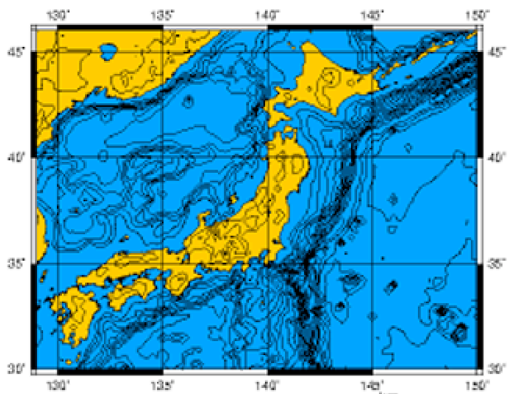
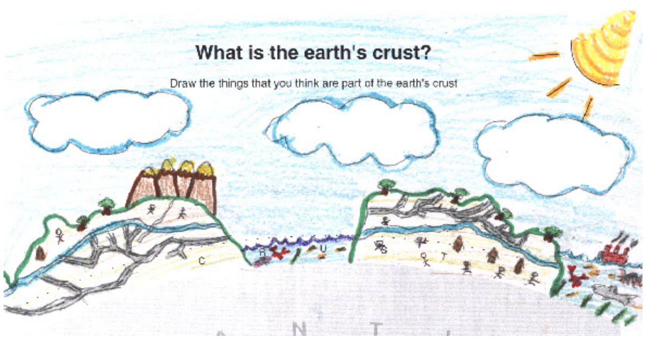
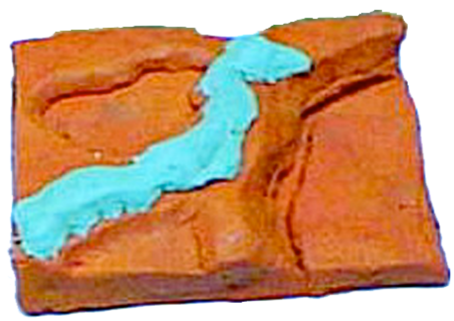
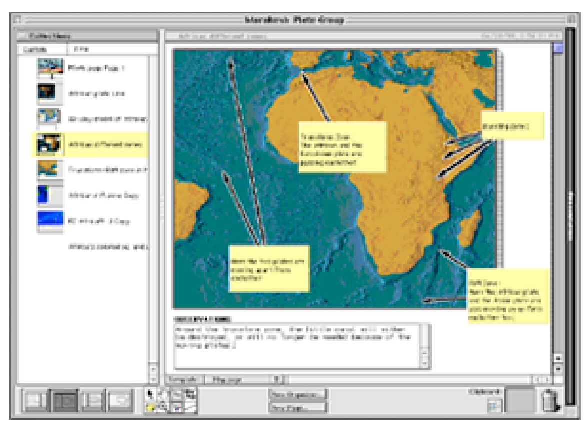
Earth Structures and Processes

Exploring Earth's Crust with Models and Data









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Exploring Earth's Crust with Models and Data

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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Principal Investigator
Daniel Edelson

Lead Curriculum Developer
Jennifer Mundt Leimberer

Curriculum Developers
Mary Pat Pardo
Josh Radinsky

Contributors
Lindsey Own
Ben Loh
David Smith
Darlene Slusher

Consultant
LeeAnn Sutherland, University of Michigan
Rebecca Schneider, University of Toledo
Colleen Reilly

Pilot and Field Test Teachers

Joan Billingham	*Alcott Elementary School, Chicago*
Jean Bramelette	*Haines Elementary School, Chicago*
Lou Ellen Finn	*Hayt Elementary School, Chicago*
Sonia Flores	*Saucedo Community Academy, Chicago*
Jennifer Mundt Leimberer	*Daniel Boone School, Chicago*
Kathleen North-Tomcyzk	*Saucedo Community Academy, Chicago*
Jennifer Olson	*Inter-American Magnet School, Chicago*
Mary Pat Pardo	*Mark Sheridan Academy, Chicago*
Thea Raedeke	*Hayt Elementary School, Chicago*
Carlos Rodriguez	*Inter-American Magnet School, Chicago*
Sandi Terry	*Haven Middle School, Evanston*
Judith Lachance-Whitcomb	*North Kenwood/Oakland Charter School, Chicago*

Undergraduate Research Assistants
Elizabeth Van Buren
Andrew Watson
Samuel Hong

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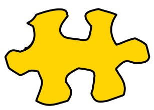
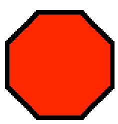
Icons for Earth Structures

Throughout your text there are several icons:

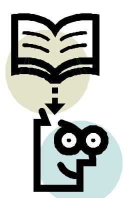
The Science Journal icon marks a place where you will write a reflection about something you have just done or data you have just analyzed.



The puzzle piece icon marks “Figure It Out” questions, which follow readings or large data analyses. These questions ask you to comprehend and analyze information, data, or concepts.



The Stop sign icon marks “Stop and Think” questions. These may come in the middle of instructions or of a reading. Sometimes the directions ask you to write down your answers in your journal or on a worksheet, but often you should just stop to consider the question. These questions are often questions that ask you 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 you to think about the purpose of the activities within a lesson.

Lesson 1

This Just In

To tackle a problem – or start to solve it – you first need to figure out how to think about that problem. In this unit, you will be observing complex data and trying to explain what is happening.

Activity 1.1: Myths and Science

Overview:
People have always tried to explain the changes happening around them. In this activity you will read stories told by ancient cultures to help explain natural phenomena like volcanoes, earthquakes, or how mountains come to be.

Think About This!!

Below are two very short myths. A myth is a traditional story passed on from one generation to another. Myths are accepted by a culture of people as history. They often explain the world view of a group of people. Read the myths and think about what it is that the ancient Peruvians and Greeks were trying to explain.

The ancient Peruvians believed that:

> "Whenever their god visited the earth to count how many people were there, his footsteps caused earthquakes. To shorten his task, the people ran out of their houses to shout, 'I'm here, I'm here!'"

The ancient Greeks believed that:

> Two races of gods, the Titans and the Trojans, went to war. The Titans were led by Atlas, and the Trojans were led by Zeus. The Trojans won the war, and Zeus punished Atlas by making him hold up the Earth on his shoulders forever. While Atlas could hold the Earth up, he sometimes shifted it to make the burden more comfortable. Whenever he did this, the Earth shook, resulting in earthquakes.

Procedure:

1. **Read the myth assigned to your group and discuss the following questions**. Each group in the class will be assigned a different myth to read and share with the class. Answer these questions in your science journal or on the worksheet *Myths and Science*.

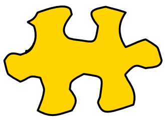


Figure It Out

1. Where did this myth take place?

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

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

4. How would YOU explain these natural events?

2. **Create a short reader's theater for the myth you just read and discussed.**

> *Reader's Theater*
> What is a reader's theater? In reader's theater, people use parts of the text to act out the story. Members of the group (called "the cast") can be props, like trees or the sun, or they can be people in the story. If someone needs to *tell* the story as other people act it out, that person can be the narrator.

3. **Create an illustration for the myth that incorporates the explanation**. Be sure to include the myth's origin (where in the world it began) in your illustration.

4. **Share and discuss mythological explanations of the world around us**. Each group will share its myth, illustrations, and reflections on the myth with the class.

Reflection Questions

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

B. **<u>It's Your Turn:</u>** 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?

A STRANGE SLED RACE
Hawaii

The goddess of snow, Poliahu, lives high on the slops of Mauna Kea* on the northern side of Hawaii. That side is free of lava flows because of the goddess's skill at sled-racing . . . .

Poiliahu and her snow maidens one day covered their dazzling snow mantles with mantles of golden sunshine. They took their long, slender sleds to the race course below the snowfields. There a narrow grassy track had been laid, dropping swiftly toward the sea.

High, tinkling laughter filled the air as the maidens urged the goddess to race. Poliahu was very willing. She made a running start, threw herself upon her sled, and plunged down. Far below she came to a stop, marked the spot, and lifted her sled aside.

One after another the snow maidens followed, but none reached the goddess's mark. As they gathered below they discovered a stranger in their midst, a handsome woman dressed in a black mantle and robe.

Fixing gleaming black eyes upon the goddess of snow, she spoke. "I should like to race with you, but I have no sled."

"You may use one of ours," Snow Goddess said, and a maiden quickly offered hers.

The stranger took it without a word of thanks.   Then she and Poliahu climbed up the mountain slope.   The maidens watched from below. The stranger swooped down the slope and flashed past them. There was no doubt she was skillful. Poliahu followed and passed the other's stopping place.

**Mauna Kea is a volcano on the island of Hawaii.*

A Strange Sled Race– Hawaii

“That sled did not fit me!” said the dark-eyed stranger.

A taller maiden offered her a sled. Again the long, slow climb. Again the short, swift descent. Both sleds went farther than before, but Poliahu’s still led.

“An inferior sled!” the woman said with scorn.

“We have no inferior sleds,” Snow Goddess replied coldly. “Let us race again, and you shall take mine.”

“I have always raced on a longer course,” said the woman. “Let us go higher up the mountain. You shall race first this time.”

They exchanged sleds and climbed to the new snow line. The stranger waited until Poliahu had started down, then she stamped her foot. The earth trembled. A jagged crack split open across the lower part of the racing course.

The snow maidens, watching below, lost sight of their goddess as steam rose from the crack and formed a curtain. They ran up the slope.

For a moment, the steam cleared. They caught a glimpse of Poliahu racing toward the widening crack. The woman in black was close behind her, standing upright on her speeding sled. In horror they saw her black robe turn red and her eyes glow like burning coals. They knew now! She was Pele – Volcano Goddess!

She stamped again. They felt the molten lava come rumbling through underground passages in answer to her signal. It spurted out along the crack.

Swiftly the snow maidens raised their arms toward the snowy peaks and began to chant. The air grew chill as gray Cloud Goddesses gathered to aid Poliahu. They sent snow swirling down from the top of the mountain hissing as it struck the heated earth. The spurting lava died.

Pele, in a fury, gave a crackling shout. The lava leaped up again, forming a row of fiery fountains directly ahead of Poliahu.

The snow maidens watched fearfully. There was no way that Poliahu could slow her sled nor turn it aside. She plunged through the wall of fire.

Her golden mantle burst into flame. Throwing it off and leaping from her sled, Snow Goddess stood robed in dazzling white. A red-gold river raced toward her from the fire fountains. On its crest rode Pele. Poliahu waited, unmoved.

Volcano Goddess burst through the flames without harm. She sprang from her sled to face the young woman who dared to defy her.

Snow Goddess swung her mantle in a wide arc. A blast of icy wind swept down the mountain. Her silvery hair and dazzling garments streamed out behind her.

Volcano Goddess shivered. The leaping fountains dwindled. The racing river slowed.

She screamed at the lava, “Swallow her up!”

But the lava fountains died. The lava river grew sluggish. Still deadly, it flowed to the very feet of Snow Goddess. She flung her arms wide. The river split in two, leaving her unharmed in the center. It made its way beyond her, moving slowly down to the sea. There it formed a long, flat point of land, known to this day as Leaf-of-Smooth-Lava.

Volcano Goddess stared, unable to believe what she saw. Her red mantle turned black again. Her glowing eyes dulled. Shivering with cold, she disappeared as mysteriously as she had come.

High, tinkling laughter filled the air once more as the snow goddess and her maidens picked up their sleds and returned to their snowy home.

Pele never again crossed over Mauna Kea to Poliahu's side of the island, although she still sent lava pouring down the southern side.

* Thompson, V. "The Strange Sled Race." *Hawaiian Myths of Earth, Sea, and Sky*. Honolulu: University of Hawaii Press, 1966. 28-32.

A BATTLE NOBODY WON

Hawaii

Dead craters stand black and cold on the islands of Kauai, Oahu, and Maui. Only on the island of Hawaii do living volcanoes smoke and seethe. There in the crater of Great Kilauea the volcano goddess Pele makes her home . . . .

On Floating Island lived a large family of brothers and sisters who were gods. Each one had a special power but none was as powerful as the four great gods of creation.

This family was ruled by the eldest brother Ka Moho, the god of steam. His brothers were gods of thunder, earth-shaking, and fire-keeping. His sisters were goddesses of sea, volcano, lightning and clouds.

Pele, a handsome young woman with a back straight as a cliff, was Volcano Goddess. Steam God ordered Fire-keeper God to teach Pele all his secrets of fire-making. When she had learned them, he gave her a magic spade and fire sticks and she dug her first fire pit.

Red-gold lava bubbled up, overflowed the pit and ran down to the sea. Pele watched, fascinated, but Namaka, Sea Goddess, was furious. The lava had killed hundreds of fish. She went to Ka Moho, the god of steam, and demanded that Pele be punished.

Steam God called a family council. He looked at the angry faces of the two sisters and knew there could never be peace between them. Then he spoke.

"Pele, it is best that you go forth and find a home of your own. Brothers, get her a fine strong canoe. You, Namaka, lend her your two servants, Tide and Current to be her canoe helpers."

The brothers agreed willingly, and the sister sullenly.

Pele said to Namaka, "Soon, dear sister, you shall see my fiery cloud rising from an island where I am the ruler -- I, alone!

Namaka, about to make an angry reply, was interrupted by the youngest sister Hiiaka the goddess of lightning. “Let me go with you, Pele!” she cried.

Ka Moho shook his head. "When Pele has found a home, she may send for you."

So it was decided and so it was done. Pele, carrying her fire sticks and magic spade, bid her family farewell, and stepped into the canoe. Tide and Current pushed the current out to sea.

Day followed day, and night followed night. The canoe came to a chain of islands. At Kauai, Pele ordered her helpers to land. There, with her magic spade, Volcano Goddess dug a pit and kindled a blaze. A cloud of smoke arose, making a dark smudge in the sky.

From Floating Island, Namaka saw the smoke and remembered Pele's words. Spitefully, Sea Goddess sent waves rolling across the water and drowned the fire.

Pele ordered Tide and Current to take her to the larger island of Oahu. There in several places she dug pits and started fires, sending clouds of sulphur smoke billowing upward.

When Namaka saw these, she churned up a great storm and lashed the island of Oahu with sheets of rain until the last spark of Pele’s fire sputtered and died.

Pele ordered Tide and Current on, to the island of Maui. There she climbed a high mountain and dug deep. Soon fiery fountains leaped high, spreading a red glare across the sky.

This time Namaka decided to go herself and destroy Pele. She rode her sea monster and skimmed across the waters to the Maui shore. Climbing the mountain, she saw Pele on the western slope.

There the two goddesses, Sea and Volcano, met and fought. Each goddess used every trick she knew with water or with fire. For days, on and on, the battle raged. Finally, Sea drowned the last of Volcano's fires and returned home.

But Namaka had not drowned Pele.

Pele soon found her fire sticks and magic spade and returned to her canoe. She looked across the water and saw, hanging above the island of Hawaii, a mantle of smoke. It was not of her making. Curious, she ordered Tide and Current to take her there.

When Pele landed at the Place-of-Quiet-Burning, she saw that the smoke came from the crater called Great Kilauea. This was the home of a fire god, Forest-Eater. His appetite was so huge nothing could satisfy it. He devoured trees, crops, houses, people.

Pele heard that no one but his small white dog dared approach him. She smiled – Pele dared approach him! If she joined Forest-eater that should put an end to Namaka's trouble-making.

Up the mountain slope, along a chain of craters, went Pele. Though she found spatter cones and steaming cracks, she caught no glimpse of Forest-Eater.

She reached Little Kilauea. Still no sign of Forest-Eater. She came at last to the Great Kilauea and there, at the edge of the huge pit, sat a small white dog, howling mournfully. Of Forest-Eater there was no trace.

Pele searched for days without success. Then she settled down in Forest-Eater's home and sent Tide and Current back for her sister Hiiaka, goddess of lightning.

Namaka, convinced at last that she could never destroy Pele, decided to ignore her.

No one ever saw Forest-eater again. Some say that he moved to an unknown island rather than share his crater home with the volcano goddess. Others say he simply ate himself to death.

In time, even his dog stopped looking for him and became Pele's follower. Sometimes this small white dog is seen running across the bleak lava fields. Sometimes people tell of meeting Pele on the lonely roads near Kilauea.

If the volcano remains quiet, people know that Volcano Goddess is pleased with those she met. But if the earth trembles, they know that someone has roused her anger, and there will soon be another eruption.

* Thompson, V. "The Battle Nobody Won." *Hawaiian Myths of Earth, Sea, and Sky*. Honolulu: University of Hawaii Press, 1966. 15-19.

WHEN GRIZZLIES WALKED UPRIGHT

North America: the Modoc

Before there were people on the earth, the Chief of the Sky Spirits grew tired of his home in the Above World, because the air was always brittle with an icy cold. So he carved a hole in the sky with a stone and pushed all the snow and ice down below until he made a great mound that reached from earth almost to the sky. Today it is known as Mount Shasta*.

Then the Sky Spirit took his walking stick, stepped from a cloud to the peak, and walked down to the mountain. When he was about halfway to the valley below, he began to put his finger to the ground here and here. Wherever his finger touched, a tree grew. The snow melted in his footsteps, and the water ran down in rivers.

The Sky Spirit broke off a small end of his giant stick and threw the pieces into the rivers. The longer pieces turned into beaver and otter; the smaller pieces became fish. When the leaves dropped from the trees, he picked them up, blew upon them, and so made the birds. Then he took the big end of his giant stick and made all the animals that walked on the earth, the biggest of which were the grizzly bears.

Now when they were first made, the bears were covered with hair and had sharp claws, just as they do today, but they walked on two feet and could talk like people. They looked so fierce that the Sky Spirit sent them away from him to live in the forest at the base of the mountain.

Pleased with what he'd done, the Chief of the Sky Spirits decided to bring his family down and live on the earth himself. The mountains of snow and ice became their lodge. He made a big fire in the center of the mountain and a hole in the top so that smoke and sparks could fly out. When he put a big log on the fire, sparks would fly up and the earth would tremble.

Late one spring while the Sky Spirit and his family were sitting round the fire, the Wind Spirit sent a great storm that shook the top of the mountain. It blew and blew and roared and roared. Smoke blown back into the lodge hurt their eyes, and finally Sky Spirit said to his youngest daughter, "Climb up to the smoke hole and ask the Wind Spirit to blow more gently. Tell him I'm afraid he will blow the mountain over."

As his daughter started up, her father said, "But be careful not to stick your head out at the top. If you do, the wind may catch you by the hair and blow you away."

The girl hurried to the top of the mountain and stayed well inside the smoke hole as she spoke to the Wind Spirit. As she was about to climb back down, she remembered that her father had once said you could see the ocean from the top of their lodge. His daughter wondered what the ocean looked like, and her curiosity got the better of her. She poked her head out of the hole and turned toward west but before she could see anything, the Wind Spirit caught her long hair, pulled her out of the mountain, and blew her down over the snow and ice. She landed among the scrubby fir trees at the edge of the timber and snow line, her long red hair trailing over the snow.

There a grizzly bear found the little girl when he was out hunting for food for his family. He carried her home with him and his wife brought her up with their family of cubs. The little red-haired girl and the cubs ate together, played together, and grew up together.

When she became a young woman, she and the eldest son of the grizzly bears were married. In the years that followed they had many children, who were not as hairy as the grizzlies yet did not look exactly like their spirit mother, either.

All the grizzly bears throughout the forests were so proud of these new creatures that they made a lodge for the red-haired mother and her children. They placed the lodge near Mount Shasta -- it is called Little Mount Shasta today.

After many years had passed, the mother grizzly bear knew that she would soon die. Fearing that she should ask the Chief of the Sky Spirits to forgive her for keeping his daughter, she gathered all the grizzlies at the lodge they had built. Then she sent her oldest grandson in a cloud to the top of Mount Shasta, to tell the Spirit Chief where he could find his long-lost daughter.

When Grizzlies Walked Upright – Modoc

When the father got this news he was so glad that he came down the mountainside in giant strides, melting the snow and tearing up the land under feet. Even today his tracks can be seen in the rocky path on the south side of Mount Shasta.

As he neared the lodge, he called out, “Is this where my little daughter lives?”

He expected his child to look exactly as she had when he saw her last. When he found a grown woman instead, and learned that the strange creatures she was taking care of were his grandchildren, he became very angry. A new race had been created that was not of his making! He frowned on the old grandmother so sternly that she promptly fell dead. Then he cursed all the grizzlies:

“Get down on your hands and knees. You have wronged me, and from this moment all of you will walk on four feet and never talk again.”

He drove his grandchildren out of the lodge, put his daughter over his shoulder, and climbed back up the mountain. Never again did he come to the forest. Some say that he put out the fire in the center of his lodge and took his daughter back up to the sky to live.

Those strange creatures, his grandchildren, scattered and wandered over the earth. They were the first Indians, the ancestors of all the Indian tribes.

That’s why the Indians living around Mount Shasta would never kill a grizzly bear. Whenever a grizzly killed an Indian, his body was burned on the spot. And for many years all who passed that way cast a stone there until a great pile of stones marked the place of his death.

* Erodes, R. and Ortiz, A. “When Grizzlies Walked Upright.” American Indian Myths and Legends. New York: Pantheon Books, 1984. 85-87.

HOW THUNDER AND EARTHQUAKE MADE OCEAN

North America: the Yurok

Thunder lived at Sumig. One day he said, “How shall the people live if there is just prairie there? Let us place the ocean there.” He said to Earthquake, “I want to have water there, there so that people may live. Otherwise they will have nothing to live on. What do you think?”

Earthquake thought. “That is true,” he said. “There should be water there. Far off I see it. I see the water. It is at Opis. There are salmon there and water.”

“Go,” said Thunder. “Go with Kingfisher, the one who sits there by the water. Go and get water at Opis. Get the water that is to come here.”

Then the two of them went. Kingfisher and Earthquake went to see the water. They went to get the water at Opis. They had two abalone shells that Thunder had given to them “Take these shells,” Thunder had said. “Collect the water in them.”

First Earthquake and Kingfisher went to the north end of the world. There Earthquake looked around. “This will be easy,” he said. “It will be easy for me to sink this land.” Then

Earthquake ran around. He ran around and the ground sank. It sank there at the north end of the world.

Then Kingfisher and Earthquake started for Opis. They went to the place at the end of the water. They made the ground sink behind them as they went. At Opis they saw all kinds of seals and salmon. They saw all the kinds of animals and fish that could be eaten there in the water at Opis. Finally, they took water in the abalone shells.

"Now we will go to the south end of the world," said Earthquake. "We will go there and look at the water. Thunder, who is at Sumig, will help us by breaking down the trees. The water will extend all the way to the south end of the world. There will be salmon and fish of all kinds and seals in the water."

Now Kingfisher and Earthquake came back to Sumig. They saw that Thunder had broken down the trees. Together the three of them went north. As they went together they kept sinking the ground. The earth quaked and quaked and water flowed over it as Kingfisher and Earthquake poured it from their abalone shells. Kingfisher emptied his shell and it filled the ocean halfway to the north end of the world. Earthquake emptied his shell and it filled the ocean the rest of the way.

As they filled the ocean, the creatures which would be food swarmed into the water. The seals came as if they were thrown in handfuls. Into the water they came, swimming toward shore. Earthquake sank the land deeper to make gullies and the whales came swimming through the gullies where the water was deep enough for them to travel. The salmon came running through the water.

Now all the land animals, the deer and elk, the foxes and mink, the bear and others had gone inland. Now the water creatures were there. Now Thunder and Kingfisher and Earthquake looked at the ocean. "This is enough," they said. "Now the people will have enough to live on. Everything that is needed is in the water."

So it is that the prairie became ocean. It is so because Thunder wished it so. It is so because Earthquake wished it so. All kinds of creatures are in the ocean before us because Thunder and Earthquake wished the people to live.

* Caduto, M. and Bruchac, J. "How Thunder and Earthquake Made Ocean." Keepers of the Earth. Colorado, USA: Fulcrum, Inc., 1989. 92-95.

How Thunder and Earthquake Made Ocean – Yurok

T H E   C R E A T I O N
North America: the Mohawk

Many Winters in the past the Earth was entirely covered by a great blanket of water. There was no sun, moon, or stars and so there was no light. All was darkness.

At that time, the only living creatures of the world were water animals such as the beaver, muskrat, duck and loon. Far above the earth was the Land of Happy Spirits where lived Rawennio, the Great Ruler. In the center of this upper world was a giant tree. This great tree was an apple tree whose roots sank deep into the ground.

One day, Rawennio pulled this giant tree up by its roots. The Great Spirit called his daughter who lived in the Upper World and commanded her to look into the pit caused by the uprooted tree. This woman, who was to be the mother of the Good and Evil Spirits, came and looked into the hole by the uprooted tree. She saw far below her the Lower World, covered with water and surrounded by heavy clouds.

"You are to go to this world of darkness," said the Great Spirit. Gently lifting her, he dropped her into the hole. She floated downward.

Far below on the dark water floated the water animals. Looking upward, they saw a great light, which was the Sky Woman, slowly falling toward them. Because her body shone as a great light they were at first frightened. Fear filled their hearts and they dove beneath the deep waters. But upon coming to the surface again, they lost their fear. They began to plan what they would do for the woman when she reached the water.

"We must find a dry place for her to rest on," said the beaver, and he plunged beneath the water in search of some earth. After a long time, the beaver's dead body floated to the top of the water. The loon tried next, but his body never came to the surface of the water. Many of the other water creatures dived, but all failed to secure any earth. Finally, the muskrat went below and after a long time, his dead body floated to the surface of the water. His little claws were closed tight. Upon opening them, a little earth was found.

The water creatures took this earth, and calling a great turtle, they patted the earth firmly on her broad back. Immediately, the turtle started to grow larger. The earth also increased.

This earth became North America, a great island. Sometimes the earth cracks and shakes, and waves beat hard against the seashore. White people say, "Earthquake." The Mohawk say, "Turtle is stretching."

The Sky Woman had now almost reached the earth. "We must fly up and let her rest upon our backs so as to make her landing easy," said the chief of the white swans. Flying upward, a great flock of white swans allowed the Sky Woman to rest upon their backs. Gently, they bore her to earth.

After a time, the Sky Woman gave birth to twins. One who became the Good Spirit was born first. The other, the Evil Spirit, while being born, caused his mother so much pain that she died during his birth.

The Good Spirit immediately took his mother's head and hung it in the sky. It became the sun. The Good Spirit, from his mother's body, fashioned the moon and stars and placed them in the sky. The rest of his mother's body he buried under the earth. That is why living things find nourishment from the soil. They spring from Mother Earth. The Evil Spirit put darkness in the west sky to drive the sun before it.

The Good Spirit created many things which he placed upon the earth. The Evil Spirit tried to undo the work of his brother by creating evil. The Good Spirit made tall and beautiful trees such as the pine and hemlock. The Evil Spirit stunted some trees. In others, he put knots and gnarls. He covered some with thorns, and placed poison fruit on them.

The Good Spirit made animals such as the deer and the bear. The Evil Spirit made poisonous animals, lizards, and serpents to destroy the animals of the Good Spirit's creation.

The Good Spirit made springs and streams of good, pure water. The Evil Spirit breathed poison into many of the springs. He put snakes into others.

The Good Spirit made beautiful rivers protected by high hills. The Evil Spirit placed rocks and dirt into the rivers causing the current to become swift and dangerous.

Everything that the Good Spirit made, his wicked brother tried to destroy. Finally, when the earth was completed, the Good Spirit fashioned man out of some red clay. He place man upon the earth, and told him how he should live. The Evil Spirit, not to be outdone, fashioned a creature out of the white foam of the sea. What he made was the monkey.

After mankind and the other creatures of the world were created, the Good Spirit bestowed a protecting spirit upon each of his creations. He then called the Evil Spirit, and told him that he must cease making trouble upon the earth. The Evil Spirit refused to do. The Good Spirit became very angry with his wicked brother. He challenged his brother to combat, the victor to become ruler of the earth. They used the thorns of a giant apple tree as weapons.

They fought for many suns (days). Finally, the Evil Spirit was overcome. The Good Spirit now became ruler over the earth. He banished his wicked brother to a dark cave under the earth. There he must always remain.

But the Evil Spirit has wicked servants who roam the earth. These wicked spirits can take the shape of any creature that the Evil Spirit desires them to take. They are constantly influencing the minds of men, thus causing men to do evil things.

That is why every person has both a bad heart and a good heart. No matter how good a man seems, he has some evil. No matter how bad a man seems, there is some good about him. No man is perfect.

The Good Spirit continues to create and protect mankind. He controls the spirits of good men after death. The Evil Spirit takes charge of the souls of wicked men after death.

* Elder, J. and Wong, H. "The Creation." Family of Earth & Sky. Boston: Beacon Press, 1994. 32-39.

THE WOMAN WHO FELL FROM THE SKY

North America: the Huron

The Creation – Mohawk

In the beginning, there was only water and the water animals that lived in it.

Then a woman fell from a torn place in the sky. She was a divine woman, full of power. Two loons flying over the water saw her falling. They flew under her, close together, making a pillow for her to sit on.

The loons held her up and cried for help. They could be heard for a long way as they called for other animals to come.

The snapping turtle came to help. The loons put the woman on the turtle's back. Then the turtle called all the other animals to aid in saving the divine woman's life.

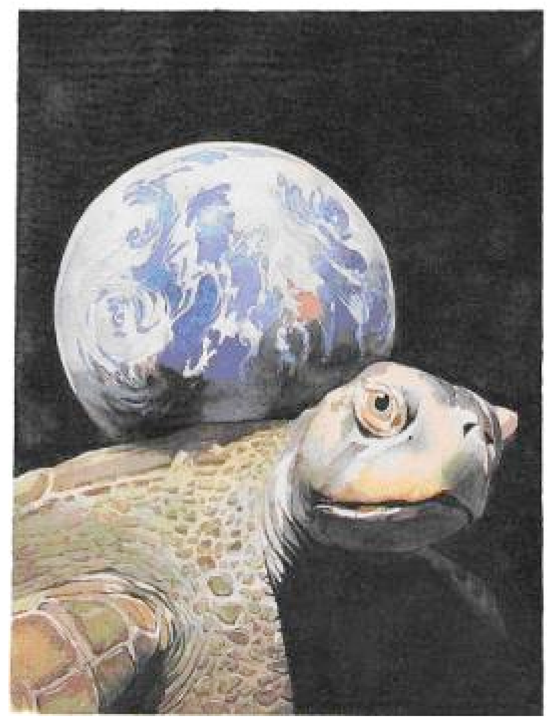
The animals decided the woman needed earth to live on.

Turtle said, "Dive down in the water and bring up some earth."

So they did that, those animals. A beaver went down. A muskrat went down. Others stayed down too long, and they died.

Each time, Turtle looked inside their mouths when they came up, but there was no earth to be found.

Toad went under the water. He stayed too long, and he nearly died. But when Turtle looked inside Toad's mouth, he found a little earth. The woman took it and put it all around Turtle's shell. That was the start of the earth.



Dry land grew until it formed a country, then another country, and all the earth. To this day, Turtle holds up the earth.

Time passed, and the divine woman had twin boys. They were opposites, her sons. One was good, and one was bad. One was born as children are usually born, in a normal way. But the other broke out of his mother's side, and she died.

When the divine woman was buried, all of the plants needed for life on earth sprang from the ground above her. From her head came the pumpkin vine. Maize came from her chest. Pole beans grew from her legs.

The divine woman's sons grew up. The evil one was Tawis-karong. The good one was Tijus-keha. They were to prepare the earth so that humans could live on it. But they found they could not live together. And so they separated, with each one taking his own portion of the earth to prepare.

The bad brother, Tawis-karong, made monstrous animals, fierce and terrifying. He made wolves, bears, snakes, and panthers of giant size. He made huge mosquitoes the size of wild turkeys. And he made an enormous toad. It drank up the fresh water that was on the earth. All of it.

The good brother, Tijus-keha, made proper animals that were of use to human beings. He made the dove, the mockingbird, and the partridge. One day, the partridge flew toward the land of Tawis-karong.

"Why do you go there?" Tijus-keha asked the partridge.

"I go because there is no water. And I hear there is some in your brother's land," said the partridge.

Tijus-keha didn't believe the bird. So he followed, and finally he came to his evil brother's land. He saw all of the outlandish, giant animals his brother had made. Tijus-keha beat them down.

And then he saw the giant toad, cutting it open. Out came the earth's fresh water. Tijus-keha didn't kill any of his brother's creations. But he made them smaller, of normal size so that human beings could be leaders over them.

His mother's spirit came to Tijus-keha in a dream, warning him about his evil brother. And sure enough, one day, the two brothers had to come face to face. They decided they could not share the earth. They would have a duel to see who would be master of the world.

Each had to overcome the other with a single weapon. Tijus-keha, the good, could only be killed if beaten to death with a bag full of corn or beans. The evil brother could be killed only by using the horn of a deer or other wild animal. Then the brothers fixed the fighting ground where the battle would begin.

The first turn went to the evil brother, Tawis-karong. He pounded his brother with a bag of beans. He beat him until Tijus-keha was nearly dead. But not quite. He got his strength back, and he chased Tawis-karong. Now it was his turn.

He beat his evil brother with a deer horn. Finally, Tijus-keha took his brother's life away. But still the evil brother wasn't completely destroyed.

After he died, Tawis-karong came to Tijus-keha, appearing before him.

"I have gone to the far west," he said. "All the races of men will follow me to the west when they die."

It is the belief of the Hurons this day. When they die, their spirits go to the far west, where they will dwell forever.

* Hamilton, V. "The Woman Who Fell From the Sky." In the Beginning: Creation Stories from Around the World. San Diego: Harcourt Brace Jovanovich, 1988. 59-63.

TRAVELING TO FORM THE WORLD

North America: the Blackfoot

He was out there, traveling all over and making things. Old Man. He had been south and was on his way north. He created the birds and animals as he went. He made prairies, always traveling north, and mountains.

They say that first he made timber and brush lands. He put red paint in the soil, and formed rivers and waterfalls. He was making the world that stands here today. He formed the river called Milk, the Teton. Then he went across it.

He was getting tired, so he climbed a hill and lay down to take a rest.

Old Man stretched out on his back on the hill. He laid his arms straight out from his shoulders. He had stones to outline himself. Those stones are right where they marked him, even today.

After a good rest, Old Man again headed on to the north. He stumbled once and fell. There was a knoll there; it brought him to his knees when he tripped.

"You are something bad to be stumbling on," said Old Man.

He raised two buttes there, large ones. And he named them Knees, which they are still called today.

He went on. And he carried more rocks. These he used to make the Sweet Grass Hills of Montana.

Old Man decided one day that he would make a mother and her child. He formed them out of clay, molding it in the shape of humans. And he spoke to them.

"You will be people," he said. He covered up the clay shapes and went away.

Next morning, Old Man went to the place, taking the covering off the shapes. They seemed to have changed just a little. The morning after that, the shapes had changed some more. And the next day, they were different still.

On the fourth morning, Old Man went over and looked at the shapes that were images of people now.

"Rise up. Walk," Old Man told them. And they rose up and started walking. They, the woman and child and their maker, walked to the river.

"My name is Na'pi," he told them, which means Old Man.

The woman looked at the water and said to Old Man, "Tell me, how will it be? Will we live always? Will there be no end to our living?"

"Well, I haven't ever thought about it," Old Man said. "We'll have to decide. Let me take this buffalo chip and throw it in the river. If it floats, then people will die. But they will die for only four days. Four day after they die, they will live once again."

Then, Old Man said this: "If the buffalo chip sinks, then there will be an end to people's lives."

He threw the chip in the water. It floated.

The woman bent down and picked up a stone.

"No," she said. "Let me throw this stone in the river. If it floats, we will live forever. But if it sinks, we will feel sorry for one another, that we must all die."

The woman threw the stone in the water. It sank.

"So, you have chosen," said Old Man. "There will be an end to people."

*Hamilton, V. "Traveling to Form the World." In the Beginning: Creation Stories from Around the World. San Diego: Harcourt Brace Jovanovich, 1988. 25-27.

T H E F R O S T G I A N T
Iceland

In the beginning, there were two realms. Muspell was in the south, and it was full of fire and blinding light. Niflheim, the home of fog, ice, and snow, lay in the north.

Between the two realms was a vast stretch of empty space called Gin-nun-ga-gap, or Yawning Gap. Warm air drifted from Muspell and mixed with the cold from Niflheim. This breath of summer and winter met in a thaw above the middle realm of Yawning Gap. The drips and drops started life growing. And life took the form of a great giant, named Imir. From the beginning he was evil.

Imir was a frost giant. He lay down to sleep in Yawning Gap and sweated through the night. A woman and a man grew from his armpit. A son came forth from his leg. From Imir came the first family of ice-crusted frost giants.

Melting ice from the middle realm of Yawning Gap formed into a giant cow. Imir drank the rivers of milk from the cow. The cow lived off the ice itself. She licked blocks of it.

A man's head appeared from one block. For three days and nights the cow fed on the ice block. And finally a whole man was born from it. He was called Buri, so tall and strong.

Soon Buri had a son he called Bor. Bor married a daughter of a frost giant, and they had three sons. These were the gods Odin, Vili, and Ve.

The god brothers hated the evil Imir and the ever-growing number of brutal frost giants. They attacked Imir and killed him. Imir bled, drowning all of the frost giants except two. The two got in a hollow tree trunk and rode away on a blood tide.

Odin, Vili, and Ve carried the dead Imir to the middle of Yawning Gap. They made the world from his body. The earth was shaped like his flesh. Mountains were formed from his bones. Rocks, stones, and boulders came from his teeth and jaws.

After they had formed the earth, Odin, Vili, and Ve took the blood that was left from Imir and made the ocean in a ring.

The three brothers lifted the skull of Imir and made the dome of the sky. They placed a dwarf at each of the four corners to support the sky high above the earth.

Then the gods went to the southern realm of Muspell and took sparks and embers. From these they made the sun, moon, and stars way up over Yawning Gap to light up both heaven and earth.

