes if applicable.

Activity 7.4: Volcano Types Data (Optional)

Students will look at patterns in volcano data to help them explain what is happening at their earth structure and plate boundaries.

Engaging Your Students

Say: ***In the last activity you looked at how the difference in earthquake depth told you more about the movement of the plates. In Lesson 6, you noticed difference in the types of volcanoes and the magma they eject. Do you think these differences will tell us anything about the movement of the plates?***

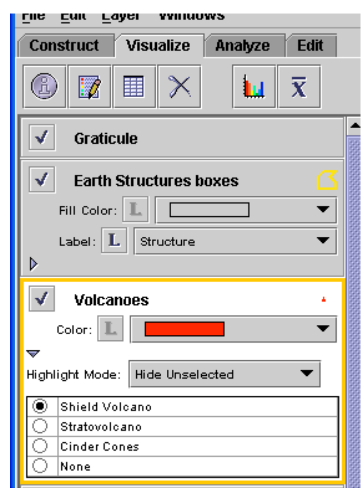
Ask the class to describe the volcano activity at each of the zones. Go back to the *Zones* reading to find descriptions of the kinds of volcanic eruptions at each of the different kinds of zones. Write these descriptions in your science journal.

Ask the class to determine what type of volcano they would expect to find at each of the zones. Where would they expect to find stratovolcanoes? Where would they expect to find shield volcanoes? On a *Small World Map* worksheet, students should mark where they would expect to find different types of volcanoes. They should mark stratovolcanoes in red, shield volcanoes in blue, and cinder cones in yellow. These predictions will later be used as a comparison when looking at the data.

Guiding Student Activity

Ask students to compare the depths of earthquakes using *MyWorld.* The class can look at this data together or each team can take its *Small World Map* worksheet to the computer. Use the directions below to look at the depth of the earthquakes.

a. **Open the *MyWorld* map view "ESInquiry."**
b. **Show 3 years of medium earthquake data and the volcano data.** . The map displays a colored dot for the location of each earthquake in the data set and a different color dot for each volcano in the data set.
c. **Identify a place on the map where you would expect to find a subduction zone.**
d. **Select the Volcano Layer**. Show the selection menu. You should see a selection menu with a few different types of volcanoes.



e. **Change the Projection of the Map to Orthographic (Globe)**. Data is distorted at the North and South Poles when using most flat maps. The globe shape is also the best representation of what the data really looks like.
f. **Use the volcano type selections to analyze the volcano data pattern.** Students should record their observations on their *Small World Map* worksheet.
    - Where are the stratovolcanoes? Mark these in red. *Students should notice that there are a lot of these and that they are near subduction zones.*
    - Where are the shield volcanoes? Mark these in

blue. *Students should notice that there are few of these and that they are generally associated with rifts and hot spots.*

- Where are the cinder cone volcanoes? Mark these in yellow. *Students should notice that these are EVERYWHERE!*

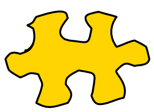
Content Note: Volcano Types
In this unit, we identify three different types of volcanoes. There are actually many more types but these are enough to analyze the data. Using *MyWorld,* you can look at these types more closely by looking at them with different colors. You would use similar steps to the ones you used to look at earthquake depth. Each types would be mapped a different color.

Making Meaning of the Activity

Check the places where the class expected to see the different kinds of volcanoes. Do these data support the idea that these places are subduction zones or rift zones?

Use Figure It Out question 2 as a closing discussion. Students should notice that stratovolcanoes are generally associated with subduction zones and shield volcanoes are generally associated with rifts and hot spots.

Figure It Out



1. Where do the stratovolcanoes occur? Where do the shield volcanoes occur? Where do the cinder cones occur?
2. Look at the Ring of Fire. We know that at the north and west edges of this plate there are many subduction zones. Where do the stratovolcanoes happen in relation to these subduction zones? Where do the shield volcanoes happen?

Homework

Assign Figure It Out question 1 and the Reflection Question for homework.

Reflection Question

What types of movement zones are happening at your earth structure? Describe the data you have to support that idea.

Assessment

What work is assessed?	What are you looking for?
Small World Map worksheet with different kinds of volcanoes marked in different colors	Description of the patterns in the volcano data.
Figure It Out question 2	Stratovolcanoes are associated with subduction zones and shield volcanoes are generally associated with rifts and hot spots.

Activity 7.5: What is Happening at Your Earth Structure?

In this final activity, students will summarize their evidence and explain the changes that are happening at their earth structure.

Engaging Student Activity

Read the letter from NESS outlining what Dr. Wave would like students to put in their final report. Use Lesson 7 Transparency 9 to show students the letter.

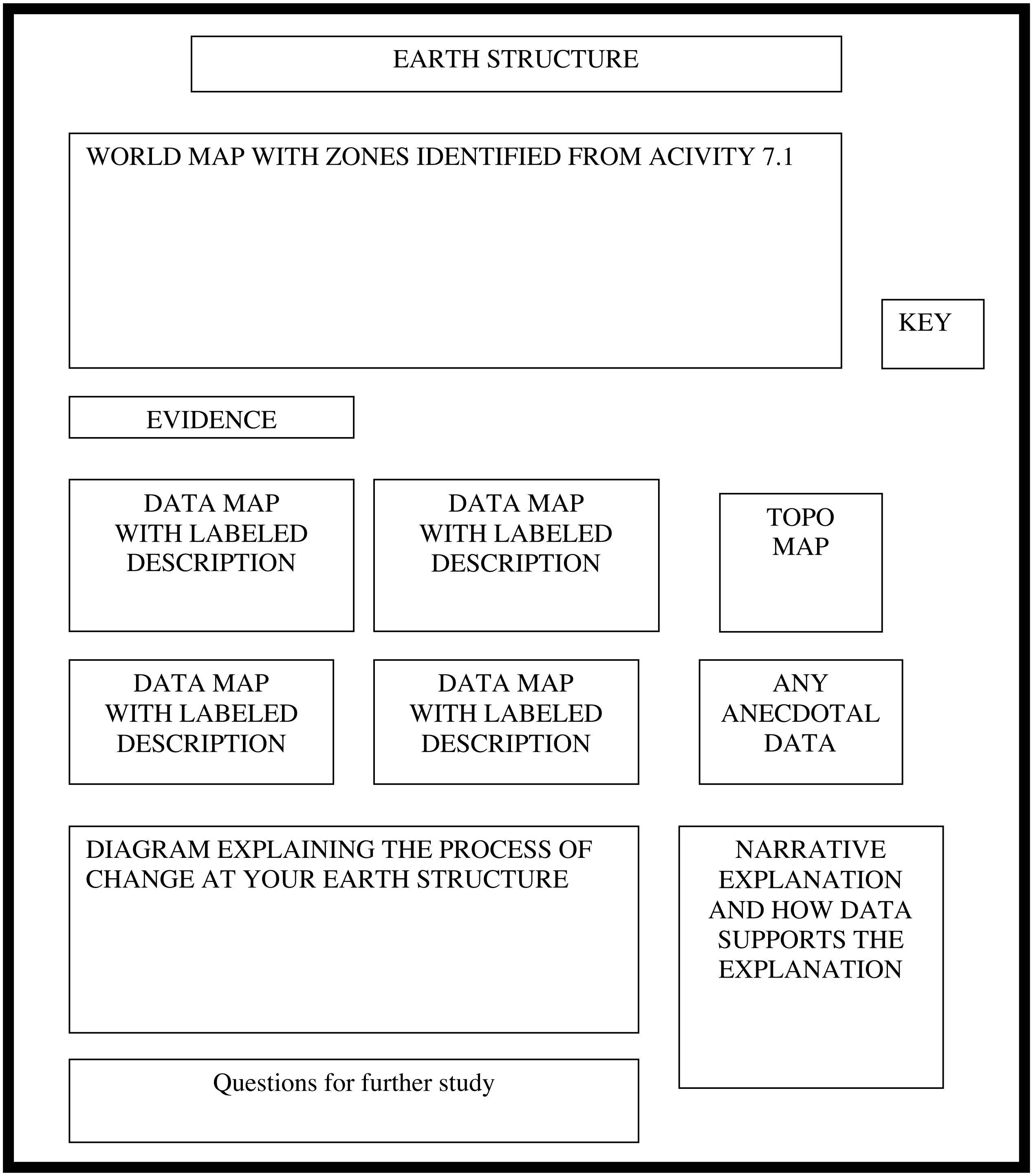
Help students decide what they need to do. Students have already done much of the work requested by Dr. Seismic P. Wave.

Plate boundary identification, zone identification, and direction of movement	Three Page Map from Activity 7.1 Data map with notes
Description of process at earth structure	Diagram and description started in Activity 7.1 Data maps of earth structure with notes

Guiding Student Activity

Help the class decide how they are going to present this information for NESS. There are a variety of ways that students can present this information. They can create a display board, a computer presentation or a report. It is important that students can display the evidence and their explanations of the process that is causing changes at their earth structures.

If you decide to have the students produce display boards here is a possible layout.



Making Meaning of the Activity

Organize the class into small groups to share their explanations and supporting data. Before groups begin, set expectations for the conversations that should take place in the group. You may choose to have a computer with *MyWorld* available for each group so that data can be looked at if it is needed. While students are listening to the other groups, look for:

- explanations that are clearly supported with evidence
- explanations that contradict their explanations
- accurate descriptions of the supporting evidence (analyzing accurately and with "enough" data)
-

Students should also give the other groups feedback. The class can determine what kinds of feedback should be given. One possibility is to have students look for multiple types of supporting evidence: earthquake, volcano, topography, anecdotal, earthquake depth, and volcano type.

Teacher Tip: *Peer Feedback*
At the end of the first day of this activity, ask students to develop a feedback sheet. The feedback sheet will help give all groups some feedback and will also focus the discussion. Before the small groups meet, generate enough copies for each student to give feedback to all the teams in the group.

Homework

Assign the Reflection Questions for homework.

Reflection Questions

A. Did any group agree with your explanation or analysis of the data? Explain.
B. Did any group contradict your explanation or analysis of the data? Explain.
C. What questions that came up in your group do you think are worth pursuing and why?
D. **<u>It's Your Turn:</u>** Write a brief letter to your pen pal describing your experience with this project.

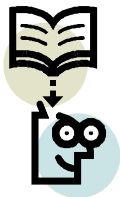
Assessment

What work is assessed?	What are you looking for?
Earth Structure Team Final Report	Explanations that are well supported with data. Students should be able to describe the patterns they are seeing in the data and explain the process causing changes at their earth structures. There are no right or wrong answers, just those that are better supported with evidence.

Additional Extension Activities

Have a Parent Open House so students can show off what they have learned and created. It is especially nice for parents to see the work the students have been doing on the computer and with their team.

Have students explain what they learned to a younger or older class of students. Having a real audience is a great way to motivate students to refine their ideas. Be sure the younger students would not do the unit eventually. An older group of students that have already done the unit can be a great audience for conversation and push current students to support ideas with data.



WHAT'S THE POINT?

Students have successfully explained the processes that are changing the crust of the Earth. This field of science is relatively new and is constantly changing and tweaking its ideas. New technologies are watching the Earth from many points of view, so there is a lot of data to analyze and explain.

Students should be left with some questions to keep them curious about this field of science and the work that scientist do.

Teacher Reflection

Describe a student explanation that met your expectations.

Describe a student explanation that did not meet your expectations.

What would you do differently to help this student meet your expectations?

How engaged were your students throughout the unit? High achieving students? Low achieving students?

How did your students present their explanation information to NESS? Was this format effective? Why or why not?

Describe some of the content knowledge your students learned through this experience.

Describe some of the process skills your students learned through this experience.

What do your students need to do next to further develop these process skills?

Name__________________________

Activity 7.1: Characterizing Both Data Patterns

Reflection Questions

A. Name one earth structure you think has the same kinds of earthquake and volcano patterns as your earth structure. Why do you think they are similar? What is causing the changes happening at your earth structure?

Answers will vary. Students should be predicting that there are different things happening at different earth structures. Structures that are the same have patterns are changing the same. The changes are caused by the moving crust.

B. You know that each time a volcano erupts; new crust is added to the surface. In the letters you read in Activity 6.1, you learned that the crust is added when magma rises and oozes through the cracks in the crust, forming narrow ridges of volcanic mountains and pushing the plates apart. Based on the data you have analyzed do you think crust is added at your earth structure in that same way? Why do you think that? What might make it different? Is crust added at your earth structure? If so, how?

Answers will vary.

Name______________________________

Activity 7.1: Characterizing Both Data Patterns

Figure It Out: *Zones*

1. Which zones are places where crust is being added?

Crust is added at rifts. But crust is also being added at volcanoes, just not as much.

2. Which zones are destroying crust?

Subduction zones: one plate is being crushed by another plate.

3. Why does one plate subside under another plate?

One plate is more dense than another.

4. Most earthquakes happen near the surface, within the thin crust. At which zone do earthquakes happen deep in the upper mantle? Why?

Subduction Zones because the one thin plate is diving under the other plate. This diving plate causes deep earthquakes under the "floating" plate.

5. What type of volcano eruption pattern do you expect to see at a subduction zone? What types of volcanoes are generally created at a subduction zone?

Volcanoes generally blast rather than ooze at a subduction zone.
Volcanoes that blast are stratovolcanoes and cinder cones.

6. What type volcano eruption pattern do you expect to see at a rift zone? What types of volcanoes are generally created at a rift zone?

Volcanoes generally ooze at rift zones. Shield volcanoes ooze.