Odin and Vili and Ve were walking one time at land's edge where it met the sea. They saw an ash tree and an elm tree, both fallen down. The three brothers lifted them and created from them a new man and woman. Odin breathed life into the man and woman. Vili gave them wit and feelings. Ve brought them hearing and sight.

The man's name was Ask, and the woman was Embla. The brothers gave them the land of Midgard as their home. Midgard was protected from the giants' world by a wall made from the eyebrows of Imir.

So it is that all nations and all families and every race of human beings came from Ask and Embla. They were the first of their kind in the new world created by Odin, Vili, and Ve, the sons of Bor.

The Frost Giant – Iceland

* Hamilton, V. "The Frost Giant." In the Beginning: Creation Stories from Around the World. San Diego: Harcourt Brace Jovanovich, 1988. 69-71.

T H E   E A R T H   D R A G O N

North America: Unknown

Before this world was formed, there was another world with a sky made of sandstone rock. Two gods, Thunder and Nagaicho, saw that old sky being shaken by thunder.

"The rock is old," they said. "We'll fix it by stretching it above, far to the east."

They stretched the sandstone, walking on the sky to do it, and under each of the sky's four corners they set a great rock to hold it up. Then they added the different things that would make the world pleasant for people to live in. In the south they created flowers. In the east they put clouds so that people wouldn't get headaches from the sun's glare. To form the clouds they built a fire, then opened a large hole in the sky so that the clouds could come through. In the west they made another opening for the fog to drift in from the ocean.

Now the two gods were ready to create people. They made a man out of earth and put grass inside him to form his stomach. They used another bundle of grass for his heart, round pieces of clay for the liver and kidneys, and a reed for the windpipe. They pulverized red stone and mixed it with water to form his blood. After putting together man's parts, they took one of his legs, split it, and turned it into a woman. Then they made a sun to travel by day and a moon to travel by night.

But the creation of the gods did not endure, for every day and every night it rained. All the people slept. Floodwaters came, and great stretches of land disappeared. The waters of the oceans flowed together; animals of all kinds drowned. Then the waters completely joined, and there were no more fields or mountains or rocks, only water. There were no trees or grass, no fish or land animals or birds. Human beings and animals all had been washed away.

The wind no longer blew through the portals of the world, nor was there snow, or frost, or rain. It did not thunder or lightning, since there were no trees to be struck. There were neither clouds nor fog, nor did the sun shine. It was very dark.

Then the earth dragon, with its great, long horns, got up and walked down from the north. It traveled underground, and the god Nagaicho rode on its head. As it walked along through the ocean depths, the water outside rose to the level of its shoulders. When it came to shallower places it turned its head upward, and because of this there is a ridge near the coast in the north upon which the waves break. When it came to the middle of the world, in the east under the rising sun, it looked up again, which created a large island near the coast. Far away to the south it continued looking up and made a great mountain range.

In the south the dragon lay down, and Nagaicho placed its head as it should be and spread gray-colored clay between its eyes and on each horn. He covered the clay with a layer of reeds, then spread another layer of clay. On it he put some small stones, and then set blue grass, brush, and trees in the clay.

"I have finished," he said. "Let there be mountain peaks on the earth's head. Let the waves of the sea break against them."

The mountains appeared, and brush sprang up on them. The small stones he had placed on earth's head became large, and the head itself was buried from sight.

Now people appeared, people who had animal names. (Later when Indians came to live on the earth, these "first people" were changed into their animal namesakes.) Seal, Sea Lion, and Grizzly Bear built a dance house. One woman by the name of Whale was fat, and that is why there are so many stout Indian women today.

The god Nagaicho caused different sea foods to grow in the water so that the people would have things to eat. He created seaweed, abalones, mussels, and many other things. Then he made salt from ocean foam. He caused the water of the ocean to rise up in waves and said that the ocean would always behave that way. He arranged for old whales to float ashore so that people would have them to eat.

He made redwoods and other trees grow on the tail of the great dragon, which lay to the north. He carved out creeks by dragging his foot through the earth so that people would have good fresh water to drink. He created many oak trees to provide acorns to eat. He traveled all over the earth making it a comfortable place for men.

After he had finished, he and his dog went walking to see how the new things looked. When they arrived back at their starting point in the north, he said to his dog: "We're close to home. Now we'll stay here." So he left this world where people live, and now he inhabits the north.

*Erodes, R. and Ortiz, A. "The Earth Dragon." American Indian Myths and Legends. New York: Pantheon Books, 1984. 107-109.

The Earth Dragon – unknown California tribe

Activity 1.2: Breaking News

Overview:

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 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.

Procedure:

1. **Introduction to the articles:** each person in your Home Group will be assigned a different article about an earthquake or a volcanic event. Read the headlines to the four articles.
    - 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?
    - Have you ever experienced any other natural event like a tornado, hurricane, or monsoon? What was that experience like?

2. **Read the article you have been assigned with your Article Expert Group.** In your group, ***describe the event*** and try to ***explain*** what you think is happening. List any questions that come up in your group discussion. When you return to your Home Group, you will need to describe the event, explain it, and share the questions that your group had, so make sure you take notes that will help you do that. Use the student handout *Breaking News! Expert Group* to help take notes and guide your discussion.

3. **Return to Home Group and share**. Now that you are an expert on one of the articles, return to your Home Group and share your observations, explanations, and questions. The student handout *Breaking News! Home Group* will help guide your group discussion. Your Home Group should come up with a short list of observations, explanations, and questions to share with the class.

4. **Home groups share with the class**. Each Home Group will be asked to share the group's short list of observations, explanations, and questions with the whole class. You also need to post and save these for later review. Later, the class will explore the different explanations and choose those they think can be supported by the observations and data.

5. **In the closing discussion,** you'll discuss these questions.
    - o 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?
    - o 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?

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. St. Helens erupted?

A "fat" question is one that encourages you to measure, observe, or compare something.

For example: I wonder if there are more small earthquakes or more large earthquakes around the Java Trench?

The class will use fat questions to figure out what to observe in order to explain what is happening during these seismic events.

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 idea.

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.

KILLER QUAKE HITS MEXICO
Capital in chaos; death reports rise

From the Chicago Sun - Times on September 19, 1985.□

A major earthquake today caused severe damage in three Mexican states, collapsed buildings in Mexico City and sent the city into chaos. Death reports ranged from the dozens to the thousands.

Television scenes from Mexico City showed buildings in rubble and streets ablaze from natural gas from broken pipelines. One report said 35 percent of the city's buildings were damaged.

Howard L. Lester, an amateur radio operator in Schenectady, N.Y. said he monitored a transmission between a Mexico City operator and another in Tucson, Ariz.

Speaking in English, the Mexico City operator said:

"This is no joke. . . . We have only one radio channel left. It's a government channel. We're trying to get it working so we can tell the world what is happening."

The government was asking for donations of blood and gasoline for emergency vehicles.

The Mexican Embassy in Washington said cathedrals had collapsed in Jalisco, Guerrero and Michoacan states, all on the country's west coast, and that several buildings collapsed in the capital. Telephone and Telex circuits to Mexico City were out and flights from the United States were canceled, one airline official said, "because we didn't know what we would find when we got there."

The quake struck at 8:18 a.m., Chicago time, and registered 7.8 on the Richter scale, an open-ended measurement of ground motion.

The U.S. Geological Survey put the epicenter in the Pacific Ocean about 250 miles southwest of Mexico City.

In Washington, State Department spokesman Bernard Kalb said the U.S. Embassy was undam - aged and communications with the embassy had been established.

Kalb said there was significant damage in the old section of the city, including the popular tourist area of Zona Rosa, a fashionable and hotel district in the center of the city.

A Laredo, Texas, radio station said it had a report from Mexico City station XEQ that it had confirmed at least 20 deaths.

XEQ said 200 injuries had been reported, that one-third of the city was without electricity and that several gas leaks had been reported.

A reporter for the station said one hospital was full and had asked that the injured be taken elsewhere. Residents of the city were told to stay in their homes, XEQ said.

The Mexican reporter told Laredo station KVOZ that much of the destruction was felt in the business district of Mexico City.

Amateur radio operator Glenn Baxter of Belgrade Lakes, Maine, said he had been in radio contact with Carlos Sartorius of Mexico City.

Baxter said Sartorius, a Motorola engineer, had found highways blocked by "pieces of buildings," had passed many dead people in the streets and had seen doctors and nurses from one hospital "taking all the people out to the street because they thought it was safer."

A spokeswoman for the Mexican Embassy in Washington, Pilar Franzoni, said two areas to the north of downtown Mexico City - Colonia Roma and Colonia Doctores - sustained heavy damage.

"In Mexico City several buildings have fallen," she said. "Part of an office of the Ministry of the Navy in Mexico City's downtown area fell down. There was fire in the communications tower in Mexico City and also part of a building of the Ministry of Labor."

Sartorius said he had seen little damage in the southern sections of the capital.

In Tijuana, a local cable TV channel showed pictures from Mexico City and an announcer said deaths were considered to be in the thousands. Ambulances and rescue crews were being hampered by a lack of gasoline. Hotels and other buildings on the Paseo Dela Reforma, and Insurgentes Avenue, the city's major thoroughfares, were heavily damaged.

The University of Mexico was shown to have been damaged.

In Houston, several large buildings were reported to have swayed, with window shades banging against the windows. Water was reported sloshing out of swimming pools in Texas and New Mexico.

Doug Whitehead, assistant property manager at the Transco Tower, a 64-story, glistening skyscraper in southwest Houston, said tenants reported hearing a creaking noise and saw the blinds swaying.

No damage was reported in South Texas, although many people reported they felt the quake.

The earthquake was the strongest in the world since another 7.8-magnitude earthquake near the coast of central Chile on March 3, 1985, that killed at least 177 people, injured more than 2,500 others, and caused extensive damage, the survey said.

More than 700 people were killed and more than 300 miles of southeastern Mexico were left a shambles by a quake measured at 6.5 on the Richter scale in September 1973, when at least 24 cities, towns and villages were damaged.

An earthquake of 3.5 on the Richter scale can cause slight damage in the local area; 4 moderate damage; 5 considerable damage, and 6 severe damage. A 7 reading is a "major" earthquake, capable of widespread heavy damage; 8 is a "great" quake, capable of tremendous damage.

The San Francisco earthquake of 1906, which occurred before the Richter scale was devised, has been estimated at 8.3 magnitude.

The Richter scale is a measure of ground motion as recorded on seismographs.

Every increase of one number means a tenfold increase in magnitude. Thus a reading of 7.5 reflects an earthquake 10 times stronger than one of 6.5.

Quake Flattens Ancient Iran City; At least 5,000 killed, mud-brick medieval fortress crumbles

From the Chicago Sun Times on December 27, 2003

KERMAN, Iran – Entire blocks of buildings lay crushed and survivors lined up blanket-wrapped bodies in the street after a devastating earthquake leveled nearly three-quarters of the Iranian city of Bam on Friday, killing at least 5,000 people and injuring 30,000 others.

The quake also destroyed much of Bam's historic landmark – a giant medieval fortress complex of towers, domes and walls, all made of mud-brick, overlooking a walled Old City, parts of which date back 2,000 years.

Television images showed the highest part of the fort – including its distinctive square tower – crumbled like a sand castle down the side of the hill, though some walls still stood.

Local officials said the death toll could reach up to 12,000, though the deputy governor of Kerman province said an accurate count was impossible with many victims still trapped under the rubble. "Rescue operations are going slowly because of darkness," deputy governor Mohammad Farshad said.

"The disaster is far too huge for us to meet all of our needs," President Mohammad Khatami said. "However, all the institutions have been mobilized."

The government asked for international assistance, particularly search and rescue teams. The United States promised to send aid, as did numerous European nations.

By nightfall Friday, little outside relief was soon in Bam, a city of 80,000 people in southeastern Iran. With temperatures dropping to 21 degrees, survivors built bonfires in the rubble-strewn streets to keep warm, many shivering in their nightclothes, the only clothes they had since the pre-dawn quake.

At Bam's only cemetery, about 1,000 people wailed and beat their chests and heads over some 500 corpses that lay on the ground as a bulldozer dug a trench for a mass grave.
"This is the Apocalypse. There is nothing but devastation and debris," Mohammed Karimi, in his 30s, said at the cemetery, where he had brought the bodies of his wife and 4-year-old daughter.

"Last night before she went to sleep she made me a drawing and kissed me four times," he said of his daughter, Nazenine, whose body he held in his arms. "When I asked, 'Why four kisses?' she said, 'Maybe I won't see you again, Papa," Karimi said.

The quake struck at 5:28 a.m. (7:58 p.m. Thursday, Chicago time) while many were asleep. The U.S. Geological Survey measured it at 6.5 magnitude. Survivors were panicked throughout the day by aftershocks, including one that registered a magnitude of 5.3, according to the geophysics institute of Tehran University.

The interior minister said 70 percent of residential Bam had been destroyed, and there were no electricity, water or telephone lines.

THEY SAID THERE WAS NO DANGER
Volcano survivors recall a night of horror, heroes and death

From the Houston Chronicle on November 20, 1985

ARMERO, Colombia - The old volcano had rumbled for months, spitting a little ash and gas now and then, but it had done no harm for a century and no one thought it would now. Its last major eruption was in 1595, while Spanish explorers watched from the distance.

Between 3 and 4 p.m. Wednesday, Nov. 13, ash began floating down on Armero, a farming town in the lush Andes valley at the base of the Nevado del Ruiz volcano.

Smoke drifted upward from the snow-capped cone three miles above Armero.

Some people were apprehensive enough to leave, but most of the 28,000 to 30,000 people in the main part of town, nestled in a bend of the Lagunilla River, did not want to abandon their homes and crops.

The radio said there was nothing to worry about; it was not the first grumble from the mountain. Many people seldom even glanced up at it any more because it had always been there, like the river or the trees.

Marco Aurelio Gonzalez kept on selling lottery tickets.

``I didn't think anything of it,'' he said later. ``It was my wife who was nervous.''

The hot ash was heavier by 5:30 p.m., and pebbles were mixed in. The ash continued to come down through the evening, heavier and lighter by turns. Rain began to fall.

Children and some adults went to bed. Gonzalez dropped off the money from his ticket sales at the lottery office and went home for dinner at 9:30. His wife listened to the radio as he ate.

``They said there was no danger, no cause for alarm, even at 10 o'clock at night,'' he said.

Maria Alicia Munoz Corredor had just nursed her 18-month-old daughter Yibe, but the baby was restless.

``I got into bed and held her near my body. Then there was a loud noise, but I thought something big had fallen to the floor and I hugged my little girl close to me again,'' she said.

``I remember that Yibe smiled and began to nurse, when all of a sudden I felt another great rumble and with it a voice screaming and screaming to please run into the street because something bad was happening.''

At 9:10 p.m., Mayor Ramon Antonio Rodriguez of Armero had called an amateur radio operator in a nearby town to tell him about the new rain of ash from Nevado del Ruiz.

Suddenly, Rodriguez said: ``Wait a minute. The water's come into town.''

That remark to radio ham Jesus Antonio Rivera was the last anyone heard from the mayor of this town in western Colombia, 105 miles northwest of Bogota, the capital.

Several survivors said the mud swept into Armero at about 10 p.m., but they dwelt more on the sound of the 150-foot-high wall of mud that thundered down the river canyon.

``One of the younger children who still lived with us woke us up at 11 screaming that it was raining burning sand on the roof,'' Gilberto Villegas said.

``We left with what we had on and ran to the closest hill. From there we saw people screaming until they were swallowing mud. With other neighbors we managed to save four, but many others disappeared in seconds.''

His six grown sons, who lived in other houses with their own families, are missing.

Black sand and water rushed down the street in front of Munoz's house. A hard rain was falling.

She grabbed Yibe in one arm and her son Carlos in the other. Then, suddenly, she was floating in mud, clutching her daughter in her arms, her son in sight a few feet away.

A wave of mud and rock tore Yibe away. She could see the baby for several minutes, ``floating like a piece of paper on the water and crying.'' Munoz reached Yibe twice, and touched her hands several times, but each time the slippery mud stole the child again.

Munoz remembered that she had not seen Carlos again. ``Wanting to die with my children, I threw myself into the mud, but unfortunately the current carried me to a truck where three badly injured men took me by the hand and saved me.'' she said.

``Finally she was devoured by a wave of gravel.''

Gonzalez the ticket seller, his wife, three children and a cousin ran for a hill two blocks away, saw the mud and turned back. They were swept away.

He was pulled under by the current but was thrust back to the surface on a second wave of mud. He caught a piece of zinc roofing and floated on it until he was thrown onto the top of a pickup truck.

Rescuers reported finding 13 more survivors Tuesday. The RCN radio network said 22 people were found alive Monday, a day after the government attempted to call off rescue efforts, believing there was no hope of finding additional survivors.

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

VANCOUVER, Wash., May 18 – Mount St. Helens exploded at 8:39 A.M. today with a thud felt 100 miles away and with a drifting column of steam and pumice that turned day into night. At least eight people lost their lives fleeing flood waters, fires and mudslides that hit the Toutle River valley shortly after the volcano's eruption.

David Hubert, a spokesman for the Washington Department of Emergency Services, said that police officers working from helicopters had found some of the dead. "We have many overturned vehicles in the Toutle River valley," he said, "and our communication with the helicopters is so fragile that all I can tell you is that we have found five bodies." Two of them, found at a Weyerhaeuser Company logging camp near the mountain were flown to Kelso, Wash., by a helicopter of the Air Force reserve.

A helicopter pilot saw three persons in a pickup truck drown in the floodwaters near the town of Toutle. It was not known where officials had found the eighth body.

As hot ash flowed down the peak, mud and logs flowed down the river. "I could hear it crackling from my house," Tom Huntington said. At 9:30 A.M., he said, the river was "wall-to-wall logs."

Earlier Eruptions Dwarfed

The earlier ash and steam eruptions this year were dwarfed today, but it is not clear whether lava was being expelled. In the absence of a lava eruption, the major worries were drifting ash, which is hazardous to crops, water supplies and health; forest fires and flash floods resulting from melting glaciers.

Minutes before the top of the 9,677-foot peak explode with a shower of ash, two earthquakes registering about 5.0 on the Richter scale were recorded. Their impact was felt as far away as Port Angeles at the entrance to Puget Sound.

Within hours after the pillar of ash rose to a height measured by radar at 60,000 feet, wind had pushed it 160 miles east to Walla Walla, Wash., where automatic equipment turned on street lights as if dusk had come.

Elsewhere in Washington, the low visibility resulting from the snowstorm of gritty ash may have led to the death of a crop-dusting plane's pilot. His plane crashed into a power line near Teanaway, according to Kittitas County Sheriff Bob Barret.

The eruption came from the old summit crater and a vent on a north side of the peak. It made a roar "like a truck," according to Greg Meyer, who was fishing at Mosquito Lakes about 40 miles east of Mount St. Helens.

The black cloud, carried by the high-level winds that blow from west to east at this time of year, was carried over the lake with pumice falling from it, he said. His visibility was cut to between six and 10 feet. Mr. Meyer abandoned his fishing equipment and canoe.

Almost all residents of the sparsely settled area high on the mountain have been evacuated in recent weeks. About two thousand others from lower areas, such as the Toutle region, were leaving today.

Some other people were unaccounted for. One of these is Harry Truman, 84 years old, who has steadfastly refused to leave the collection of cabins that he rents to fishermen at Spirit Lake, Wash., in the most dangerous area.

The dense cloud of dust, ash and steam prevented any surface examination of the northeast shoulder, where a bulge has grown over the last several weeks at a rate that caused scientists to believe that a lava eruption was possible.

Scientists who have monitored steam from vents on the peak found no increase in sulfur dioxide, one measure of build-up that would lead to lava eruption. They said today that they could not confirm that any lava had appeared.

Inactive Since 1857

Mount St. Helens had been quiet from 1857 until earlier this year, when its slopes began to stake with localized earthquakes that geologists said
indicated the inactive volcano's reservoir was filling with molten material.

On March 27, with an explosion, the peak began to spew steam and ash that drifted across into eastern Washington.

Today at a briefing at volcano watch headquarters here, Sheriff Les Nelson of Cowlitz County, Wash., said that "it looked as if the whole north side of the mountain blew away."

Traffic controllers closed airspace around the peak. Observed from a commercial flight as it landed in Portland three and a half hours after the eruption began, the column was dark and forbidding. Its interior writhed sinuously with the heat and when it reached about 15,000 feet, its top was whisked away in the wind.

Dan Miller, a geologist with the United States Geological Survey, said that at 12:17 P.M. today the color of the peak's discharge changed from dark gray to light gray, a change he thought might be significant.

The area around the mountain, which is in the Pacific Northwest's fir belt, the nation's major supply of soft wood, was hit with dozens of fires burning out of control, according to Jim Unterwegner, a spokesman for the Gifford Pinchot National Forest.

The blazes were caused, he said, by hot ash from the volcano and from the spectacular lightning storm that occurred when the mass of hot material was ejected into the air.

Governor Dixy Lee Ray of Washington has ordered the National Guard to be prepared to truck in water supplies, and residents are being told to drink water only from wells, won from open reservoirs.

At Randle, Wash., 25 miles northeast of the peak, three inches of fine ash had accumulated on the ground by midday, and cars were stalling because of ash drawn into their engines, Mr. Unterwegner said.
This afternoon, the state police in Idaho reported up to half an inch of ash on the ground in the state's northern panhandle. By late evening, people as far away as Boise, in the southern part of Idaho, nearly 500 miles east of the volcano, were being warned to expect low visibility and to stay inside if they had respiratory problems.

Some roads were closed because of darkness in both states. The officials are advising people not to wash ashes off cars because it might release sulfuric acid and damage the finish.

Jack Folliott, 25 years old, said that he thought "this will be the end" when the mountain shook with the earthquake that preceded the eruption. "My whole life is tied up in those five
acres," he said of his home near the Toutle River. "I don't know what I'll have when this is over."

Activity 1.3: Mission and Team Introduction

Overview:

For this unit, the class is going to imagine that it is part of a National Earth Structure Survey (NESS) team, which is trying to figure why, where, and when earthquakes and volcanoes happen. As you have noticed, earthquakes and volcanoes often surprise people and can be devastating to communities. Wouldn't it be helpful if these events could be predicted? NESS has invited you to be part of a science team to help answer these difficult questions. In this activity, you will receive your invitation from NESS and meet your team members.

Procedure:

1. **Review and accept your mission**. Read the letter from the National Earth Structure Survey and discuss it with your class to make sure you understand what the NESS researchers would like you to do. Although you will be trying to understand the earthquake and volcano activity of a whole region, your "home base" will be just one earth structure that you are assigned.

2. **Make predictions about where earthquakes and volcanoes happen**. Your teacher will introduce you to a computer program called *MyWorld* and help you make predictions about where earthquakes and volcanoes happen. *MyWorld* is a computer program that plots real data on maps. At the start of the discussion, answer the following Stop and Think questions.

> **Stop and Think**
> Answer this question in your science journal or on your worksheet.
>
> 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?

After your class has explored some of your predictions about where earthquakes happen, do the following**:**

> **Stop and Think**
> Answer this question in your science journal or on your worksheet.
>
> Why do you think earthquakes and volcanoes happen?

3. **Read and reflect on the enclosed letters from the Junior Science Assistants**. Find and read the enclosed pen pal letter that was sent to your earth structure team. While you are reading, make a list in your science journal of any interesting facts or questions you have about your earth structure. Use the questions below or the student worksheet *Pen Pal Letter Reflections* as a guide.

   Observations:
   f. Describe where your earth structure is located.
   g. Give a brief physical description of your earth structure.
   h. Describe any changes happening in the region of your earth structure.
   i. What are some other interesting observations about your earth structure?
   j. Does your earth structure have a lot of seismic activity (volcanoes or earthquakes)? How do you know?

   Explanation:
   k. How would you explain the changes happening in the region of your earth structure?

   Questions:
   g. What questions do you have about your earth structure?

4. **Prepare to introduce the earth structure to the class**.
   - Create a flag for your research team.
   - Write any interesting observations on sentence strips
   - Write any explanations on sentence strips.
   - Write any key questions you would to share on sentence strips.

5. **Prepare to write a letter** to your Junior Science Assistant pen pal**.**

Reflection Question: 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.

6. After groups have introduced their earth structures to the class, answer the Reflection Questions.

Reflection Questions: Part 2

Answer the following questions in your science journal or on your worksheet after you've heard all the information.

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.

National Earth Structure Survey
111 E. Old Trench Road
Washington D.C. 20005

Dear Explorers:

In response to the effects of catastrophic earthquakes and volcanoes on our growing population, the National Earth Structure Survey (NESS) is pulling together a team to study patterns of these events and possibly explain why these events are occurring.

Your class has the honor of being selected to participate in this project. We searched high and low for a group that could meet the challenge. Below is a brief description of project goals. We look forward to your contributions.

Your class will be divided into teams that will each look closely at the seismic and volcanic activity of specific regions we have identified. Each region is identified with a structure of the earth: volcano, mountain, trench, or rift. These earth structures will be home base for your team. Teams will come together periodically to compare their observations and explanations.

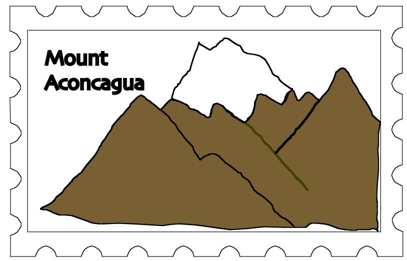
Your task:

- See if there is a predictable pattern of earthquakes and/or volcanoes.
- If so, what is that pattern?
- What evidence do you have to support that pattern?
- Why are these events occurring? What changes are resulting?
- Are there areas in a particular region that require further analysis?

We have found a Junior Scientist Assistant from each region to help you get acquainted with the region and earth structure. Enclosed you will find letters from these fellow team members. We look forward to your hard work and contributions.

Thank you and best regards,

Dr. Seismic P. Wave



Hello friends!

My name is Pablo and it's my job to get you acquainted with the Andes Mountains, the largest mountain chain in the world! My family has lived in the steep Andes Mountains for many generations and knows the region well. We live in the town of Mendoza, Argentina, which is near Mount Aconcagua (pronounced Ah *cone* kah gwah), the highest peak in the Western Hemisphere.

During the summer, my older brother, Raul, leads groups of climbers who wish to reach the summit of Mount Aconcagua. A few mules carry most of the gear up the steep slopes, but it still takes several days to reach the top of this giant volcano at 6,960 m (22,835 ft). It is an active volcano, meaning it could explode at any time!

Cordillera Huayhuash, AncashRenzo Uccelli / PromPer´

Mount Aconcagua is in the middle of the longest mountain range in the world, the Andes Mountain Range, which is 7,250 km long! The Andes stretch from the hot tropical rainforests of Venezuela in the north to the cold tip of Patagonia in the south.

But this area isn't just snow-capped mountain peaks and harsh, unforgiving weather. There are many different environments in the Andes. For example, I just got back from visiting some of my relatives in the *altiplano*, which is a stretch of flat land between two mountain chains. Did you ever think you could grow crops and raise livestock at such high elevations? My relatives on the *altiplano* between Peru and Bolivia grow grains and potatoes. They also raise sheep, llamas and alpacas.

We also have some extreme ecosystems. There are deserts as well as rainforests in the lower elevations of the Andes, especially in places where the mountains drop sharply in elevation near the Pacific Ocean. Last summer, I was with a team of young scientists who visited the Atacama Desert in the Northern Andes. From there we went to the southern Andes and dense rainforests where the climate is warm but moist.

If you ever decide to visit the mountain chain, you'll have to bring lots of different types of clothing since you'll be going through all kinds of climates. And you wouldn't want to forget a camera, either! One of the greatest sights here is the sunset from the top of Mount Aconcagua. As the sun dips down towards the west, the mountain peaks all turn a very pleasing copper-brown shade. It's a good reminder of all the minerals they mine here in the Andes, such as copper, gold, tin, platinum, lead and zinc. In fact, the word “Andes” means “copper color” in the Peruvian Indian language. Without the mining industry, people such as my uncle, who owns a small jewelry store in Buenos Aires, wouldn’t be able to make a living.

There’s some other cool stuff to see here, especially wherever the mountains meet the ocean. There are rivers cutting huge canyons, majestic cliffs next to sandy beaches, and a beautiful coastline. Too bad you can’t take pictures deep underwater or you could look at the huge trench that runs parallel to the Andes at the bottom of the Pacific Ocean. It’s a huge underwater canyon that is thousands of meters deep and filled with sediment. My younger brother, Roberto, and I like to go scuba diving around that area and collect shells. We could never dive into the depths of this trench, which plunges more than 5,000 m (16,404 ft) below sea level.

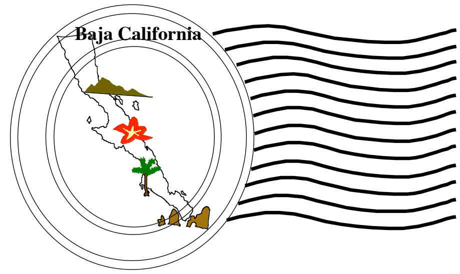
Let me tell you about the natural disasters we have to deal with as natives of this area. First, there are about thirty active volcanoes. Although they are quite beautiful to look at, the ash clouds that pour out of them create hazards for airplanes, as well as for people on the ground. I also had relatives in Chile whose homes were destroyed by mudflows. Mudflows occur when volcanic debris mixes with water. The mudflows race down steep slopes at great speeds and destroy everything in their paths!

Earthquakes happen all the time around here – small and big ones. In fact, the biggest earthquake ever recorded in history (8.5 on the Richter scale) occurred near here in 1960. Thousands of people were killed and millions of homes were destroyed. The intense shaking caused by earthquakes also causes landslides that can injure residents and creates tsunamis (big ocean waves) that can affect places as far away as Australia!

Good luck studying the beautiful Andes!

Sincerely,
Pablo Fuentes
33°S 70°W

Hola amigos!



My name is Raul, and I'll be telling you all about the section of Mexico called Baja California. I was born in Baja California and have lived here all my life. I currently live in Loreto, a town of over 10,000 people located in north-central Baja California. But I have been up and down this peninsula many times, so I think I can be of much assistance! My family owns a small motel here in Loreto, where we host people visiting the area.

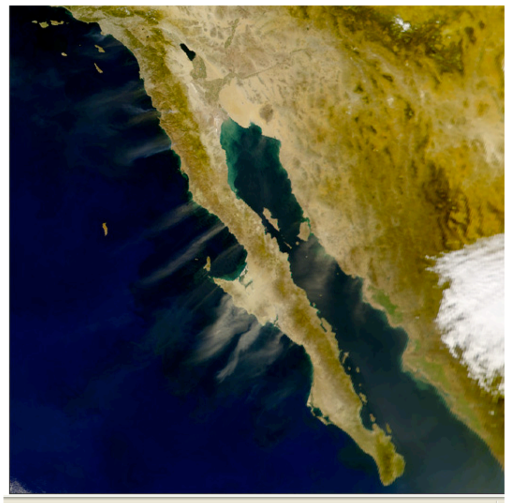
I hope you've had a chance to look at the map of the area. If you haven't, please take a quick look now! Baja California is very different from other landforms you might be familiar with. For one, it looks like it is detaching itself from the rest of Mexico. Some people call it a heel that is breaking off from a woman's shoe. I think it looks more like a broken tree branch that's hanging by a thread!

Baja California is a very long and narrow peninsula that is 1,288 km (800 miles) long. It is bordered on the north by the state of California. Baja California is separated from the rest of Mexico by the Gulf of Cortez to the east and is bordered by the Pacific Ocean to the west.

Since my aunt and uncle live in San Diego, California, we travel up through Baja California to visit them every year. San Diego is minutes away from the US-Mexico divide, which is the northern border of Baja California. I also have a sister, Isabel, who just got married and now lives in Cabo San Lucas. Cabo San Lucas is at the southern tip of Baja California and is a very popular tourist attraction with its many lagoons and beaches.

The way Baja California looks today is the result of many different geologic processes occurring at different times in history. This would be clear to you if you could see all of the different mountain types on the peninsula. Barren and rugged mountains, represented by the Sierra de la Victoria and the Sierra de la Laguna mountain ranges, are in the south. These mountains are much steeper than the major ranges found in the north, such as the Sierra Juarez and Sierra San Pedro, which slope gently towards the Pacific coast. There are also mountainous islands off the coast of Baja, such as the Cedros Island Mountains.

Our mountains are not overwhelmingly tall, and they cover only about a quarter of the land. Otherwise, the area is made up of a lot of flat desert. Mountain climbers looking to conquer really challenging heights would be a little disappointed by the mountains we offer here. They pale in comparison to the world's taller mountains and are not as jagged and rough as other major global chains. In fact, the highest peak on Baja California is Cerro de la Encantada, in



http://earthobservatory.nasa.gov/NaturalHazards/natural_hazards

northern Baja. It is more than 12,880 m (8,000 ft) above sea level. As far as mountains go, that isn't very high.

If you're looking for volcanoes, you'll only find a few active volcanoes in the area around my hometown. One is Tres Virgenes Volcano (which means "Three Virgins"), located in central Baja, not too far from Loreto. It is 1,940 m (6,365 ft) above sea level and has not erupted since the late 1700's. There is some underwater volcanic activity under the water here also, I hear, though I haven't seen it.

Be aware of other natural hazards such as earthquakes, which happen on the Baja peninsula all the time. Most of Baja's earthquakes happen underwater in the middle of the Gulf of California. I know you're probably confused – most people don't understand how an earthquake can be underwater. Maybe this is something you could research!

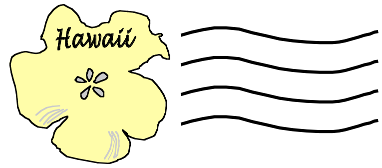
If you were ever to visit this area, you'd have to bring plenty of bottled water. Northern Baja is extremely hot and dry, dominated by nearly 1,550 square km of desert. To give you an idea of how dry it is down here, my hometown of Loreto didn't receive a single drop of rain all last year!

However, even these deserts are rich and valuable because they are full of strange forms of cacti and other rare plant life. Some people even call Baja California a botanist's paradise since it contains so many rare plant species.

But not all of Baja is full of inhospitable desert. If you head down towards my sister's house in Cabo San Lucas, you'll see that southern Baja receives a bit of rainfall. In fact, the lowlands of southern Baja California are used to grow crops such as cotton, sugar cane, and olives. Some of the southern mountains also have forests that are used for the local economy.

I think that's all you need to know for now. You won't experience the best of Baja California until you actually get here. Think about visiting! Think about all that good Mexican food you'd get to eat if you did visit! Fish tacos and big bean burritos… I'm getting hungry just thinking about them! It's time for dinner – I hope you have fun learning about Baja.

Your friend,
Raul Cabrera
28°N 113°W



Aloha everyone!

My name is Keona, and I'm so glad to be a part of the team! My family and I are excited to assist you junior scientists in your investigation of Hawaii. Our small town of Kea'au, on the Big Island, is close to Kilauea Volcano. This is a great place to research for your project because Kilauea is one of the most active volcanoes in the world!

I remember my grandfather telling me the story of this volcano, a story that goes way back into the generations of my family. A long time ago, when European explorers first began appearing on the Hawaiian islands, a man named Kamehameha led an army. He was about to attack an area called Pau, and the men from that region were gathering together to defend it. It was then that Kilauea began rumbling – it sent a dark cloud into the air. Then the thunder and lightning started, and the cloud rose and grew until the whole area was covered in darkness, blocking out the sun. The men could only see the glow from the volcano. As it erupted, Kilauea threw up sand and burning rock, which killed most of the men, even though they were miles away from the top of the mountain when it erupted. The few survivors returned to their home, but they didn't stand a chance against Kamehameha. Kamehameha could tell from the survivors' stories that Pele, goddess of fire, favored him over all the other leaders. This certainty helped him conquer and unite all the islands, and he became the ruler of Hawaii.

USGS

With stories like this one about the dangers of Kilauea, it may seem strange that so many people come to visit the volcano. But most of the time, Hawaiian volcanoes are not dangerous. In fact, my older sister Lea used to lead tours at the Hawaii Volcanoes National Park, showing Kilauea to visitors. Hawaiian volcanoes usually have lava that comes out quietly or spouts straight up like a fountain. It's rare for them to spit out rocks and clouds of ash like in this old story.

I can only remember one time that Kilauea did that – in the late 1990s. I was still little then, but I remember all the commotion. The scientists had been warning about an eruption for days; I guess they had some way of figuring out what was going to happen. My parents made Lea stop giving tours at the park after that, but she still works in a village near Kilauea. Right now though, it's perfectly safe to view the volcano and its lava flows.

The lava flows are one of the most spectacular sights at the volcano; if you're ever here visiting, you have to check them out. While most of the lava I've seen has come out of the mountain quietly, it doesn't always move slowly. There are two kinds of lava; one is called *pahoehoe* and the other is *aa*. *Pahoehoe* is thin, fast moving lava – it can move as fast as 35 mph! That's faster than cars can drive on some of the mountain roads! When Kilauea really erupted, we saw firefighters spraying the *pahoehoe* with water to slow it down. It hissed and steamed, but it stopped moving so fast. *A'a* lava moves more slowly, but because of this, it forms rocky, rough surfaces when it cools. Ground surfaces formed from *a'a* lava can be sharp and painful to walk across.

Speaking of lava flows, you should see the way lava comes out of underground tubes right into the ocean. As it hits the water, the lava creates giant clouds of steam. It also creates land underneath the water! I think that the best part of living near the volcano is seeing the island grow right in front of my eyes – when the hot lava runs into the cool sea, new land is created. Over 50 acres of new land are created every year! I've heard that over 90% of the surface of Hawaii (my island) is covered by lava less than 1,000 years old, so it's pretty young compared to other islands, and it's all due to the volcanoes erupting!

One of my favorite spots in the park is the Kilauea caldera. A caldera is the large, shallow depression at the summit of a volcano. When the lava flows out from under the volcano, the overlying rock doesn't have anything to support it, and it collapses into a shallow bowl. I've hiked right up to the caldera but not across it.

I recommend that anyone who's on the Big Island visiting Kilauea also stop by Mauna Loa Volcano. My cousins live close to it, so I've visited there. It's much taller than Kilauea and the largest active volcano in the world, but I don't think it's as exciting. Of the five volcanoes that make up the island of Hawaii, I think Kilauea is the best.

There's more than just the main island of Hawaii to investigate. There are eight main islands in the state of Hawaii, but the full island chain includes almost twenty. They're all spread out in a line – it looks sort of like a necklace of shells – stretching northwest from my island. When I've flown over them in a plane, it's easy to imagine that they're all a string of mountains connected under the water. The Big Island is the newest and the largest, while the island farthest northwest is the oldest one. As the islands get farther from my own, they also get smaller and smaller. Mine is the only island still spewing lava and forming new land, but I've heard that the it's moving 12 cm (5 in.) per year, so who knows what will happen in the next few years?

I've also heard that there's a diving team exploring a new volcano off the coast of Hawaii. Maybe that's something you can look into as well. It's supposedly a new island forming underwater, called Loihi. One day it will build high enough to form a new island above water.

If you ever get here to see the volcano for yourself, you should take some time off from your scientific exploration and enjoy the sun and the beaches a little. I can show you Hawaii's famous black sand beaches. In the meantime, I hope this information helps you in your investigation!

Your friend,
Keona Kawena
19°N 155°W

The Hawaiian Islands

Hello there!

My name is Tenzing, and I have been instructed to give you a quick overview of the Himalayas. First, let me tell you about my family, who lives here in Tibet. We live in a town right on the border with Nepal. I'm sure you've heard lots about the Himalayas, and I'm happy to help with your investigation. I have been giving tours of the Himalayas for years now and I always get very excited when people want to learn more about the largest and highest mountain range in the world!

No doubt you will want to hear about the two famous peaks in the Himalayas – Mount Everest, the tallest peak in the world at 8,850 m (29,035 ft), and K2, which is the second-tallest peak at 8,611 m (28,250 ft). In fact, the ten highest mountains on Earth are found right here in the Himalayas. By the way, the Nepalese call the Himalayas the "home of the snows."

http://www.nasa.gov/multimedia/imagegallery/image_feature_152.htm

Mt. Everest: Taken from the International Space Station

The Himalayas aren't just found here in Tibet and Nepal. They stretch across northern India and make a border between India and the rest of Asia. This "wall," as locals call it, leads to two very distinct climates around the region. My father studies weather patterns around the area, and he tells me that the mountains block the warm and moist Indian monsoon winds, so the plateau of Tibet is one of the driest and coolest places on Earth! In contrast, these monsoon winds heap heavy rainfall on India.

Along with the differences in climate comes a rich mix of ecosystems and habitats. The area around the Himalayas has all kinds of forests and even deserts. The ecosystem has great biodiversity, but my father says that with all the incoming tourists and economic development (new roads and settlers), the area may encounter many kinds of environmental problems in the future.

But don't worry about that for now. Let me tell you about the rich history of these mountains, especially Mount Everest. First, does my name sound familiar to you at all? If you've heard of it, it's because my name has a special bond to Mount Everest. Why? My parents named me after the famous Sherpa Tenzing Norgay, who accompanied Sir Edmund Hillary of New Zealand as he became the first man to reach the top of Mount Everest in 1953. So my name is etched in history! By the way, the Sherpas are a group of traditionally Buddhist people that live around this area. They are world famous for being expert guides on mountain climbing expeditions. Since 1953, 550 people from 20 different countries have successfully climbed to the peak of Mount Everest – many with the help of Sherpas.

Sadly, many people have died trying to climb the peaks of Mount Everest and K2. It's commonly said that even though Mount Everest is taller, K2 is more dangerous and difficult to climb, or summit. In 1954, two Italians reached the top of K2 after many tries. I have a group of friends at the local high school I attend that always boast about how they're going to climb K2 one day, even though it is only for the most expert mountain climbers of the world. I hope they think that journey through!

Another interesting bit of information about the Himalayas – it grows about 3 cm every year. Forces from the surrounding area push these mountains upward, but the ground erodes away almost as fast, so the mountain range stays about the same elevation. At the summit of Mt. Everest, scientists have found fossils of ancient sea cucumbers and plants. Imagine that – the highest peak in our world today was once at the bottom of a deep ocean.

But one thing is certain – the area has its share of problems. Earthquakes and avalanches are common occurrences here, always making the Himalayas dangerous, especially to those who are unfamiliar with the area. There are volcanoes scattered throughout the area. It's kind of hard to imagine volcanoes in a snow-filled place, right? Maybe you can visit one day and see for yourself!

Your pal,
Tenzing Sharwa
27°N 80°E

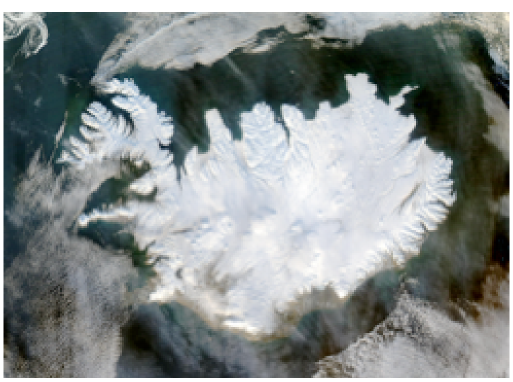
The Himalayas

Greetings friends!

My name is Suna, and I have been instructed to tell you more about Iceland. I write this letter to you at 11 PM from a park near my house in the town of Akureyri, which is in northern Iceland. There are no lights in the park, nor do I have a flashlight. I can write this letter because in the summertime, the sun sets at 1 AM! Then it rises an hour later. Isn't that amazing?

Iceland is a relatively new island that has not been around very long compared to other landforms on Earth. When you see how unique and different our blend of landscapes is, you'll see why Iceland is such a popular tourist attraction.

So where should I start on this overview of my home country? First, there's the wide variety of plant species in gardens around Akureyri. It may seem like a small town to most Americans because there are only 15,000 people. But it is the second largest city in Iceland after Reykjavik, the capital. Akureyri, which is only a few miles from the Artic circle, is one of the northernmost cities in the world! And just because we're so far north doesn't mean we don't grow crops. There are kilometers of rich farmland up here, especially in the southern and southwestern regions of Iceland. And few children grow up in Iceland without being very good at fishing. Just ask my younger brother Henrik, who is so good at fishing that my parents said that they don't need to go to the market anymore!



http://earthobservatory.nasa.gov/Newsroom/NewImages/images.php3?img_id=16443

In the south are glaciers such as Vatnajokull ("water glacier"), which is Europe's largest glacier! It is in southeastern Iceland, rising over 2,000 m (6560 ft) and covering an area of 8,538 square km. That's the size of Rhode Island. Sometimes, the ice can be 1,000 meters thick – that's over half a mile! We use snowmobiles to get to the glacier (since it is impossible to build roads in the surrounding areas), but it's good experience. Have you ever driven a snowmobile? I do it all the time! I drive Henrik to school every day on the snowmobile.

If you are interested, we have many active volcanoes in the area. But don't expect to see the kinds of volcanoes that you're used to seeing in movies. Most of these volcanoes erupt under the ice. Iceland is truly a land of fire and ice. These volcanoes are mostly concentrated in the uninhabited center of the country and roughly line up in a north-south direction. Rapidly flowing mixtures of water, ice, and rocks result from volcanic eruptions; they are very dangerous and destroy everything in their path!

Iceland

Have you ever heard of "Old Faithful?" Well, we have hot springs and geysers, too. Besides being an interesting sight and a tourist attraction, the Icelandic hot springs are a source of power and energy for Iceland's natives. We don't use fossil fuels or gasoline to heat our homes and cook our food. Instead, all of our energy comes from heat-producing underground processes. And believe me, you need plenty of energy to keep warm in the long, cold winters here!

Iceland is almost completely made up of lava flows. New land is added to the island when all the underwater volcanic activity deposits material onto the ocean floor, eventually piling up to reach above the water surface and adding to our country's total surface area. You can imagine how the island of Iceland formed! In 1963, when an underwater volcano exploded, it left behind a new island that we call Surtsey, after the Norse god of fire.

Landforms in Iceland are also constantly changing. In 1973, a huge volcanic explosion on the island of Heimaey forced an evacuation of 5,000 residents and caused unspeakable damage to the town. It wasn't until a year later that the volcano stopped activity and it was safe for residents to return to the island. When they returned, a new 2,240 m (735 ft) tall volcano was there to greet them! Imagine how surprised they all were.

Tourists also like to visit the many large lakes and rivers in the country. One of the best lakes is Lake Myvatn, which is near Akureyri. The region around Lake Myvatn has caves with hot springs. My older brother, Markus, serves as a tour guide for these exciting trips. Last summer, we both went there and had an amazing time.

Then there's Stokkseyri, which is a town in southern Iceland. It has a nice beach with BLACK sand! I bet there's not much of that where you guys live. When I went there two summers ago, I remember an American boy who was so fascinated by the color that he scooped a sample of the sand into a plastic bag!

You should also become familiar with things like fjords, which are a dime a dozen here. Fjords are long, narrow inlets of the sea that cut deeply into the high slopes. My hometown of Akureyri is located right on a fjord.

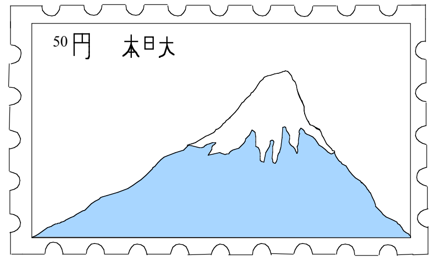
Earthquakes are also a daily occurrence here in Iceland. Hundreds of earthquakes with magnitudes of at least 2.0 on the Richter scale occur every year in our country. All that volcanic activity causes the land to move and settle. The largest earthquake happened in 1784 and had a magnitude of 7.25!

If you ever come to Iceland, don't forget the camera because you'll see some of the most breathtaking natural scenery you'll ever lay eyes on!

Your pal,
Suna Ericsson
65°N 21°W

Iceland

Konichiwa (that means ‘hello’ in Japanese) friends!



My name is Kazuo, and along with my cousin Saburo, we will be your personal advisors as you learn about Japan! Surely you have heard of the sushi, sumo wrestlers, and video games that come from our country. But there’s a whole other side to Japan that we’ll be exploring. Are any of you avid mountain climbers? I hope so, because we’ll be learning a lot about our great heights.

http://eol.jsc.nasa.gov/EarthObservatory/MtFuji.Japan.html

First, use your imagination and picture yourself taking an actual trip to Japan. But before you say “sayonara” to your homes, keep in mind a few things. The first sight you’ll see as your plane descends into Japan will likely be tall, steep and rugged mountains. My cousin and I both live in Odawara, a coastal city of about 200,000 people. It’s about 50 km from the capital city of Tokyo and less than 32 km from Japan’s most famous mountain, Mount Fuji! Mount Fuji is the highest point in Japan (3,776 m or 12,389 ft) and is an active volcano! Since it is not far away, my family and I take regular trips to visit this sacred landmark. Am I ever scared that Mt. Fuji will erupt? No; it hasn’t exploded since 1707 and there are no earthquakes or gas emissions indicating activity, so I don’t think there is much to worry about!

Mount Fuji is just one of 200 volcanoes in Japan, and one of 40 active volcanoes. Dormant volcanoes (ones that haven’t erupted for hundreds of years) often surround these active ones. My sister, Kayori, and I enjoy exploring and learning about volcanoes so much that we have been to all of Japan’s famous volcanoes. Last spring, we went to Mount Sakurajima. This mountain is on the island of Kyushu.

When you’ve had enough of our mountains on land, you can learn about our mountains underwater! The seafloor next to Japan is filled with jagged underwater mountain chains that are extremely steep. These underwater mountain ranges are located next to deep canyons called trenches. It's an awfully dangerous place, so think twice about scuba diving in these rough waters! The Japan Deep is a north-south trench in the Pacific Ocean that is 8,534 m deep – that's over 5 miles!

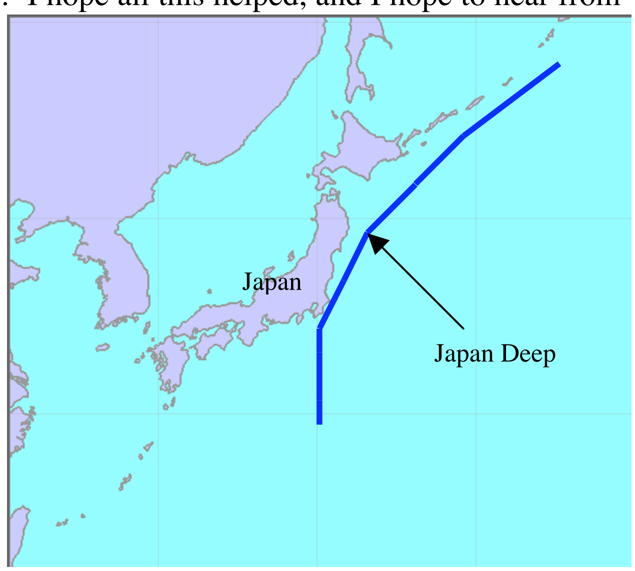
Japan records about 1500 earthquakes every year. Some of these are large quakes, some lead to volcanic activity, and others have been so large they have made the history books. In 1923, a huge 8.0 earthquake and the fire that followed killed about 143,000 people and destroyed over 300,000 buildings! In 1995, when I was a little kid, we had another large earthquake near Kobe that killed about 5,000 people. Earthquakes of this magnitude are able to make land rise and fall. The reason earthquakes are so damaging in our country is that we have a large population, and everyone lives near each other. In fact, Japan is roughly the size of California but has a population that is nearly 3.5 times larger!

As if the shaking on land isn't enough, Japan faces disaster from offshore. Seismic activity under the ocean creates huge sea waves (tsunami) that can rise to over 30 meters! These high waves can cause destruction and severe erosion when they hit the low-lying coastal areas. My hometown of Odarawa is one of the cities that must be on the lookout for these sea waves.

I hope the tsunamis, earthquakes and volcanoes aren't scaring you, because Japan has a lot to offer culturally – sushi, sumo wrestling, and Kabuki Theater (this is a kind of play where men must dress up as women). Maybe I'll send you a postcard from Japan. Most postcards from here have pictures of majestic mountains, rice paddies, and dense downtown areas of Japan's cities.

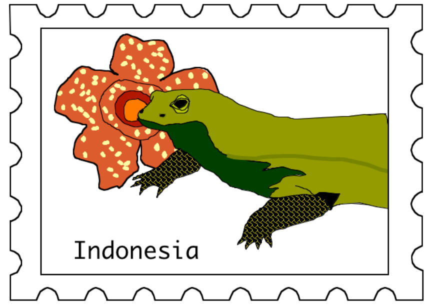
If you ever visit, I'm sure Saburo will give you a boat tour of the area around our hometown, and maybe you can all watch one of my baseball games. My high school team is going to the local championship game, and I'm the starting pitcher! I hope all this helped, and I hope to hear from you soon!

Your friend,
Kazuo Matsuyama
35°N 140°E



Japan

Selamat Pagi friends!



My name is Benny and I write to you from my hometown of Bandung, a city of 2 million people on the island of Java. Java is one of about 13,000 islands that make up the nation of Indonesia. I heard you are interested in learning more about our country and the Java Trench, so I've offered to tell you a little bit about my homeland.

Just imagine for a second that you will be coming here to visit. I would have so many trips set up for us to go on! The first trip would be to the local wildlife preserve, where you will acquaint yourself with the Komodo dragon, the world's largest lizard. Native to our country, the Komodo dragon can grow to over 3 m in length! I bet you don't have lizards of that size back home! But the Komodo dragon is endangered and protected by the government. I volunteer at the wildlife preserve, so I get to interact with them all the time.

http://earthobservatory.nasa.gov/Newsroom/NewImages/images.php3?img_id=16320

Our second destination would be Anak Krakatau. Back in 1883, there was an island off the west coast of Java in the Sunda Strait called Krakatoa (it is called 'Krakatau' in our native language). On this island were three active volcanoes. Beginning in May of that year, small eruptions and a large earthquake occurred, leading people to believe that something great was going to happen. By the beginning of August, all three of the volcanoes were spitting out ash and steam. On August 26, the island exploded.

By the morning of August 27, most of the island was gone and rocks and lava continued to shoot into the sky. The entire mountain – all 790 meters (2,600 ft) of it – was gone. And to make matters worse, the eruptions had triggered tsunami waves that battered the coastal towns on the islands of Java and Sumatra. These waves reached heights of up to 40 meters and were powerful enough to fling ashore coral blocks that weighed up to 600 tons (that's 1.2 million pounds!). When all the waves had run their course, more than 36,000 residents of these towns were killed! My great-great-great grandparents experienced these tidal waves but managed to survive. They wrote about it in a journal that has been passed down to me.

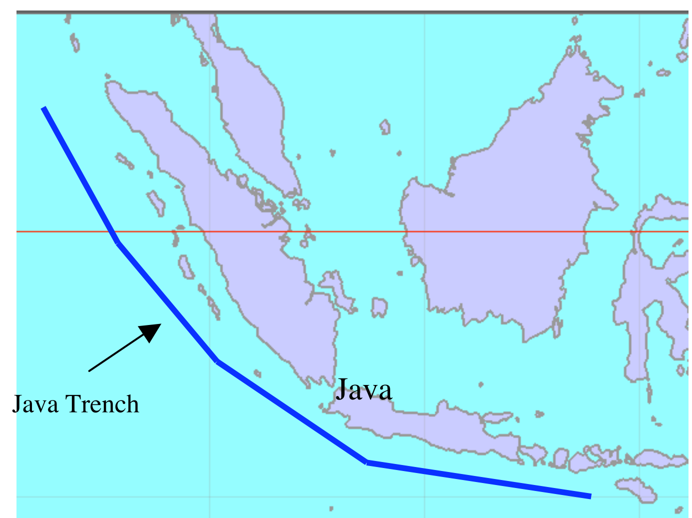
After the huge explosion of Krakatoa, only about one-fifth of the original island remained above water. A short distance away, a small new island formed. It was called Anak Krakatau (meaning "child of Krakatoa") and it surfaced in 1959. Since then it has been very active and has been growing in size and height with every small eruption. My uncle is a volcanologist, and he said that he would take me there to see the island up close! This will be my first time there so I'm extremely excited. Many people say that Anak Krakatau will one day experience an explosion similar to that of Krakatoa. It's all part of living in a country that boasts the most active volcanoes in the world – 76! A lot of people here are constantly on their toes because most of our eruptions have come in the past 100 years.

The third place I want to tell you about is off the shores of Java – the great Java Trench! Trenches are like deep underwater valleys that are often found running side-by-side with a chain of volcanic islands. Indonesia is a chain of volcanic islands between Australia and the main continent of Asia. These islands run alongside the Java Trench. The Java Trench is the deepest point of the Indian Ocean, at 7,450 m (24,442 ft) below sea level. It runs 2,575 km in an east-west direction. It is the second deepest point in the world, after the Mariana Trench located in the Pacific Ocean! Thanks to my father, who works at a government lab, I frequently tag along with his team of oceanographers as they go offshore to do their research on the Java Trench. They send underwater craft to take pictures, and I watch as they analyze some of the data that come in!

The last thing we'd do if you came to visit Indonesia is take a road trip to the island of Sumatra, which is a larger island located a little to the northwest and connected to Java by roads. Sumatra, just like the rest of Indonesia, is home to many rare and unusual plant species. On preserves you will see more Komodo dragons and also get a whiff of the Rafflesia – the world's largest flower that gives off a really foul odor that smells like rotting meat! A lot of times, I like to meet up with some of my cousins who live in Padang and go scuba diving!

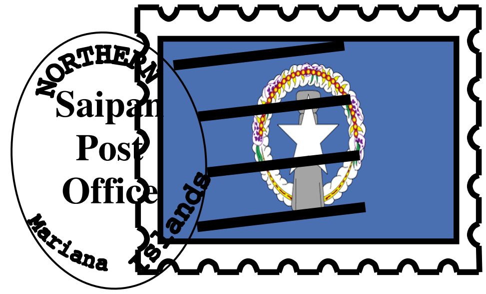
Hopefully, you will have a great time learning about Indonesia, especially exploring the Java Trench, which many people call the "Shadow of Indonesia." And just in case you ever do visit, don't forget to pick up some handy Indonesian phrases. For starters, you should know "selamat tinggal," which means "good bye"!

Hope that was helpful,
Benny Makmur
2°S 102°E



The Java Trench

Hafa dai friends!



Welcome to the deepest, darkest place in the world! Doesn't sound too pleasing, does it? But this is what we are famous for here at the Mariana Islands, right next to the Mariana Trench. (A trench is like a deep underwater canyon.) At more than 10,970 m (36,000 ft) below sea level, the Mariana Trench is the deepest point on the Earth! It is even deeper than Mt. Everest is high, at 8,850 m (29,035 ft).

So now that I've introduced the place you'll be learning about, let me tell you a little bit about myself. My name is Ashley, and I was born in Seattle, Washington, but I have been living here on Saipan, one of the Northern Mariana Islands. The Northern Mariana Islands are different from the Southern Marianas in that the northern ones are volcanic and younger. My father is a researcher and works with the United States government, who moved our family out here about six years ago. It's a great place to visit but a little remote for me, having lived in the big city of Seattle.

The Northern Mariana Islands are a popular tourist attraction, and we get lots of visitors around here from different places. However, most of the visitors aren't really interested in the Mariana Trench, which runs from northeast to southwest for 2,544 km and is an average of 64 km wide. My dad has been down there in a submarine before, and he says that it gets really dark and cold as you get deeper. At its deepest parts, the temperature at the Mariana Trench is as cold as 4° C – only a few degrees above freezing! And the pressure at the very bottom is unbelievable. The weight on top of you if you were at the bottom would be the same as 48 jumbo jets – I don't think any human could scuba dive down there!

No one even knew how deep the Mariana Trench was until 1968, when the *Challenger* reached the bottom. The Challenger was a specially designed submarine that was built just so it could reach the deepest parts of the Mariana Trench. Did you know that the deepest point of the Mariana Trench is named after the submarine? Yup, it's called the "Challenger Deep."

Since 1968, other deep-sea submarines have regularly made the trip down to the bottom of the Marianas to collect soil samples and take lots of pictures. My dad is an oceanographer, so he has been making maps of the ocean floor around the area since he got here. From the top of the ocean, he and his team send sound waves all the way down to the bottom that bounce back up to the surface. In this way, he can tell how deep the ocean is at various points and make accurate maps. It's exciting when I get to see him doing this type of thing up close!

I bet you don't think anything could live at the bottom of Mariana Trench, especially since it's so deep that the sun's rays cannot reach down there. How could anything live there? How could anything see, or bear the extremely cold conditions? Well it turns out that there *are* living creatures at the bottom of the ocean here! There's the Brotulid fish, also known as the "sea pig." This fish has no eyes! There are also echinoderms (sea cucumbers) and giant squid.

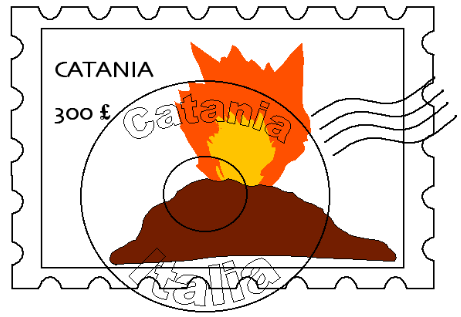
The Mariana Trench

In addition to the darkness, near-freezing temperatures, and extremely high pressure, the Mariana Trench, as well as the islands themselves, are riddled with frequent earthquakes and volcanic eruptions. Anatahan Volcano is an active volcano just a few hours north of here by boat. It erupted this past year, spewing ash and lava. This created havoc for aircraft trying to pass overhead! There are 12 above-water volcanoes, as well as 40 submarine volcanoes in the Northern Marianas that are lined up in a north-south direction. When they erupt, these deep-sea volcanoes spew hot lava. In fact, the Mariana Islands, lined up just west of the Mariana Trench, were formed by this kind of underwater explosion.

Even though conditions can be scary around here, it's still possible to have a good time scuba diving because the shallow parts of the area have tropical fish famous around the world for their colors. The coral reefs are also a magnificent sight and make for some very lovely pictures! If you ever get the chance to visit, I'll show you around them!

Sincerely,
Ashley Emery
15°N 145°E

Anatahan Island erupting in July 2003.
http://news-info.wustl.edu/news/page/normal/235.html



Buon Giorno!

My name is Lucia and I am from the small town of Catania on the island of Sicily. If you've never seen a map of Italy before, Italy looks like a giant boot and Sicily looks like a rock that's being kicked by the boot! I hear you're all very interested in Mount Etna, a volcano on the east coast of our island, so let me tell you a little about the mountain and our island.

My entire family lives right at the base of Mount Etna! Scary, isn't it? Can you imagine living at the bottom of a 3,350 m (10,991 ft) volcano that has erupted more than 190 times since 1500 B.C? But it's not scary at all. Mount Etna (which is not too far from Mt. Vesuvius, located on the Italian mainland) isn't in some remote, unpopulated area like many volcanoes around the world are. In fact, there are tons of people living at its base. My sisters, Donna and Bianca, and I were born and raised in this town. My sisters are both married and live less than a mile from me. We have a university here and over 330,000 people!

Mt. Etna erupting in 1993.
http://volcano.und.nodak.edu/vwdocs/volc_image/img

People live here because of the good soil quality. The soil is rich in nutrients because it is composed of old lava and ash that have erupted from the volcano over the past 300,000 years. This kind of land attracts farmers. My family has farmed the land here for generations. People here grow olives, grapevines, other fruits, and all kinds of vegetables. We also raise different kinds of trees, such as chestnut, beech, oak and pine. Currently we have olives, grapevines, lemons, limes, and of course lots of vegetables that we take to the farmers market each week to sell. We also recently planted some small chestnut trees. They should have chestnuts ready for harvest in a few years. Have you ever cooked fresh chestnuts over a fire on a cold winter night? If you haven't, you're missing out!

Unfortunately, there's always this ancient mountain looming above us, threatening to go off at any second! You might be wondering how there can be such a large population right underneath an active volcano. But this volcano's eruptions affect only the area around its summit, far, far away from the base; we are pretty safe here. In the past 3,500 years, Mt. Etna has erupted 190 times, and only 7 of those eruptions have led to fatalities. One of the contributing factors to the low number of fatalities is the slow speed of the lava as it moves down the mountain, allowing people below enough time to evacuate the area.

Although small ash and steam eruption occur all the time, and it may seem like we live in constant fear of the great Mount Etna, we're quite carefree. In fact, we love this mountain for all the unique history it has, along with all the tourists it attracts. I get to meet all sorts of people who come to look at Mount Etna. Sometimes, my mama says that the mountain is part of our family, and she calls it "the friendly giant."

However, the people in Catania have also had some pretty hard lessons in dealing with Mount Etna. Back in 1669, when Mount Etna had its worst known eruption, the townspeople tried to outsmart the volcano and build 18-meter high walls to keep the lava flow away from the town. Sadly, the plan didn't work and millions of metric tons of lava poured out of Mount Etna and completely destroyed Catania and a neighboring town of Nicolosi in just 18 days. Hopefully, that will never happen again. Earthquakes are also a pressing concern around these parts. Sicily is a hotbed for seismic activity because of magma movement, with many small earthquakes occurring every year.

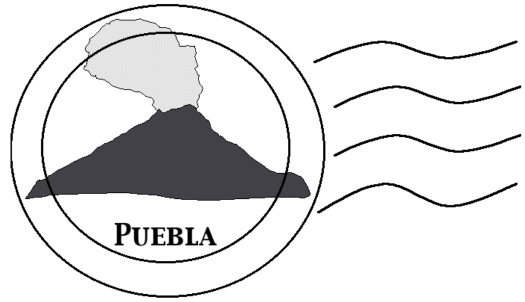
Mt. Etna was once thought to be the highest peak on earth! This has put Mt. Etna at the center of many mythological stories from the people of the area. There's the story of the great giant named Enceladus, who breathed fire (volcanic eruptions) and caused motion (earthquakes). He lived at Mount Etna along with the Cyclopes (the one-eyed monster). Early Romans also believed that the god of fire, Vulcan, lived at Mount Etna and used its hot lava as a way to forge weapons and armor for the other gods. Mt. Etna is also thought to have trapped an ancient, angry monster thousand of years ago. When the monster periodically lost his temper, he spurted spectacular columns of fire from one of his 100 dragon heads. My grandfather loved to tell these stories to my sisters and me when we were younger, and sometimes he still does!

Of course, scientists now know a lot more about Mt. Etna than these ancient cultures did. Scientists believe that Mt. Etna has been an active volcano for more than two and half million years. It probably started as an underwater volcano and then rose above the surface.

So that's it! I hope my letter helped. I must be off now to pack so I can visit my cousin Benito, who lives in Naples (the closest large city to Mount Vesuvius.) He's agreed to take me on an exclusive tour, so I'm excited! Hope to hear from you soon.

Your pal,
Lucia Totti
38°N 15°E

Mt. Etna



Hola amigos!

On behalf of my family, I'd like to welcome you to Mexico. My name is Consuela and I am writing to tell you all about the area of Mexico that I live in. It's a shame that you are not coming to visit for real because you could stay with me! My mother is a very good cook and would prepare a grand Mexican feast if you came!

We have an active volcano formally called Mount Popocatepetl, and it is the main attraction for geologists and volcanologists traveling to southern Mexico. I recently began conducting research on this mountain for my school. If you're wondering about the long and difficult name, Mount Popocatepetl was named by the ancient Aztecs. Translated literally, it means "Smoking Mountain." They called it this because steam and volcanic gasses were constantly pouring out of its large crater. In fact, small columns of steam have been observed coming out of the crater even in recent years.

Popocateptl most recent activity was from 1995 to 1997.
http://volcano.und.nodak.edu/vwdocs/volc_images/north_america/mexico/popocatepetl.html

My family lives in the city of Puebla. We're only about 16 km southeast of Mexico City, which is the second biggest metropolitan area in the world. Over 20 million people live there! Our city of Puebla is also pretty large, with over 1.2 million people. "Mount Popo," as it is commonly referred to, is only 40 km to the southeast of our town. The volcano is part of a range of volcanoes in Southern Mexico that line up from east to west. You can see Mt. Popo from afar because it is snow-capped and its peak is 5,000 meters above sea level!

When I began research on Mount Popo last month, it was my first time there! A geology professor at the local university accompanied me on my trip up the mountain, so I saw firsthand the gigantic crater, which is 612 meters across – that's almost 7 entire football fields! In the coming months when I return, we'll be studying the composition of the minerals that have been deposited around the volcano to find out how often the volcano erupts.

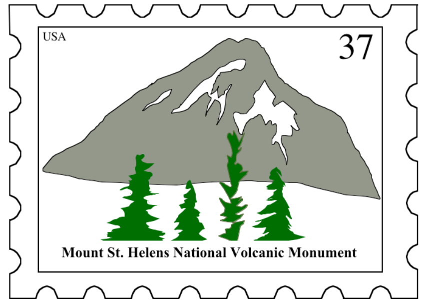
Mt. Popo

For me, the threat of an eruption is always in the back of my mind, especially since so many of us live pretty close to it. I know it is 40 km away from our home, but when a volcano of this size has a huge eruption, 40 km doesn't mean much! In fact, I remember that when I was in elementary school, we had a huge scare. It was December 21, 1994 and I was about to walk to school when it started raining. But this wasn't the kind of rainwater we usually get – it was raining ashes! I also remember there were a series of earthquakes, and everyone thought that the ash clouds and earthquakes meant that Mount Popo was going to have a gigantic eruption. The volcano kept having very minor eruptions that were scaring the townspeople, so the government moved everyone in the town to a safer area away from the volcano. Geologists from around the world got together to predict what the mountain was going to do. Luckily, there was no gigantic explosion…whew!

I still remember that winter, and my parents are always saying that we should move away from the volcano. Scientists say that a huge eruption could have an impact on up to 30 million people, affecting Mexico City and its surrounding areas. The volcano hasn't acted up too much in recent years and the major eruptions took place more than 10,000 years ago. The last serious eruption occurred around the 9th century, and about 20 minor eruptions have been recorded ever since then. My professor is on a team of scientists that is constantly trying to predict what the volcano will do in the future. My parents might worry, but I don't think there is anything to worry about. It's a surprise that they let me do research on the mountain!

Well I must be off now to soccer practice. Do you play? If so, we should play if you ever come visit! Until then, take care and learn a lot about Mount Popo. Adios!

Your buddy,
Consuela Sanchez
19°N 98°W



Hello there!

I'm Brendan and I live in Vancouver, Washington, just 80 km southwest of the site you want to learn about in the Pacific Northwest – Mount St. Helens! It's one of the most famous volcanoes in North America due to the huge blast that took place in 1980. I hope I can help you as you learn more about the area. I go to the mountain at least once a month to monitor the volcano with instruments and collect samples. Maybe one day you can visit and come with me on one of these trips!

Mount St. Helens with small plume, reflected in Spirit Lake, May 19, 1982

http://vulcan.wr.usgs.gov/Volcanoes/MSH/NatMonument/framework.ht

Mount St. Helens and my hometown of Vancouver are both in southern Washington. Vancouver is right on the Washington-Oregon border – the next closest big city is Portland, Oregon. My parents used to live in Vancouver but now work as researchers in a lab in Portland, while I still live here with my older brother Jeremy. He's not into volcanoes like I am, but he comes with me on my trips every now and then.

Do you like hiking? I love it, and I do it a lot when I go see the mountain. This area is a really popular site for hikers and photographers. People come here to take pictures because we're right in the middle of the Cascade Mountain Range. These beautiful mountains have snow-covered peaks and stretch all the way from northern California through Oregon, Washington, and all the way to southern British Columbia, Canada – a total distance of over 1,120 km (700 mi). Mount St. Helens is just one of several volcanoes located in the Cascades. Local Native Americans originally called Mount St. Helens "loo-wit," which translates into "smoking mountain."

I'm sure you want me to cut to the chase and talk about the big blast! I wasn't around when it happened, but the eruption of Mount St. Helens is a huge part of our culture around here. Those that were around when it happened have lots of stories to tell. One of these people is Ranger Gary Adams. He's been a park ranger in the local area for 25 years and was just starting out his career when the volcano erupted on the morning of May 18, 1980 – 8:32 AM, to be exact. A 5.1 magnitude earthquake triggered a landslide. A bulge of magma in the side of Mount St. Helens had been building up pressure and then was released in a large blast. This released a huge downpour of rocks, which was followed by an eruption of pumice and ash. It's sort of like if you were to shake a can of soda before opening it, pressure would build up, making it explode when you opened it!

Mt. St. Helens

The release of pressure caused by this earthquake and landslide led to a huge blast out of the north side of the volcano. You usually think of volcanoes erupting from the top and hot magma and ash pouring out from the peak of the mountain, but Mount St. Helens' eruption wasn't like this. Instead, rock and debris poured out of the side. These kinds of eruptions are not as common as out-of-the-top blasts, and they are typically more destructive. They cause more damage because the energy produced by the explosion can go straight across land rather than being shot upwards first and then falling to the ground. Have you ever tried to spray your friend with a water house? This sideways explosion was like shooting a water hose directly at your friend rather than aiming it upwards first and hitting your target on the way down. Today, there is a dome of magma where the volcano's side blew out. The dome is building up and one day it will fill in the volcano so that it will be as if it never erupted.

In all, the Mount St. Helens eruption not only killed 57 people but also caused hundreds of millions of dollars in property damage! Over 200 homes were wrecked and nearly 185 miles of paved roads were lost. You might also think that volcanoes erupt just lava. But Mount St. Helens erupted ash, rock, and debris. There was so much ash in the air that in Yakima, a town east of the mountain, day literally turned to night!

The blast was so powerful that it was the same as exploding 10 million tons of dynamite! It blew down trees, which fell like matchsticks in the path of the explosion. Entire forests were wiped out in a matter of minutes, and mudflows wiped out houses as if they were made of paper.

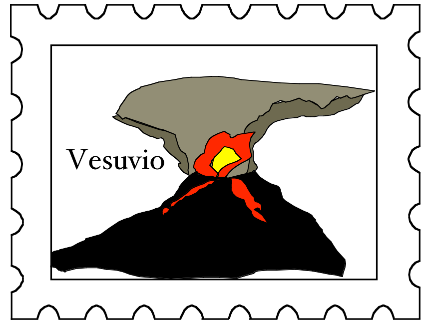
Scientists advised people to leave, and areas close to the mountain were restricted. However, no one knew when the blast was actually going to happen, and some people were stubborn about leaving. Thankfully Ranger Adams listened when the scientists gave the evacuation order. He and his family moved to a safe zone about 65 km away. His entire office and home were swept away by the blast in the first couple of seconds. How scary is that!

Ranger Adams has told me that no one really expected Mount St. Helens to explode the way it did. For one thing, as early as the 1800s, Native Americans in the area had reported ashes, steam, and small amounts of lava pouring out of Mount St. Helens, and they had witnessed many eruptions, none of which were as big as this one. In addition, earthquakes are common around these parts, even of the magnitude that triggered the blast. For example, just last week, there was a small earthquake a little bit north of here that woke me up in the middle of the night!

I hope that some day you can observe Mount St. Helens and experience a part of American history! I'm actually very proud to have such a famous site right next to me – I can go visit the area often, while most people travel hundreds of miles just to get a glimpse of it. If you ever do visit, be sure to bring your raincoat and lots of extra clothes. It rains buckets up here!

Keep in touch!
Brendan Harrison
46°N 122°W

Mt. St. Helens



Buon Giorno!

My name is Benito and I live in Naples, a large city in Italy that is a little bit west of one of our country's two giant volcanoes, Mount Vesuvius (Mount Etna, located on the island of Sicily, is the other). It is my job to tell you all about this 1,280-m high (4,202 ft) mountain that is now about 17,000 years old.