7. You have learned some more terms in this lesson. Add these new terms to your picture dictionary. Improve the definitions and pictures you have already done.

8. **<u>It's Your Turn</u>:** Draw a picture of what you think is happening at your earth structure. Describe the evidence that you have to support this.

Name____________________________

Activity 7.2: Identifying Zones

Reflection Questions

E. How did you determine what direction your plate was moving?

Students should be looking at all of the movement zones around their plate to determine what general direction the plate is moving.

F. Why do some plates subside and other buckle up when the plates collide?

The density of the crust. The denser crust always subsides under the less dense crust.

G. I[illegible] re that explains the process changing your earth structure. After today's discussion and a closer look at the data, make any changes or additions to your picture to better represent this process.

H. Describe the evidence you have to support your explanation. Earthquakes? Volcanoes? Topographical data? Anecdotes from your pen pal?

Answers will vary. Be sure students have a variety of supporting evidence.

Name____________________________

Activity 7.3: Depth of Earthquakes

Figure It Out

5. Compare oceanic crust to continental crust.

See Activity in TE for comparison table.

6. Is the plate your earth structure is part of primarily oceanic crust or continental crust?

Answers will vary. Some earth structures are obvious and others will require some discussion.

7. Why might you expect to see deep earthquakes at a subduction zone?

Student answers will vary. This is a prediction question. The oceanic crust is diving under the "floating" crust. The movement of this material cause deep earthquakes under the "floating" crust.

8. **<u>It's Your Turn:</u>** Go back to the picture you drew in Activity 7.1 and improved in 7.2. How did you represent oceanic and continental crust in your diagram? Label oceanic and continental crust on your drawing.

Answers will vary.

Figure It Out

1. Where do the deep earthquakes happen? Where do they happen in relationship to the plate boundary? How can you explain this pattern?

Deep earthquakes happen at subduction zones away from the plate boundary.

2. The earthquake and volcano data indicate that the Aleutian Islands and Japan are subduction zones. Compare them. How are they similar? How are they different? How do you explain the differences?

Japan has deeper earthquakes than the Aleutian Islands. Why? At the Aleutian Island oceanic crust is subsiding under another oceanic crust. At Japan the oceanic crust is subsiding under a continental crust.

3. Name another place where there is a subduction zone. Explain how the data supports that location.

Answers will vary. Be sure students are using earthquake depth data, as well as patterns in earthquake and volcano data.

Reflection Question

What types of movement zones are happening at your earth structure? Describe the data you have to support that idea.

Answers will vary.

Name____________________________

Activity 7.4: Volcano Types Data

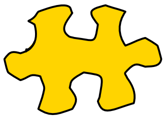


Figure It Out

1. Where do the stratovolcanoes occur? Where do shield volcanoes occur? Where do cinder cones occur?

Strato happen at subduction zones, shield at rifts and hot spots, and cinder cones everywhere.

2. Look at the Ring of Fire. We know that at the north and west edges of this plate there are many subduction zones. Where do the stratovolcanoes happen in relation to these subduction zones? Where do shield volcanoes happen?

The stratovolcanoes happen at the subduction zone on the "floating plate". The shield volcanoes happen in the center of the plate (hot spots) or on the other side of the plate (rifts)

Reflection Question

What types of movement zones are happening at your earth structure? Describe the data you have to support that idea.

Answers will vary.

Name____________________________

Activity 7.4: Volcano Types Data

Reflection Questions

A. Did any group agree with your explanation or analysis of the data? Explain.

Answers will vary.

B. Did any group contradict your explanation or analysis of the data? Explain.

Answers will vary.

C. What questions that came up in your group do you think are worth pursuing and why?

Answers will vary.

D. **<u>It's Your Turn:</u>** Write a brief letter to your pen pal describing your experience with this project.

Answers will vary.

Apply What You Know

Assessment Activity
Teacher Guide

The best way to see what students know is to have them apply the knowledge to a new (yet similar) situation. In this assessment activity students receive yet another letter from Dr. Seismic P. Wave. In this letter he asks to explore some earthquake and volcano events through newspaper articles and other items sent in by members of the Junior Science Team. The basic task is to explain the process changing the crust at the place in the article. If there is an earthquake at Mt. St. Helens, what is happening there?

These articles can come right out of the headlines. Besides the articles students will need access to some maps and data maps to gather data about the places they are assigned. It is recommended that a few different places be distributed throughout the class rather than the entire class doing the same place. Students should be assigned to a place different from their earth structure. For example, the team that studied Hawaii throughout the unit should not be assigned another hot spot for the assessment.

You will need to decide how students are going to access the data. The most efficient way would be to have each student use *MyWorld* at the same time. Students can capture or capture and print the needed maps to support their explanations. For a low-tech method, print the data maps from the project website (http://www.geode.northwestern.edu/pbi/). Print these out prior to class; students can write on them. The drawback to this is missing the interaction with *MyWorld*.

Students will also need a Three Page Map and be able to see the class plate boundary map.

[These articles are coming]

Below is a list of what students will need to include:

- **description of the topography**
- **characterization of the earthquake and volcano data with supporting data maps**
- **map showing the plate where this event took place, with supporting data map**
- **movement zones identified and the general direction identified with supporting data map**
- **drawing of a model explaining the process that is causing these events at this place.**

Children's Literature Resources

You may want to collect some of these books for your classroom or school library.

Journey to the Center of the Earth
by Jules Vern
Penguin Books, London, England 1965

This book is referred to in Lesson 3. It would make a great read aloud book, or students could read it in their literature classes while doing this unit.

How to Dig a Hole to the Other Side of the World
by Faith McNulty
Harper & Row Publishers, New York, New York 1979

In this book, a boy starts to dig a hole to the other side of the world. During this adventure, the reader learns about the differences in the layers of the interior of the Earth. This is a great book to read aloud along with Lesson 3.

Earthquakes
by Seymour Simon
Morrow Junior Books, New York, New York, 1991

This book has some excellent pictures of earthquakes and the affects earthquakes have on people. However, this book also has a map of the plate boundaries, so it should not be available to students until after Lesson 5.

How the EarthWorks: 100 Ways Parents and Kids Can Share The Secrets of the Earth
by John Farndon
Reader's Digest Association, Inc. Pleasantville, New York 1992

This book has lots of models and demonstrations of Earth science concepts. The models use everyday materials to build models that help explain various concepts.

Hill of Fire
by Thomas P. Lewis
Harper Collins Publishers, New York, New York 1971

A farmer in Mexico is plowing a field when the earth opens up and a volcano is created. This easy read describes the actual 1943 birth of a cinder volcano, Paricutin, in Mexico. This could be used as a read-aloud to accompany the Lesson 6 reading, *Oozing and Blasting Volcanoes.*

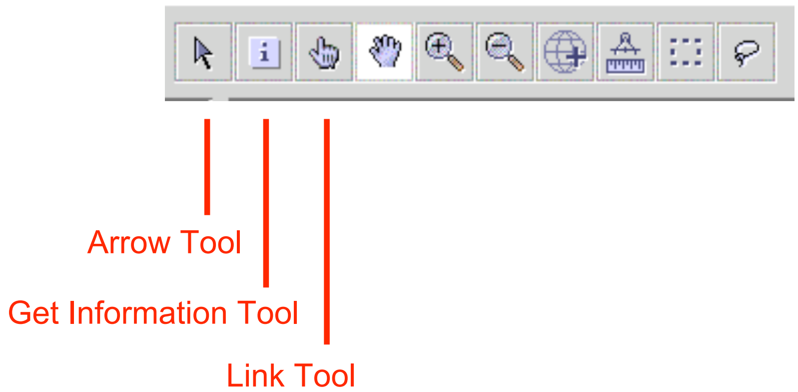
Magic School Bus: Blows Its Top
by Patricia Lauber
Bradbury Pree, New York 1986

The class takes a field trip with Ms. Frizzle to witness the eruptions of underwater volcanoes. An underwater volcano rises above sea level to become an island, a description of a volcano born at a subduction zone. The book could accompany Lesson 6.

Volcanoes
By Seymour Simon
Murrow Junior Books, New York 1988

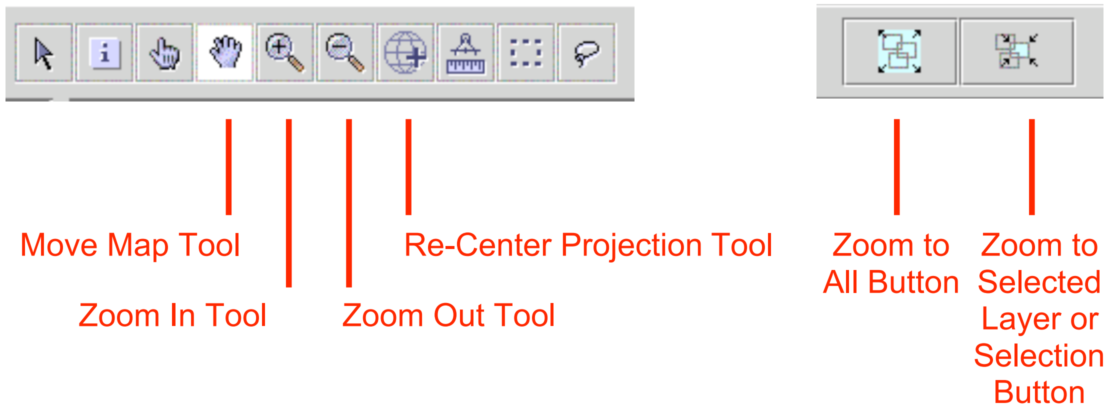
This book, like Simon's other books, has excellent photos. The photos in this book include volcanic eruptions in Hawaii and of Mt. St. Helens.

My World Tool Box: Visualize Mode



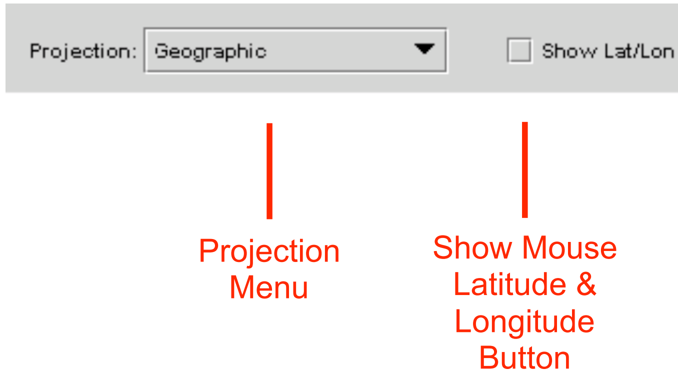
What information is on my data map?

Arrow Tool	**Arrow Tool:** Clicking on the map will highlight the value of the item(s) you clicked on (if any) in all visible Layer Legends
Get Information Tool	**Get Information Tool:** Clicking on the map will display a pop-up window with information about the item you clicked on (if any) in the selected Layer. It also highlights the value of any item(s) selected in any layer that has visible Legends, just as the Arrow tool does.
Link Tool	**Link Tool:** If any of the Layers in the Map have links in their data, clicking on the Map with the Link Tool will show a pop-up menu with links associated with any of the items under the cursor. You can select one of the links to open a Web Browser window to display the linked page or picture.

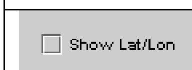


How do I move around the map view?

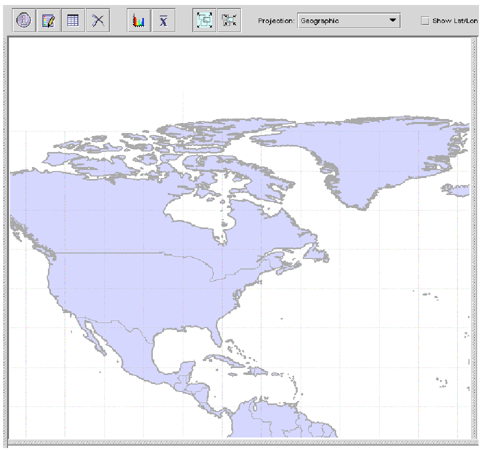
Move Map Tool	**Move Map Tool:** Clicking and dragging moves the contents of the map, allowing you to see parts of the map that aren't currently visible.
Zoom In Tool	**Zoom In Tool:** Clicking once zooms in on the clicked point. Clicking and dragging draws a rectangle, then zooms in on that rectangle when you release the mouse button.
Zoom Out Tool	**Zoom Out Tool:** Clicking once zooms out and centers on the clicked point. Clicking and dragging draws a rectangle then zooms out and centers the map on the center of the rectangle.
Re-Center Projection Tool	**Re-Center Projection Tool:** Some map projections can only display things within a certain distance from their center, and some projections distort shapes in different ways depending on a shape's position relative to the center of the projection. You can use this tool to change the center of projection and minimize projection-related distortion.
Zoom to All Button	**Zoom to All Button:** Clicking on this button allows you to adjust the Map so that all items in every Layer in the Map are visible.
Zoom to Selected Layer or Selection Button	**Zoom to Selected Button:** This button adjusts the Map so that all items in the selected Layer are visible.