Before I give you an introduction to the area, let me first ask you a question. Have you heard of the twin cities of Pompeii and Herculaneum? If they sound familiar, it's probably because they're famous for being destroyed by Mount Vesuvius back in the year 79 AD! Pompeii, which is about five miles from the volcano, was totally buried by hot gas, rock, and ash flows that probably rushed toward the town at speeds of over 160 kilometers per hour. Can you imagine that? What's so interesting about Pompeii and Herculaneum is that we didn't find out that these cities even existed until the 17th century – a gap of over 1600 years! And it wasn't until recently that we figured out the story behind what happened.

So the story goes something like this: at about midday on August 24th, 79 A.D., clouds of rock and ash erupted from Mount Vesuvius, billowing up to 32 kilometers into the air. It was around midnight when these clouds collapsed and sent hot gas, ash and lava down the mountain, and buried Herculaneum with 23 meters of debris! By the next morning, Pompeii was gone too. When archaeologists uncovered the ruins of the two cities, it was like time had stood still. Dogs were chained to posts, loaves of bread were in ovens, babies were in cradles, and meals were still on the table. Two cities were preserved in stone by Mt. Vesuvius. We know so much about what happened because of the written account of Pliny the Younger, a survivor of the blast whose uncle died in the tragedy. He wrote about the events in a letter to a historian.

Interestingly, not many human remains were found in the two cities. For years after finding the ancient cities, scientists believed that the people feared the mountain and so most people tried to escape it. In 1982, my friend's dad, who is an archeologist, helped uncover the remains of hundreds of human skeletons that were all crammed together at the ancient sea wall. Hundreds of people died trying to escape the rushing hot debris. Very sad, if you think about it!

But our townspeople are far from being scared, since the last time Mount Vesuvius had a major eruption was about 1,000 years ago (we had minor eruptions from 1913 to 1944). Scientists monitoring the volcano see no evidence of an eruption at this time, but it is always a possibility in the future. There are also lots of volcano-related earthquakes in the region, so we know that things are still moving and changing.

My aunt always refers to Mt. Etna and Mt. Vesuvius as the sister volcanoes with opposite personalities. Some call Mt. Etna the "gentle giant," but Mt. Vesuvius is a much more dangerous

Old photo of Mt. Vesuvius erupting.
http://volcano.und.nodak.edu/vwdocs/volc_images/img_vesuvius.html

and deadly volcano. Mudflows and lava flows have destroyed cities and killed thousands of people.

Despite the possibility of volcanic eruption, this area is densely populated. People have lived here for thousands of years, and they still choose to live here. Since the volcano hasn't been a threat recently, people have no trouble settling in and living around the mountain. In fact, we get tons of tourists around here that want to see the cities of Pompeii and Herculaneum since they can't fathom a city being "lost" and going undetected for over a thousand years. I don't blame them!

People also come to live at the base of Mt. Vesuvius because the land is great for farming. The plants do well in the soft, nutrient-rich soil and the Mediterranean Sea provides wonderful seafood. My mother makes a great dish with shrimp.

If you ever visit both Mount Etna and Mount Vesuvius, you will see a lot of similarities in the geology of the two areas. This is no coincidence, of course, when you see how close together these two huge volcanoes are. Etna and Vesuvius are two of Italy's four active volcanoes. But Etna and Vesuvius are by far the most popular and well-known of the four.

If you ever come to visit, we could also take a tour of Rome! You'll get to see the Vatican, the Coliseum, and all those other famous sights.

Hope that helped!
Benito Del Piero
41°N 14°E

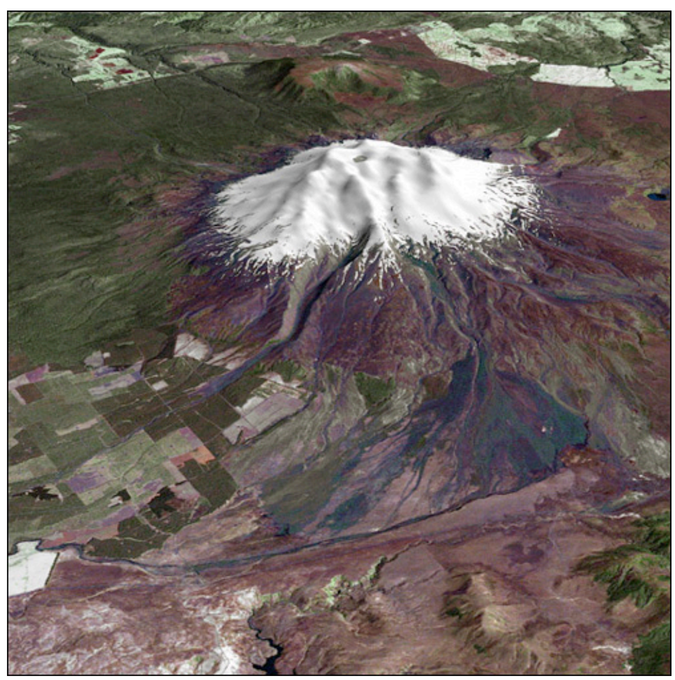
Good day mates!

My name is Cate and I will give you a quick description of the beautiful country of New Zealand – my home and birthplace! If you have no idea where New Zealand is or what it looks like, our country is made up of two main islands (North and South island), which are separated by the Cook Strait. A smaller island, Stewart Island, is located off the southern coast of South Island. Many other smaller islands are in the area as well. We are in the South Pacific Ocean right next to Australia, which I'm sure you're all familiar with. The only landmass south of us is Antarctica!

Let me tell you about my family first. Our home is in the coastal city of New Plymouth. Our town is of modest size; there are close to 45,000 people here, and it is a very recreational city. Since we're right by the ocean and a huge snow-capped mountain called Mount Taranaki (also called Mount Egmont), people can surf, water ski, and snowboard all in the same day!

I'm sure you're anxious to hear about the geology of our country. We have a ton of volcanic activity here, more than any other country in the world. We have over 400 volcanoes that have been active in the past 10,000 years. That is four times as many volcanoes as any other country has. Mount Taranaki, a 2,440-m (8,000 ft) volcano located an hour away from my home, is one of them. Mount Taranaki is known to be a young volcano that is now dormant—it hasn't had any activity in 250 years.

http://earthobservatory.nasa.gov/



Some of the other more famous volcanoes on North Island are Mount Ruapehu, an active volcano that is the tallest on North Island at about 3,000 m (10,000 ft). North Island is also home to the Taupo volcanic zone, a row of volcanoes that stretches southward from White Island. Mount Ruapehu is at the southern tip of this zone. Small eruptions occur in this zone all the time. In fact, when I was visiting some relatives up in that area in 1996, Mount Ruapehu erupted. New Zealand's most powerful explosion also happened in this zone, when Mount Tarawera exploded in 1886 in a blast that was thirty times more powerful than the Mount St. Helens blast that is famous in the United States! In this explosion, a series of small earthquakes was followed by a gigantic earthquake. Eventually, all three of Mount Tarawera's peaks erupted, sending ash and smoke thousands of meters into the air. The blast was so loud that many in New Zealand and in the capital city of Auckland (also on North Island) thought that our country was being invaded by Russian warships!

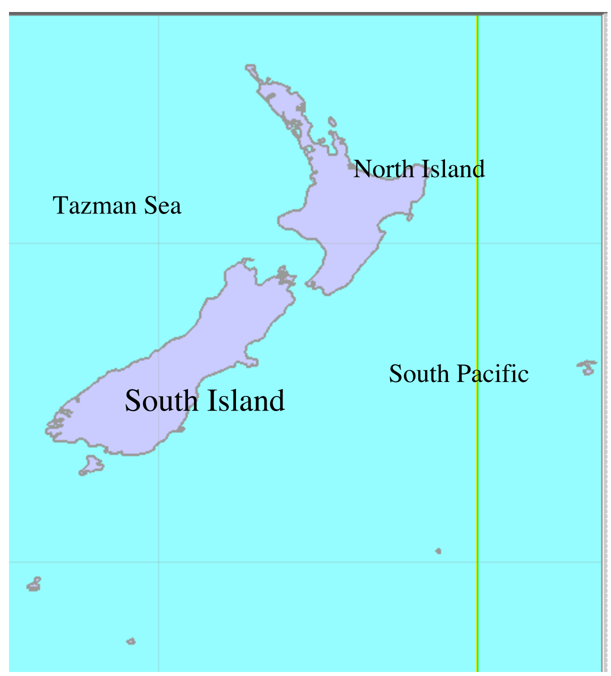
South Island is by far the more mountainous island. If you were to fly over the island, you'd notice that the island is divided down its length by a mountain range called the Southern Alps. The tallest peak in this range is also the tallest peak in the entire country – Mount Cook, which is in the center of South Island. My aunt works as an environmental scientist for Mount Cook National Park. If you ever decided to visit, she and her team could show us around the 3,750-m (12,300 ft) tall mountain that is a very popular tourist attraction as well as a common mountain climbing challenge. Mount Cook has two large glaciers occupying its slopes, called the Tasman and Hooker Glaciers. These glaciers can be up to 27 km long and over 3 km wide!

There's also something exciting to witness when we get to the Southern Alps. My cousin runs a commercial gliding site up in the mountains. Since the Southern Alps are perpendicular to some strong winds, it people can go gliding above the peaks!

One great point of interest is a couple of wilderness preserves; New Zealand is home to many different kinds of endangered species. New Zealand is a country known for a lack of predatory animals, so oversized and relatively primitive species have been able to survive. The prime example of this is the cacapo, a nocturnal parrot that can't even fly! We're also home to flesh-eating snails and the only reptile survivor from the dinosaur age – the Tuatara. But if you're looking for land mammals, the only ones you'll see in our country will be bats – and yourselves, of course.

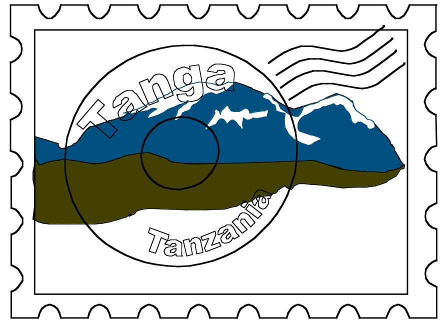
I hope you can visit one day. New Zealand is one of the most picturesque countries in the world, known for its unspoiled landscapes and clean environment. We also have a unique culture, and if you like sports, try to watch a game of Aussie Rules football on television. It's not exactly like the kind of football you have back in the United States, but it's just as fun. So let me know if you ever decide to visit!

Sincerely,
Cate Philips
43°S 170°E



New Zealand

Jambo friends!



My name is Akili and I just said 'Hello' in Swahili, the native language of Tanzania. You must excuse me because I am quite tired from my most recent trip. I just came back from climbing the great Mount Kilimanjaro! But I cannot wait to tell you all about Tanzania, my homeland and birthplace.

My family lives in the town of Tanga, which is on the coast of the Indian Ocean. We're located in northern Tanzania and, with a population of over 200,000, our city is one of the largest in the country. We are in southern Africa, bordered by countries such as Rwanda, Congo, Mozambique. Kenya, Zambia and Malawi. The border with Kenya is about 80 km away from Tanga, which is nice because my grandparents live there.

Kilimanjaro! Notice the gradual slope. Easy to climb.
http://volcano.und.nodak.edu/vwdocs/volc_images/img_kilimanjaro.html

But let's get back to my most recent adventures at Mount Kilimanjaro. I've been to the national park to take pictures, but this is the first time I've felt confident enough to actually climb. Reaching the summit was one of the greatest feelings I've ever had! The mountain is a volcano that is almost 6,100 m (20,000 ft) tall! It's the highest point in Africa and one of the tallest in the world. Mount Kilimanjaro seems to rise out of the grasslands. The base is 80 km on one side and 40 km on the other.

So you probably think I'm some kind of expert mountain climber who has climbed many tall and dangerous mountains before, right? Wrong! This is the first time I've ever gone mountain climbing aside from climbing some hills around my neighborhood. You see, Mount Kilimanjaro is known as one of the easiest tall mountains to climb. If you take one of the safe routes, any person of normal health can reach the top even without any mountain climbing experience. The only thing you have to be careful about is altitude sickness. But I know of tons of beginners who climb it all the time. In fact, 15,000 people try to reach the top of Mount Kilimanjaro every year, and nearly half of them are successful.

But you should know the background of Mount Kilimanjaro. The mountain is part of the great African Rift Valley, a north-south stretch of land in Africa where the land is splitting apart and cracking! A rift is any kind of crack in the land. The land on either side of the crack is moving apart. In fact, many scientists think the continent will one day split apart and that the Indian Ocean will flood the valley, creating another ocean where the Rift Valley once was! But don't worry – if that does ever happen, it won't be for a few million years.

Mount Kilimanjaro is one of 20 volcanoes in the southern end of the African Rift Valley. Some of the other more famous mountains are Mount Kenya, Mount Karisimbi, Mount Elgon and the Crater Highlands. This entire area is buzzing with seismic activity. Earthquakes happen here quite a lot, and volcanic eruptions are always feared (although not many people think Mount Kilimanjaro will erupt anytime soon). My mother, who is a geology professor at the national university, says that there are those who are scared the volcano might collapse and trigger a violent eruption similar to the 1980 eruption of Mount St. Helens in the United States. I hope this is not the case, but landslides and minor collapses have been reported on one of Kilimanjaro's peaks. There hasn't been any official recorded history of volcanic activity, so what Mount Kilimanjaro is going to do is anyone's guess!

The African Rift Valley is also home to lots of lakes. Because of the geologic activity underneath them, the waters on the surface are warm and salty. One of these lakes I like to visit is Lake Bogoriam, which is located in eastern Africa. My older brother, Emeka, often comes with me on these trips. He works at the national university with my mother and he knows a lot more about the rift valley. He says that this lake is famous because it is home to countless flocks of pink flamingoes! Have you seen a flamingo up close before?

I started my climb today in the mists of the equatorial jungle. As I climbed the temperature dropped, there was less water in the air, and the plants changed. When I reached the top there was snow. That is the only place we find snow and ice around here. It felt like a little bit of the Artic standing high above the tropics.

I can't wait to get my pictures developed from my trip up to the top of Kibo, which is the name of Mount Kilimanjaro's highest peak. From Kibo you have great views of the grasslands of Tanzania. Once you reach Kibo, there's an icy mile-wide crater surrounded by steam. The whole place smells like rotten eggs from the sulfur! You definitely need to see the pictures!

So if you ever decide to visit, be sure to brush up on some Swahili phrases and get ready to see one of the tallest mountains in the world – and perhaps the site of the world's next ocean!

Sincerely,
Akili Ngwonko
3°S 37°E

Hello friends,

Take a look at the nearest map of the Atlantic Ocean. Look at that vast body of water that separates Africa from South America. See anything there? At first glance, you just see a lot of blue water, huh? But if you take a closer look, you'll see a small little island about 1,900 km from the west coast of Africa called Saint Helena Island. My name is Jeremy, and I was born on Saint Helena and have lived here all my life! I heard you're learning about our island, and I am happy to tell you a little more about this place.

If you see pictures of St. Helena, you probably won't think too much of the landscape. There aren't any extremely high peaks anywhere nearby. Our highest peak is Diana's Peak, which is only about 820 m (2,680 ft) tall. That's less than one-tenth the height of Mount Everest! You'll see many jagged peaks dominating the coastline of the island and extremely steep, rocky cliffs overlooking the shore. You can't see any really high peaks because we're actually standing on top of a gigantic volcano! From top to bottom, this volcano measures 4,220 m (14,000 ft), reaching all the way to the bottom of the ocean floor. So you can't just consider what's above the water because there's a whole other world of St. Helena in the deep ocean. In fact, the total volume of the volcano is about 20 times that of Mount Etna, which is Europe's largest volcano.

Although we're on top of a huge volcano, we haven't had any kind of eruption in six million years. Geologists in the area say that they think most of the rock on St. Helena came from the volcanic eruptions of two volcanoes on opposite sides of the island – one on Flagstaff Hill in the north, and the other in Sandy Bay Valley in the south. This, of course, happened millions of years ago.

The island is very small! We only have about 7,000 residents here, and that's probably because the land itself is pretty compact. The island is only about 17 km long and 10.5 km wide. And like I said before – we're pretty much in the middle of nowhere. Back when I was younger, I used to fantasize about being a long distance swimmer and swimming out to the next island. Once I found out that the next closest land was over 100 km to the northwest (Ascension Island), I quickly gave up on that dream. Most people arrive at our island by way of the one airport near our capital city – Jamestown.

Coastal areas of our islands are different from the middle parts of the land. The interior of St. Helena isn't barren. It's full of vegetation, and there's a pretty good variety of different ecosystems – forests, grasslands and even a few valleys where there are streams of running water. There are even a few spots where the land is flat, such as Francis Plain. These areas of flat land are sometimes right next to steep cliffs that are up to 300 m high. I've done quite a bit of exploring, including climbing some treacherous, steep cliffs. People who visit us all have different opinions of the island. One lady said it was the harshest and most barren place she'd ever been to and one man said it was beautiful and green. Another lady just said she was confused! I think you have to see the entire island to make a fair judgment.

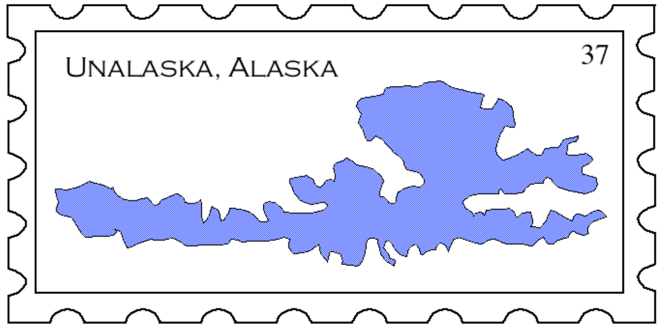
As for my family, we live in Jamestown, which is right in the middle of James Valley. Our island is pretty dry for the most part, and the climate is pretty mild. Even on this small island there is a difference in climates as you go from our town to Longwood, a town at higher elevations in the east.

Speaking of Longwood, a tourist never leaves without visiting our most famous point of interest – a prison cell in this small town where Napoleon was held captive for six years until his death in 1821. Napoleon was a great French general who was eventually defeated after nearly conquering all of Europe! I think my family and I go to this landmark at least once a year and my brother, Eric, works there as a tour guide. Our island was used as a holding place for prisoners of war also. After all, there's nowhere to escape to on this island!

Other places that tourists enjoy are Castle Rock and "the Barn," two jagged peaks on the coastline of St. Helena. There are also farms on the hillsides, as well as flax plantations. If you don't know, flax is a type of flower that is made into textile fibers. And just in case you ever decide to visit in the future, don't worry about any kind of language barrier –- English is the official language here, since we're part of the British Commonwealth!

See you soon,
Jeremy Stevens
16°S 6°W

St. Helena Island



Qanuipit friends!

My name is Kirima, and I'm a lifelong resident of the Aleutian Islands; I just said "hello" to you in Inuit – my native language! I have been instructed to tell you about the Aleutian Islands since you will be learning all about my homeland. I am so excited to tell you about the Aleutian Islands, especially since some of my relatives living in Anchorage are coming here for the first time!

Most of the Aleutian Islands are part of Alaska, so we are all Americans here, just like you guys! The islands are simply an extension of the Alaskan Peninsula, and if you look at the map, the Aleutians are sort of like a bridge between Asia and North America. In fact, the extreme western Aleutian Islands are part of Russia. I'm sure you think that's really weird! We had some visitors here near our neighborhood the other day that thought it was really strange how Russia is so close even though they were still on American soil.

The Aleutian Islands are divided into four main groups of islands – the Fox, Andreanof, Rat and Near. 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. This curved formation is due to the volcanic cracks that correspond to the location of these islands. The islands all formed as a result of volcanic activity that occurred many years ago. These curved formations of islands are a common occurrence all over the Pacific Ocean because volcanic activity exists all around the edges of the ocean. This is commonly known as the Pacific Ring of Fire.

There is a volcano called Mount Makushin, which is 1,735 m (5,690 ft) tall. Mount Makushin is visible from our house. We live in a settlement called Unalaska, which is the largest community of people within the Aleutian Islands. Unalaska is an island of about 4,300 people, which is about half of the entire Aleutian Islands population. The Native American population, of which I am a part, makes up about one-third of the total number. My parents, my brother Jordin, and I have been living here in the same house for as long as I can remember. Each morning, I walk out and climb on top of the hill nearby to see the mountain. In fact, my name Kirima means "hill" in the Inuit language. Cool, huh?

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.

The Aleutian Islands

One of the coolest geological features of the area is the formation of new landforms. As a result of underwater volcanic eruptions, the two recently formed volcanic islands of Bogoslof and Grewingk now lie a little bit west of Unalaska. These new islets (very small islands) formed in the past 250 years, with Bogoslof appearing in 1796 and Grewingk following nearly a century later in 1883. How weird is that – to wake up one morning and see that there's *new* land in the ocean?

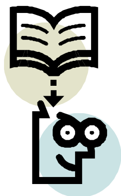
Many of the volcanoes on the Aleutian Islands are still active, and my mother, who is a geologist with the state science bureau, regularly goes from island to island to study them. Earthquakes are also a common occurrence in the surrounding area. They become more frequent and larger just before a volcano erupts.

But think about coming here to visit! For one thing, in the summer months, the sun is out for almost 24 hours! I bet that never happens where you live!

Talk to you soon!
Kirima Chinqua
54°N 166°W

I found this great picture of Mt. Cleveland of the Aleutian Islands.
http://www.avo.alaska.edu/avo4/atlas/Cleveland.htm

The Aleutian Islands



WHAT'S THE POINT?

You now have collected observations about earthquakes and volcanoes and been introduced to the earth structures you will study as part of the NESS mission.

When an earthquake shakes the ground or a volcano blasts, what is happening?

Why? Where do you think the ground is moving to? What changes are those movements causing?

How would you explain why those changes are happening? What would you want to observe to support your explanation?

Lesson 2
Topography of Earth Structures

What have you learned so far?
In Lesson 1, you observed and tried to explain earthquakes and volcanic eruptions. Your class has been invited to be part of a mission to look for patterns in earthquakes and volcanoes. Your class also decided that earthquakes and volcanoes indicate that something is moving and changing. You have also learned a little bit about several different earth structures.

Some of these places might be familiar and some you may not recognize at all. When someone treks to the highest peak on the planet, it makes the headlines in the news. But a small volcano in the vast ocean does not get coverage in the news. Yet, all earth structures are important parts of the Earth's crust. How are these earth structures the same? How are they different?

In this lesson, you will learn more about your earth structure. You will also compare it to other earth structures using topographic maps, which are sometimes called topo maps.

Activity 2.1: How High and How Low
Overview:
In this activity, you will look at maps of earth structures. You 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.

Procedure:
1. **How are elevation and depth represented on this world map?** Look at an Elevation and Depth Map of the World using *MyWorld*. Your teacher will display this map for the class. Use the following questions to guide your observations:
    - Where on the map are the high peaks? How do you know?
    - What does a mountain range look like on the map?
    - Where are the highest peaks on these mountains?
    - Where on the map are the deepest parts of the ocean? How do you know?
    - Where is the water shallow?
    - How is sea level represented?
    - Where is the dry land close to sea level?

2. **How are elevation and depth represented on this region map?** Look at an Elevation and Depth Map of the Aleutian Islands using *MyWorld*. Your teacher will reposition the map to

take a closer look at Alaska. Use the following questions to guide your discussion and observations.

- 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?

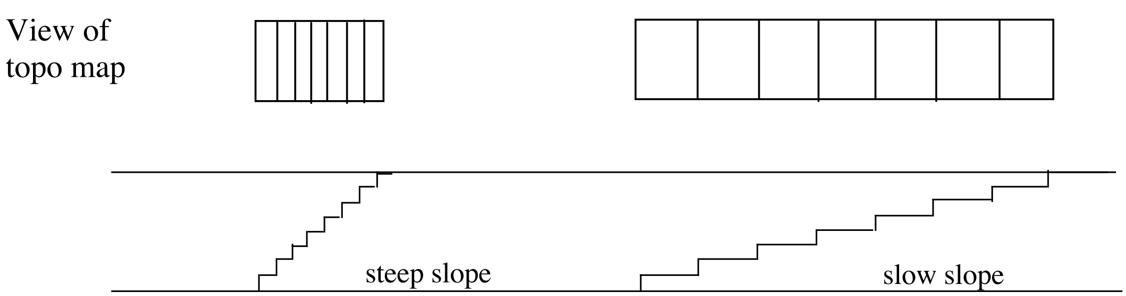
Stop and Think

Answer this question in your science journal or on your worksheet.

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?

3. **Look at a topographic map of the Aleutian Islands**. This map is in your Student Text after this lesson.
    - How are elevation and depth represented on this map?
    - What does the key tell us?
    - Where is there a high elevation?
    - Where is there a low elevation?
    - Where is the ocean deepest?
    - How is sea level represented on the map?

4. **How is a change in elevation shown on the topographic maps?** A topographic map is drawn from a bird's eye view – from above the land. Think of the lines on the map (called contour lines) as steps. When the lines are close together the elevation of the land is changing rapidly in a short distance. Both of these slopes rise the same distance, but the one on the right changes more gradually.



Imagine a building with two stories. The illustration showing the steep slope is like getting to second floor of that building with a ladder: a steep climb in a short distance. In contrast, 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 the building. Look at the picture below:

Which of these would be easier to climb? Why?

Using the map of the Aleutian Islands, answer the following questions:

- According to this map, where might you have a difficult time climbing?
- According to this map, where on this map might you have an easy time climbing?
- How did you determine the answer to these two questions?

5. **Color the topographic map using similar colors to ones used in the Elevation and Depth maps we looked at in *MyWorld*.** Use greens, yellows, and browns and grays for land above sea level. Use blues for the land below sea level. Notice how the colors help you see the shape of the land.

Reflection Question

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

Activity 2.2: Building 3-D Models

Overview:
In this activity, you will build a three-dimensional model of your earth structure from the topographic map. You will then compare different earth structure models.

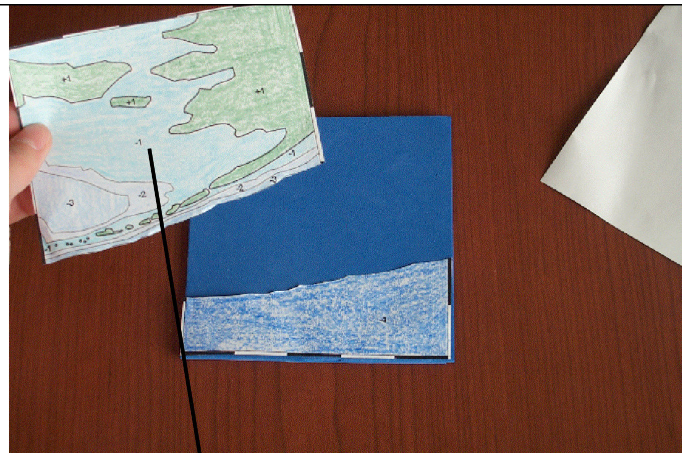
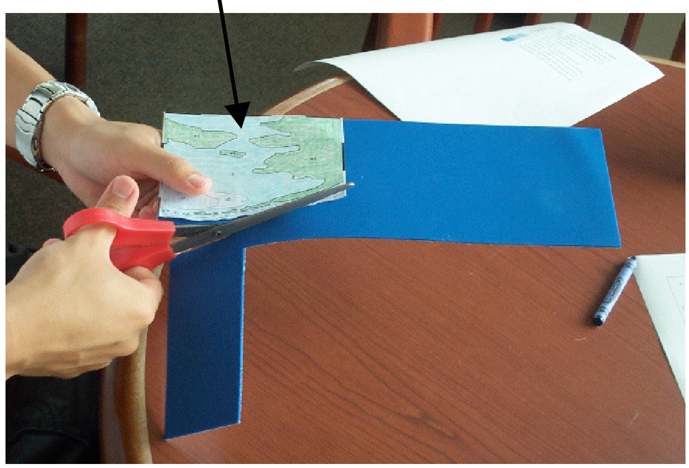
Procedure:
1. **Build a three-dimensional model of the earth structure from the topo map.** Follow the instructions below to build a three-dimensional model of your earth structure using the topographic map from the previous activity. The example here is for the Aleutian Islands. The lowest elevation is –4.

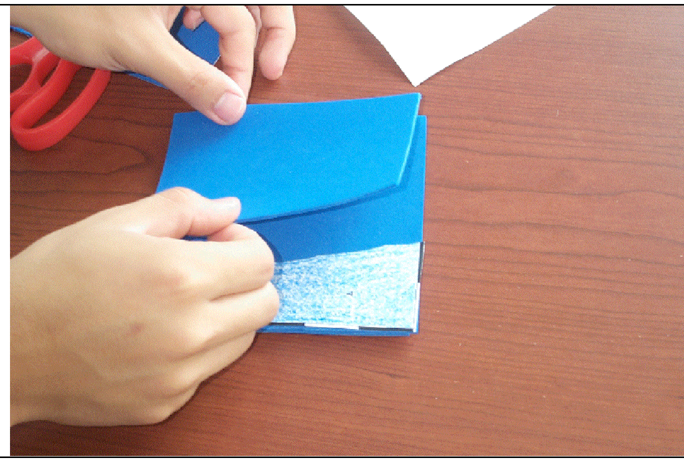
   The main steps in creating the model are:
   1. coloring the maps by elevation
   2. cutting out foam for each level
   3. cutting out map areas one by one
   4. stacking and gluing the layers until all are done

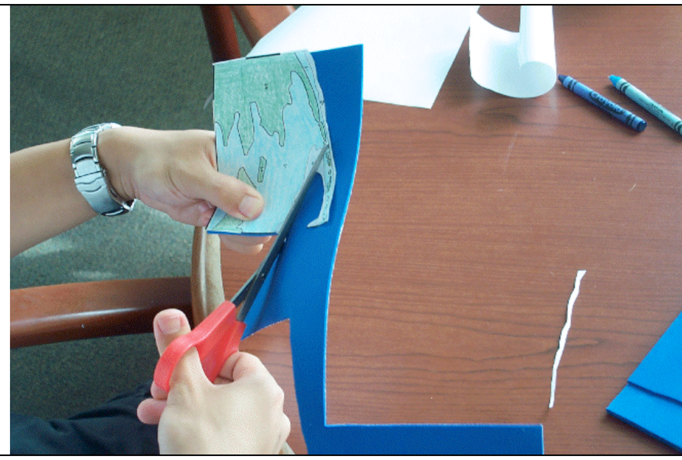
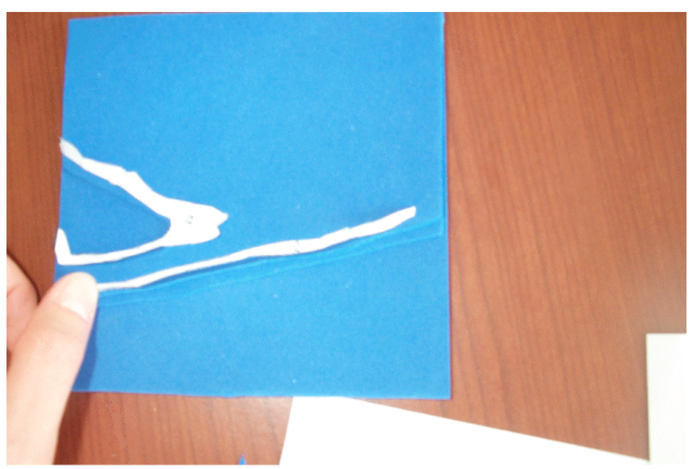
Making a 3-D Model from a Topographic Map

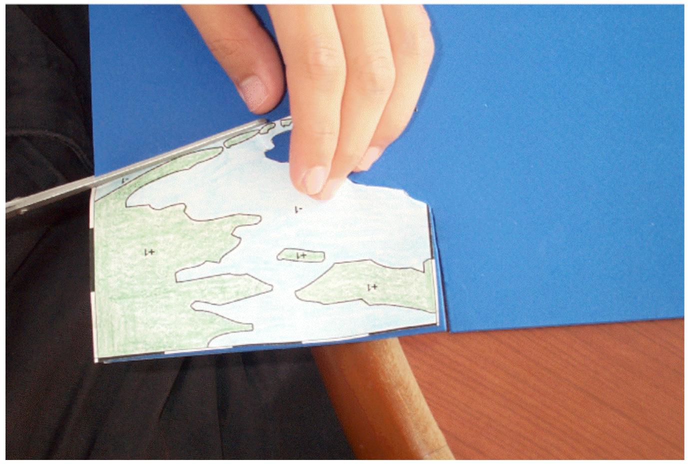
Materials:
2 Copies of the Topographic Cutout Map Worksheet
Modeling material in two different colors
Scissors
Glue stick

1. Carefully cut out the colored map of ONE member of your group. Save the other maps!!	
2. Trim the foam (or other material) until it is exactly the same size as the map you just cut out. This is the -5 layer. ** If your map does not have a -5 layer repeat step 2 until you reach your lowest depth layer. For example, the lowest depth for Iceland is -2 so four layers are needed to represent -5, -4, -3 and -2 layers. So you will have 4 whole squares as your bottom. Once enough layers are built up in the model to represent the DEEPEST elevation on the map, go on to step 3. For Alaska, there is no –5 layer; that full piece of foam is the bottom. –4 is the lowest elevation, so that layer remains whole too. The next step describes what to	

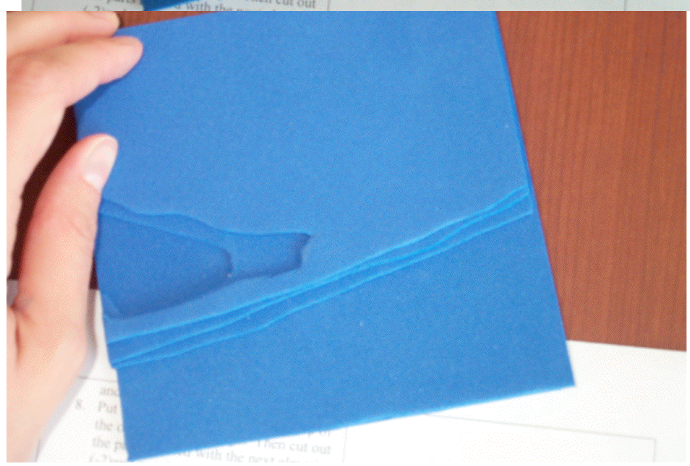
do when you have reached your lowest elevation and are ready to begin cutting out pieces.	
3. Carefully cut out ONLY the part of the map that's the deepest elevation. Lay this piece of paper on top of the square for that elevation, in the spot where it goes on the map. (Use the other pieces to see exactly where it should go.)	
4. Take what is left of your map and trace and cut out a piece of foam in that shape. This is the shape of the next lowest layer on your map. In this example, you cut out a piece of foam for everything above –4.	

5. Place the foam piece in the appropriate place on your model, on top of the lowest layer. Use the map pieces as a guide.	
6. From the remaining map, cut out all parts marked the next depth (-3)**. 7. Put these paper pieces from the map on top of the foam in the appropriate place.	

8. Take the other pieces of the map and carefully trace and cut out a piece of foam in this shape. For this example, this is the (-2) layer.	
9. Put these new pieces of foam on top of the others in the appropriate place. Glue together the foam pieces you have already completed.	
10. Take what is left of your map and cut the area marked the next elevation (-2) and put them on top of the foam. The white strip in the picture at the right are the paper map pieces labeled (-2).	

11. Repeat these steps for the remaining layers that are below sea level.	

This is what the model of Alaska looks like after cutting layers –5,-4,-3, and layer –2.



12. Now remove the sections labeled layer –1 from the paper map. All that remains is +1 and higher, which are above sea level. Switch to the other color of foam. Trace the patterns and place on top of the last layer of foam.

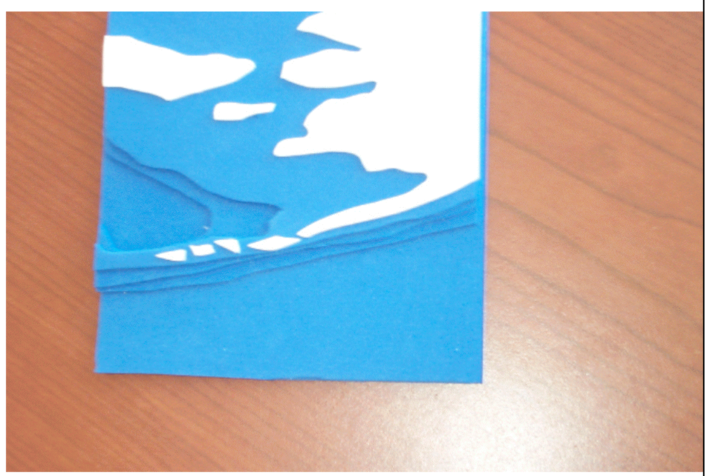
13. Glue the +1 layer down. Continue with the rest of the layers that are above sea level until you reach the top of your earth structure.	
This is what the finished model of the Aleutian Islands looks like. Notice the change in color or shading for the land above sea level.	

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 Question

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?