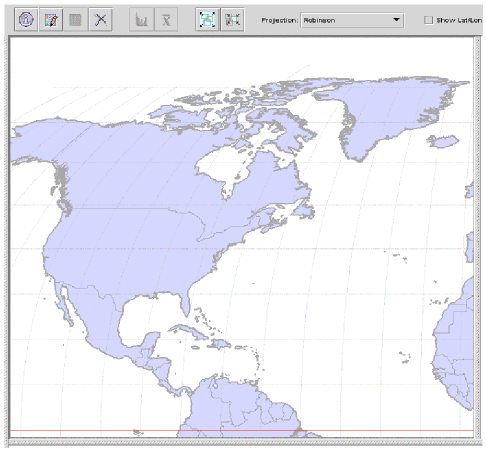


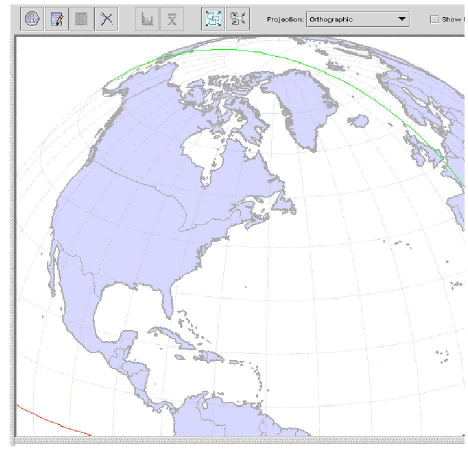
How can I change the map projection and show/hide the latitude/longitude coordinates?

 Projection Menu	**Projection Menu:** This menu allows you to select what Map Projection is used to convert three-dimensional geographical coordinates to two-dimensional pictures on your computer screen.
 Show Mouse Lat/Long Button	**Show Mouse Lat/Lon Button:** When this box is checked and you put the mouse over the Map, the latitude and longitude of the location of the mouse (in decimal degrees) will be displayed in the lower left corner of the My World window.

A note about map projections: Map projections display a three-dimensional object, like the Earth, onto a flat surface. This surface could be a piece of paper or a computer screen. Every map projection distorts the size, shape, distance, or direction of the object to varying degrees. For example, the Geographic projection below tends to distort the size of the continents closer to the North and South Pole. The Robinson projection lessens this distortion, while the Orthographic projection is the closest representation of what the world really looks like when viewed from space. Notice how the size of Greenland varies in each projection.



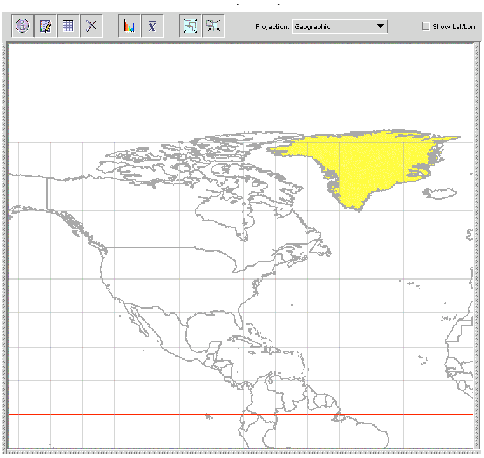


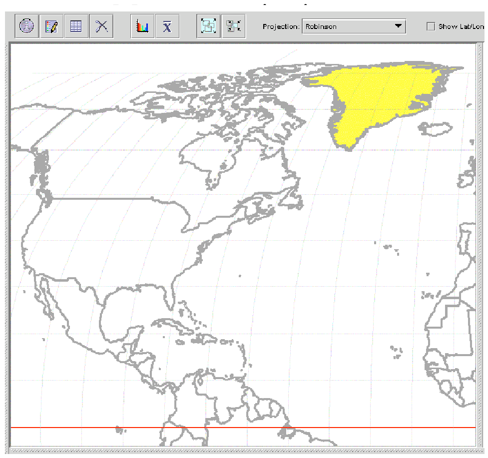


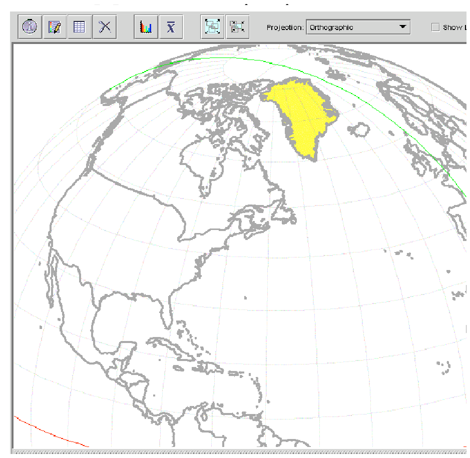
Geographic projection

Robinson projection

Orthographic projection

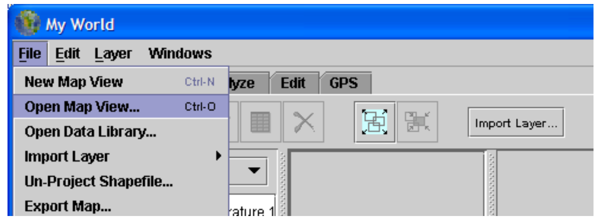




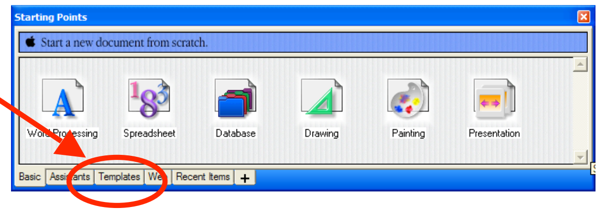


Capturing Screens in AppleWorks

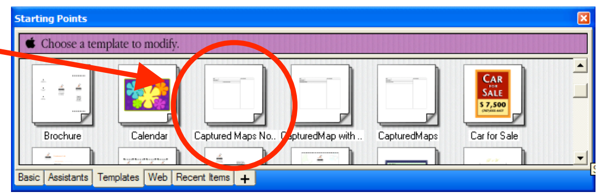
1. Start *MyWorld*. Open your map view.
   FILE → OPEN MAP VIEW



2. Start AppleWorks. Click on **Templates**

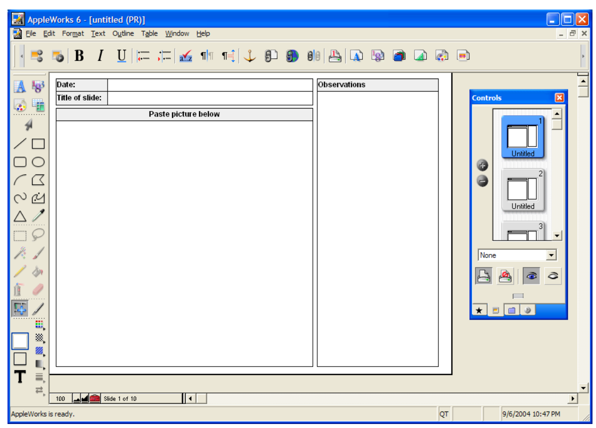


3. Find **Captured Maps** template.



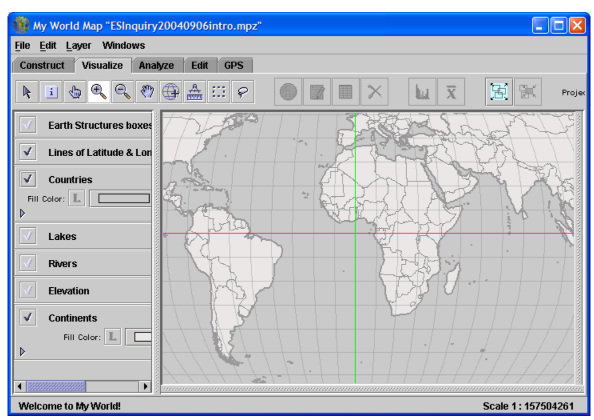
4. Use these pages to capture maps and make observations.

   Go to **FILE → SAVE AS…**



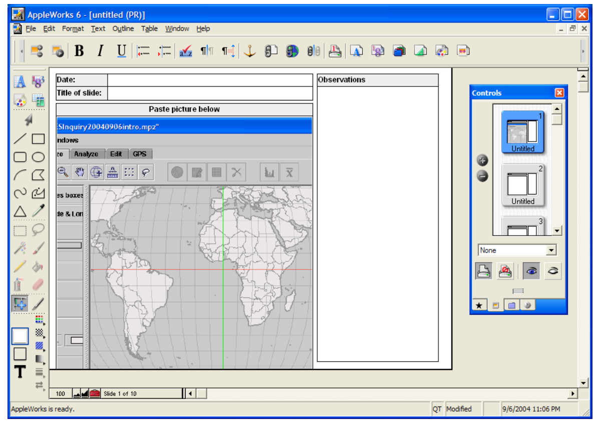
5. Go back to *MyWorld*. To capture a screen hold down 4 keys together:

Shift	Ctrl	Apple	3



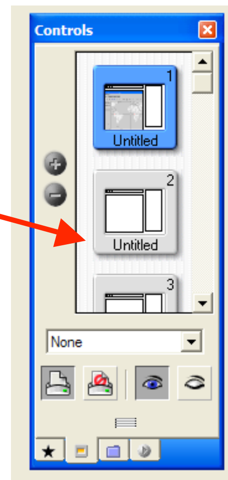
6. Go back to AppleWorks.
   Click under "**Past picture below**"

   EDIT → PASTE



7. Type in your observations next to the captured map.   Save your work!

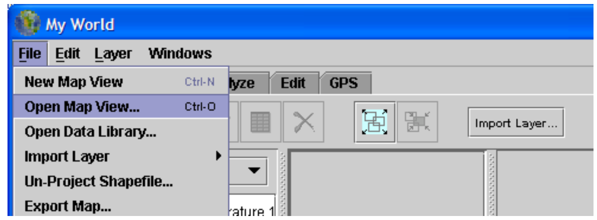
   To go to a new page use the **Controls** box, click the next numbered slide.



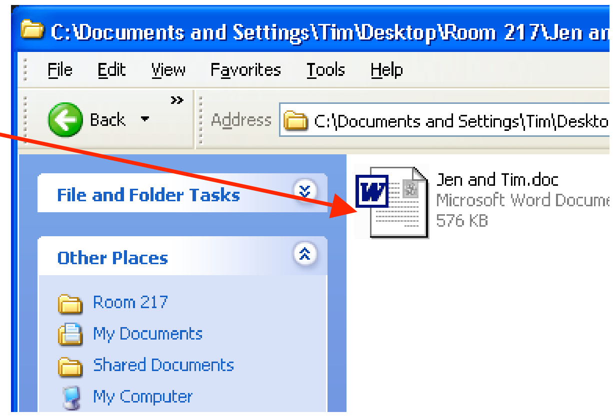
Capturing Screens in Word

Capturing screens on a PC using

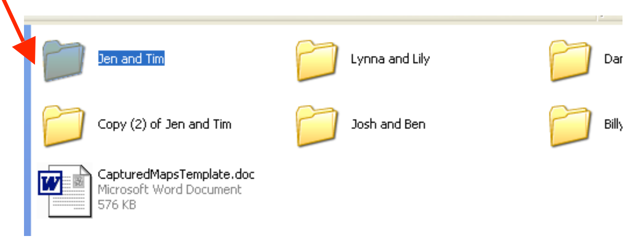
1. Start *MyWorld*. Open your map view.
   FILE → OPEN MAP VIEW



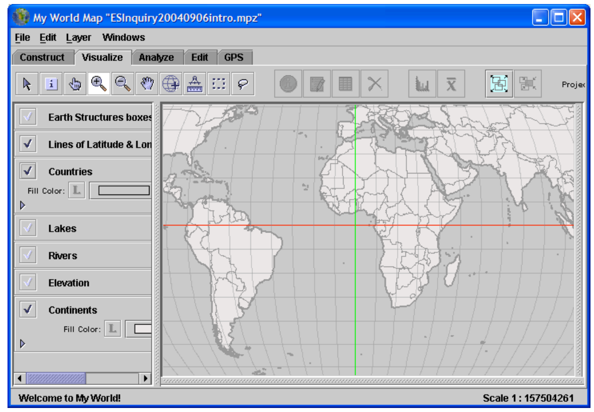
2. Open Word Template (this should be in a folder for you and your partner on the desktop).



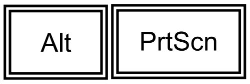
(This makes management easier. Students are then sure to save things in their folder. Leave the template in the class folder in case students need a new blank. Students can ask you to save one for them.)



3. Go back to *MyWorld*. To capture a screen hold down 2 keys together:

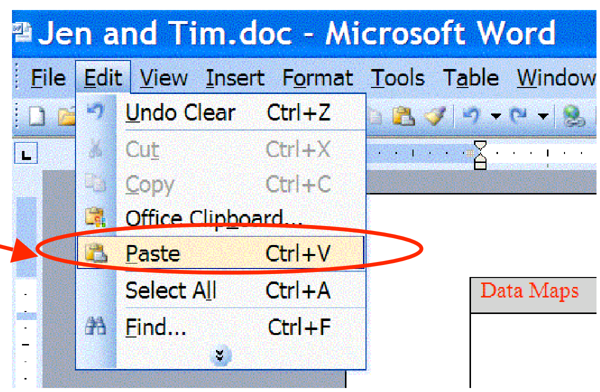


ALT PRINT SCREEN

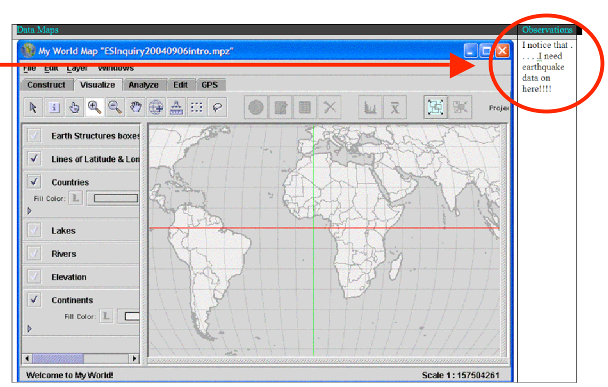


4. Go to **Word**. Under the **Edit** pull-down menu, click **Paste**.

EDIT → PASTE



5. Type in your observations next to the captured map. **Save your work!**



Plotting Earthquake Data by Region

Overview:
In the extension activity, students are able to add to the data plotted on the class map by searching for earthquakes around their Earth structure areas. Using the "Earthquake Search" Internet site, students request recent earthquakes by location.

Time: 1-2 Class Periods

Materials:
- Individual small maps
- Large class map with one week of data plotted

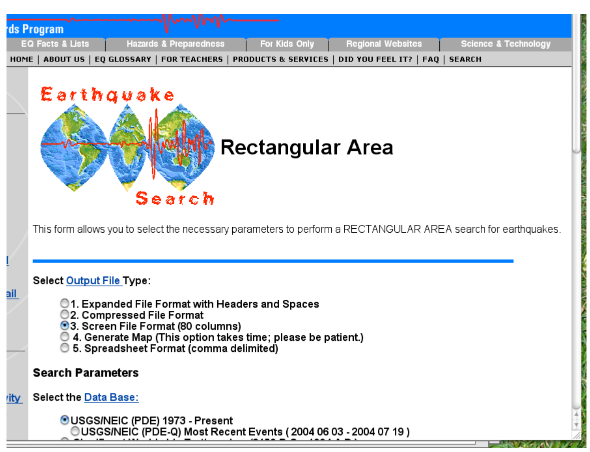
Set-Up:
- Work through this lesson yourself before you direct the students to do so. When students select their region some will get a ridiculous amount of data (i.e. Baja) and others will get very little (i.e. Iceland). They will have to play around with the search parameters to get either a manageable set of data or enough data. You should look at each of the 15 earth structures prior to the activity. You may also want to print out the data prior to class to not only save time but to select the data the students will need. If you do this, you should demonstrate how you got the data to the class so they won't miss out on seeing the thought process behind selecting the parameters.

Guiding Student Activity
Plotting Data from Each Region

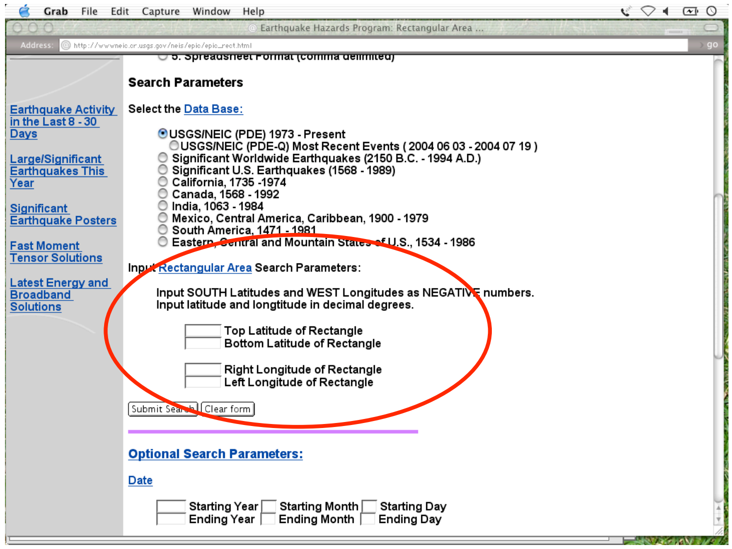
1. **Use the "Earthquake Search" Internet site.**
Students will need their *Topographic Cutout Map* sheet of their Earth structure, the one they did NOT cut up while making the 3D model.

Go to the "Earthquake Search" Internet site:
http://wwwneic.cr.usgs.gov/neis/epic/epic_rect.html

You will see this screen.

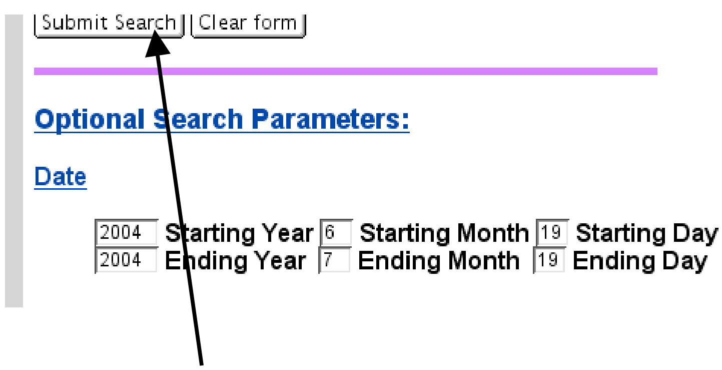


Page down to where it says, "Input Rectangular Area Search Parameters."



Students can get the latitude and longitude numbers from the four corners of the *Topographic Cutout Map*.

Students need to pick the DATES to search for. One month will usually give them a lot of data. For example, to get all the earthquakes that happened for one month, between June 19, 2004 and July 19, 2004, type those dates in the fields under the latitude/longitude parameters:



Then click the **"Submit Search"** button, and wait for the list. It may take a couple of minutes for the search to finish.
If only a few earthquakes pop up, have the students extend the time frame.

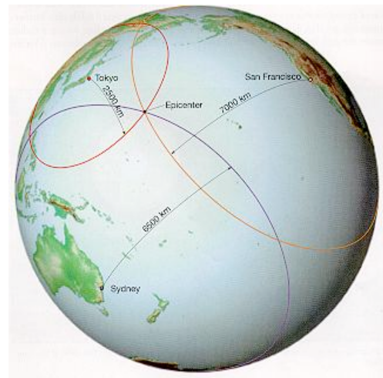
2. **Plot earthquakes from each regions list.**
Since you just have the one class map at this point, have the students plot their data on their small maps. They will find that a lot of the data points overlap. Once they are finished, they can place stickers on the large class map to represent the pattern they saw on their small map.

 Name ______________________________

Finding the Epicenter of an Earthquake

Overview:

In this activity you will do the same work a seismologist does. If you were a seismologist, you would receive seismic data from all over the world. Within minutes after an earthquake, seismographs in three different cities would record the times of the arrival of P waves and S waves. You would use this data to pinpoint the exact location of the earthquake's epicenter. The farther away the earthquake is, the greater the amount of time between the arrival of the P waves and S waves. You will be given data from three stations in the U.S. You will draw three circles using the data. The center of each circle is a particular seismic station's location. The radius of the circle is the distance from the seismograph to the epicenter. The point where the three circles intersect is the location of the epicenter.



Stop and Think

Why couldn't you pin point the exact location of the epicenter if you only drew 2 circles?

Procedure:

2. **Look at the data table** showing differences in earthquake arrival times.
3. **Find the distance to the epicenter**.

   The graph shows how the difference in arrival times between P and S waves depends on the distance from the epicenter of the earthquake.

   — To make it easier to read the graph, use a ruler and place it on the time. In this case, 3 minutes, 10 seconds.

   — Look over to where it intersects the line on the graph and then follow that down to the distance. Every line on the Y-axis represents 20 seconds—you might want to make a little mark every third line (60 seconds). Every line on the X-axis represents 200 km—you might want to make a little mark every fifth line (1,000 km).

   — To find the distance to the epicenter, read down from this point to the x-axis of the graph. Enter this distance on the data table.
4. **Repeat step 2** for Houston and Savannah.
5. **Find the radius of your circle**.

   Set your compass at a radius equal to the distance from Salt Lake City to the earthquake epicenter that you recorded in your data table. Use the scale on the map. Place the point of your compass on 0. Place the tip of you pencil on the distance. Make sure you are reading the bottom part of the scale – in **km**!!! Lock your compass.
6. **Draw your circle.**

Finding the Epicenter of an Earthquake

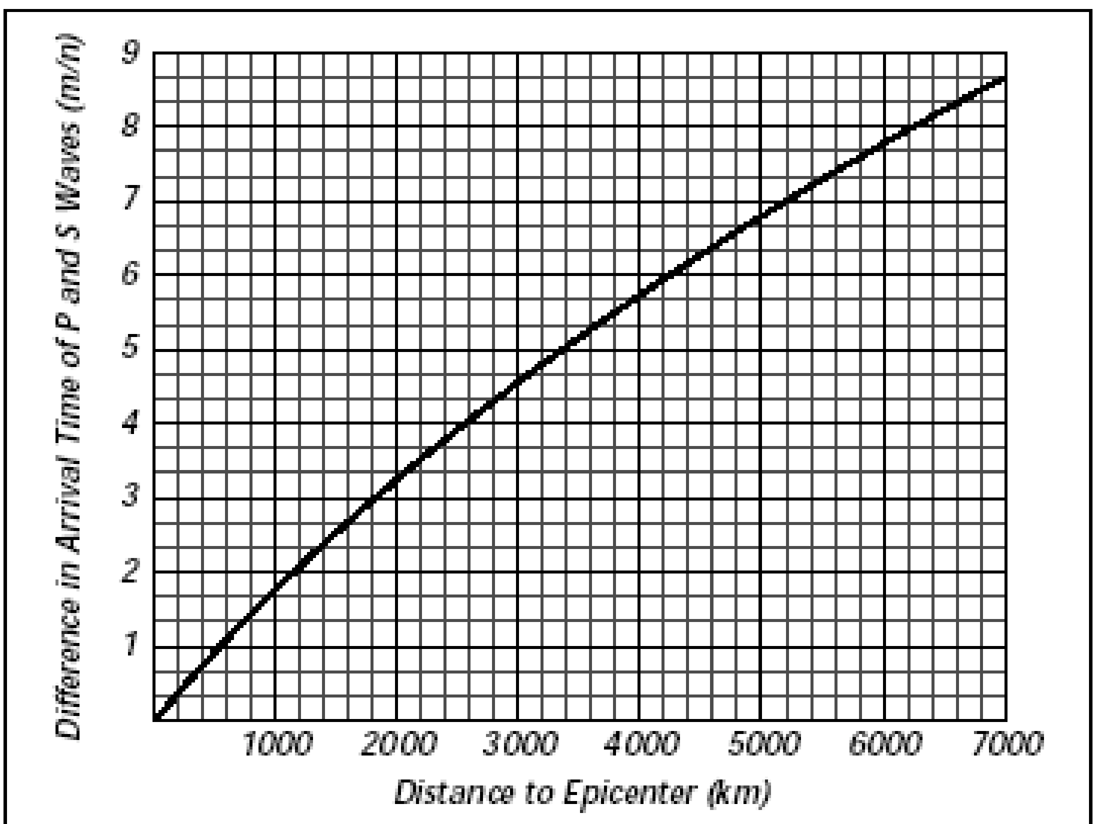
Place the point of your compass on Salt Lake City. Draw your circle on the map carefully. Sometimes it is easier to move the paper around in a circle and hold the compass still.

7. **Repeat steps 4 and 5** for Houston and Savannah.
8. **Find the epicenter.**
   Locate where all three of your circles intersect. Place a data point there. This is your epicenter. They might not intersect perfectly—you may have a little triangle in the middle between all the lines. This is still the epicenter.

Data Table

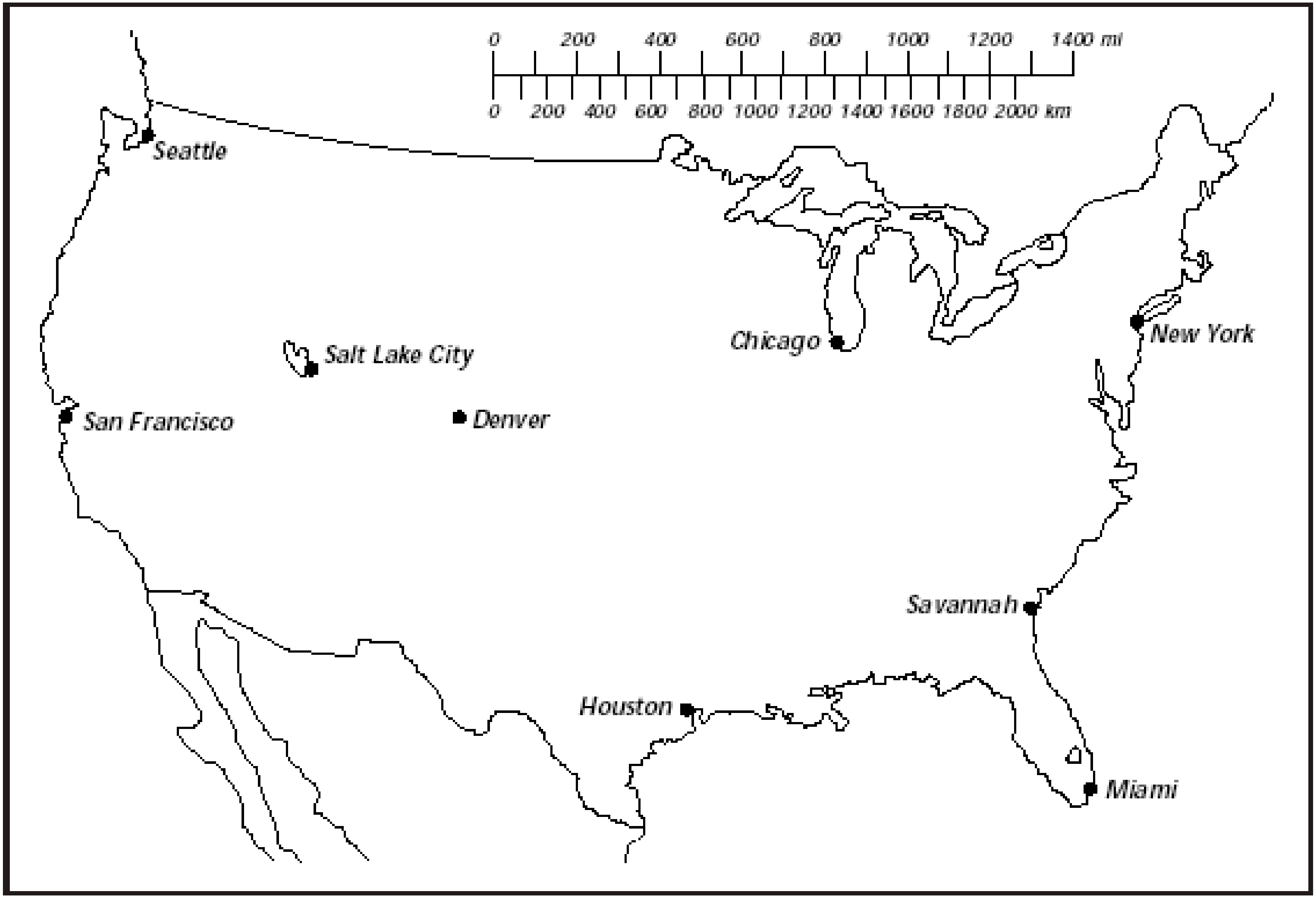
City	Difference in Arrival Times	Distance to Epicenter
Salt Lake City, Utah	3 min 10 sec	
Houston, Texas	2 min 00 sec	
Savannah, Georgia	1 min 50 sec	

Graph



 Name ________________________________

Finding the Epicenter of an Earthquake



Finding the Epicenter of an Earthquake

Analysis Questions:

1. Look at the three circles you have drawn to locate the epicenter of the earthquake. Which city on the map is closest to the epicenter?