Activity 2.3: Comparing Earth Structures

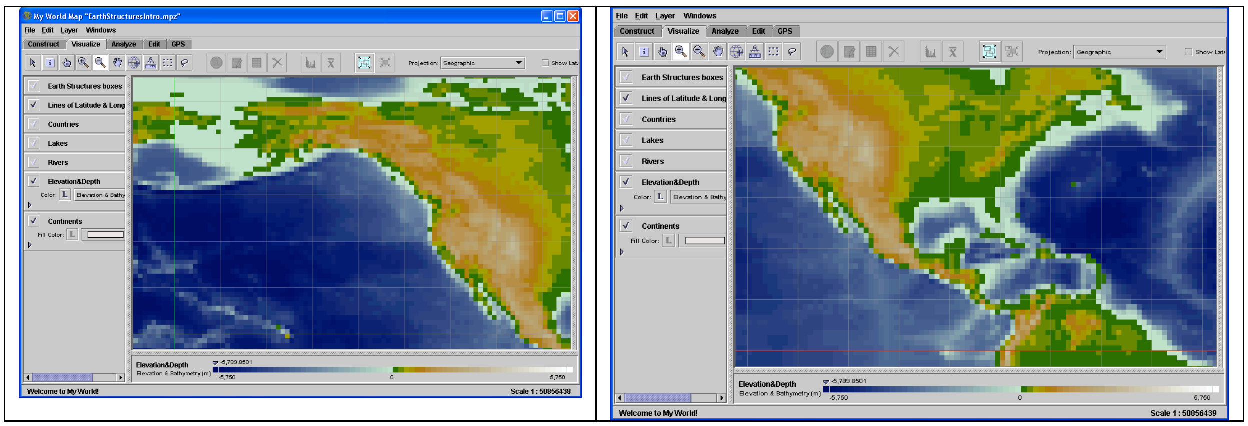
Overview:

In this activity you will use *MyWorld* to compare two earth structures and show any similarities and differences. You will also learn how to screen capture these maps on the computer and record your observations about…

Procedure:

1. **Compare the Aleutian Islands to another earth structure**. The other day in class you used maps to help describe the Aleutian Islands. How did you describe the Aleutian Islands?

Below are maps of the Aleutian Islands and the Caribbean Islands. Your teacher will show you these maps in *MyWorld* so you can compare them. How are they similar? How are they different?



2. **Compare two earth structures.   Show any similarities and differences such as:**
    - Elevation
    - Depth
    - Steepness
    - Area of mountains, flat land, deep water
    - Distance to water or land (near the ocean, far from a continent, etc.)

Your teacher will show you how to capture maps from *MyWorld* and write your observations in a word processor.

Reflection Question

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

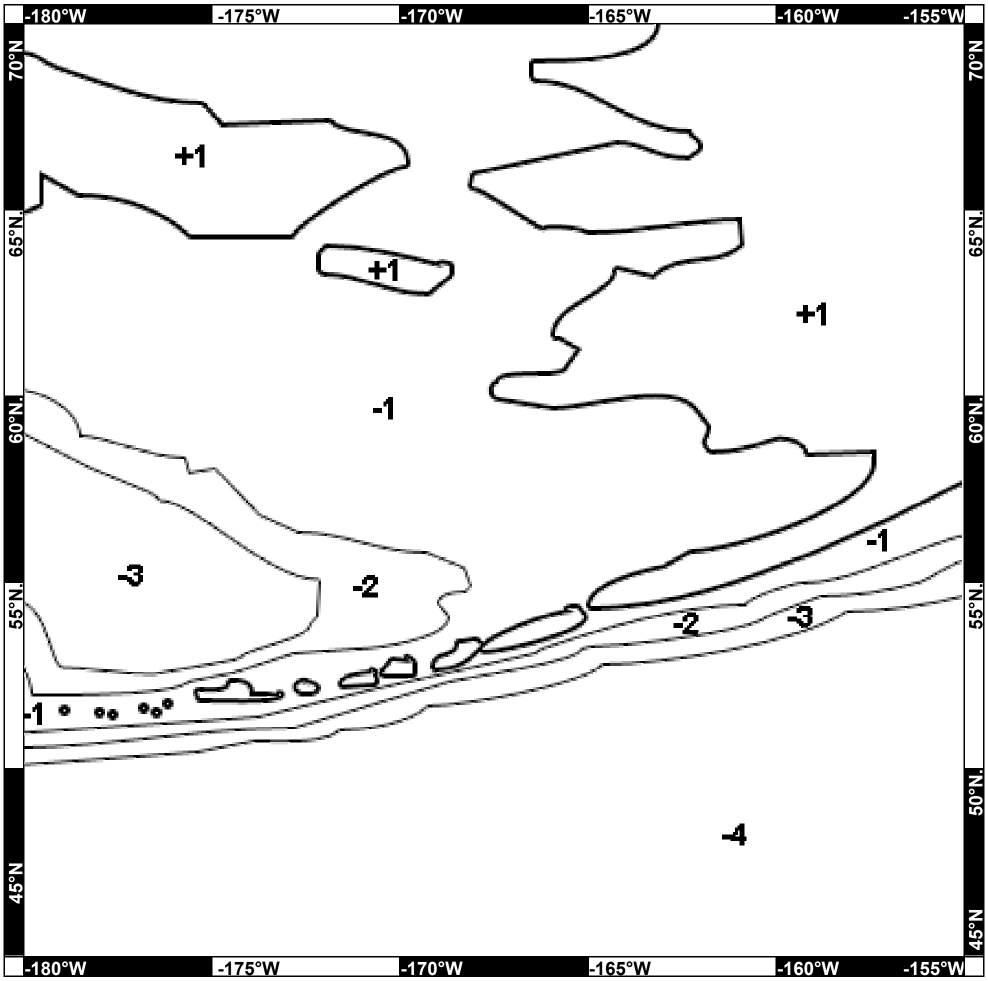
WHAT'S THE POINT?

Why do you think the earth structures are shaped differently?

Do you think there are differences in patterns of earthquakes and volcanic eruptions? Why or why not?

What patterns do you predict for earthquakes and volcanoes in your region? What helps you make these predictions?

Aleutian Islands Cutout Topographic Map



Elevation Key: Color in each number

+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

INSTRUCTIONS

- Pick a color for each elevation
- Color each number box →
- Color the map by number
- Use map for making a model

Andes Mountains Cutout Topographic Map

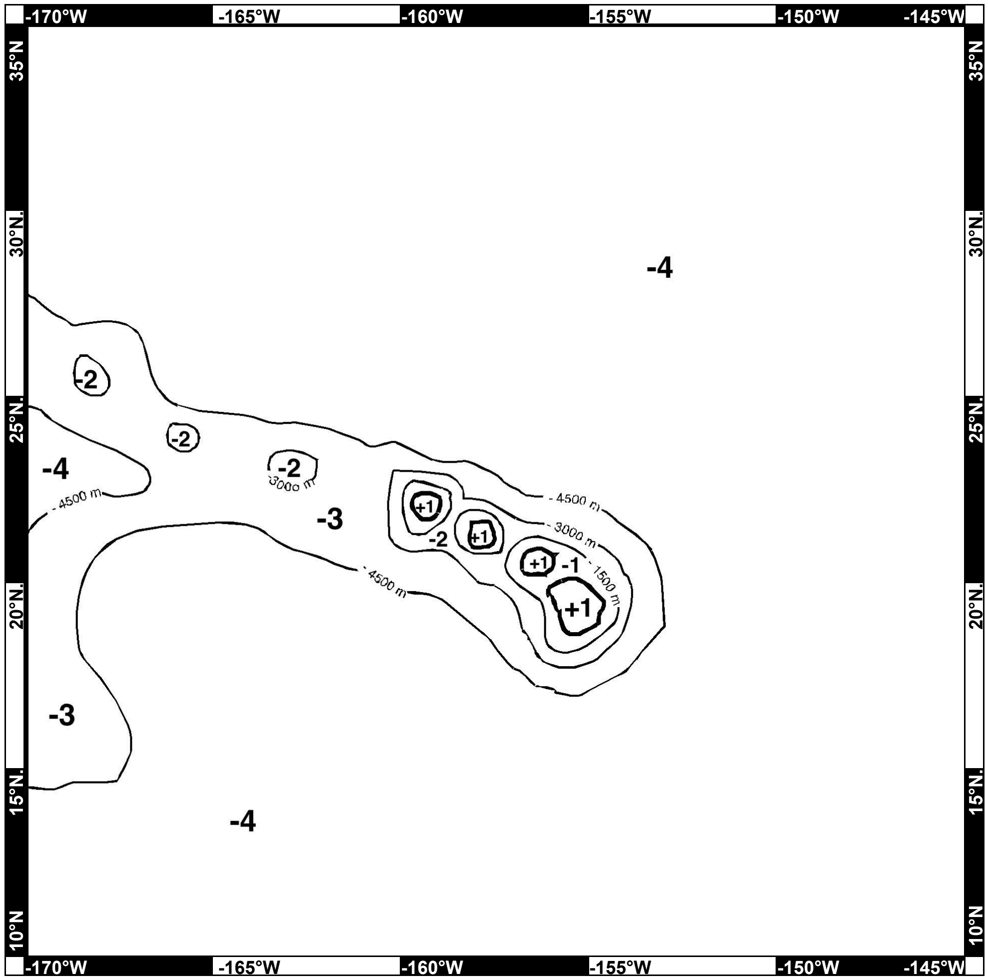
Elevation Key: Color in each number

+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

INSTRUCTIONS

- Pick a color for each elevation
- Color each number box →
- Color the map by number
- Use map for making a model

Hawaiian Islands Cutout Topographic Map



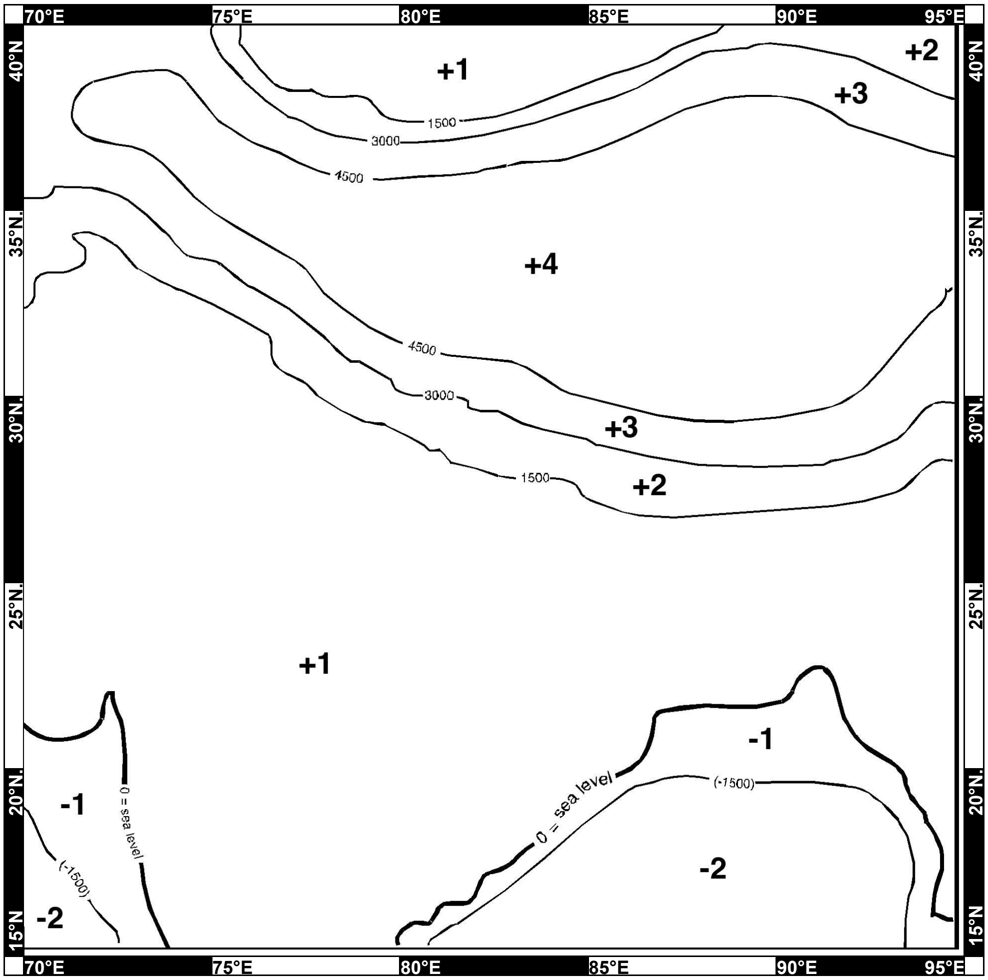
Elevation Key: Color in each number

+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

INSTRUCTIONS

- Pick a color for each elevation
- Color each number box →
- Color the map by number
- Use map for making a model

Himalayas Cutout Topographic Map



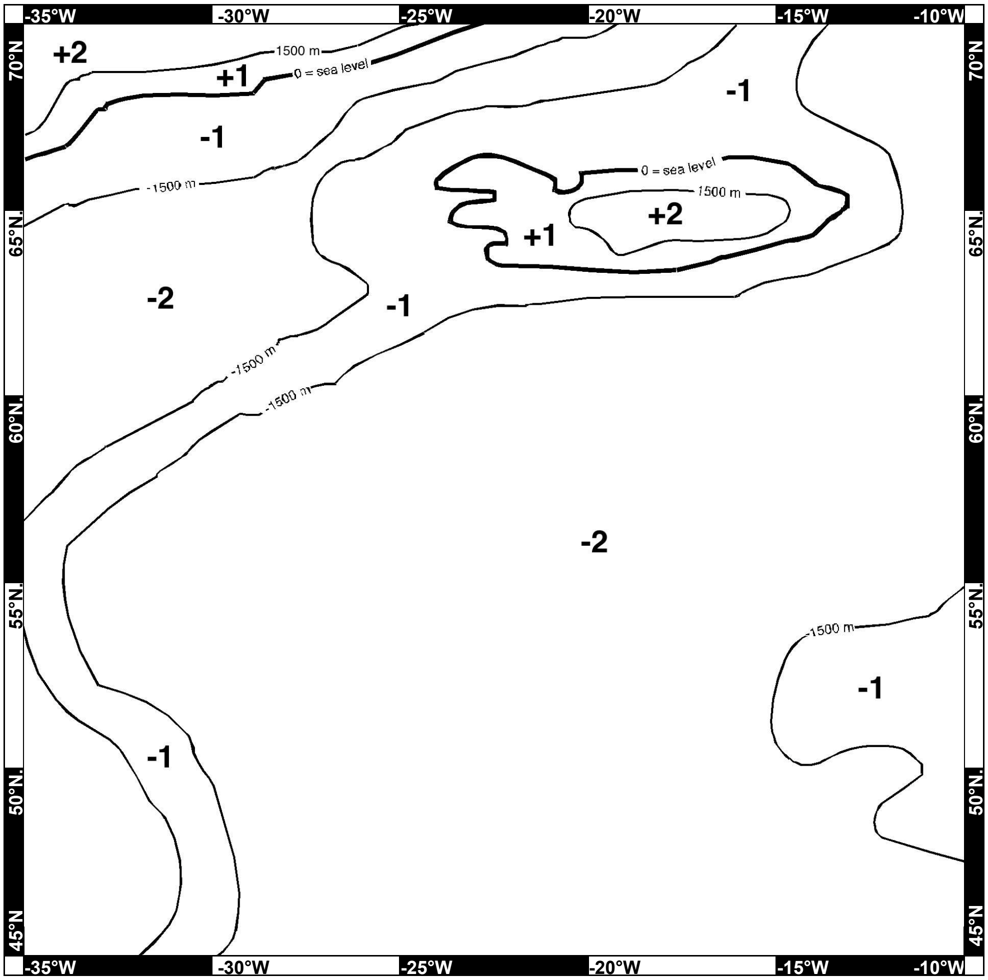
Elevation Key: Color in each number

+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

INSTRUCTIONS

- Pick a color for each elevation
- Color each number box →
- Color the map by number
- Use map for making a model

Iceland Cutout Topographic Map



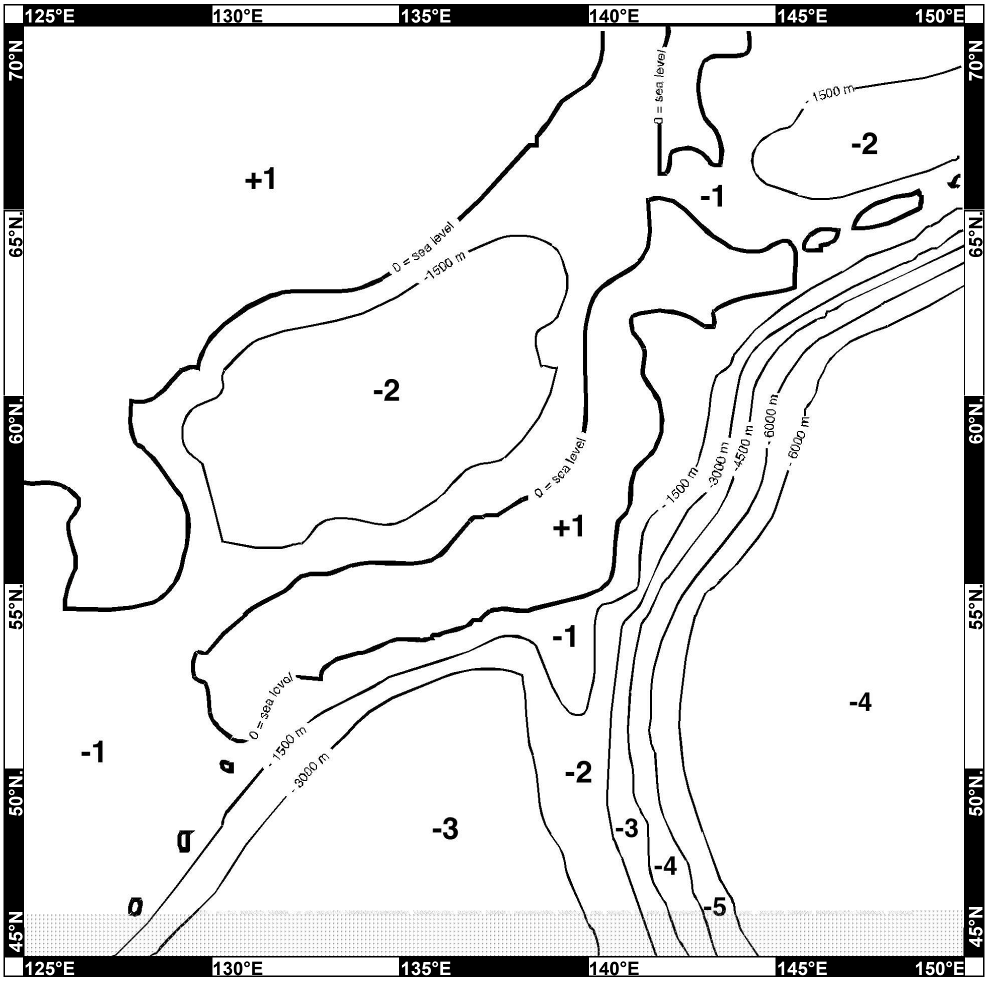
Elevation Key: Color in each number

+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

INSTRUCTIONS

- Pick a color for each elevation
- Color each number box →
- Color the map by number
- Use map for making a model

Japan Cutout Topographic Map



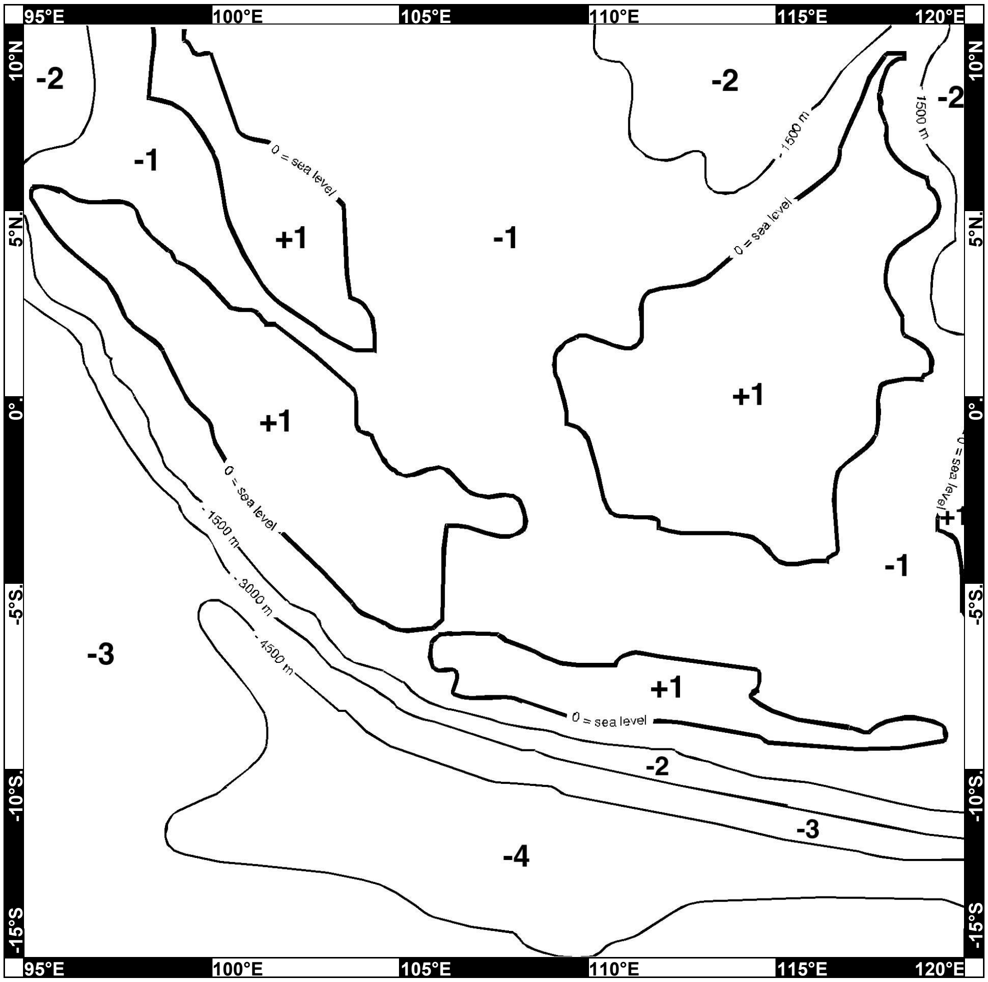
Elevation Key: Color in each number

+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

INSTRUCTIONS

- Pick a color for each elevation
- Color each number box →
- Color the map by number
- Use map for making a model

Java Trench Cutout Topographic Map



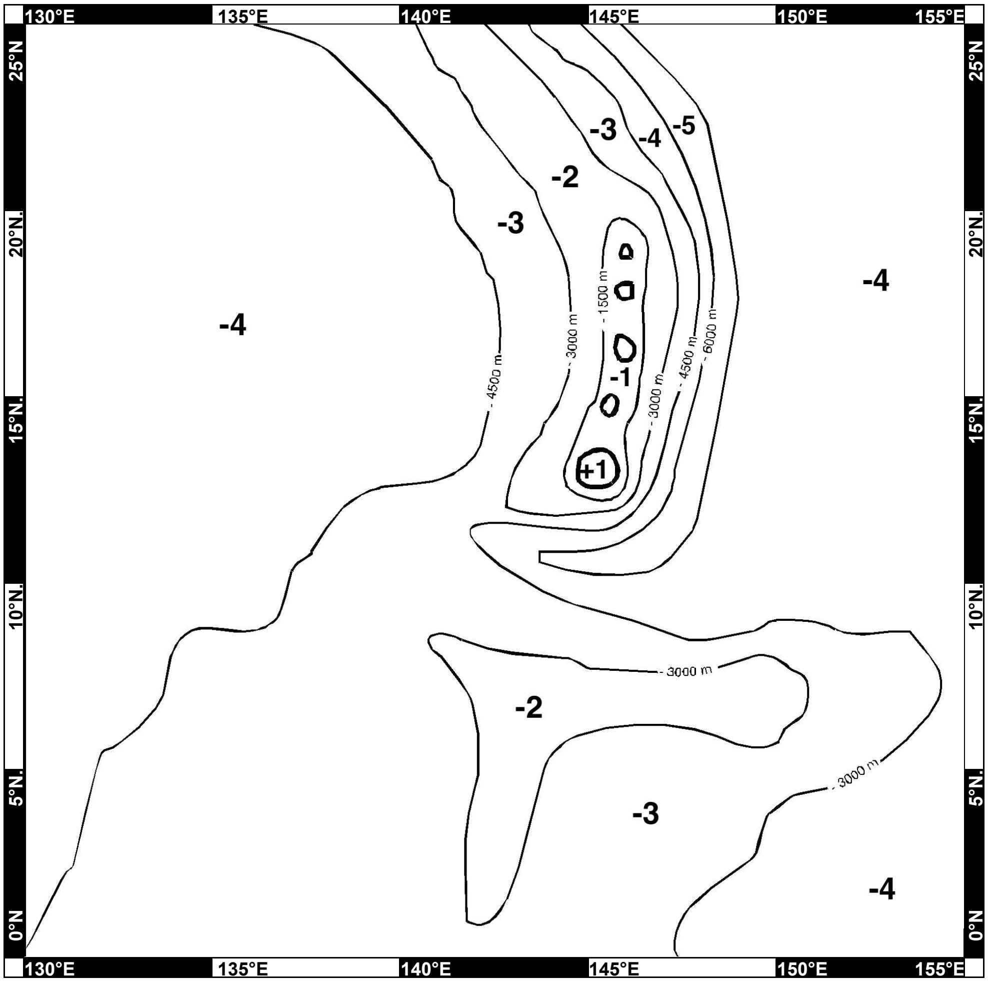
Elevation Key: Color in each number

+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

INSTRUCTIONS

- Pick a color for each elevation
- Color each number box →
- Color the map by number
- Use map for making a model

Mariana Trench Cutout Topographic Map



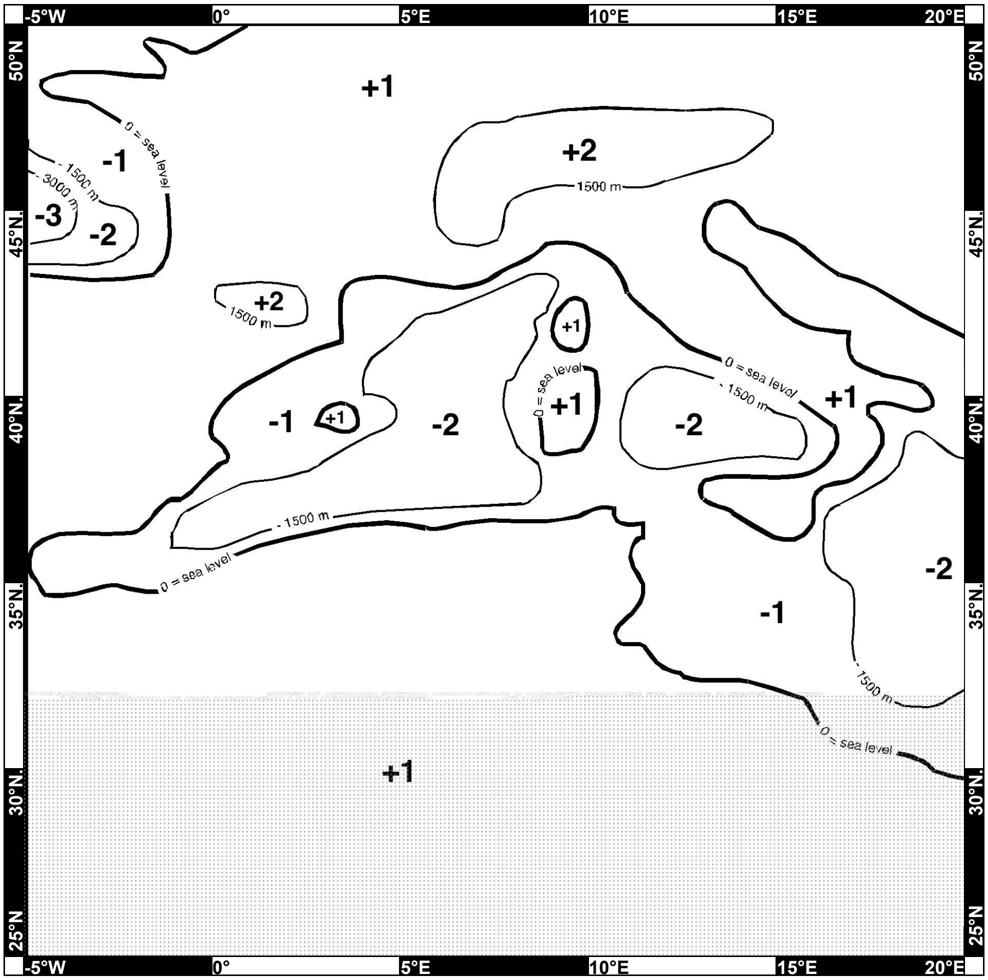
Elevation Key: Color in each number

+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

INSTRUCTIONS

- Pick a color for each elevation
- Color each number box →
- Color the map by number
- Use map for making a model

Mt. Etna Cutout Topographic Map



Elevation Key: Color in each number

+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

INSTRUCTIONS

- Pick a color for each elevation
- Color each number box →
- Color the map by number
- Use map for making a model

Mt. Kilimanjaro Cutout Topographic Map

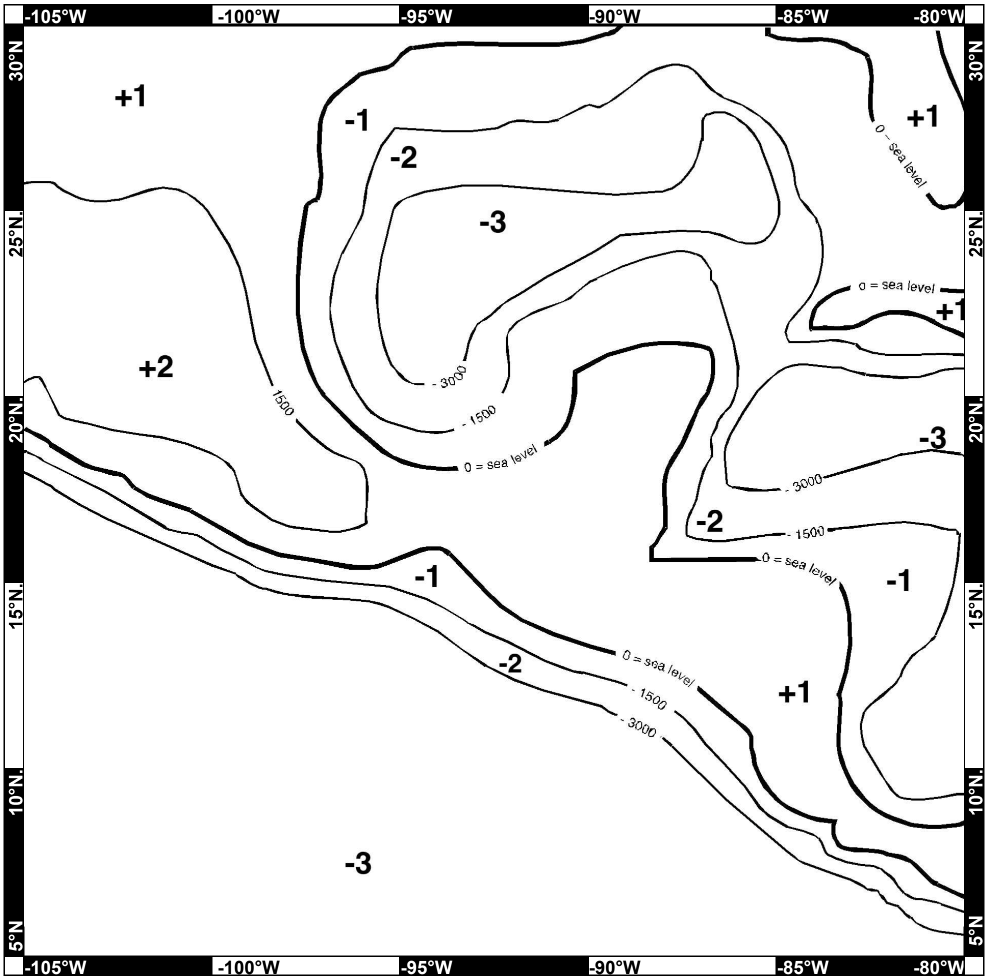
Elevation Key: Color in each number

+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

INSTRUCTIONS

- Pick a color for each elevation
- Color each number box →
- Color the map by number
- Use map for making a model

Mt. Popocatepetl Cutout Topographic Map



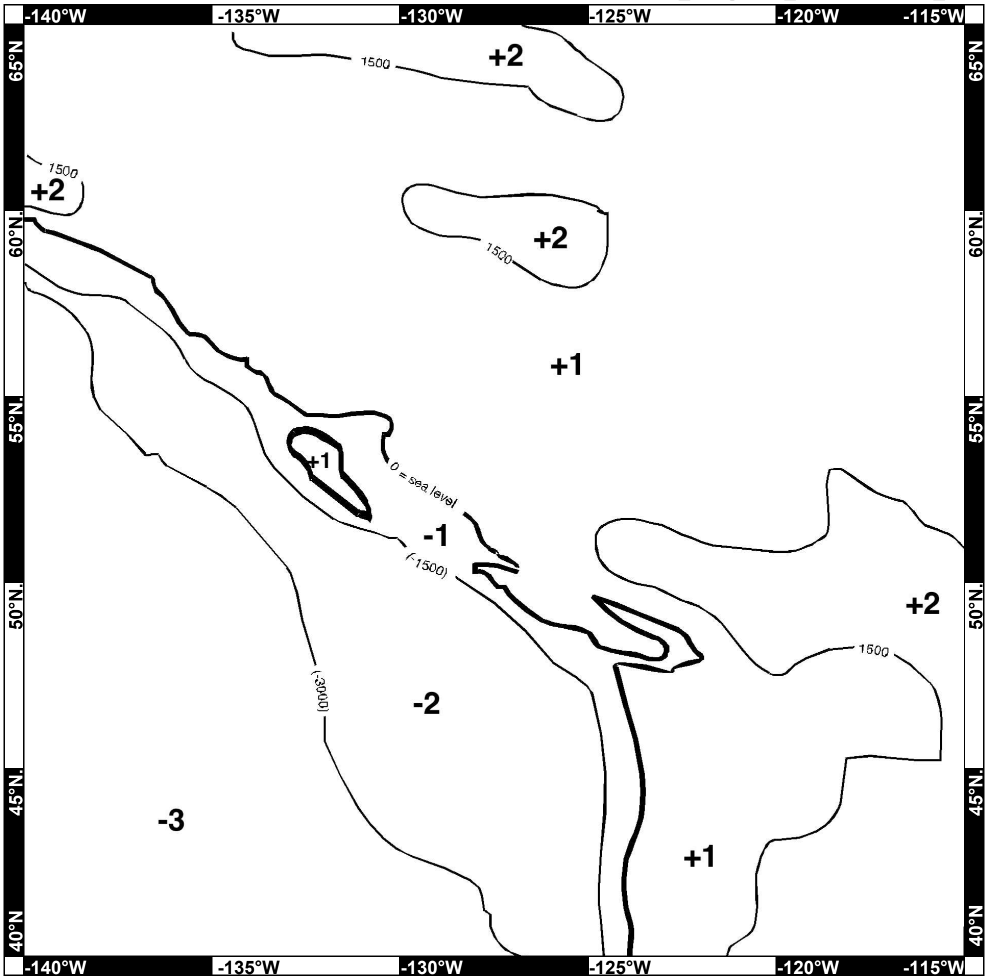
Elevation Key: Color in each number

+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

INSTRUCTIONS

- Pick a color for each elevation
- Color each number box →
- Color the map by number
- Use map for making a model

Mt. St. Helens Cutout Topographic Map



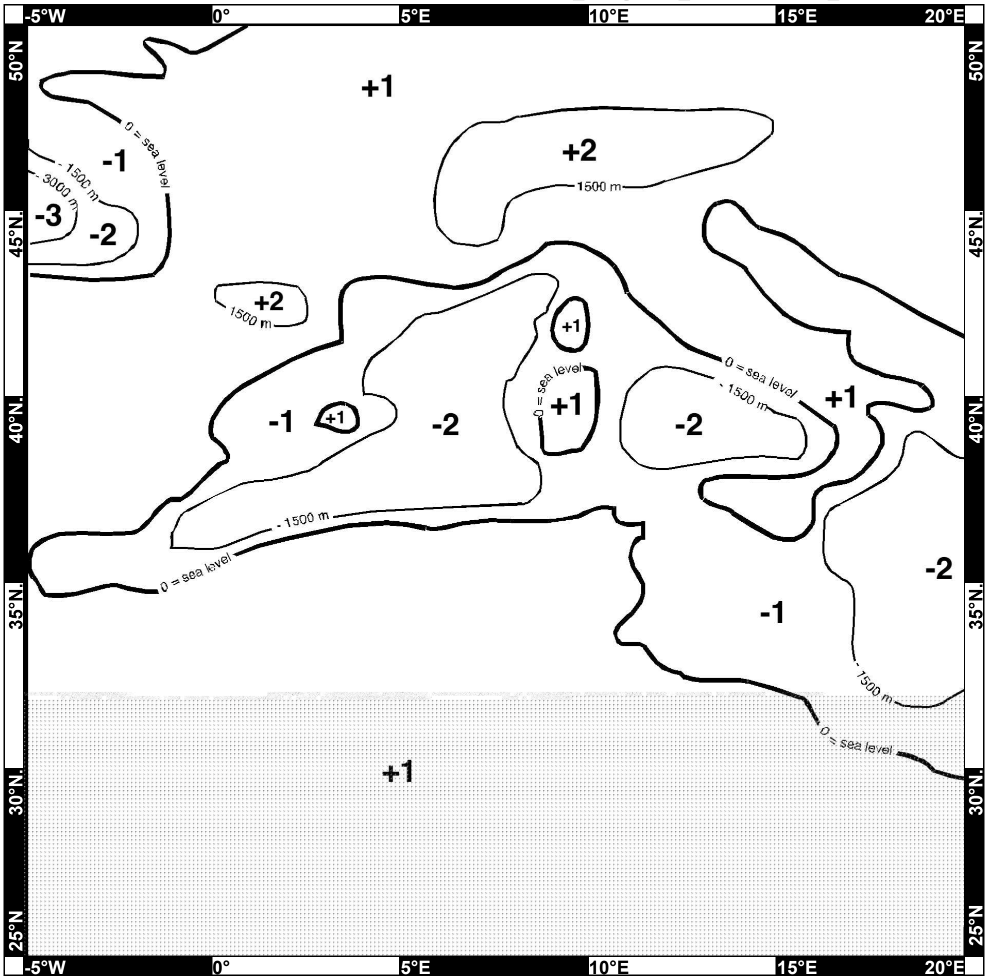
Elevation Key: Color in each number

+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

INSTRUCTIONS

- Pick a color for each elevation
- Color each number box →
- Color the map by number
- Use map for making a model