   ____

2. Which of the three cities *listed in the data table* would seismographs detect the earthquake first? Last?

   ____

   ____

3. When locating the epicenter of an earthquake, why is it necessary to know the distance from the epicenter for at least three locations?

   ____

   ____

   ____

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Contact: Jane Platt

FOR IMMEDIATE RELEASE November 19, 1999

JUPITER'S MOON IO: A FLASHBACK TO EARTH'S VOLCANIC PAST

Jupiter's fiery moon Io is providing scientists with a window on volcanic activity and colossal lava flows similar to those that raged on Earth eons ago, thanks to new pictures and data gathered by NASA's Galileo spacecraft.

The sharp images of Io were taken on Oct. 10 during the closest-ever spacecraft flyby of the moon, when Galileo dipped to just 611 kilometers (380 miles) above Io's surface. The new data reveal that Io, the most volcanic body in the solar system, is even more active than previously suspected, with more than 100 erupting volcanoes.

"The latest flyby has shown us gigantic lava flows and lava lakes, and towering, collapsing mountains," said Dr. Alfred McEwen of the University of Arizona, Tucson, a member of the Galileo imaging team. "Io makes Dante's Inferno seem like another day in paradise."

Ancient rocks on Earth and other rocky planets show evidence of immense volcanic eruptions. The last comparable lava eruption on Earth occurred 15 million years ago, and it's been more than 2 billion years since lava as hot as that found on Io, reaching 1,482 degrees Celsius or 2,700 degrees Fahrenheit, flowed on Earth.

"No people were around to observe and document these past events," said Dr. Torrence Johnson, Galileo project scientist at NASA's Jet Propulsion Laboratory (JPL), Pasadena, CA. "Io is the next best thing to traveling back in time to Earth's earlier years. It gives us an opportunity to watch, in action, phenomena long dead in the rest of the solar system."

The new data focus on three of Io's most active volcanoes -- Pele, Loki and Prometheus. The vent region of Pele has an intense high-temperature hot spot that is remarkably steady, unlike lava flows that erupt in pulses, spread out over large areas, and then cool over time. This leads scientists to hypothesize that there must be an extremely active lava lake at Pele that constantly exposes fresh lava. Galileo's camera snapped a close-up picture showing part of the volcano glowing in the dark. Hot lava, at most a few minutes old, forms a thin, curving line more than 10 kilometers (6 miles) long and up to 50 meters (150 feet) wide. Scientists believe this line is glowing liquid lava exposed as the solidifying crust breaks up along the caldera's walls. This is similar to the behavior of active lava lakes in Hawaii, although Pele's lava lake is a hundred times larger.

Loki, the most powerful volcano in the solar system, consistently puts out more heat than all of Earth's active volcanoes combined. Two of Galileo's instruments -- the photopolarimeter radiometer and near-infrared mapping spectrometer -- have provided detailed temperature maps of Loki. "Unlike the active lava lake at Pele, Loki has an enormous caldera that is repeatedly flooded by lava, over an area larger than the state of Maryland," said Dr. Rosaly Lopes-Gautier of JPL, a member of the spectrometer team.

Observations of Prometheus made early in the Galileo mission showed a new lava flow and a plume erupting from a location about 100 kilometers (60 miles) west of the area where the plume was observed in 1979 by NASA's Voyager spacecraft. New Galileo data clarify where lava is erupting, advancing, and producing plumes. The most unexpected result is that the 75 kilometer- (50 mile-) tall plume erupts from under a lava flow, far from the main volcano. The plume is fed by vaporized sulfur dioxide-rich snow under the lava flow.

Mountains on Io are much taller than Earth's largest mountains, towering up to 16 kilometers (52,000 feet) high. Paradoxically, they do not appear to be volcanoes. Scientists are not sure how the mountains form, but new Galileo images provide a fascinating picture of how they die. Concentric ridges covering the mountains and surrounding plateaus offer evidence that the mountains generate huge landslides as they collapse under the force of gravity. The ridges bear a striking resemblance to the rugged terrain surrounding giant Olympus Mons on Mars.

Scientists hope to learn more about dynamic Io when Galileo swoops down for an even closer look on Nov. 25 from an altitude of only 300 kilometers (186 miles). Because Io's orbit is bathed in intense radiation from Jupiter's radiation belts, there is a risk of radiation damage to spacecraft components. In fact, several spacecraft systems sustained damage during the October flyby. Given these radiation risks, the Io flybys were scheduled near the end of the spacecraft's two-year extended mission.

New Io images taken by the spacecraft are available at:
http://www.jpl.nasa.gov/pictures/io or http://galileo.jpl.nasa.gov..

Galileo entered orbit around Jupiter and its moons on Dec. 7, 1995, for a two-year prime mission. JPL manages the Galileo mission for NASA's Office of Space Science, Washington, DC. JPL is operated for NASA by the California Institute of Technology, Pasadena, CA.

Mount St. Helens Update
September 29, 2004 5:30 P.M., PDT
[from http://vulcan.wr.usgs.gov/Volcanoes/Cascades/CurrentActivity/2004/current_updates_20040929_PM.html USGS]

Increased seismicity overnight prompted raising the alert level to Volcano Advisory (Alert Level 2) at 10:40 A.M., PDT, this morning. Throughout the day the seismic energy level has remained at an elevated with a rate of 3-4 events per minute including an increase in the number of events between Magnitude 2 and 3. All earthquake locations are still shallow and in or below the lava dome. In addition, initial data from the GPS instrument on the lava dome that was repaired Monday morning suggest that the site moved a few inches northward Monday and Tuesday, but has since been stable. Such movement is not surprising in light of the high seismicity levels. A USGS field crew continued their deployment of GPS equipment today in order to monitor any ground movement on the lava dome, crater floor, or lower slopes of the volcano. Another gas flight this morning produced a result of no significant volcanic gas detected, as was the case on Monday. Two press conferences were held at CVO to update the media. Tomorrow's field work includes continued GPS deployments.

The current hazard outlook is unchanged from that outlined in this morning's Volcano Advisory. Updated wind forecasts from the National Oceanic and Atmospheric Administration coupled with an eruption model indicate that the wind direction will shift from northwesterly to northeasterly tonight. Therefore any ash clouds produced tonight will drift southwestward.

Confusion at this morning's press briefing at CVO regarding Alert Levels resulted in numerous calls to emergency management agencies from the public about which is the correct level. We are at Alert Level Two—Volcano Advisory. Explanation of the alert-level scheme can be found on the "News and Current Events" web site below.

Mount St. Helens Volcano Advisory (Alert Level Two)
September 29, 2004 10:40A.M., PDT

Over night, seismic activity at Mount St. Helens has accelerated significantly, which increases our level of concern that current unrest could culminate in an eruption. We are increasing the alert level to the second of three levels, which is similar to Color Code Orange of the alert system used by the Alaska Volcano Observatory and analogous to the National Weather Service's hazard watch. Earthquakes are occurring at about four per minute. The largest events are approaching Magnitude 2.5 and they are becoming more frequent. All are still at shallow levels in and below the lava dome that grew in the crater between 1980 and 1986. This suggests that the ongoing intense earthquake activity has weakened the dome, increasing the likelihood of explosions or perhaps the extrusion of lava from the dome.

The cause and outcome of the accelerating unrest is uncertain. Explosions from the lava dome could occur suddenly and without further warning. During such explosions the dome and crater floor are at greatest risk from ballistic projectiles, but the rim of the crater and flanks of the volcano could also be at risk. Explosions would also be expected to produce ash clouds that rise several thousand feet above the crater rim and drift downwind. During today, wind forecasts from the National Weather Service, combined with eruption models, show that ash clouds will move in a southeasterly direction and could dust areas tens of miles or more from the volcano with ash. Landslides and debris flows from the crater that are large enough to reach the Pumice Plain are also possible. If the current unrest is being driven by a small slug of magma at shallow depth, extrusion of lava could also occur. At present there is **no evidence** that new gas-rich magma has ascended to shallow levels and could generate a large sustained eruption. But we are being especially vigilant to become aware of such evidence should it appear.

We continue to monitor the situation closely and will issue additional updates as warranted, whether activity escalates or returns to background levels.

Experts Predict Mount St. Helens Eruption
By THE ASSOCIATED PRESS

Published: September 30, 2004 New York Times

Filed at 11:48 a.m. ET

SEATTLE (AP) -- Earthquake activity increased further early Thursday at Mount St. Helens, and one scientist put the chance of a small eruption at 70 percent.

Jeff Wynn, chief scientist at the U.S. Geologic Survey's Cascade Volcano Observatory in Vancouver, Wash., said tiny quakes were occurring at the rate of three or four a minute. Larger quakes, with magnitudes of 3 to 3.3, were occurring every three or four minutes, he said.

New measurements show the 975-foot lava dome in the volcano's crater had moved 2 1/2 inches to the north since Monday, Wynn said.

``Six centimeters may not sound like a lot, but imagine taking a 1,000-foot-high pile of rocks and moving it 2 1/2 inches. For a geologist, that's a lot of energy,'' Wynn said.

Wynn estimated there was a 70 percent chance the activity will result in an eruption.

Scientists did not expect anything like the mountain's devastating eruption in 1980, which killed 57 people and coated much of the Northwest with ash. On Wednesday, they warned that a small or moderate blast from the southwest Washington mountain could spew ash and rock as far as three miles from the crater at the 8,364-foot peak.

Scientists planned to fly over the volcano again Thursday to test for gasses that could indicate the presence of magma moving beneath the volcano.

The volcano began rumbling more intensely Wednesday, with earthquakes ranging from magnitude 2 to 2.8 coming about four times a minute and possibly weakening the lava dome in the crater of the 8,364-foot mountain, the U.S. Geological Survey said.

The heightened alert has drawn sightseers to observation areas, especially along Washington 504 leading from Interstate 5 eastward toward the volcano, Dawn Smith, co-owner of Eco Park Resort told The News Tribune of Tacoma.

``It's just been crazy the past couple of days,'' Smith said.

A sign in front of the business read, ``Here we go again.''

Few people live near the mountain, the centerpiece of the Mount St. Helens National Volcanic Monument in the Gifford Pinchot National Forest about 100 miles south of

Seattle. The closest structure is the Johnston Ridge Observatory, about five miles from the crater.

``Whoa, look at that one,'' said Barbara Wilson of Sebastopol, Calif., one of a number of visitors huddled around a seismograph registering the quakes at Johnston Ridge on Wednesday.

She said she was not at all concerned about her safety, but another in the group, Harold Hassold, 70, a retired certified public accountant from Vancouver, Wash., was more cautious.

``I don't think anyone really knows what's going to happen with the activity that's going on,'' he told the Tacoma newspaper. ``If they knew what was going to happen, they wouldn't have all those scientific instruments up here.''

The Geological Survey raised the mountain's eruption advisory from Level 2 to Level 3 out of a possible 4 on Wednesday, prompting officials to begin notifying various state and federal agencies of a possible eruption. The USGS also has asked the National Weather Service to be ready to track an ash plume with its radar system.

In addition, scientists called off a plan to have two researchers study water rushing from the crater's north face for signs of magma. A plane was still able to fly over the crater Wednesday to collect gas samples. Negligible amounts of volcanic gas were found.

The USGS has been monitoring St. Helens closely since Sept. 23, when swarms of tiny earthquakes were first recorded. On Sunday, scientists issued a notice of volcanic unrest, closing the crater and upper flanks of the volcano to hikers and climbers.

Scientists said they believe the seismic activity is being caused by pressure from a reservoir of molten rock a little more than a mile below the crater. That magma apparently rose from a depth of about six miles in 1998, but never reached the surface, Wynn said.

The mountain's eruption on May 18, 1980, blasted away its top 1,300 feet, spawned mudflows that choked the Columbia River shipping channel, leveled hundreds of square miles of forests and paralyzed towns and cities more than 250 miles to the east with volcanic ash.

September 30, 2004 LA TIMES

Seismologists Raise Alert Level for the Quaking Mt. St. Helens
A small to moderate eruption is possible in the next few days, but such predictions are not an exact science, volcano experts agree.

By Tomas Alex Tizon, Times Staff Writer

SEATTLE — Mt. St. Helens, the volatile mountain that blew its top in spectacular fashion 24 years ago, has been grumbling again, and scientists said Wednesday that a small to moderate eruption was possible in the next few days.

Such an event could spew rock and ash thousands of feet in the air, but the fallout probably would not go beyond the volcano's crater or flanks. At worst, scientists say, some debris could travel as far as three miles — nowhere near the closest towns of Cougar and Toutle.

Seismologists monitoring the volcano, which is about 100 miles south of here, on Wednesday afternoon raised the alert level to "volcano advisory" — level 2 on a three-step scale — after a series of small earthquakes indicated the mountain was, in the words of local seismologist Seth Moran, "ramping up."

Moran said a hardened dome of lava inside the crater also appeared to be growing, which meant that gases or molten rock could be building just below the surface. The lava dome, now about 900 feet tall, grew inside the crater in the years after the May 18, 1980, eruption that killed 57 people and razed more than 150 square miles of forest.

The eruption blew off the top 1,300 feet of the mountain and caused one of the largest recorded landslides in history. Ash from the explosion eventually circled the globe.

That type of eruption "is not in the cards this time," said Steve Malone, a seismologist at the University of Washington. But, Malone and other scientists added, predicting volcanic eruptions is not an exact science; it's possible the eruption could be bigger than expected, or it may not happen at all.

"We're not guaranteeing an eruption," said Cynthia Gardner, a research geologist for the Cascades Volcano Observatory in Vancouver, Wash. The observatory is operated by the U.S. Geological Survey.

The U.S. Forest Service has closed hiking trails near the crater and above the 4,800-foot level of the mountain, which is 8,364 feet high. The Weyerhaeuser Co., which owns 435,000 acres surrounding the mountain, closed off areas within a 12-mile radius of the volcano.

Since 1980, Mt. St. Helens has experienced three minor — and largely ignored — explosions. A larger one occurred in 1986 after pressure under the lava dome burst. Scientists say the volcano's current buildup resembles the one in 1986.

On Sept. 23, instruments began detecting intermittent swarms of earthquakes beneath the crater; by Tuesday, the quakes — the largest measuring between 2 and 2.8 — were coming at a rate of two to three per minute.

"Most of these earthquakes are very, very small. You wouldn't feel them even if you were standing right on top of them," Moran said.

After a quiet period Tuesday evening, the quakes began again early Wednesday and lasted nearly eight hours, Moran said during a briefing in Vancouver. He said the swarms were accelerating "in both frequency and intensity." During that period, instruments recorded up to four quakes per minute.

Scientists have been making daily helicopter trips to the top of the mountain since Monday, trying to collect gas samples and planting measuring instruments on the lava dome and on the slopes of the crater. Their main mission is to determine the cause of the quakes and the apparent buildup of the dome. Once they determine this, scientists can better predict what kind of "explosive event," if any, is likely to take place.

Meanwhile, officials at the Mt. St. Helens visitors center, which has remained open, have reported a noticeable increase in tourists since Sept. 23. Instead of being frightened away, people seem to be drawn toward the volcano.

"There's nothing more alluring than a volcano, and there's nothing more alluring than a volcano that looks like it might erupt," Gardner said.

In the community of Toutle, about 25 miles west of the volcano, it's been business as usual. "The main thing is to not overreact," said school Supt. Scott Grabenhorst. He said while residents don't seem particularly worried, it's probably a good time to revisit some of the safety drills devised after the 1980 eruption.

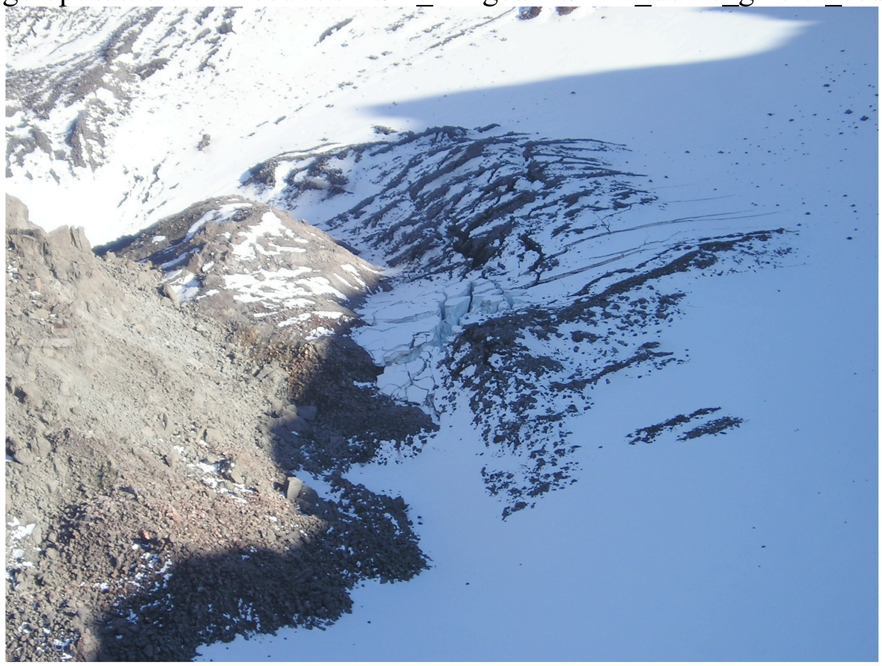
In Portland, Ore., which is about 50 miles southwest of Mt. St. Helens, Mayor Vera Katz directed all city bureaus to update their preparedness plans. "The greatest threat to Portland from a major eruption is the ash that in 1980 seemed to cover everything," Katz said in a statement.

U.S. Geological Survey, Vancouver, Washington
University of Washington, Pacific Northwest Seismograph Network, Seattle, Washington

Mount St. Helens Information Statement
October 1, 2004, 12:45 P.M., PDT

This Information Statement describes a new feature that has developed in the crater of Mount St. Helens over the past few days. Photographs taken by scientists during gas flights show that an area of about 5 to10 acres on the crater glacier, just south of the 1980-86 lava dome, has risen up to several tens of feet (exact amount is not known) and has become increasingly crevassed (cracked). The crevasses are up to several feet wide and perhaps tens of feet deep. We think that this localized deformation is caused by a portion of the south side of the lava dome and crater floor pushing upward in a piston-like motion and lifting overlying snow, glacier ice, and rock debris that is tens to several hundred feet thick. Because there is no sign of steaming or rapid melting, we infer that old, cold dome rock is in contact with the glacier and not new lava, which would be hot enough to cause steaming. This morning a USGS scientist from the Alaska Volcano Observatory is flying over the crater with an instrument that measures surface temperatures of the dome and crater floor.

This deformation accompanies the intense seismic activity of the past week and suggests that the dome has been weakened sufficiently that forces at depth are large enough to allow upward displacement of part of the dome and crater floor. Evidence from GPS instruments on the flanks of the volcano indicate that this deformation is limited to a relatively small area between the lava dome and south crater wall and that other sites are stable.

A picture of this feature can be obtained from:
ftp://ftpext.usgs.gov/pub/wr/wa/vancouver/MSH_Images/MSH04_dome_glacier_south_side_9-29-04.jpg 

Amendment made at 12:45 P.M. This area is the source of the steam and ash emission that began shortly after noon. We continue to monitor the situation closely and will issue additional updates as warranted

Mount St. Helens Information Statement,
October 1, 2004, 1:45 P.M., PDT

Mount St. Helens remains at Alert Level 2—Volcano Advisory

Shortly before noon today, Mount St. Helens emitted a plume of steam and minor ash from an area of new crevasses in the crater glacier south of the 1980-86 lava dome. This area was described in the prior Information Statement issued at 12:45 P.M. The event lasted from 11:57 to 12:21 PDT and created a pale-gray cloud that reached an altitude of about 9700 ft (from pilot reports). It drifted southwestward, where nearby residents should receive no more than a minor dusting of ash. USGS scientists making thermal measurements witnessed the emission and noted that the clouds were not particularly hot. Blocks of rock and ice ejected by the event fell in the crater and rim areas. The emission was accompanied by an abrupt drop in seismicity, which remains at low levels.

Similar events are possible in the future. We will monitor the situation closely over the next several hours and days in order to determine the outlook for future behavior. Additional updates will be issued as needed.

Mount St. Helens Update, October 3, 2004, 8:00 A.M.

Current status is Volcano Alert (Alert Level 3); aviation color code RED

Overnight (about 3 am) there was a tremor burst that lasted about 25 minutes. No eruptive plume was detected as a result of this tremor. Following the tremor, seismic activity dropped, but now is at a level similar to that before the tremor burst. Earthquakes are occurring at a rate of 1-2 per minute with maximum earthquake magnitudes of about M3. All earthquake locations remain shallow. During yesterday's gas flight, scientists saw an increase in the number of fumaroles on the lava dome and detected some carbon dioxide. The total amount awaits further data reduction. Scientists also reported intermittently the smell of hydrogen sulfide (rotten-egg smell) over the crater. Data from the GPS instruments on the flanks of the volcano show no significant changes. Results from the FLIR (thermal imagery) data to date show no significant thermal anomalies in the crater or on the dome. Scientists will be in the field today to harden GPS sites, do another FLIR flight, and conduct another gas flight.

A notice of *Volcano Alert (Alert Level 3) was issued today at 2:00 p.m. PDT*

Immediately after the small steam emission at 12:15, seismic activity changed from principally rock breakage events to continuous low-frequency tremor, which is indicative of magma movement. We are increasing the alert level to Volcano Alert the highest alert level indicating that an eruption could be imminent.

The cause and outcome of the accelerating unrest is uncertain. Explosions from the vent could occur suddenly and without further warning. During such explosions the dome and crater floor are at greatest risk from ballistic projectiles, but the rim of the crater and flanks of the volcano could also be at risk. Explosions would also be expected to produce ash clouds that rise several to tens of thousands of feet above the crater rim and drift downwind. Currently wind forecasts from the National Weather Service, combined with eruption models, show that ash clouds will move to the northwest. If ash emissions are large, drifting ash could affect downwind communities. Minor melting of the glacier could trigger debris flows from the crater that are large enough to reach the Pumice Plain. There is very low probability that downstream communities would be impacted by these hydrologic events. .

We continue to monitor the situation very closely and will issue additional updates as warranted, whether activity escalates or returns to background levels.

Scientists Fear Aftermath of Eruption
By THE ASSOCIATED PRESS

Published: October 4, 2004 in the New York Times

Filed at 10:29 a.m. ET

The boiling magma rumbling and rising within Mount St. Helens isn't the only thing scientists fear. When large volcanoes erupt they can unleash an awesome arsenal of natural weapons, devastating communities and landscapes even hundreds of miles from the blast.

First, there's the gritty, glassy ash that travels for miles. That's what scientists consider to be the main hazard from Mount St. Helens during the current volcano alert.

But bigger volcano blasts can produce more frightening scenarios: high-speed mudslides caused by a rush of water carrying house-sized boulders and intensely hot clouds of rock fragments and lava.

You think the hurricanes in Florida have been vicious? Don't try boarding up your windows and riding out a pyroclastic flow, a lahar or a tephra blizzard -- the technical names for all those hazards, which are among Earth's most powerful forces.

In the mountain's historic 1980 eruption, they combined to turn a swath of the Pacific Northwest into a moonscape, killing 57 people.

Scientists believe Mount St. Helens is ready to erupt again, although perhaps not with the kind of power seen when the mountain literally blew its top.

``There is a wide range of explosivity,'' said geologist Willie Scott of the U.S. Geological Survey. ``It's that uncertainty that makes us cautious.''

But it's more than molten rock that makes a volcano dangerous. It's the dissolved carbon dioxide and other gases in the magma. Fresh, foaming magma contains more gas than old magma. Even the water dissolved in magma expands violently when it reaches the surface and hits the air.

Scott compared it to shaking a can of soda pop.

``If the gas content is high, the explosivity is greater,'' he said.

Sometimes gases vent from the magma even without an eruption. Leaking carbon dioxide can silently kill trees, or people who venture too close. Sulfur dioxide creates smoggy air pollution that contributes to respiratory disease and generates acid rain that kills forests and aquatic life.

The most likely and widespread danger from any volcano is ash. Initially, ash is blasted 60,000 feet into the atmosphere. Then winds carry it for dozens or even hundreds of miles.

Volcanic ash is not the product of combustion like the fluffy ash from a wood stove or charcoal barbecue. Gritty and abrasive, it is made up of tiny fragments of rock, natural glass and minerals that get pulverized by earthquakes and internal explosions.

In its 1980 eruption, Mount St. Helens belched some 500 million tons of ash over surrounding states, where it fell like a gray, minerally snowfall. It caused most of the $1 billion in property damage attributed to the eruption.

The plume can choke the engines of passing aircraft. Ash can clog and wreck machinery, electronics, cars, air conditioners, furnaces and irrigation systems. Dry ash can collapse roofs and scratch windows. Large clouds disrupt telecommunications signals.

Ash poses real health risks, especially to children, the elderly, people with chronic respiratory illnesses, as well as wildlife and pets. It settles on the leaves of plants, preventing photosynthesis.

In this current explosive phase, researchers expect Mount St. Helens to generate less ash than in 1980. So far, it has sprinkled ash on nearby Vancouver, Wash., and other downwind communities.