Mt. Vesuvius Cutout Topographic Map



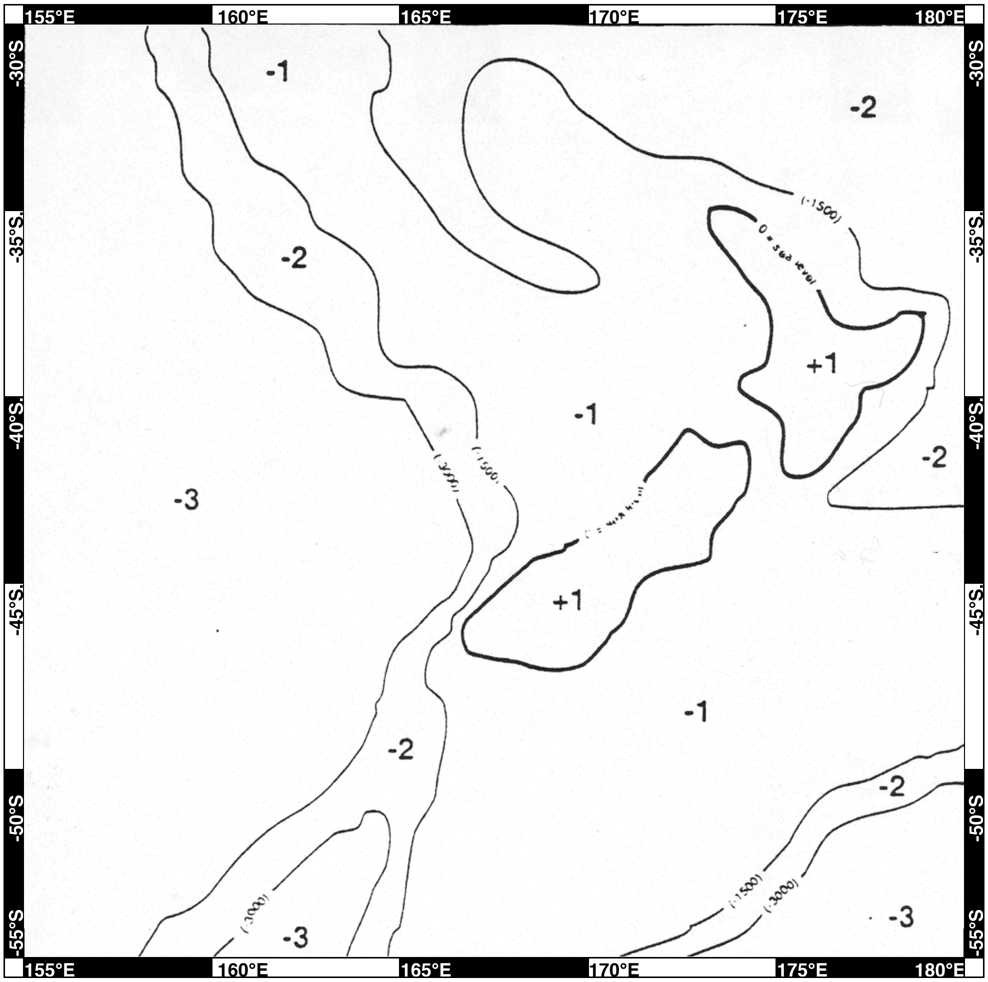
Elevation Key: Color in each number

+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

INSTRUCTIONS

- Pick a color for each elevation
- Color each number box →
- Color the map by number
- Use map for making a model

New Zealand Cutout Topographic Map



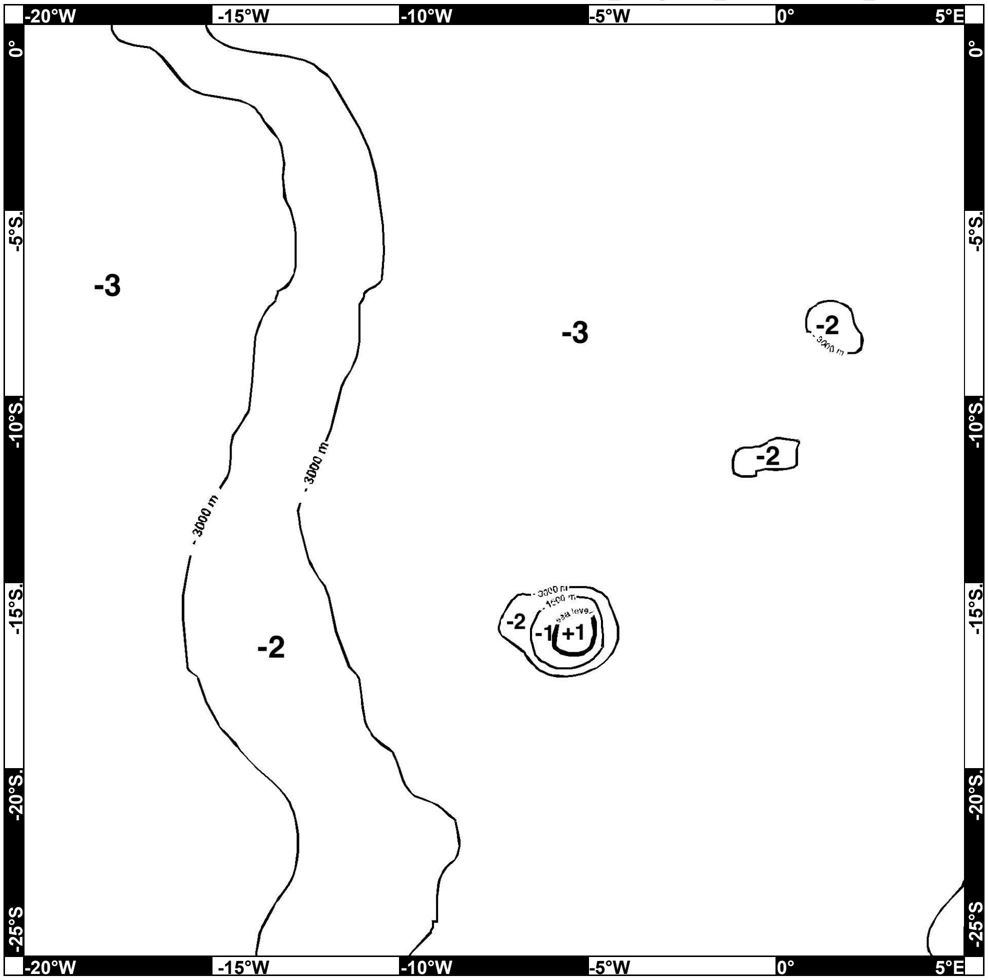
Elevation Key: Color in each number

+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

INSTRUCTIONS

- Pick a color for each elevation
- Color each number box →
- Color the map by number
- Use map for making a model

St. Helena Island Cutout Topographic Map



Elevation Key: Color in each number

+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

INSTRUCTIONS

- Pick a color for each elevation
- Color each number box →
- Color the map by number
- Use map for making a model

Lesson 3
Journey to the Center of the Earth

What have you learned so far?
In Lesson 1, you gathered observations about earthquakes and volcanoes. You also learned about earth structures from your pen pals. In Lesson 2, you constructed a three-dimensional model of your earth structure and compared it to other earth structures. You decided that earthquake and volcanoes tell us that the ground is moving and changing.

What exactly is moving and changing? Some of the Junior Scientists think they have some answers. In this lesson, you will look at their ideas and decide what data you need to help figure out what changes are happening at your earth structures and why.

Activity 3.1: The Cool Crust

Overview:
In this activity, you will explore models of the Earth's crust and interior and then draw your own model of the Earth's crust. This model will help you understand what is moving and changing when you observe earthquake and volcano data.

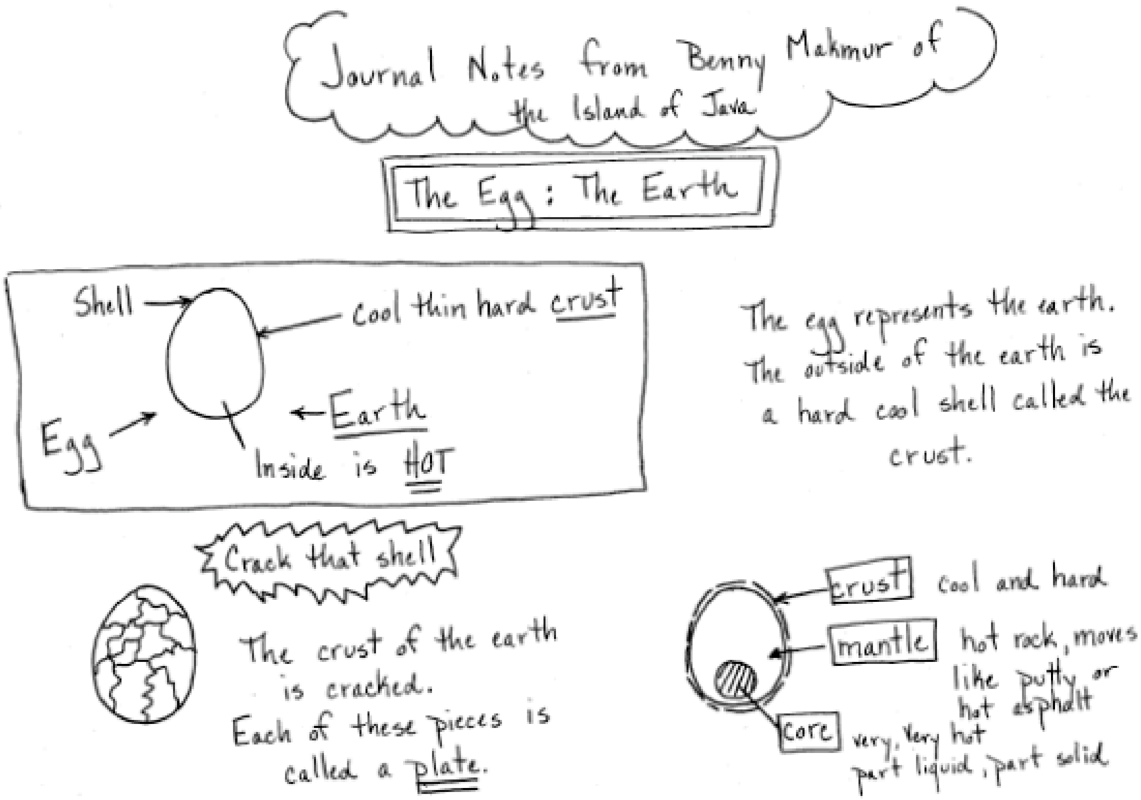
Procedure:
1. Brainstorm with your teacher**. What do you think is moving or changing during an earthquake or volcanic eruption? How can you explain or illustrate what is moving and changing?**

2. Read Benny's letter. Then explore Benny's model and his ideas **about what is moving and changing. After you have looked at his model and ideas, answer the Stop and Think questions that follow.**

Hi there fellow Junior Scientists!!

I am writing to you because I think I have an idea about what is moving and changing during an earthquake or a volcanic eruption. In my science class, my teacher told us about the structure of the Earth. I'm pretty sure scientists don't know this structure for sure because they can't actually look into the Earth. They can only observe earthquakes and volcanoes and try to figure out what is happening. I know that one of the things scientists can observe is the patterns of waves from the earthquakes and volcanoes. Because the Earth is so big and we can't look inside it, scientists use models to illustrate what they understand.

Below is a copy of my notes from science class. In my class, we used an egg as a model to illustrate Earth's crust (the outside layer) and its interior. See what you think!



The pieces of the cracked shell are like the giant puzzle pieces that make up the Earth's crust. These pieces are called plates, and they move on the Earth during an earthquake or volcanic eruption. I think the interior of the Earth is helping to move the crust. What do you think? I look forward to hearing from you.

Sincerely and Keep Rocking and Rolling,

Benny Makmur
Island of Java

Stop and Think: The Egg: The Earth

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 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?

3. **What is Earth's crust?** As a class, make a list of list things that are part of the Earth's crust.

4. **Draw the Earth's crust**. Using the student handout *The Cool Crust,* draw a picture of the things that you listed. Be sure to label the things you draw.

5. **Share your drawing with another student**. What do your 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? Do you notice anything might want to add to your own drawing?

6. **As a class, review the crust drawings. In your discussion, use the following questions to help you think about the things that should be represented.**
    - 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 broken into pieces (plates)?

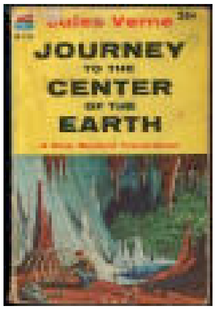
Reflection Questions: The Egg: The Earth

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.

7. **Read *It's All Cracked Up*** and answer the *Figure It Out* questions so you can figure out what is moving and why it is moving during earthquakes and volcanoes.

<u>It's All Cracked Up</u>



www.frugalbooks.com/ pg/julesverne.html

In the novel *Journey to the Center of the Earth,* Jules Verne wrote of an earth science professor who finds directions to the center of the Earth on a scrap of paper in an old book. The note says that the journey to the center of the Earth is possible. The scrap of paper leads the professor to Iceland, the land of fire and ice. He sets out with his nephew and finds the gateway at an extinct volcano, one that has not erupted in several thousand years. They travel down through a shaft in the extinct volcano to get to the center of the Earth. As they descend, they find great adventure in lost lands and strange creatures. Do you think they were actually able to make it to the center of the Earth? What conditions would you expect them to experience as they descended deeper and deeper into the Earth?

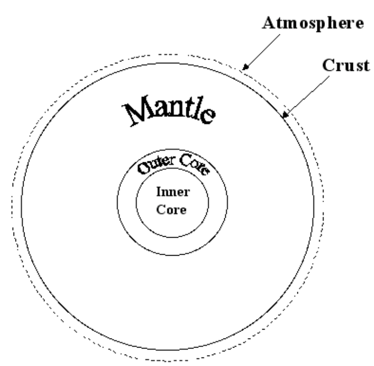
How do we know anything about the middle of the Earth if we can't go there and observe this for ourselves?

"What's inside the Earth?" Is one of the hardest questions **geologists** (scientists who study the forces that make and shape planet Earth) have tried to answer. How do we know what is below the thin shell of the Earth when we cannot see it?

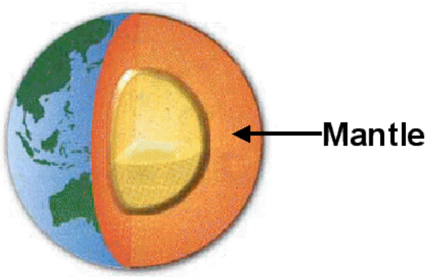
Have you ever shaken a wrapped gift to try to guess what was inside? You know that based on the sound it makes; you can narrow down what might be inside the box. When you do this, you are making an **indirect observation**. When geologists want to study the Earth's interior, they also use an indirect method. But instead of shaking a gift box, geologists use **seismic waves**. Seismic waves are vibrations that travel through Earth carrying the energy released during an earthquake. These vibrations are like what you feels when you shake a box. **Earthquakes** are the shaking and trembling that result from the movement of rock beneath Earth's surface. The geologists look to see the paths the waves take and how fast they travel through the Earth. Using the data from these waves, they have learned that Earth's interior is made up of several layers.

<u>What are the layers of the Earth?</u>

Three main layers make up Earth's interior: the **crust**, the **mantle**, and the **core**. Each has its own conditions and materials. The **crust** is the layer of rock that forms Earth's outer shell. This layer is brittle and cool compared to the rest of the earth. The crust is also divided into large pieces called **plates**. The plates are like big puzzle pieces.



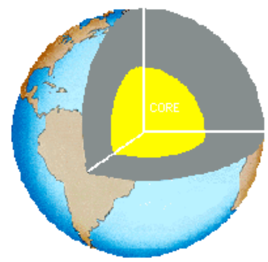
The crust varies in thickness from 5 to 75 km (3-47 miles). The thinnest parts of the crust are under the oceans; these are called **oceanic crust**. The thickest parts are the continents, called **continental crust**. The continental crust at the Himalayas is 75 km (47 miles) thick. The rock in the crust is brittle and crumbling, like a piece of cold wax. If you squeeze the wax between your fingers, it will crack and crumble.



www.personal.psu.edu/ users/d/a/dap211/int3.htm

The layer below the cool crust is a layer of hot rock called the **mantle**. The mantle is like wax that has been heated to just below the melting point. Just before the melting point, the rock is able to flow and deform like putty. The mantle is the thickest layer, about 2900 km (1800 miles) thick. The temperature in this thick layer varies from 1600 degrees Fahrenheit at the top to about 4000 degrees Fahrenheit near the bottom. The wide temperature range causes this layer to flow and move. When this layer moves, the crust moves with it.

Below the mantle is the core. It consists of the **outer core** (a layer of molten metal), and inside that, the **inner core**. The inner core is a dense ball of solid metal; extreme pressure squeezes the atoms of iron and nickel so tight that they form a solid and have no room to spread out and become liquid. The energy to move rock in the mantle comes from this hot core.



www.thetech.org/.../ quakes/inside/core.html

So what does this have to do with the earth structures we are studying?


http://exploringafrica.matrix.msu.edu/curriculum/lm1/3/students/1_geography.html

The plates float on top of the semi-solid mantle. As the plates move, they cause changes in the Earth's surface. Some of the plates are pulling away from each other, some are pushing toward each other, and some are sliding past each other. The edges of different parts of the crust meet at cracks called **plate boundaries**. Movement at these boundaries can create a mountain, a volcano, a rift valley, an island, or even a deep ocean trench. The plates move at really slow rates. This explains why it has taken millions of years for Earth to look like it does today!

Figure It Out

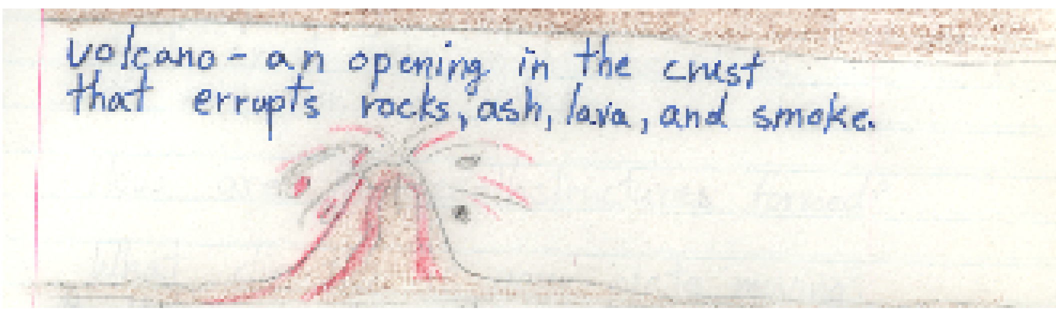
1. What kind of indirect evidence do geologists use to study the structure of the Earth? Why can't they use direct evidence?

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 feel 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?

Activity 3.2: Moving Forward

Overview:

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

Procedure:

1. Review what you have studied so far. In the last lesson, you learned a lot of new terms and scientific ideas. As a class, review the science vocabulary and the ideas that you have studied.

2. Review the observations that the class has collected.

3. **Pick your top three observations**. Choose observations that you think are going to be helpful in understanding what is happening in the Earth's crust.

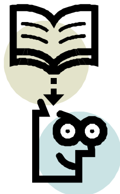
4. **Review the explanations**. The class has gathered explanations for the changes happening at each earth structure and in the Earth's crust. Review these explanations.

5. **Pick your favorite explanations**. Choose what you think is the best explanation for the changes happening at each kind of earth structure: mountain, island, trenches, volcanoes, and rifts.

6. **As a class, develop a plan to support your explanations.** Use the questions below as a guide.
    - What do you want to do next?
    - What do you need to do to support your explanation?
    - What data do you think you would need?
    - Where are you going to find these data?

Reflection Question

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



WHAT'S THE POINT?

You have now focused your explanations and observations. You have also decided which data you want to support your explanations of the changes happening at the earth structures. Now you need to look at some data to support your explanations.

What changes are happening at the earth structures?

What helps you to know these movement and changes are happening?

Where do you think these changes are happening?

What data do you need to support your explanations?

Lesson 4

Earthquake! Observations from Data

What have you learned so far?

In Lesson 3, you 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. That cool crust is divided into giant puzzle pieces called plates, and earthquakes happen where these plates meet, places called plate boundaries. In the last activity your class also decided that earthquakes would be good data to use to look for these plate boundaries.

In this lesson, you will look at some real-time earthquake data. Real-time earthquake data is posted within minutes of an earthquake every time one happens in the world. After plotting some of this data, you will look for patterns in the data. Hopefully you will find the plate boundaries for your earth structure.

Activity 4.1: Real-Time Observations of Data

Overview:

You will look at current real-time earthquake data at the United States Geological Survey (USGS) website. USGS is an organization that watches and reports changes in the Earth's crust, atmosphere, living organisms, and resources. You will then read about two historical earthquakes and learn more about what happens during an earthquake and how earthquakes are observed and reported.

Think About This!

Have you ever experienced an earthquake? Do you know anyone who has experienced an earthquake? What is it like? Or what do you think it is like? On January 17, 1994, there was a 6.7 magnitude earthquake in Northridge, California. Below are some firsthand descriptions from people who were there! These were collected from a questionnaire distributed by USGS.

"I had just gotten up to give my baby daughter her bottle when I felt a violent jolt. I knew we were having an earthquake so I tried to run into her room to get her but it was so hard to walk! I could hear things outside falling and hitting the ground, and all of the pictures in the hall were falling and breaking. I was so scared!" Zip Code 90037

"My wife woke me up and asked if I felt anything. I told her that I certainly did not feel anything except her shaking me. She said she thought she felt an earthquake but maybe it was a big truck – we live close to the freeway. Turns out it was an earthquake, a pretty big one! Who knew!" Zip Code 90650

"I am from Virginia and I was in California visiting my grandchildren. In the very middle of the night I woke up and felt a strange rumbling. Then things started to shake a bit and my grandson ran into my room and told me to stand in the doorway, that we were having an earthquake. Well, that door was swinging back and forth and I told him that I would stay right where I was, thank you very much! I wasn't going to get knocked out by some door and have to be taken to the hospital in my nightclothes!" Zip Code: 90808

"*I was asleep in my tent when I felt the earthquake. It woke up my whole family, and all of the other campers in the campground. Since there were no rocks, trees or buildings around we all felt pretty safe. It was a thrilling way to experience the power of nature."* Zip Code 93060

Procedure:

1. Your teacher will lead you in a discussion about earthquakes occurring in real-time on the computer. You will be looking at the United States Geological Survey (USGS) website.

   Discussion Questions (before viewing site):
   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?

   Discussion Questions (while viewing site):
   f. Why don't we hear about earthquakes every day?
   g. Where was the last recorded earthquake? How large was it? Do you think it made the news? Why or why not?
   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?
   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?
   j. How are earthquake data recorded?
   k. What does the magnitude of an earthquake mean?
   l. How does magnitude vary?
   m. What does the depth of an earthquake mean? How does depth vary?
   n. How is this earthquake data collected?

   Discussion Questions (after viewing site):
   o. 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?

Reflection Questions

Today you learned that there are many earthquakes occurring every day all over the world. Answer these in your science journal or on your worksheet.

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?

Data Estimation Note: *Kilometers and miles*
Earthquake depth data is measured in kilometers (km). How big is a kilometer?
1 mile = 1.609344 kilometers. You can estimate that 1 mile is a little less than 2 kilometers. Or if it helps to think about it another way, 1 kilometer is a little more than a mile. The earthquake happened at depth of 30 kilometers, or a little more than 15 miles (about 18 miles).

2. **Read** *Ground Shaking* and answer the *Figure It Out* questions that follow.

GROUND SHAKING

John Farish, a mining engineer, was staying at the St. Francis hotel pictured below when the earthquakes started about 5:15 am in San Francisco on Wednesday, April 18, 1906. Below is his recollection of that day. John Farish, a mining engineer, was staying at the St. Francis hotel pictured below when the earthquakes started about 5:15 am in San Francisco on Wednesday, April 18, 1906. Below is his recollection of that day. *" I was awakened by a loud rumbling noise which might be compared to the mixed sounds of a strong wind rushing through a forest and the breaking of waves against a cliff. In less time than it takes to tell, a concussion, similar to that caused by the nearby explosion of a huge blast, shook the building to its foundations and it began a series of the most lively motions imaginable. Accompanied by a creaking, grinding, rasping sound, it was followed by tremendous crashes as the cornices of adjoining buildings and chimneys tottered to the ground."*

http://www.exploratorium.edu/faultline/1906/
Photo credit: Steinbrugge Collection, Earthquake Engineering Research Center, University of California, Berkeley

U.S. Weather Service forecaster Alexander McAdie recorded the times of the tremors, an account published in the *San Francisco Chronicle* on April 24, 1906.

> *The first one occurring at 5:13 o'clock in the morning lasted forty-seven seconds. Another one came at 5:18 and lasted a few seconds; another came at 5:20 another at 5:25, another at 5:42, and then came a lapse until 8:13. This shock lasted five seconds as was the most severe since the big shake-up. The occurrence of the following shocks came at 9:13, 9:25, 10:49, 11:05; 12:03, 12:10, 2:23, 2:27, 4:50, 6:49 and 7 o'clock.*
>
> *The great movement of the earth in the bay region can hardly be said to be over. McAdie says that he has records of numbers of shocks for every day since the fateful Wednesday but he hastens to assure the public that the danger from heavy shock of a destructive character is gone. The minor temblors which*

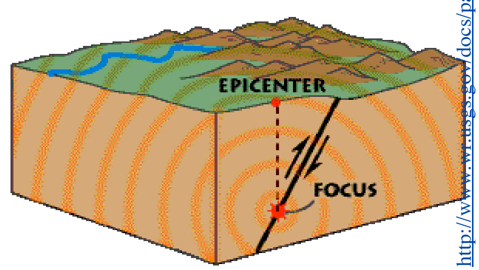
are still coming and one of which occurred at an early hour yesterday morning, are merely the necessary movements of the earth in the process of adjustment. They will come at greater intervals and grow weaker until they become absolutely imperceptible. http://www.sfmuseum.net/press/clips13.html

Both of these accounts are about the Great San Francisco Earthquake, which ranks as one of the most significant earthquakes of history. This earthquake affected about 290 miles (470 km) of the Earth's surface and was felt from Oregon to just south of Los Angeles, California. The violent shocks sparked a catastrophic fire that burned for days and, most importantly, sparked a community of scientists to learn more about earthquakes.

What are earthquakes and what causes them?


http://earthquake.usgs.gov/faq/effects.htm

An earthquake is a rapid shaking of the ground caused by the release of energy stored in the rocks of the Earth. When the hot, asphalt-like mantle changes and moves, so do the Earth's cool plates. The movement of Earth's plates can cause stress and strain on these rigid plates. This stress and strain can build up pressure in the layers of rock in the crust. This stress causes rocks to bend, squeeze, or break. When the stress and pressure are great enough, they are released in one quick event, an **earthquake**. Where several of these earthquakes occur, a crack develops. We call this crack a **fault**. (This may be a different meaning from the "fault" that you know. It's one of the many words that people have an everyday meaning for which also has a special meaning in science.) In places where there are volcanoes, the shifting mantle causes earthquakes also. When the mantle moves, the ground shakes.



http://www.wr.usgs.gov/docs/parks/deform/gfaults.html

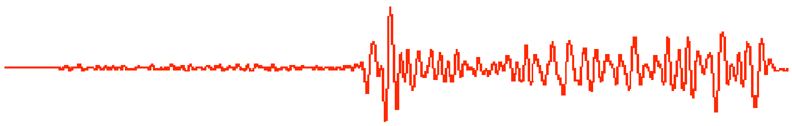
Where does the earthquake start?

The **focus** is the point under the earth where the earthquake starts and the energy is released. The **epicenter** is the point on the surface of the Earth directly above the focus. The epicenter of an earthquake is important. While the shock waves from an earthquake can be detected around the world, most of the damage occurs at the epicenter, or close to it.

How does the force of the earthquake travel through the Earth?

Imagine that you have dropped a large rock in a bucket of water. You can see the vibrations in the rippling of the water on the surface. Imagine you dropped that large rock again but this time you put your hand on the bottom of the bucket before you dropped the rock. You can feel the vibrations of the rock hitting the surface of the water. You can feel the vibrations the rock makes because its energy travels through the water.

The energy from an earthquake moves in much the same way; it travels out from the center in wave-like patterns called **seismic waves**. Some of these seismic waves travel on the surface, like the ripples you can saw in the water, and some travel through the Earth, like the vibrations you could feel on the bottom of the bucket. The **surface waves** can travel thousands of miles from the epicenter of an earthquake, and they can cause lots of damage. Like the waves that moved through the bucket of water, some of these waves travel through the Earth instead of on its surface. We call these **body waves**.



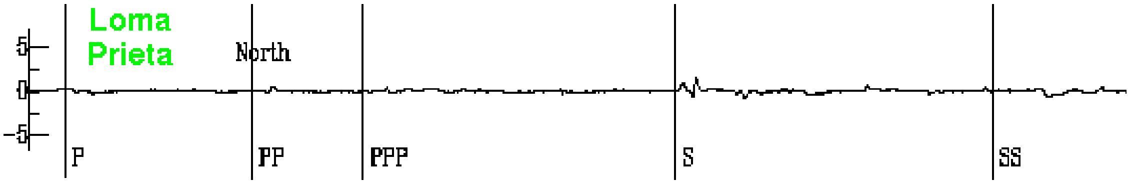
http://quake.wr.usgs.gov/info/1906/seismogram.html

The seismic waves from the 1906 earthquake in San Francisco were felt some 9,100 miles (14642 km) away in Gottingen, Germany. Above is the record from a **seismograph** (an instrument used to record waves from earthquakes). The part of the record shown here spans about 26 minutes. Only body waves are shown in this record. When surface waves arrived later, the instrument went off-scale (that means the waves were larger than the seismograph could record).

In 1989, an area near San Francisco called Lom Prieta was hit with another large earthquake. Highways collapsed, buildings crumbled, and fires began once again. Because this area was more populated than in 1906, this earthquake caused more damage, even though the ground shook more in the earlier earthquake. Below is a seismograph recording from the 1989 earthquake. The same seismograph that recorded the 1906 earthquake was there to record the 1989 earthquake.

Lom Prieta, California 1989

http://wrgis.wr.usgs.gov/dds/dds-29/web_pages/sf.html



http://quake.wr.usgs.gov/info/1906/got_seismogram_lp.html

The following are 9-1-1 recordings from immediately after the 1989 Lom Prieta earthquake in the San Francisco area.

This call began moments before the first large aftershock.

Dispatcher: 911 Emergency.

Caller: My whole house is tore up! Should I take my kids outside?

Dispatcher: Your whole house what?

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!

http://www.sfmuseum.org/1906/89.html

This call was received on the direct line from the Highway Patrol office. CHP stands for California Highway Patrol. When the officers say "280," they are referring to the name of the highway.

CHP: We're losing 280. We need all the ramps to 280 closed, if you've got any available units close the traffic coming on to 280 extension up by Sixth Street. It's going down.

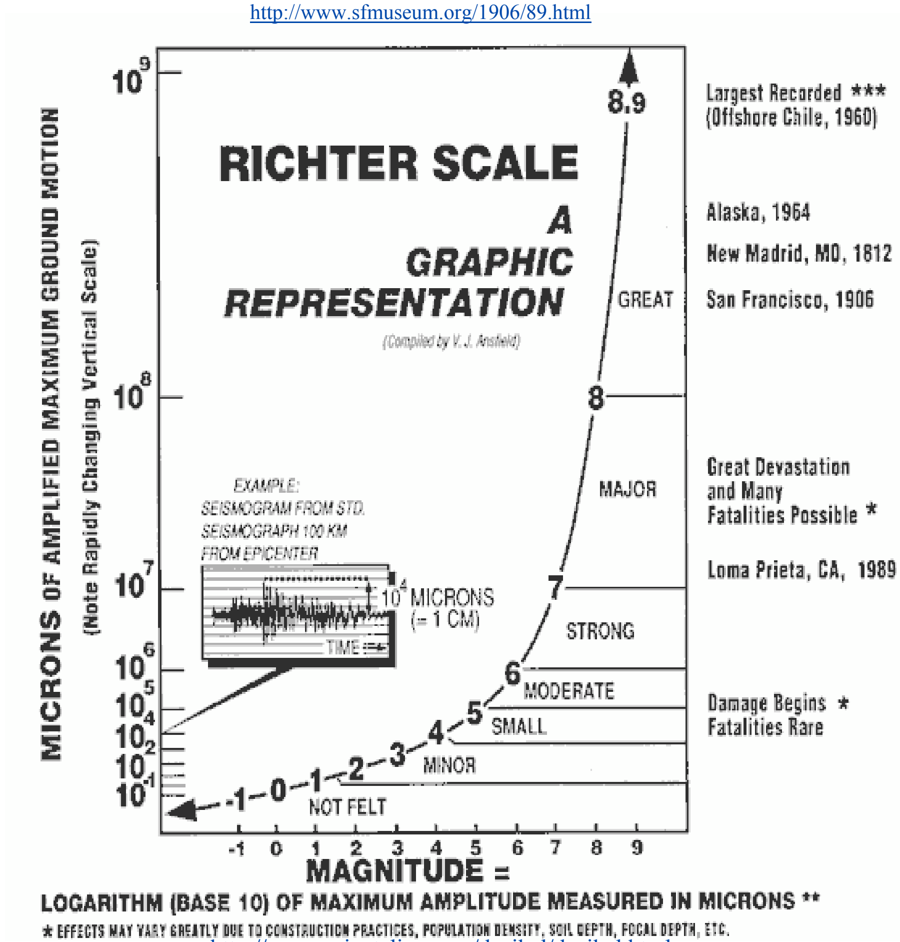
Dispatcher: What's going down? The ramp is?

CHP: The ramp is. It's collapsing!

Dispatcher: Okay, hold on, I'll tell 'em right now.

CHP: Thank you

http://www.sfmuseum.org/1906/89.html



http://www.privateline.com/decibel/decibel.html

How is the strength of an earthquake measured?

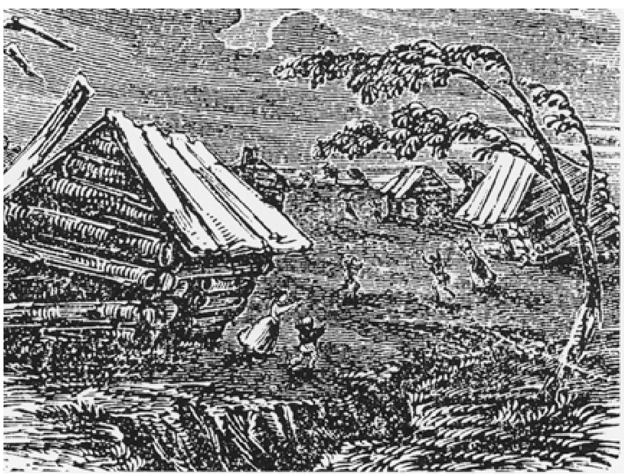
The newspaper headline read, "*Strong 7.9 Quake leaves Peru reeling Arequipa hardest hit; at least 52 dead.*" You can probably tell from the headline that this was a large and destructive earthquake. But, what does that 7.9 mean?

The 7.9 is the earthquake's **magnitude,** a measure of how much energy an earthquake has released. In the United States we use the **Richter Scale** to measure magnitude. The Richter Scale ranges from 1 to 9 with 1 being small earthquakes and 9 being large earthquakes. On the Richter Scale, earthquakes with a magnitude of 1 or 2 are small and cannot be felt by people. These small earthquakes are often not reported because they can be the result of a building being demolished as well as of a movement of the crust. Earthquakes with a magnitude of 3 or 4 are sometimes felt but are still considered small earthquakes. Earthquakes with medium magnitudes (4 to 6) are always felt and result in minor damage. Earthquakes with magnitudes larger than 6 are felt by everyone, and there is much damage and devastation.

Stop and Think

Make a prediction. How destructive an earthquake is depends on several factors. The size of the earthquake on the Richter Scale is only one factor. What else do you think might affect how destructive an earthquake is?

Size is not all that matters! In late 1811 and early 1812, New Madrid, Missouri was the site of a series of the largest and most geologically significant earthquakes in U.S. history. It is told that church bells tolled in Boston, and that the Mississippi River reversed flow and changed course. It is also told that fields were swallowed up, and new lakes were formed, all from this series of earthquakes. In 1812 this part of the country was scarcely populated or populated by people that did not read or write, so stories have been passed down through the generations and surely retold with a little more flavor. Though the personal devastation was not significant, the geological changes were.



http://quake.wr.usgs.gov/prepare/factsheets/NewMadrid

What made these earthquakes shake so much more than many other earthquakes is the geology of the area. Thousands of years of sediment have built up in this region from glaciations and old ocean bottoms. Think of a plate of gelatin. If you shake the plate the top of the gelatin really shakes. The ground in New Madrid, with all the sediment, reacted to the earthquake much like the gelatin does when you shake it. An earthquake happening in these conditions causes more ground motion and therefore more devastation. In the San Francisco earthquake, people noticed the most devastation in parts of the city that were built on reclaimed land from the San Francisco Bay. The shaking of this soft sediment results in more damage.