``We could see an explosion that throws up a column for an hour or so,'' Scott said.

Other volcanic forces are deadlier still.

Tephra is a catchall term for fragments of volcanic rock and lava thrown airborne. Some tephra is nearly four feet wide, but most of it is gravel that behaves like shrapnel and shreds whatever is in its path.

A lahar is a catastrophic slurry of water and rock fragments that rushes down the volcano's tall, steep slopes. It looks like wet concrete and can carry house-sized boulders, trees, even bridges. It follows river valleys, often growing and gaining speed as it consumes the water in the channel.

In the 1980 eruption, lahars swept downhill on three sides of the mountain at 70 mph. They left mudflows up to 30 feet deep extending for dozens of miles.

A volcano's other doomsday weapon is a pyroclastic flow. At the bottom of the flow is a layer of coarse rock fragments that burst forth like a shotgun blast. It hugs the ground, splintering entire forests like toothpicks and exploding buildings. The top layer is a turbulent ash cloud.

A pyroclastic cloud is fast -- 50-100 mph. What's worse, it's hot -- up to 1,500 degrees. It destroys everything in its path like a boiling hurricane.

In 1980, Mount St. Helens directed a blast of hot material that reached 300 mph. A ``seared zone'' of timber extended for 17 miles.

This time around, scientists don't expect the mountain to generate such a show of force.

``We're not anticipating hot flow to any great distance,'' Scott said.

Scientists on Alert at Mount St. Helens

By THE ASSOCIATED PRESS

Published: October 4, 2004 in the New York Times

Filed at 3:57 a.m. ET

MOUNT ST. HELENS, Wash. (AP) -- As Mount St. Helens reawakened fears of its fury two dozen years ago, a new generation of scientists has cranked into high gear to listen to the mountain with monitoring devices, seismic sensors and air samplers.

``There's no way to stop the natural process,'' said U.S. Geological Survey scientist Dan Dzurisin, who was on the 8,634-foot mountain with geophysicist Mike Poland a few days before the latest eruptions began. ``But we can try to keep the process from becoming a disaster.''

Scientists cranked into high gear Sept. 23, when a swarm of earthquakes began shuddering inside the snow-streaked peak less than a mile from the surface, steadily ramping up to rates as high as four per minute, with magnitude peaking at 3.3.

``It's unprecedented -- not the release of energy but the style,'' Poland said. ``They're really shallow.''

Vulcanologists cut back on trips near the crater a few days after their visit, wary of steam explosions that could hurl 200- to 300-pound rocks outside the crater.

But as Dzurisin and Poland worked, there was no sign of danger. Ladybugs buzzed by and occasionally landed on their clothing.

Behind them, inside the crater, loomed the lava dome that began emerging months after the eruption as magma forced its way up the volcano's throat and onto the surface. The last dome-building episode was in 1986.

Wisps of steam rise from the mountain's rocky top year around, as water seeps into the hot-rock core, still cooling from 1,500-degree magma flows in 1998. Little dust clouds rise from the crater's edge as rock and pumice -- lava that has cooled to pale, lightweight stone -- trickles down.

``It's never quiet inside the crater,'' Poland said.

Draped around the dome like an ermine collar is the world's youngest glacier, not even named yet. Six-hundred feet deep, it contains millions of cubic feet of ice and snow. Deep crevasses slash the glittering surface.

The mountain's last eruption in 1980 marked a quantum leap in scientists' understanding of volcanoes and how to live with them. Technology and instrumentation have improved as well.

Vulcanologists believe the current flurry of earthquakes is driven by hot rock that flowed into the dome core during '98 quakes. That magma likely ``degassed'' over time. Air samples collected during flyovers every day or two are aimed at detecting gas spikes that would indicate fresh magma.

Poland and Dzurisin brace a three-legged receiver with heavy stones over a point marked with a 3-foot length of rebar pounded into the ground. The receiver -- a protected antenna surrounded by concentric metal rings to keep out extraneous chatter -- runs on a 12-volt car battery, using GPS signals to detect the tiniest ground movement.

``This is what we do,'' Dzurisin said.

``Sometimes we come up here and the rings are filled with snow. Sometimes they're filled with ladybugs,'' Poland said.

U.S. Geological Survey, Vancouver, Washington
University of Washington, Pacific Northwest Seismograph Network, Seattle, Washington

Mount St. Helens Update 4 October 2004 7:00 A.M.

Current status is Volcano Alert (Alert Level 3); aviation color code RED

Overnight seismic activity increased until a steam (and possibly ash) event occurred about 10:40 P.M. Observers at Coldwater Ridge could see the steam plume, which barely made it to the crater rim, in the moonlight. Since then, the seismicity has been significantly lower as after prior steam-and-ash events. Earthquakes are occurring at a rate of about 1 per minute and the largest since the steam event have been in the magnitude 2s. All locations remain shallow.

Results from GPS measurements indicate no significant deformation of the outer flanks of the volcano. However, visual observations and photographic analysis show large-scale uplift (10's of meters) of part of the glacier and a nearby segment of the lava dome. Yesterday a field crew installed a new GPS instrument on the dome and also measured the distance from the Johnston Ridge Observatory to the dome.

Yesterday's gas flight did not detect significant concentrations of carbon dioxide.

Two telemetered microphones are now in operation to detect explosions.

Today we will receive a remotely operated video camera that will be installed on the crater rim from the USGS Hawaiian Volcano Observatory. Today field crews will work at installing additional seismometers on the flanks of the volcano and will continue to harden the GPS sites and download data. Time permitting, additional flights to acquire thermal imagery and gas measurements will occur.

Wind forecasts from the NOAA, combined with eruption models show winds today will be from the east and southeast and any ash clouds would drift to the west and northwest.

We continue to be concerned that additional steam-and-ash eruptions could occur at any time. The principal hazard from these types of events is for ash reaching altitudes that could affect aviation. If the current unrest continues there is also an increased probability of larger magnitude and more ash-rich eruptions.

We continue to monitor the situation closely and will issue additional updates and Alert Level changes as warranted.

Press conferences will continue to be held at the Headquarters office of the Gifford Pinchot National Forest. Press conferences are held at 9:30 A.M. and 2:30 P.M.

Future Tectonic Plate Movement

Overview:

In this activity, you will predict where the Earth's continents will be located in 100 million years. You will be given the speeds at which scientists believe six of the continents are moving. (We are going to ignore Antarctica. You should also assume that the Indo-Australian plate will split at the rift and may move in different directions.) From this data you will figure out how far from their present locations the continents will move. You will also use what you have learned about plate boundaries to predict the direction tectonic plates are moving.

Procedure:

4. Assemble the world map. You will have to cut the end off of one side of the photocopied map so it lines up with the other side of the world. Make sure the latitude and longitude lines match up. Carefully tape the two sides together. You will need to make two of these maps.

5. Label the continents on each map.

6. Locate and label the following cities on both your maps with a dot at each location:

Africa	**Cairo**, Egypt	30N 31 E
Asia	**Shanghai**, China	31N 121 E
Australia	**Perth**, Australia	31S 115E
Europe	**Rome**, Italy	41N 12E
North America	**Chicago**, Illinois, USA	41N 87W
South America	**Buenos Aires**, Argentina	38 S 59 W

7. Cut the continents out of one of your maps. Cut close to the coastlines – it doesn't have to be perfect.

8. Lay the cut out continents on the master map in their current positions. You should be able to easily move them around on the map without getting stuck on tape.

9. Predict where the continents will be in 100 million years. Slide each continent to its new location and lightly trace them with pencil.

10. Use the plate speeds in the following data table to find the rate of movement for each plate that carries a continent. Calculate how far each continent will drift in 100 million years.

Adapted and images taken from *Inside Earth. Prentice Hall, 2000.*

PLATE	SPEED (cm/yr)
Africa	0.66
Eurasia	0.95
Indo-Australian	8.50
North American	2.31
South American	3.55

The distance on the master map scale is in kilometers. You will need to set up a proportion to figure out the distance, but you will need to convert centimeters to kilometers. Remember there are 100,000 cm in 1 km.

Here is a worked problem of the African plate as an example.

100 million is the time factor. You know the African plate moves 0.66 cm per year. You want to know how many kilometers it will move in 100 million years:

$$\frac{0.66\text{ cm}}{1\text{ yr}} = \frac{X}{100{,}000{,}000}$$

$$X = 0.66\text{ cm} \bullet 100{,}000{,}000\text{ yrs}$$
$$X = 66{,}000{,}000\text{ cm/yr}$$

But, you're not done. You need to convert from cm to km. You need to set up another proportion. If there are 100,000 cm in 1 km, then how many kilometers are in 66,000,000 cm?

$$\text{So, } \frac{100{,}000\text{ cm}}{1\text{ km}} = \frac{66{,}000{,}000\text{ cm}}{X\text{ km}}$$

$$\frac{100{,}000 \bullet X}{100{,}000} = \frac{66{,}000{,}000}{100{,}000}$$

$$X = 660\text{ km/yr}$$

If you are a little confused you are probably not alone. Just plug in the information you know about each plate to figure out the distance it moves in 100 million years.

11. Now look on your master map for the scale to help you figure own how far to move each continent. **Record the distance traveled** on the data table.

12. Remember you are moving the city reference point. Not only do you need to move the continent the correct distance, you need to move it in the right direction. On your master map **make a second dot** to indicate where the plate will move.

13. **Record the new latitude and longitude location** for each city on the data table.

14. Lay your cutout of the continent matching up the city points. Trace the outline of the continent. Do that for each of the remaining continents.

Data Table

Continent	City	Present Latitude & Longitude	Distance Traveled in 100 my	Future Latitude & Longitude
Africa				
Asia				
Australia				
Europe				
N. America				
S. America				

Reflection Question

How did your predicted locations of the continents in Step #6 compare to the locations in Step #11?

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Analysis Questions:

1. What will happen to the location of North and South America as sea-floor spreading expands the Atlantic Ocean? Why?

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2. What will happen to the size of the Pacific Ocean as North America moves west? Why?

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3. How did your reference point in Africa change?

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4. What might happen to the Himalayas over the next 100 million years? Why do you think this?

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5. Which is more important to figuring out the new location of a city—the continent it is on or the plate it is on? Why?

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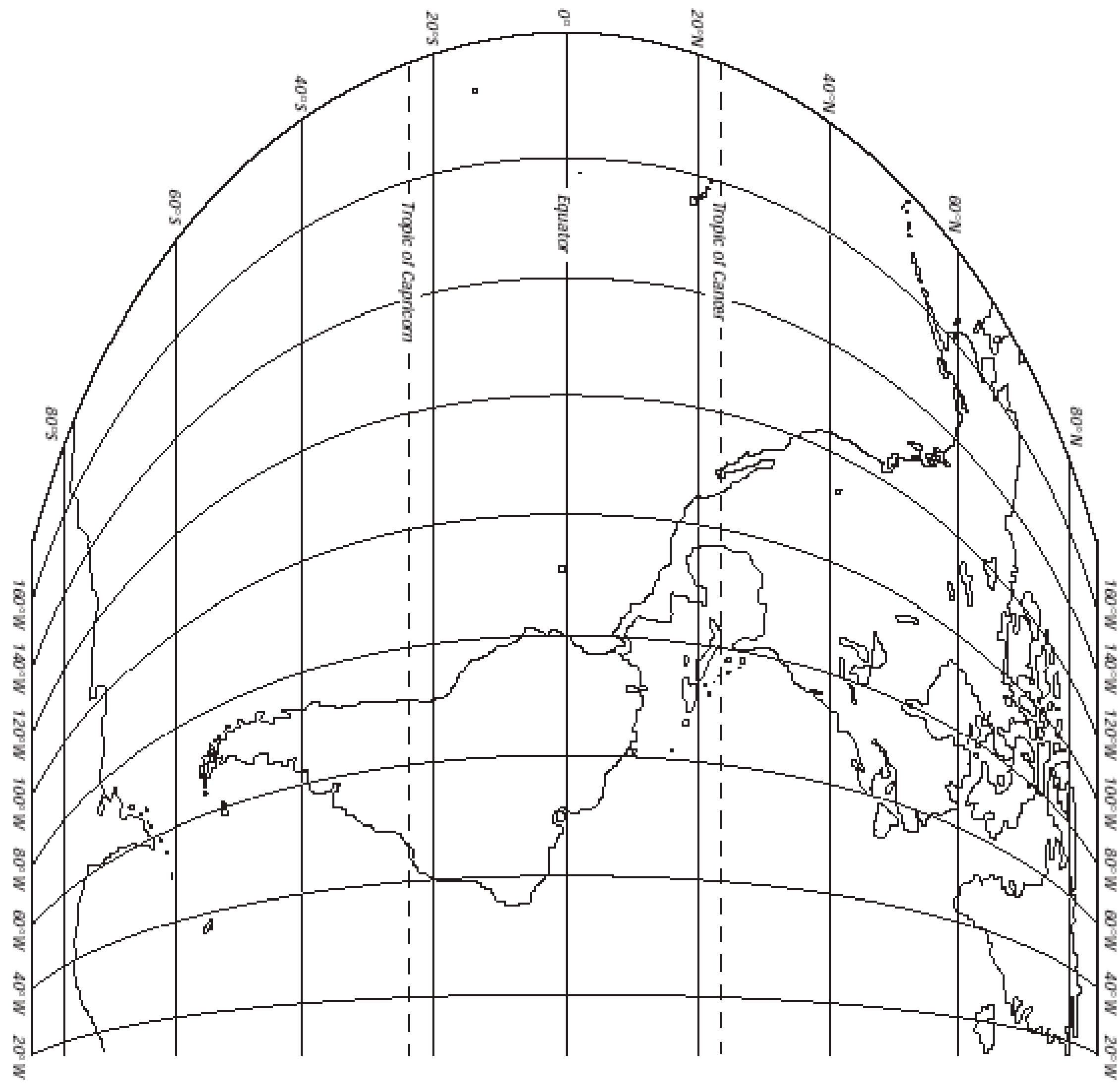