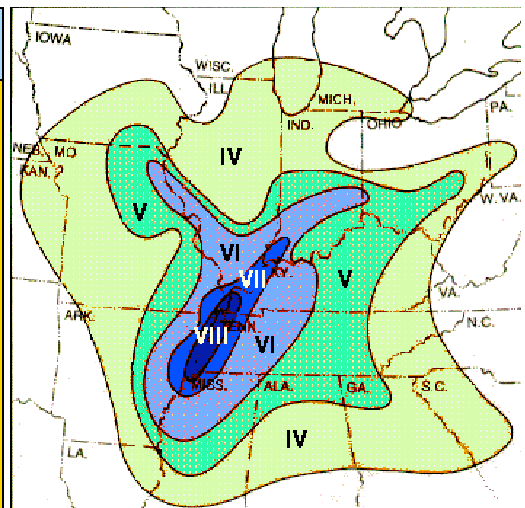
Since the geological conditions of the area play a role in the destruction of an area hit by an earthquake, seismologists use a separate method to estimate the **effects** of an earthquake, called its **intensity**. **Intensity** should not be confused with **magnitude**. When scientists measure the intensity of an earthquake, they are trying to determine the effects of the quake at a particular place. The **intensity**, or amount of damage, is determined by observing the effects on the local people, the buildings, and the Earth's surface. To report intensity, seismologists use the

Modified Mercalli Scale. The Mercalli Scale uses Roman numerals, I through XII, to establish levels of destruction, ground motion, and impact on humans.

The Mercalli Scale is not a precise measurement. It is based on observations people make after a quake. For example, if hanging objects swing back and forth, dishes and windows rattle, and there is slight damage, the earthquake may be rated a IV on the Mercalli Scale. The intensity of an earthquake for an area depends on several factors. One of these factors is how far buildings are from the epicenter. Another factor is the type of ground under the buildings. If buildings are constructed on solid rock, they will have less damage than buildings built on less stable sediments.

Below is the Mercalli Scale and to the right is a map showing the intensity of the New Madrid earthquake of 1812.

Modified Mercalli Scale		Richter Magnitude Scale
I	Detected only by sensitive instruments	1.5
II	Felt by few persons at rest, especially on upper floors; delicately suspended objects may swing	2
III	Felt noticeably indoors, but not always recognized as earthquake; standing autos rock slightly, vibration like passing truck	2.5
IV	Felt indoors by many, outdoors by few, at night some may awaken; dishes, windows, doors disturbed; motor cars rock noticeably	3
V	Felt by most people; some breakage of dishes, windows, and plaster; disturbance of tall objects	3.5, 4
VI	Felt by all, many frightened and run outdoors; falling plaster and chimneys, damage small	4.5
VII	Everybody runs outdoors; damage to buildings varies depending on quality of construction; noticed by drivers of automobiles	5
VIII	Panel walls thrown out of frames; fall of walls, monuments, chimneys; sand and mud ejected; drivers of autos disturbed	5.5
IX	Buildings shifted off foundations, cracked, thrown out of plumb; ground cracked; underground pipes broken	6, 6.5
X	Most masonry and frame structures destroyed; ground cracked, rails bent, landslides	7
XI	Few structures remain standing; bridges destroyed, fissures in ground, pipes broken, landslides, rails bent	7.5
XII	Damage total; waves seen on ground surface, lines of sight and level distorted, objects thrown up into air	8



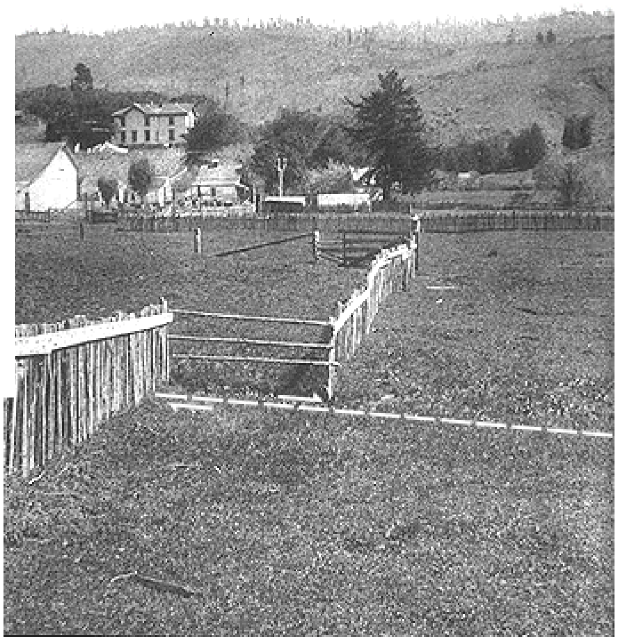
http://www.hsv.com/genlintr/newmadrd/

If you lived in Chicago during the New Madrid earthquake of 1812 mapped here, what might you have experienced?

If you lived in St. Louis during the New Madrid earthquake of 1812 mapped here, what might you have experienced?

http://www.nationsonline.org/oneworld/usa_map.htm
http://www.kgs.ku.edu/Extension/image/earthquake5.html

Size and geology is not all that matters? Depth matters! The effects of an earthquake also depend on how close to the surface the earthquake happens. In both the San Francisco and New Madrid earthquakes, the focus was near the surface. In both places you can see evidence of the ground moving, as shown in the picture below. This picture is from the San Francisco earthquake of 1906 and shows how the fence separated by about 8 feet.



http://pubs.usgs.gov/gip/earthq3/fence.gif

If earthquakes happen far below the surface, the effects are not felt. On August 19, 2002 near the Fiji Islands, two earthquakes with magnitudes greater than 7 happened just 7 minutes apart and only about 300 km (187 miles) from each other. These two very large and very close earthquakes almost went unnoticed because there was no damage, and they were only barely felt in nearby cities. These two earthquakes happened deep below the surface. The cool, brittle crust of the Earth is between 5 km and 70 km. These two earthquakes happened at 578 km (359 miles) and 674 km (419 miles) respectively below the Earth's surface.

Stop and Think
Check your prediction from the earlier Stop and Think box. What other factors besides size affect how destructive an earthquake is? How close were your predictions? Explain.

What happens after an earthquake? Below are excerpts from an account of the great New Madrid Earthquake by George Heinrich Crist. At the time of the earthquake, he lived in north central Kentucky near the present location of Louisville, Kentucky.

23 January 1812
What are we gonna do? You cannot fight it cause you do not know how. It is not something that you can see. In a storm you can see the sky and it shows dark clouds and you know that you might get strong winds but this you can not see anything but a house that just lays in a pile on the ground - not scattered around and trees that just falls over with the roots still on it. The earth quake or what ever it is come again today. It was as bad or worse than the one in December. We lost our Amandy Jane in this one - a log fell on her. We will bury her upon the hill under a clump of trees where Besys Ma and Pa

is buried. A lot of people thinks that the devil has come here. Some thinks that this is the beginning of the world coming to a end.

8 February 1812
If we do not get away from here the ground is going to eat us alive. We had another one of them earth quakes yesterday and today the ground still shakes at times. We are all about to go crazy - from pain and fright. We can not do anything until we can find our animals or get some more. We have not found enough to pull the wagons.

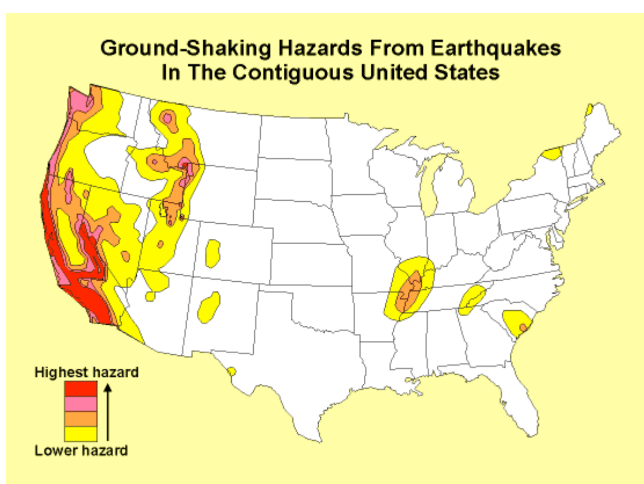
20 March 1812
I do not know if our minds have got bad or what. But everybody says it. I swear you can still feel the ground move and shake some. We still have not found enough animals to pull the wagons and you can not find any to buy or trade.

http://hsv.com/genlintr/newmadrd/accnt3.htm

As you can see from George Crist's descriptions, once the ground starts shaking it will continue to shake in that region for a while. Some of this shaking is **aftershocks**. Aftershocks are earthquakes that follow the largest shock and are near the epicenter of the largest shock. When Alexander McAdie from the U.S. Weather Service described the aftershocks he experienced in San Francisco in 1906, he said, "They will come at greater intervals and grow weaker until they become absolutely imperceptible."

Earthquakes can also lead to other earthquakes in the surrounding area. The shaking causes other pressure to be released and other earthquakes to occur. In New Madrid in 1812, the initial earthquake lead to other earthquakes in Ohio, Kentucky, and Tennessee.

When will the next earthquake hit? Today somewhere in the world there will be an earthquake. Many of these quakes are small and will not be felt by people. How do scientists know where next big earthquake will be? They don't, but they are working on it. Geologists use instruments to measure changes in the Earth's surface and movement along faults. Scientists invented ground-based and satellite equipment with radar to make images of faults and keep track of movement. This equipment might detect small changes in the elevation of the land or a slight bend in the land. Scientists determine earthquake risk by monitoring active faults and studying faults where past earthquakes



http://www.usgs.gov/themes/map1.html

have occurred. This means that they are not collecting this data everywhere, and thus earthquakes often strike without warning.

Figure It Out

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 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?

Activity 4.2: Plate Boundary Prediction

Overview:

You will use what you know so far to make a prediction of the plate boundaries for your earth structure.

Procedure:

1. Your teacher will give you a blank copy of a world map. **Label the following**:
    - North, South, East, West
    - All of the oceans and continents
    - The Equator and Prime Meridian
    - Lines of latitude (- 90 S to 90 N)
    - Lines of longitude (- 180 W to 180 E)

2. **Locate the coordinates of your earth structure and label it**.

3. **Draw** where you think the boundaries of the plate on which your Earth structure sits are located. Remember, plates are one complete piece, much like the piece of shell from the hard-boiled egg in Activity 3.1. Unlike a circle, each piece may be irregularly shaped, but like a circle, the plate has no beginning or end.
4. On the reverse of your prediction map, **explain how you decided** where to draw the plate boundaries for your earth structure. What supporting evidence do you have?

Reflection Questions

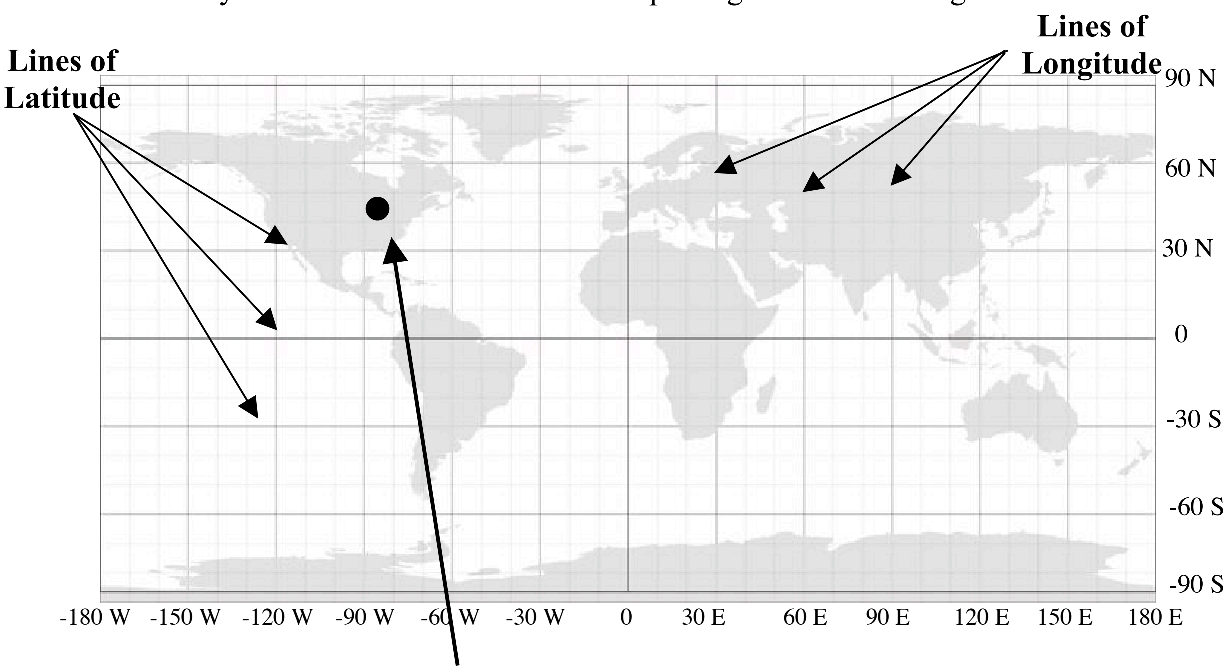
A. Were there any places you were pretty sure about? Why were you pretty confident that was a boundary? Are there any places you were unsure about?

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

Activity 4.3: Plotting Latitude and Longitude (Optional)

Overview:

You will identify several locations on a world map using latitude and longitude coordinates.



Chicago is 41^{O}N -87^{O} W

To find the location of a place exactly, you need lines that intersect. This is a grid system. Mapmakers all over the world use a latitude and longitude grid to help people find any place on Earth.

Procedure:

Using the blank map of the world your teacher gives you, complete the following activity. Write your answers either in your science journal or on the worksheet.

Match the cities with the correct latitude and longitude.

___	1.	San Francisco, California	a.	-35^{O} S, -56^{O} W
___	2.	Perth, Australia	b.	7^{O} N, 80^{O} E
___	3.	Moscow, Russia	c.	56^{O} N, 38^{O} E
___	4.	Colombo, Sri Lanka	d.	32^{O} S, 116^{O} E
___	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	______________________
7.	59^{O} N	18^{O} E	______________________
8.	-22^{O} S	-48^{O} W	______________________
9.	53^{O} N	-6^{O} W	______________________
10.	40^{O} N	116^{O} E	______________________
11.	-26^{O} S	28^{O} E	______________________
12.	19^{O} N	-99^{O} W	______________________
13.	41^{O} N	-87^{O} W	______________________

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

	City	Latitude	Longitude
14.	Anchorage, AK	__________	__________
15.	Aberdeen, Scotland	__________	__________
16.	Denver, CO	__________	__________
17.	Honolulu, HI	__________	__________
18.	Athens, Greece	__________	__________
19.	Bangkok, Thailand	__________	__________
20.	Belfast, Northern Ireland	__________	__________
21.	Warsaw, Poland	__________	__________
22.	Bombay, India	__________	__________
23.	Hong Kong, China	__________	__________
24.	Lisbon, Portugal	__________	__________
25.	Munich, Germany	__________	__________

Activity 4.4: Plotting and Analyzing Earthquake Data

Overview:

You will be downloading current earthquake data from the Internet. After you have gotten data for the past week's earthquakes, you will plot the locations of these earthquakes on a world map and look for patterns in that data.

Procedure:

1. **Download global earthquake data.**
   a. Go back to the USGS website you visited in Activity 4.1.

   b. The World Map should have been updated and now shows the latest earthquakes. Each of those little squares represents an earthquake.

   c. Look under the World Map and **click** on "M>2.5 earthquake list." This will list all the earthquakes with magnitudes great than 2.5 that were recorded in the last week.

   d. **Print** this list. (Your teacher might have this data printed for you already.)

2. **Plot the earthquakes on a world map.**
   a. On a world map, plot the data assigned to you, using the latitude and longitude coordinates. The column farthest right on your earthquake data usually gives you location. Use this information to verify the location you plotted.

	MAG	DATE y/m/d	UTC-TIME h:m:s	LAT deg	LON deg	DEPTH km	LOCATION
MAP	3.5	2004/08/26	03:13:09	62.282	-145.592	1.0	10 km (6 mi) WNW of Gulkana, AK
MAP	3.1	2004/08/26	02:58:40	32.264	-115.308	0.2	19 km (12 mi) W of Guadalupe Vict
MAP	4.1	2004/08/25	18:26:05	51.447	-175.469	1.0	95 km (59 mi) ESE of Adak, AK
MAP	3.6	2004/08/25	12:32:19	61.593	-146.407	37.8	48 km (30 mi) SSE of Nelchina, AK

3. As instructed by your teacher, **plot the same data on the *Big World Map*.** Place a sticker over the coordinates that match the data. When everyone is done, all of the earthquakes that happened over the last week should be plotted on the large class map.

4. **Analyze the data the class plotted**. Use the following questions to help guide the discussion.
   - What patterns do you see in the data?
   - What do you think the patterns tell you?
   - Where is there a lot of earthquake data plotted?
   - Where are there few earthquakes plotted?
   - 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?

5. **With your team, look for data to support your plate boundary prediction**. Answer the following Stop and Think questions in your science journal or on the worksheet.

Stop and Think

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?

6. **Discuss question C with the class**. You should come to some conclusion about the data that you would like now.

Reflection Questions:

Today your class plotted earthquake data for one week.

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 is 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 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?

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

Activity 4.5: "The Restless Earth" Video

Overview:
So far you have been looking at more and more data, trying to find patterns. This video is about some of these patterns and how scientists study the earthquakes.

Procedure:
1. As you watch the video, *The Restless Earth,* look for ideas that have been discussed in class. You may learn some new information that may help you even further with your study of your earth structure.

2. Read the Stop and Think questions before you watch the video. Then as you view the video, write down any notes that may help you answer them.

Stop and Think

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?

WHAT'S THE POINT?

You have now looked at some earthquake data to determine the plate boundaries for your earth structure. You have also learned much more about how an earthquake happens, which should help you better understand the data.

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?

Lesson 5
Assembling Earth's Puzzle

What have you learned so far?
In Lesson 4, you plotted one week of earthquake data and looked for patterns to determine where the plate boundaries are for your earth structure. You also learned more about how earthquakes happen and how the data is collected and reported.

In this lesson you will have the opportunity to refine your plate boundary predictions and use one year and then up to ten years of real earthquake data to support your prediction. At the conclusion of this lesson, you will participate in a Neighbor Plate Meeting so the class can agree upon the plate boundaries for the world.

Activity 5.1: Refining Predictions

Overview:
The Junior Science team has received another memo from NESS (National Earth Structure Survey). You will review the memo and then refine your plate boundary predictions.

Procedure:
1. **Read and discuss the letter from NESS**.

National Earth Structure Survey
111 E. Old Trench Road
Washington D.C. 20005

Dear Junior Science Team:

We are impressed with the progress you have made so far on this project. We understand that you have decided to look at patterns in the earthquake data. This makes sense, since earthquakes are more frequent than volcanoes and also happen around volcanoes. We also understand that you are looking at earthquake data in order to find the Earth's plate boundaries.

We look forward to hearing about those plate boundaries and the patterns you have found in the earthquake data. Please include the data that supports your findings.

Sincerely,

Dr. Seismic P. Wave

---

2. **Refine your plate boundary prediction**. In Lesson 4, you made a rather blind prediction about where you thought the plate boundaries for your earth structure were located. You have now had some experience with data, so in this activity you will refine that prediction.

3. Your teacher will give you a blank copy of a world map. **Label the location of your earth structure.**

4. **Draw** where you now think the plate boundaries of your earth structure are located, using any new ideas from data you've seen so far.

On the reverse of your prediction map, **explain how you decided** where to draw the plate boundaries of your earth structure. What supporting evidence did you use?

Activity 5.2: Looking for Patterns in One Year of Data

Overview:

In this activity you will look at 1 year of earthquake data plotted on a large map in order to improve your plate boundary predictions. Your teacher will also introduce the class to criteria for "enough" data. You will need to find enough data to support your plate boundary predictions.

Procedure:

1. **Assemble and review the large map with one year of earthquake data already plotted.** Use the following questions to help review the data map.
   - Over what period of time did these earthquakes take place?
   - Does this map show all the earthquakes that took place? If not, which earthquakes are shown?
   - What would the map look like if ALL the earthquakes for the year were plotted?
   - What information does this map give us about each earthquake?

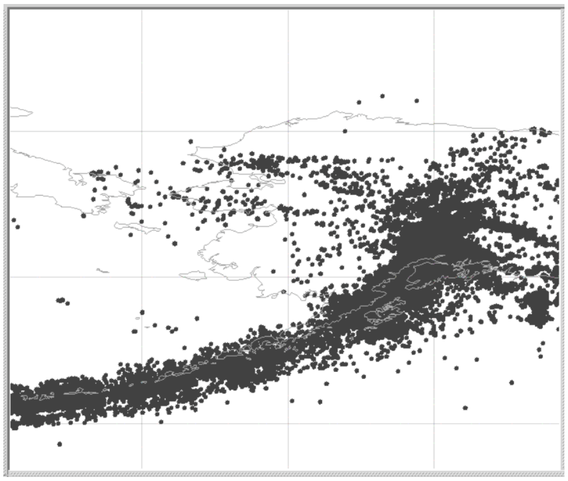
2. **Label the map with: N, S, E, W, the Equator, the Prime Meridian, the names of the continents, and the names of the oceans.** These labels will help you talk about locations on the map.

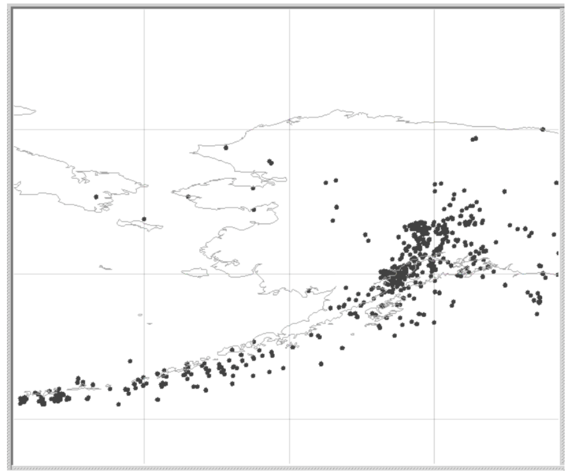
> ### Stop and Think
> Answer these questions in your science journal or on your worksheet.
>
> A. Look at the one week of data your class plotted on a map and the one year of data plotted on this new data map. What do you notice about patterns in the data? Do you see the same patterns? Do you see different 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 the earthquake data?

3. **Prepare to analyze data and find plate boundaries**. Your team should place a transparency over the part of the map where your earth structure is located. Trace some latitude/longitude numbers from Big Data Map onto the transparency, so you can put the transparency back in the same spot each time.

4. **How do you find boundaries among all these dots?** The data on your map looks like a scattered mess of dots. In some places there are clumps of dots, and in other places there is only one dot. You are looking for a general direction in the dots. Too many and the pattern

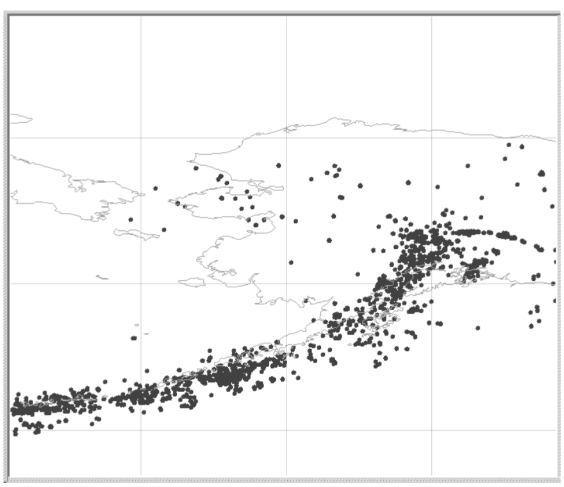
gets hard to see. Too few and you cannot tell where the pattern is between the dots. Can you connect the dots? No! You need enough data to see a clear pattern.





(1) Too much data (2) Too little data

5. **How much data is enough data to support our plate boundary predictions?** Your teacher will review some maps with earthquake data plotted. One will have "Many Quakes" and another "Few Quakes" and the other is "Just Right." The actual number of years or magnitude ranges needed to have enough data varies. So you will need to decide if you have enough data to support your plate boundary predictions.



(3) Just right data

6. **Use the one year of earthquake data to improve your plate boundary predictions.** Working as a team, you will mark your plate boundary on a transparent overlay on the data

map. Use one color marker for places where you think you have “enough data” to support your plate boundary lines and another color marker for places where you need different data and are unsure of your plate boundary lines. Please make a key that shows what your different colored lines represent.

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?

Activity 5.3: *MyWorld* Data

Overview:

In this activity, you will consult more data to improve your plate boundary prediction. You will also gather supporting evidence to justify your plate boundary prediction.

Procedure:

1. **Identify areas where you need more information to improve your plate boundary predictions.** Look at the plate boundary prediction you drew on the transparencies over the large map in Activity 5.2. Identify the areas where you are not sure of the plate boundary lines. Draw boxes on a Small World Map worksheet to represent the areas that you would like to look at more closely in *MyWorld*.

2. **Improve your plate boundary predictions with data in *MyWorld*.** Teams will bring their small maps to the computer. Use the *MyWorld Tool Box* as a guide to the software. Use the *MyWorld* map view "EsInquiry." This has information about elevation and depth, earthquakes, and volcanoes.

3. **Gather supporting evidence** for your plate boundary predictions by using screen capture with a word processor.

4. **Revise your plate boundary prediction**. Using the information that you gathered from *MyWorld*, revise your prediction lines on the transparencies over the world maps. Use a different color pen to make your revisions. In Activity 5.4 you will show the class your old prediction in comparison to your new prediction.

5. **Name the plate you have discovered.** Be prepared to tell the class how you came up with the name for the plate.

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.

A. How have your predictions changed?

B. Why have your predictions changed?

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

Activity 5.4: Neighbor Plate Meeting

Overview:

You will meet with other earth structure teams to share and debate your 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.

Procedure:

1. **Gather with your neighbors.** For this activity the class will be divided into 4 groups. Your teacher will let you know which earth structure teams will be working together. When your group gets together, stack up the transparencies from each group on one map. Tape them to the top of the map so you can easily lift the layers.

2. **Convene Neighbor Plate Meeting**

<u>Meeting Agenda</u>

a. **Share your plate boundary predictions and supporting evidence**. Each earth structure group should share its predictions by showing the large group its current prediction and its original prediction map. Each group should also point out places it is sure and unsure about the supporting evidence.

   For example, *"This is where we think our plate boundaries are and this is the evidence that supports it . . ."*

b. After each team shares, the larger group should answer the question, ***Did the team use "enough" data to support their plate boundary prediction?***

c. After all the groups have had a chance to share their predictions, **DEBATE the patterns in the data**. Keep track of any changes you made to your prediction. The meeting group should come to a consensus about the plate boundaries. If you decide to change your own predictions based on this debate, keep track of your changes. Here are some questions that might help you debate:
   - What evidence supports this line you drew?
   - Where are there differences between your lines?
   - How do you know the line that you agreed on is the best one? What evidence supports it?
   - Are there gaps in the plates?
   - Are there places the plates overlap?
   - What places need more investigation?

- Who changed their lines? Why did you change them?
- What questions do you have now?

d. Each Neighbor Plate Meeting Group should **combine all of the plate boundary lines** on the transparencies if they are close together, to use for their presentation. You may need to overlay new transparencies.

e. Each Neighbor Plate Meeting Group should also **prepare a short report** about their meeting that will be shared with the rest of the class.
   - 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?
   - What are the names of the plates you discovered?

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? If so, why did you change them?

Activity 5.5: Neighbor Plate Meeting Reports

Overview:
You will make final revisions to your plate boundary predictions and combine all teams' predictions to make a plate map that covers the entire earth.

Procedure:
1. **Prepare with your Neighbor Plate Group.** You will be asked to report about your plate boundary lines today so that the class can make a plate boundary map of the world. In your report you 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?

2. **Each Neighbor Plate Group reports to the class.** While each group is reporting, watch for plate boundary predictions that are similar to your own. Consider these questions while you listen: What supporting evidence was used? Was there "enough" supporting evidence? What questions do you have about the earthquake data or the plate boundaries?

3. **After the groups have presented, participate in 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? Have you 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 we add to the list now?

4. **Decide which plate your earth structure is part of**. On a *Three Page Map* worksheet, mark your earth structure and then draw a sketch of the plate boundaries for your earth structure.

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? Do you have any new questions?

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.

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. **<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.

Activity 5.6: A Closer Look at Earthquakes

Overview:
You have looked at a large set of earthquake data and decided where the patterns show the plate boundaries of the Earth's crust. In this activity, you will look more closely at the patterns in the earthquake data for your earth structure.

Procedure:
1. **Plot earthquake data on your 3-D model of your earth structure using the following steps:**
   a. Open the *MyWorld* map view that you have been using to analyze earthquake data.
   b. Show the medium layer of earthquakes and select 3 years of data.
   c. Show the Earth Structure Boxes layer.
   d. Find your earth structure box and zoom in to that box so your map looks similar to your 3-D model of your earth structure.
   e. Using small stickers, plot the earthquake data on your 3-D model.

2. **Screen capture this map of your earth structure**. Describe the pattern you see in the earthquakes. Are they happening on one side of the earth structure? Are the earthquakes in a straight line? Are the earthquakes scattered? Are there lots of them or are there very few?

3. **Compare the earthquake patterns in your earth structure to the pattern in another earth structure**. Look at some of the other earth structure boxes and find one you think has a different earthquake pattern from yours and one that has a similar earthquake pattern to yours. Capture these maps and describe why you think these are different or similar.

4. **Tape your 3-D model with the earthquake data plotted to the Big World Map.**

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 earthquakes in the letter. Write a letter to your pen pal describing your comparison.

WHAT'S THE POINT?

What is a plate boundary? What happens at plate boundaries?

Where is your earth structure in relation your plate boundaries?

How do you think the earthquakes at your plate boundary relate to the changes happening at your earth structure?

Lesson 6

Escaping Heat

What have you learned so far?

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

At these plate boundaries there are lots of earthquakes, which means that the plates are moving. In this lesson, you will explore how and why the plates of the crust are moving. This will help you explain the changes happening at your earth structure.

Activity 6.1: Heating Soup

Overview:

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

1. **Make a Prediction.** Look at the sketch of your plate you made on the *Three Page Map* in Activity 5.5. You know that earthquakes indicate that the crust is moving. How does the Earth's crust move? What makes it move?

Think About This!

Below are some ideas about how and why Earth's crust moves from some of the Junior Scientist Team members. What do you think about their ideas? Do you agree? Do you disagree? Whose idea do you think makes the most sense?

"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

"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

"I don't understand how a solid rock can move without something pushing it."

- Kazuo Matsuyama from Japan

"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 Mexico

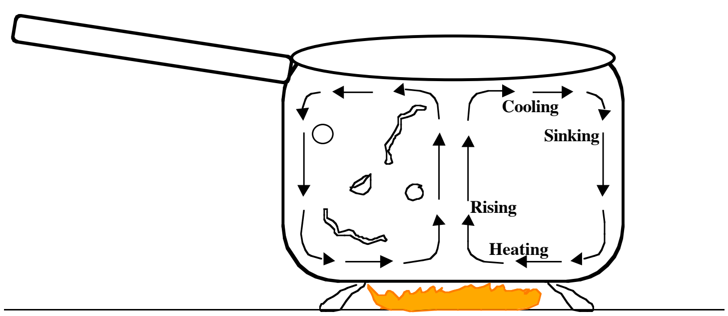
2. **Read some other explanations about <u>how</u> and <u>why</u> the crust is moving.** The first one is by Jacob Emery, Ashley's father from the Mariana Islands. The other is by Suna Ericcson from Iceland. These were written in response to the questions and predictions given by the Junior Science Team.

Dear Junior Science Team:

I like your ideas about how and why the crust of the earth is moving. In some ways I agree with all of you. This is what I understand:

Heat makes it move

The core of the Earth is the source of heat that drives plate motion. Material in the mantle is heated by the energy in the Earth's core. This heat causes **convection currents** in the mantle. Have you ever watched soup boil? Look at the illustration below. As the heat energy from the stove is transferred to the pot and then to the soup, the soup at the bottom of the pot gets hot. It expands, and the hot soup becomes less dense. The warm, less dense soup moves up and floats over the cooler, denser soup. Once it gets to the surface, the soup spreads out and begins to cool. As it cools, it becomes denser, and it sinks. A constant flow starts up as the cooler soup continues to sink and the warmer soup continues to rise. That flow is called a convection current.



This same process happens in the mantle of the Earth. The very hot inner core transfers heat to the mantle material. The mantle material expands and becomes less dense so it rises. When molten material reaches the crust, it spreads out and cools. As the mantle material spreads out under the crust, it carries the crust with it. Sort of like a conveyor belt carrying your groceries at the store. The cooler material now becomes less dense and sinks back to the bottom of the mantle layer [or wherever]. The heating and then cooling of the fluid mantle, changes in the density, and the force of gravity combine to set the convection currents in motion within the Earth.

Sincerely,
Jacob Emery

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?

Dear Fellow Junior Science Team Members:

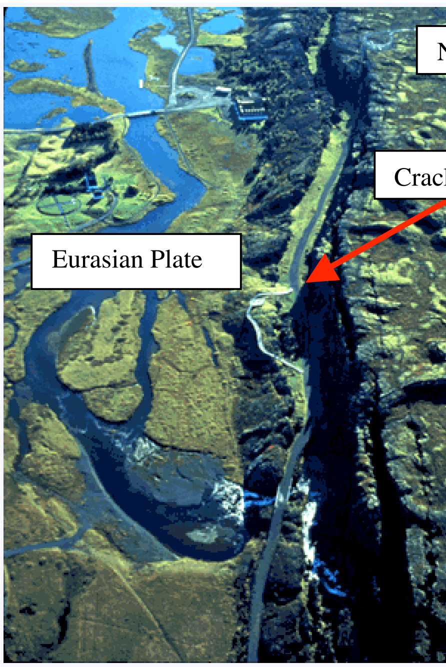
My name is Suna and I live in Iceland. I really enjoyed hearing about your ideas. I live in a place where the magma from the mantle is oozing out of a crack in the crust and the crust is moving apart.

What happens if there is a crack in the crust?
As you would expect, something escapes. Someone described the creation of mountains like the white of an egg oozing out through a crack of a hard boiled egg. That is a pretty good illustration of what happens. As the **magma** (mantle material) rises, it pushes its way out of the cracks in the crust and pushes the crust apart to create a **rift** (a narrow opening). As magma builds up at this rift, it creates a ridge. A **ridge** is a long narrow band of hills or mountains. In fact, the longest mountain chain in the world was formed this way. The Mid-Atlantic Ridge is a chain of volcanic mountains that runs right down the middle of the Atlantic Ocean and from the North Pole to the South Pole. Most of this ridge is underwater, so many of these volcanic eruptions go unnoticed. However, there are a few places where the mountains rise above sea level. Iceland is one of those places. Along the ridge, the land is always changing. Volcanoes erupt, magma oozes through cracks to add more crust, and islands are surfacing. It's an exciting place.

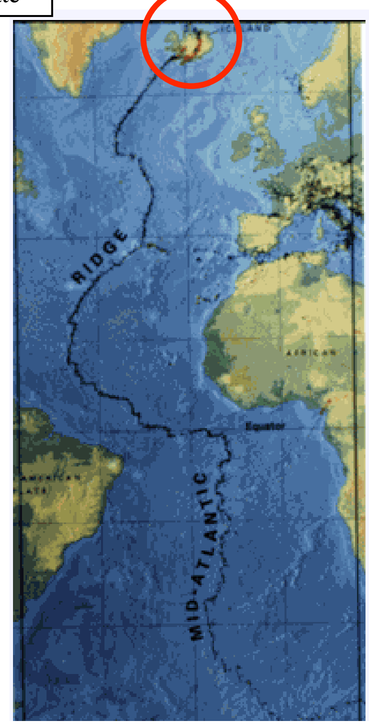
Your pal,

Suna Ericcson

P.S. Below is a photograph of a part of Iceland where you can see the crack in the crust and the plates of the crust separating. The other picture is a map of the Mid-Atlantic Ridge and Iceland is circled.



http://pubs.usgs.gov/publications/text/Thingvellir.ht



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

Figure It Out

Answer the following questions in your science journal or on the worksheet your teacher gives you.

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.

Activity 6.2: Comparing Volcanic Activity

Overview:

In this activity, you will compare the volcanic activity at the different earth structures using the descriptions from your pen pal letters. You will begin to explain why there are differences in volcanic activity.

Procedure:

1. **Make a prediction.** Yesterday you read about the role of Earth's hot interior in how and why plates move. We also read about new crust being added during this processes. Is crust always added in the same way? Do all volcanoes erupt the same way?

2. **What kind of volcano activity happens at your earth structure?** With your teammate, go back to the letter sent to you by your pen pal to find descriptions of the volcano activity. Summarize the description on an index card or small sheet of paper. The following questions will help you write your description:
   - How often do volcanoes erupt?
   - Describe an eruption?
   - How many volcanoes are in the area?

   Example: the Aleutian Islands

   Aleutian Islands:

   Lots of Volcanic Islands
   Violent eruptions
   Most volcanoes under water
   Volcanoes erupting all the time

3. **Is crust being added the same way at each earth structure?** One of your team members should take your volcanic activity description and your 3-D model to participate in organizing the class into groups that have similar volcano activity. Within each group, crust is being added in a similar way the earth structures. The group should then share why these earth structures go together. Post the index cards together in theses groups so that you remember later how the structures were grouped.

4. **The class will then discuss the organization and compare groups**.
   - What is similar?
   - What is different?

Reflection Question

Why are there differences in volcanic activity?

Activity 6.3: Oozing and Blasting Volcanoes

Overview:

You will be looking at some real-time volcano data at the Volcano World web site. You will then read about and compare three volcanoes.

Think About This!
Have you ever experienced a volcanic eruption? Do you know anyone who has experienced a volcanic eruption? Have ever seen news coverage or movie footage of one? What is an eruption like? What do you think it is like?

Procedure:

1. Your teacher will lead you in a class discussion about volcanoes while the class looks at how volcano data is collected and reported.

   Discussion Questions (before viewing):
   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?

   Discussion Questions (while viewing site):
   e. When and where was the last recorded volcanic eruption?
   f. What does "ongoing" mean in the volcano data?
   g. How is volcano data reported?
   h. Where are most of the volcanoes?
   i. What are some differences in the eruption patterns of different volcanoes?