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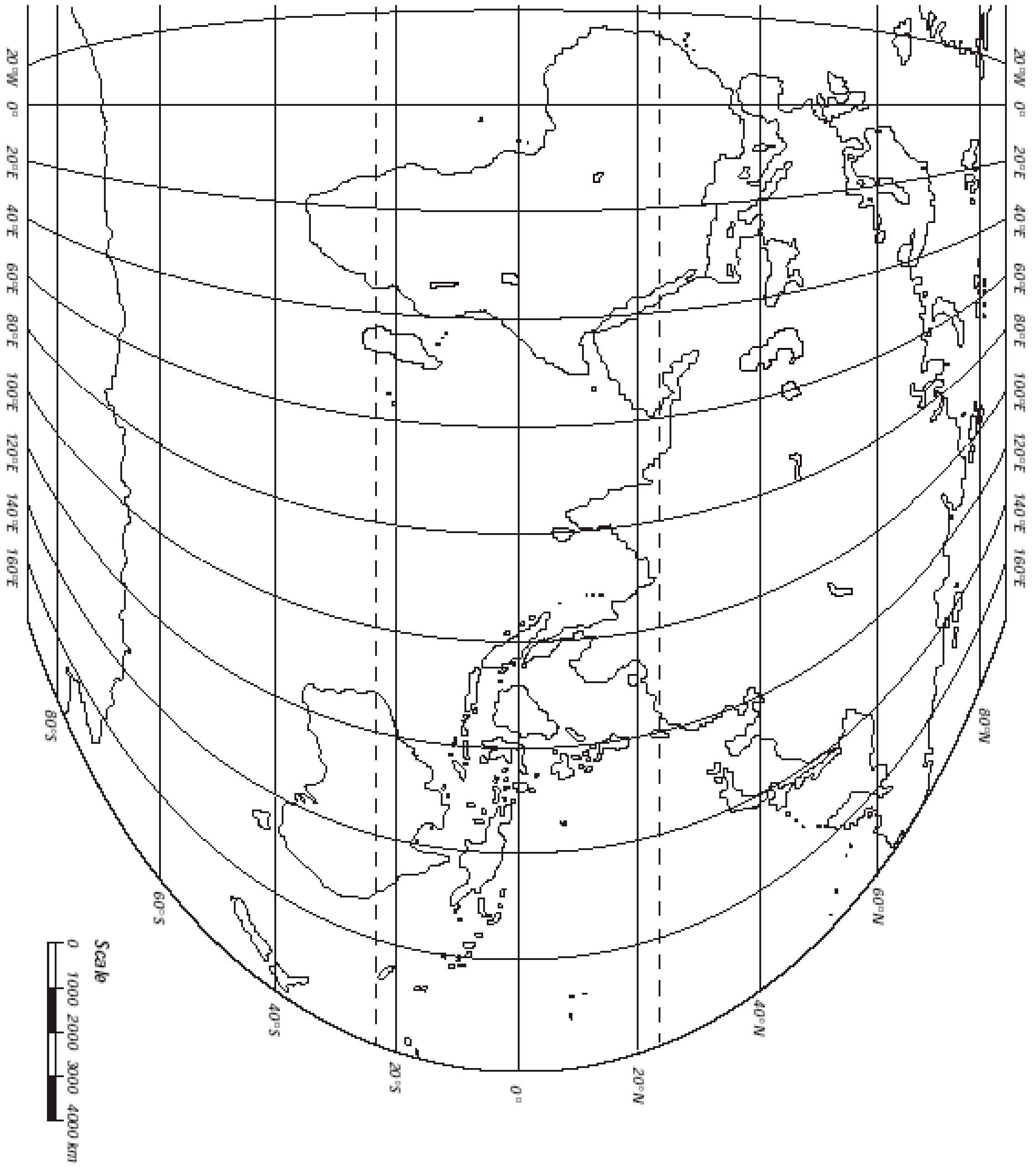
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Future Tectonic Plate Movement

Overview:

In this activity, you will predict where the Earth's continents will be located in 100 million years. You will be given the speeds at which scientists believe six of the continents are moving. (We are going to ignore Antarctica. You should also assume that the Indo-Australian plate will split at the rift and may move in different directions.) From this data you will figure out how far from their present locations the continents will move. You will also use what you have learned about plate boundaries to predict the direction tectonic plates are mov

Complete the activity yourself prior to having your students complete it. The activity can be very confusing if you are not prepared ahead of time.

Procedure:

1. Assemble the world map. You will have to cut the end off of one side of the photocopied map so it lines up with the other side of the world. Make sure the latitude and longitude lines match up. Carefully tape the two sides together. You will need to make two of these maps.

   You can also tape them together, shrink them a little and photocopy on legal size paper.

2. Label the continents on each map.

3. Locate and label the following cities on both your maps with a dot at each location:

Africa	**Cairo**, Egypt	30 ^{O}N	31^{O} E
Asia	**Shanghai**, China	31^{O}N	121^{O}E
Australia	**Perth**, Australia	31^{O}S	115^{O}E
Europe	**Rome**, Italy	41^{O}N	12^{O}E
North America	**Chicago**, Illinois, USA	41^{O}N	87^{O}W
South America	**Buenos Aires**, Argentina	38^{O}S	59^{O}W

4. Cut the continents out of one of your maps. Cut close to the coastlines – it doesn't have to be perfect.

5. Lay the cut out continents on the master map in their current positions. You should be able to easily move them around on the map without getting stuck on tape.

6. Predict where the continents will be in 100 million years. Slide each continent to its new location and lightly trace them with pencil.

7. Use the plate speeds in the following data table to find the rate of movement for each plate that carries a continent. Calculate how far each continent will drift in 100 million years.

8. Use the plate speeds in the following data table to find the rate of movement for each plate that carries a continent. Calculate how far each continent will drift in 100 million years.

PLATE	SPEED (cm/yr)
Africa	0.66
Eurasia	0.95
Indo-Australian	8.50
North American	2.31
South American	3.55

The distance on the master map scale is in kilometers. You will need to set up a proportion to figure out the distance, but you will need to convert centimeters to kilometers. Remember there are 100,000 cm in 1 km.

Here is a worked problem of the African plate as an example.

100 million is the time factor. You know the African plate moves 0.66 cm per year, You want to know how many kilometers it will move in 100 million years:

$$\frac{0.66 \text{ cm}}{1 \text{ yr}} = \frac{X}{100{,}000{,}000}$$

$$X = 0.66 \text{ cm} \bullet 100{,}000{,}000 \text{ yrs}$$
$$X = 66{,}000{,}000 \text{ cm/yr}$$

But, you're not done. You need to convert from cm to km. You need to set up another proportion. If there are 100,000 cm in 1 km, then how many kilometers are in 66,000,000 cm?

So, $$\frac{100{,}000 \text{ cm}}{1 \text{ km}} = \frac{66{,}000{,}000 \text{ cm}}{X \text{ km}}$$

$$\frac{100{,}000 \bullet X}{100{,}000} = \frac{66{,}000{,}000}{100{,}000}$$

$$X = 660 \text{ km/yr}$$

If you are a little confused you are probably not alone. Just plug in the information you know about each plate to figure out the distance it moves in 100 million years.

9. Now look on your master map for the scale to help you figure own how far to move each continent. **Record the distance traveled** on the data table.

10. Remember you are moving the city reference point. Not only do you need to move the continent the correct distance, you need to move it in the right direction. On your master map **make a second dot** to indicate where the plate will move.

> **TIP:** You may decide to assign one continent per student and then after you have modeled the African Plate have them complete the data table in groups of 5. You could also have them work in pairs on all the continents. However if they work in pairs you may need to hold the analysis questions until the next class period because they will both need their map to complete the assignment.

11. **Record the new latitude and longitude location** for each city on the data table.

12. Lay your cutout of the continent matching up the city points. Trace the outline of the continent. Do that for each of the remaining continents.

Data Table

Continent	City	Present Latitude & Longitude	Distance Traveled in 100 my	Future Latitude & Longitude
Africa	*Cairo*	*30 N 31E*	*660 km*	
Asia	*Shanghai*	*31 N 121 E*	*950 km*	
Australia	*Perth*	*31 S 115 E*	*8500 km*	Answers will vary.
Europe	*Rome*	*41 N 12 E*	*950 km*	
N. America	*Chicago*	*41 N 87 W*	*2310 km*	
S. America	*Buenos Aires*	*43 S 22 W*	*3550 km*	

Reflection Question

How did your predicted locations of the continents in Step #6 compare to the locations in Step #11?

Answers will vary.

Analysis Questions:

1. What will happen to the location of North and South America as sea-floor spreading expands the Atlantic Ocean? Why?

North and South America will move farther west away from the mid-ocean ridge.

2. What will happen to the size of the Pacific Ocean as North America moves west? Why?

It will get smaller as it subducts under the continental crust.

3. How did your reference point in Africa change?

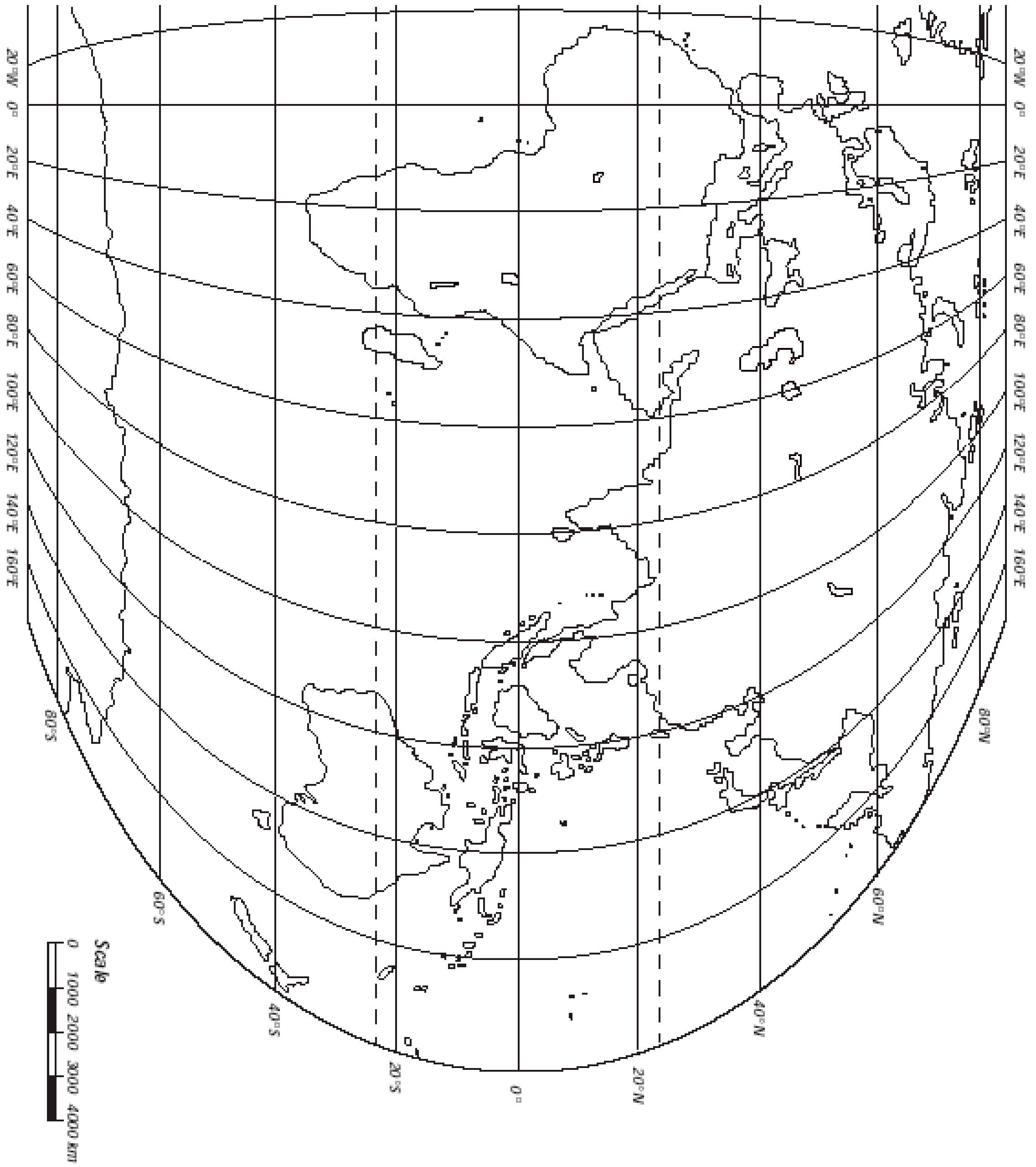
It moved farther east.

4. What might happen to the Himalayas over the next 100 million years? Why do you think this?

It will continue to grow in elevation. The Eurasian and Indo-Australian plates are colliding. When two continental plates collide they buckle and push the mountains higher.

5. Which is more important to figuring out the new location of a city—the continent it is on or the plate it is on? Why?

The continent sits on the plate. So when a plate moves the continent moves with it. So the location of the plate is more important.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