   Discussion Questions (after viewing site):
   j. Do all volcanoes erupt in the same way? Is all crust added the same way?

Reflection Questions

What questions did you ask yourself about volcanoes as you looked at the real-time web-site?

2. **Read *Oozing and Blasting Volcanoes*** and answer the *Figure It Out* questions that follow.

Oozing and Blasting Volcanoes

On February 20, 1943 there was a loud crack that disturbed a small farming community in Mexico. The loud crack was the earth opening to release the heat rising from below the surface. Fire and smoke came pouring out of the hole in the middle of some corn fields. An entire town of people watched as their town was enveloped by the lava, ash, and smoke erupting from this new volcano. During the first year, this volcano rose to 336 m (1100 ft). In the following 8 years, layers of hot rock and ash piled up adding another 88 m (290 ft) to the volcano. Today many people come to visit this new volcano, Paricutin, that sits quietly among the cornfields. They also come to see the town taken over by the volcano. People rarely see the birth and growth of a volcano.

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

As described above, a **volcano** is a place at the Earth's surface where **magma** (molten rock), **ash**, and gases erupt, and where a cone-shaped landform is built. As you read this, there are probably 20 volcanoes oozing lava or blasting debris into the air. There about 1300 volcanoes identified. Of these, about 600 border the Pacific Ocean. This region of volcanoes and earthquakes is often called the Ring of Fire. And these numbers only reflect the volcanoes that have been seen and observed. It is estimated that there could be over a million volcanoes adding crust deep on the ocean floor that go undetected. When these underwater volcanoes finally reach the surface, they make an island. In 1963 the new island of Surtsey (meaning Norse god of fire) was born off the coast of Iceland after a large volcanic eruption.

How many active volcanoes are known?*

Erupting now:	Perhaps 20
Erupting each year:	50-70
Erupting each decade (10 years):	About 160
Historically documented (observed by people):	About 550
Number of volcanoes known to erupt during the last 10,000 years:	About 1300

<u>What is an eruption?</u> When the magma rises through cracks in the Earth's crust, it eventually escapes from the crust, pushing any rock or ash out when it finally does erupt. When the magma escapes the crust, it is called **lava**. Sometimes these eruptions are quiet, while at other times they are explosive and violent.

In October 1955, a volcano that was thought to be extinct came out of its more than 1,000-year sleep with a dramatic explosion. **Bezymianny** is located on the Kamchatka peninsula in Russia, northeast of Japan. The event started with an explosive eruption that deposited fine- to medium-grained ash and ended with a crater in the side of the mountain. The picture below is after Bezymianny erupted.

http://kamchatka.ginras.ru/main/textpage/bezymianny.html

In contrast, a volcano in Hawaii called Kilauea has been continually erupting for the past 20 years. The lava is thin, flows fast, and can "fountain" above the volcano. This lava forms rivers and lakes and cools slowly if on the surface of the volcano. Under the cool seawater, the lava cools quickly into blobs called pillow lava.

Stop and Think

Answer this question in your science journal or on the worksheet.

Do the volcanoes at your earth structure erupt more like Bezymianny or more like Kilauea? Explain.

Types of Volcanoes

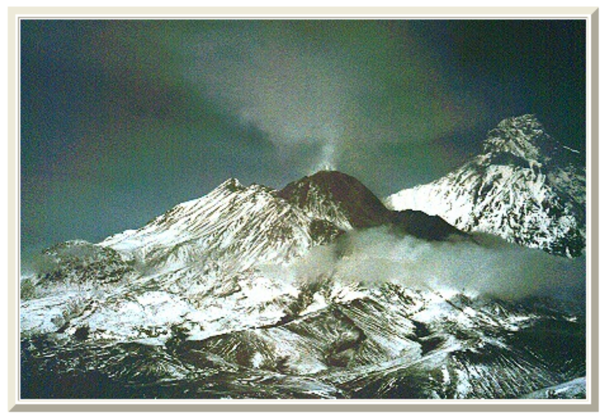
http://www.volcano.si.edu/world/region.cfm?rnum=13&rpage=list

Different kinds of eruptions yield different kinds of volcanoes. At Kilauea the magma comes from the mantle and breaks through the thin crust. Dark runny lava flows for long distances before cooling enough to become solid. These flows create rivers that can pool into lava lakes.

The volcanoes that come from this type of eruption are called **shield volcanoes**. The lava spreads out quietly and creates a volcano with gently sloping sides. The picture above is of Mauna Loa in Hawaii, the largest volcano in the world.

Notice the gentle slopes of this massive mountain, shown in the picture to the left. This mountain is 7 miles long and rises 30,000 feet from the ocean floor. Mauna Loa last erupted in 1984 and started rumbling again in September of 2004.

Imagine shaking a can of soda and then opening it. The pressure that forces the liquid to spray out of the can is similar to the pressure that causes a volcano to erupt in an explosion like the one at Bezymianny. At Bezymianny in 1955, the eruption started with an explosion that deposited fine gray ash. At the end of November the side of the volcano bulged out. On March 30th, this side of the volcano blew out. Large amounts of gas, dust, ash, and hot lava fragments then ejected out of the crater. Debris from the collapsed side slid down the volcano's side in an avalanche. This directed blast caused trees to fall for 15 miles. You can see the how the side collapsed in the picture at the right. Bezymianny is the mountain closest to you in the picture.



http://volcano.und.nodak.edu/vwdocs/current_volcs/bezymianny/bezymianny.html

Volcanoes that result from this type of eruption a called **stratovolcanoes** (sometimes also called composite volcanoes.) They are typically steep–sided, symmetrical cones of alternating layers of ash and lava. The lava sprays out of the volcano and flows slowly down the sides of the mountain. Most of the time the lava is not fluid like the lava at shield volcanoes but rather lumpy and slow-moving, maybe even containing bits of hot rock. Notice the symmetrical shape of the stratovolcano located near Bezymianny in the picture above.

The simplest type of volcano is the **cinder cone**. Pari□cutin in Mexico, described at the start of this reading, is an example of a cinder cone. These volcanoes are built from particles and blobs of lava ejected from a single vent. A **vent** is a tube or channel in the crust magma escapes through to the surface. As lava is blown violently into the air, it breaks into small fragments that solidify and fall as cinders. Cinder cones are common in volcanic regions. They are also small compared to shield volcanoes

http://volcano.und.nodak.edu/vwdocs/volc_images/img_paricutin.html and stratovolcanoes. The photo at the right of Paricutin was taken in 1947 at night. As you can see in the photograph, lava is in the form of glowing rocks blasting out of the top and tumbling down the sides of the volcano. Hot rock and ash are scattered over the surface.

Figure it Out

1. What is a volcano?

2. How long does an eruption last?

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?

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.

Activity 6.4: Characterizing Volcano Data Patterns

Overview:
In this activity, you will plot and analyze real volcano data. You will then compare volcano data patterns across earth structures.

Procedure:
1. **Plot the volcano data pattern on your 3-D model of your earth structure.** In Lesson 5 you plotted the earthquake pattern in one color of small sticker dots. Use a different color sticker dot to plot the volcano data pattern. Use the *MyWorld* map view "**ESInquiry**."

2. **Find an earth structure with similar patterns of volcanoes.** Using *MyWorld* and the "Earth Structures Boxes" layer, capture a map of an earth structure that has similar volcano patterns to your earth structure's. Describe how the volcano patterns are similar.

3. **Find an earth structure with different patterns of volcanoes.** Using *MyWorld* and the "Earth Structures Boxes" layer, capture a map of an earth structure that has different volcano patterns from your earth structure's. Describe how the volcano patterns are different.

4. **Are the patterns in the volcano data the same?** One of your team members will participate in grouping the earth structures with similar volcano data. Use your 3-D models with your volcano data plotted and the index cards summarizing volcanic activity. To start you may want to return to the groups formed in Activity 6.2. In this group, discuss and describe the patterns you see in your volcano data. The following questions will guide your discussion to find common patterns in the volcano data:
   - How can your group characterize the volcano patterns? Describe the data pattern. For example: few, lots clustered, etc.
   - 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?
   - Label the 3-D models to indicate which group each earth structure is in. Large sticker dots in different colors should work.

5. Present your findings to the class. Your presentation should include:
   - a characterization of the data pattern
   - a description of the kinds of eruption activity
   - the kinds of volcanoes you think are at your earth structures
   - each earth structure volcanic activity index card taped to your chart paper

6. **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?

Reflection Questions

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.

Activity 6.5: "Rivers of Fire" Video

Overview:

You have been learning about different types of volcanoes. The location of volcanoes can give big clues as to what type of movement is occurring in an area. This video takes you to Hawaii and introduces you to a volcanologist working in the field. You'll learn about the type of work that is done to possibly predict future volcanic eruptions.

Procedure:

1. As you watch the video, "Rivers of Fire," look for ideas that have been discussed in class. You may learn some new information that may help you even further understand the changes happening at your earth structure and in Earth's crust.

2. Read the Figure It Out questions before you watch the video. Then, as you view the video, write down any notes that may help you answer them.

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?

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.

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?

How do you think volcano patterns relate to earthquake patterns?

Explain the process causing the changes happening at your earth structure.

Lesson 7

Plates on the Move

What have you learned so far?

You know that earthquakes and volcanoes indicate that the crust is moving and cause changes at your earth structure. In Lesson 5 you mapped the plates of the world. In Lesson 6 you learned that the circulation of the convection currents causes the crust to move with the currents. You 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 different eruption patterns. You have also begun to explain the processes that are causing change at your earth structure, using supporting evidence.

In this lesson, you will characterize the patterns that you see in all of these data to explain what is happening at your earth structure. You will also look some earthquake and volcano data a little closer to better support your explanations.

Activity 7.1: Characterizing Both Data Patterns

Overview:

In this lesson, you will look at both earthquake and volcano data to sort and characterize the patterns. This will help you describe the changes happening at your earth structure and at your plate.

Procedure:

1. **Describe the pattern you see in the earthquake <u>and</u> volcano data of the Aleutian Islands.** Look at a map of the Aleutian Islands with the earthquake and volcano data plotted. Describe the patterns you see in the data. How do the patterns relate to each other? How would you characterize the data patterns?

2. **Compare the earthquake and volcano data patterns for the Aleutian Islands to the patterns for your earth structure**. Are the patterns similar? How are they similar? How are they different?

3. **Group earth structures by similar earthquake <u>and</u> volcano data patterns.** One member of each team will participate in an all-class sort of the earth structures like you have done before. This time you are looking for common patterns in <u>both</u> the earthquake and volcano data. You should use your 3-D models to share the data patterns for each earth structure.

4. Once groups have been established, **write a description of the patterns for your group of earth structures**. Write these descriptions on chart paper.
   - Describe the pattern of earthquakes.
   - Describe the pattern of volcanoes.
   - Describe the topography of the land.
   - Describe the relationship of the earth structures to the plate boundaries.

5. **The group should choose some examples of the data patterns to share with the rest of the class. Find these examples in *MyWorld*.**

6. **Draw a diagram showing what is happening at your earth structure.**

7. **Each group should then share the pattern descriptions with the rest of the class**. While groups are presenting you should be asking yourself:
   - 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?

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?

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?

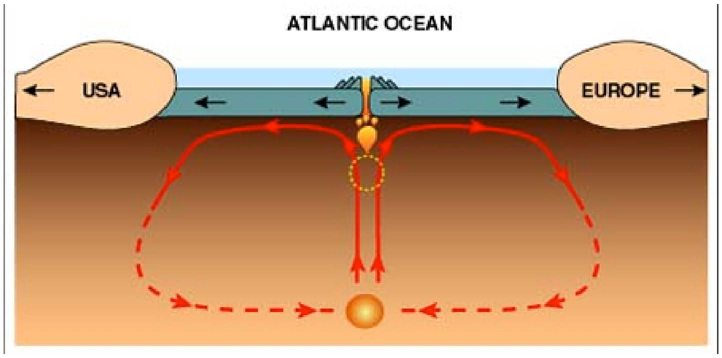
8. **Read *Zones* and answer the Figure It Out questions.** Your class has identified and named several different types of patterns you noticed in the earthquake and volcano data. Read *Zones* to learn how the scientific community currently identifies, names, and explains these patterns.

Rift Zone

What is a rift zone?

A rift zone is a region of the Earth's crust where plates are **rifting,** or spreading apart. The plates move away from each other very slowly. As they do, magma rises from the mantle. It pushes up the crust and eventually breaks through the crust. This process can take place under the ocean or on land.

http://www.soc.soton.ac.uk/CHD/classroom@sea/carlsberg/science/cont-



The magma that quietly bubbles out at rift zones is generally, runny, and dense. Each time the magma erupts; new land is added, creating a ridge of mountains.

Most eruptions happen on the ocean floor and go undetected, quietly constructing new crust. At rift zones under the ocean, when magma rises up it hits the cold water. This causes it to cool quickly into new crust on the sea floor. The cooling magma forms pillows of lava.

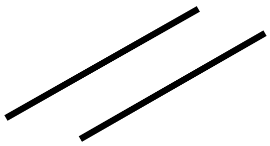
The convection currents in the mantle pull the crust in opposite directions at rift zones. This means that the volcanic debris does not have much time to build up before the plates move the crust away, taking old volcanic debris with them. When volcanic materials rise out of a rift faster than the plates are moving apart, volcanic mountains are built. Sometimes these mountains surface and become islands. The island of Surtsey in the North Atlantic was formed by this process.

When a rift zone occurs on land, the same process happens. However, on land we can observe the rising magma and volcano formation. In contrast to the rift zones underwater, the center of the ridge usually sinks to form a valley between the two mountain ranges (giving us the term 'rift valley'). The sinking valley collapses under the two plates that are moving apart. This sinking valley causes shallow earthquakes and volcanoes at the edge of the rift as well as in the main rift. Eventually this valley sinks below sea level and then fills with sea water, forming a new ocean.

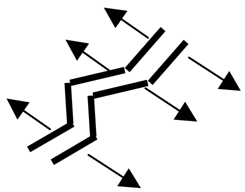
To illustrate a rift zone: Use your two hands to represent two plates next to each other. Have another student push his or her hand up in between them, representing the rising magma as the plates move apart – this is **rifting**.

Label rift zones

Mark each rift zone with this symbol:

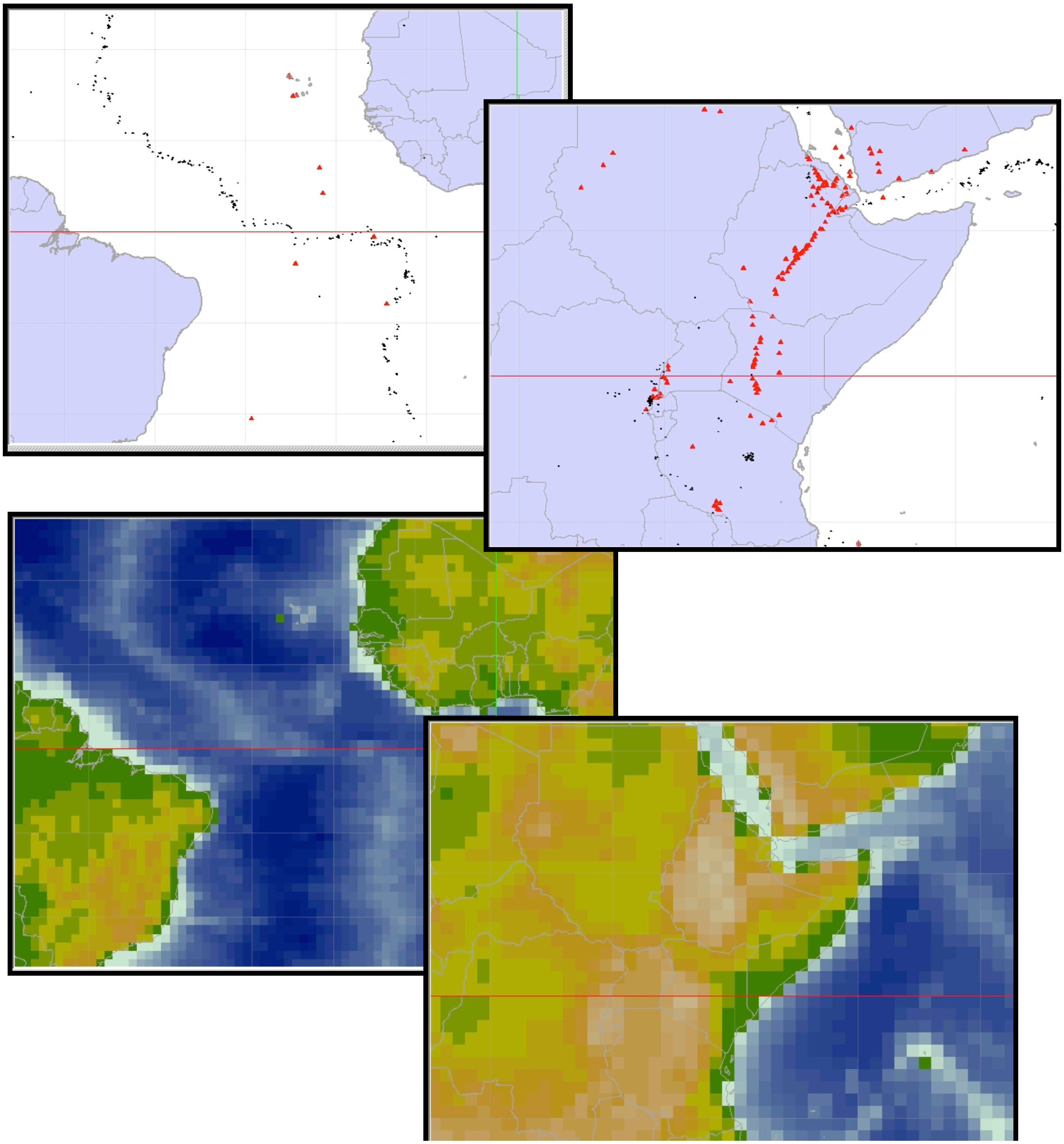


Draw arrows to show that the two plates are moving apart.



What does the data at a rift zone look like?

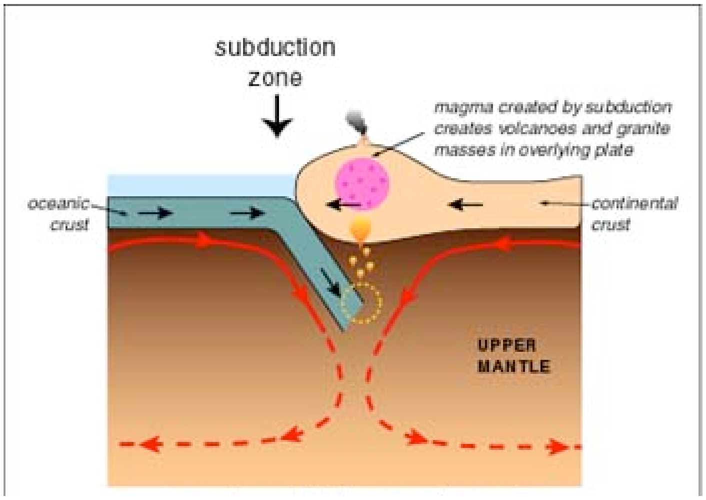
- Earthquakes are shallow and small. The data pattern forms a narrow band or line of earthquakes.
- If volcanoes are underwater, there are a few scattered volcanoes near the line of earthquakes. If volcanoes are on land, they appear as a narrow band.
- There is a narrow ridge of volcanic mountains or a narrow ridge of mountains with a valley in between.



Subduction Zone

What is a subduction zone?

A **subduction zone** is a region of the Earth's crust where two plates are coming together or converging. **Converging** plates are crashing into each other very slowly. At a subduction zone crash, one plate dives under the other plate. The plate that is moving under another is being destroyed. Where the two plates meet a **trench** is formed. Trenches are long, steep-sided depressions that can be as deep as 30,000 feet below sea level.



http://www.soc.soton.ac.uk/CHD/classroom@sea/carlsberg/science/cont-

At a subduction zone, convection currents in the mantle pull the two plates together, and crust is destroyed. These subduction zones are often found where the thin, dense oceanic crust meets the thick, less dense continental crust. The less dense continental crust "floats" over the top of the oceanic crust.

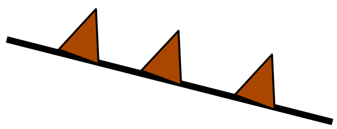
Sometimes two plates of oceanic crust collide, and one subsides under the other for similar reasons. One oceanic crust may be less dense than the other, so that plate "floats" over the other.

When the cool, denser crust dives under the other plate, the crust crumbles and melts in the mantle. This can cause earthquakes to happen as far as 700 km below the surface of the Earth. When the rock of the subsiding plate melts into the mantle, volcanoes are created on the "floating" plate. They form a steep, volcanic mountain range right next to the deep ocean trenches. These volcanoes often erupt explosively, ejecting ash, slow-moving lava, and hot rock debris. This magma material is often less dense than the magma at rift zones or hot spots.

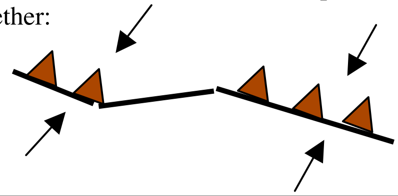
To illustrate a subduction zone: Use your two hands to represent two plates next to each other, and slide the edge of one hand under the other – this is **subduction**. The edge on the top hand gets pushed up as the bottom hand pushes under.

Label subduction zones

Mark each subduction zone with this symbol:

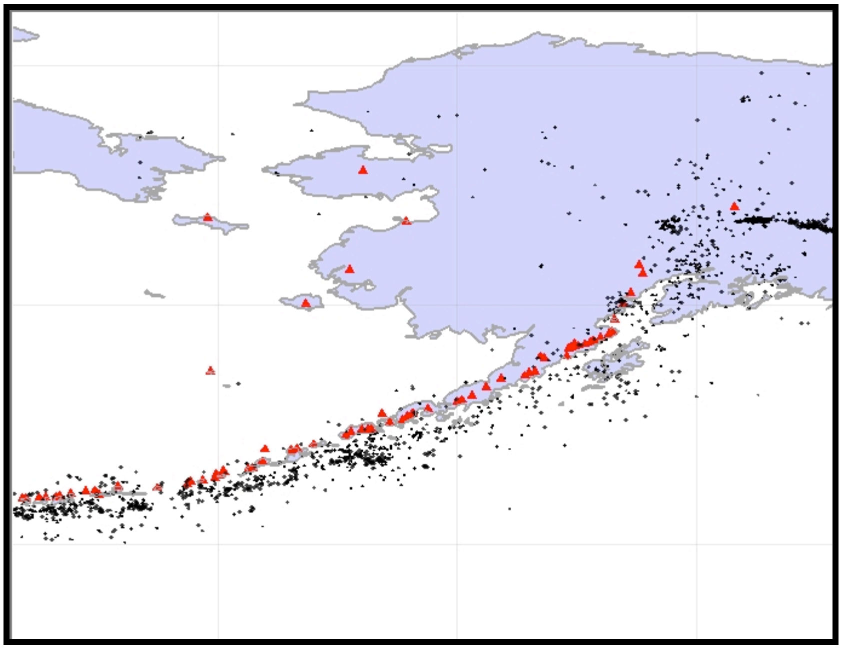


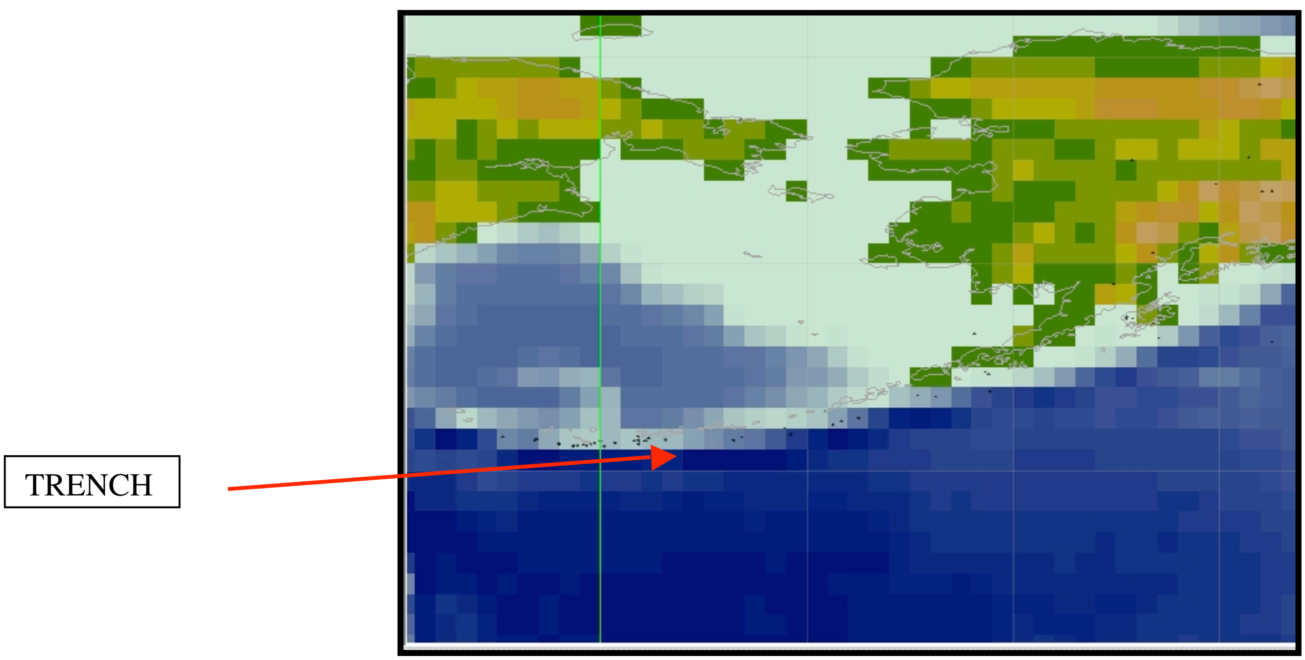
Draw arrows to show that the two plates moving together:



<u>What does the data at a subduction zone look like?</u>

- Earthquakes happen in a clear line.
- Volcanoes happen in a clear line right next to the line of earthquakes.
- Earthquakes generally happen deep below the surface as one plate dives under the other.
- A deep trench is next to a line of steep volcanic mountains.

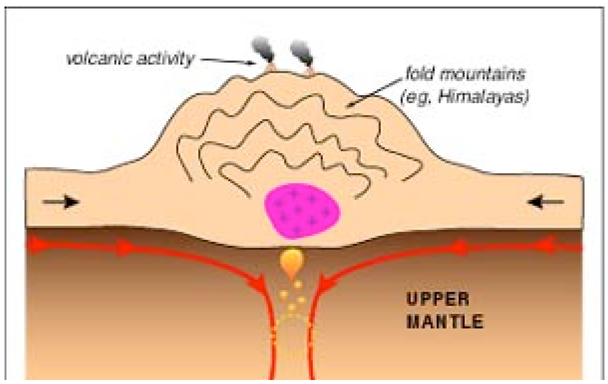




Buckling Zone

What is buckling zone?

A **buckling zone** is a region of the Earth's crust where two plates are coming together or converging. **Converging** plates are crashing into each other very slowly. At the buckling zone crash, the two plates push up together to form a large, folded mountain range. Convection currents in the mantle carry these two plates into each other. They are usually thick continental plates. Some of the largest and highest mountain ranges in the world were created in this way.



http://www.soc.soton.ac.uk/CHD/classroom@sea/carlsberg/science/cont_collision.html

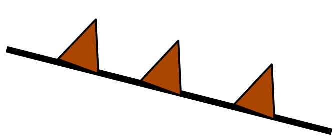
Have you ever pushed two graham crackers together? They are thick and crumbly, much like the continental crust, and both graham crackers have the same density. When they are pushed together, their edges crack and push up into a "mountain range."

When the two plates crash together and fold, the continental crust melts. This melting can cause volcanoes, but often the magma does not escape from the thick crust. The few volcanoes that are created there often eject hot rock, ash, and slow-moving lava. This magma comes from the crumbling continental plates, so it has a different consistency from the magma at rift zones and hot spots.

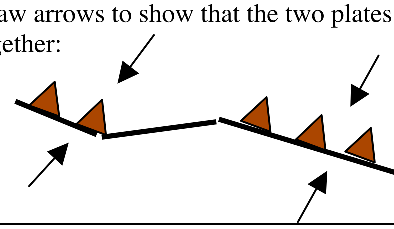
To illustrate a buckling zone: Use your two hands to represent two plates next to each other. Push your two hands against each other, with the touching edges rising up together like a mountain – this is buckling.

Label buckling zones

Mark each buckling zone with this symbol:

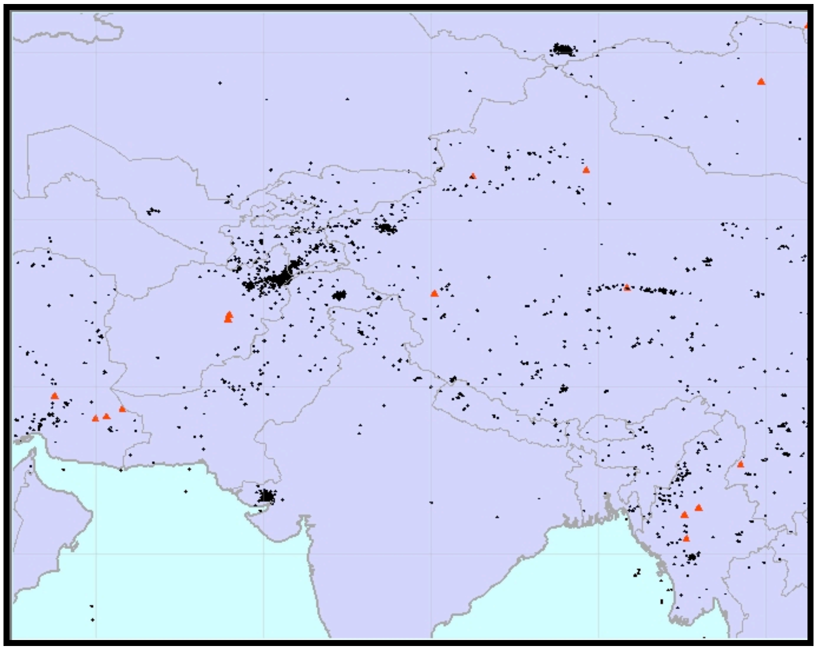


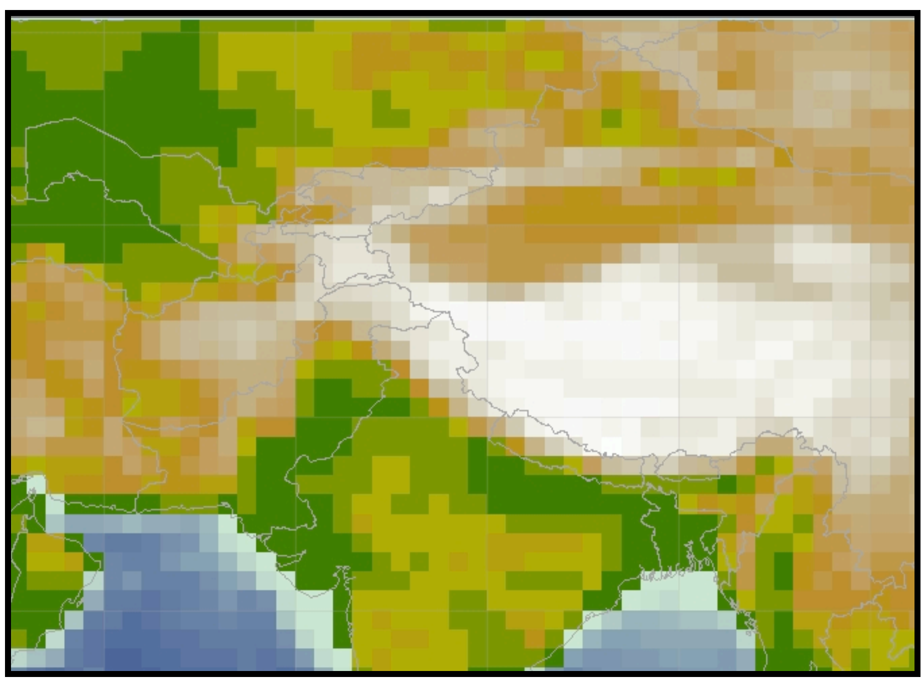
Draw arrows to show that the two plates moving together:



What does the data at a buckling zone look like?

- Earthquakes happen in a scattered pattern.
- Volcanoes are few and scattered.
- Earthquakes generally happen near the surface.
- A large, folded mountain range sits on continental crust.



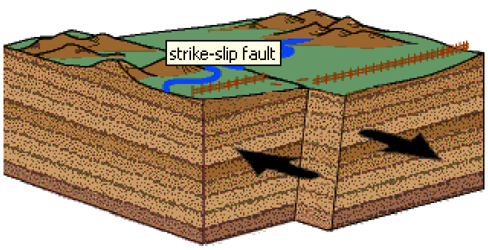


Transform Zone

<u>What is a transform zone?</u>

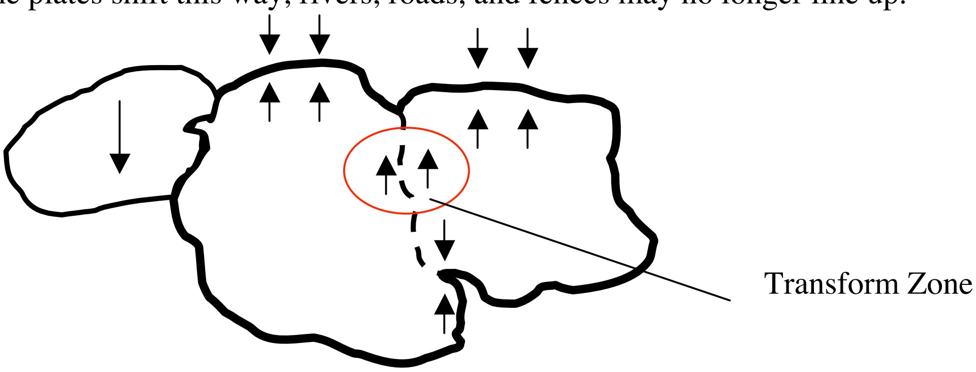
A transform zone is an area of the Earth's crust where two plates moving in opposite directions are sliding past each other. How can this happen? Sometimes one side of a plate is subducting (going underneath the plate next to it) while the other side of the plate is rifting. This plate can then slide past one of its neighboring plates. The San Andreas Fault Line in California is a good example of a transform zone: it is a place where the plates are sliding past each other. The Great San Francisco Earthquake of 1906 happened because two plates were sliding past each other.

http://www.iris.washington.edu/gifs/slides/faults/slideshow



http://wrgis.wr.usgs.gov/docs/parks/deform/gfaults.html

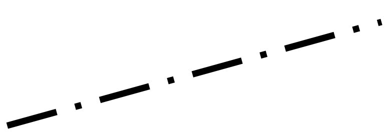
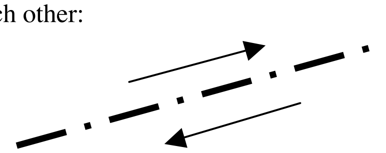
When two plates slide past each other, the rock in the crust gets bent, folded, and cracked. After the plates shift this way, rivers, roads, and fences may no longer line up.



How do the plates move past each other? The convection currents within the mantle pull the plates towards or away from each other. Sometimes these convection currents cause the two plates to move past each other.

To illustrate a transform zone: Use your two hands to represent two plates next to each other. Keeping the edges of your hands touching, move both hands, sliding one past the other.

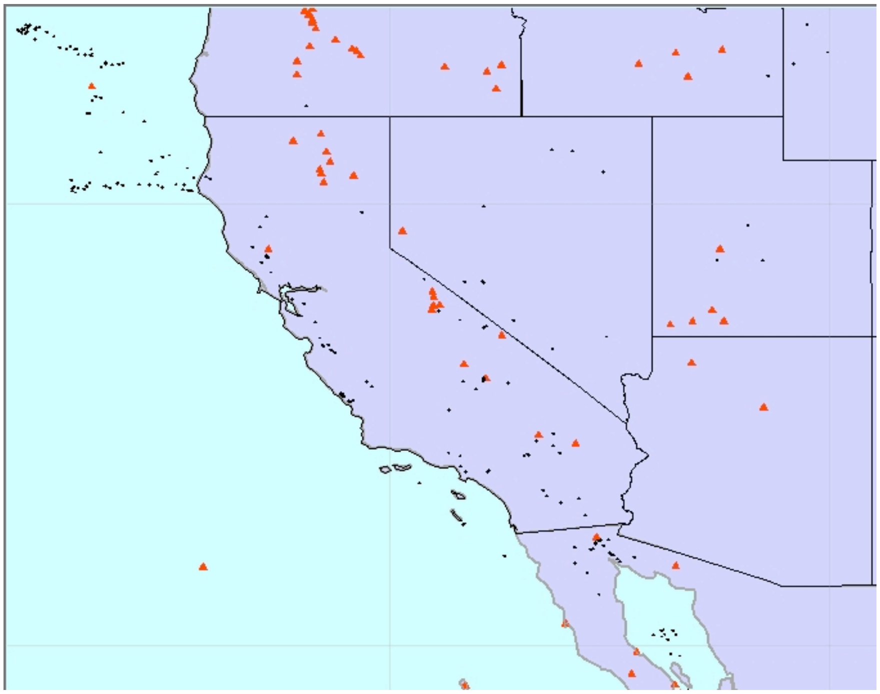
<u>Label transform zones</u>

Mark each transform zone with this symbol:	Draw arrows to show that the two plates sliding past each other:
	

<u>What does the data at a transform zone look like?</u>

Transform zones are difficult to identify from earthquake and volcano data. You can identify all other plate boundary predictions (rift, subduction, and buckling) and then try to predict which remaining boundaries must be transform boundaries.

- Lots of earthquakes happen near the surface
- Volcanoes occur in a variety of patterns



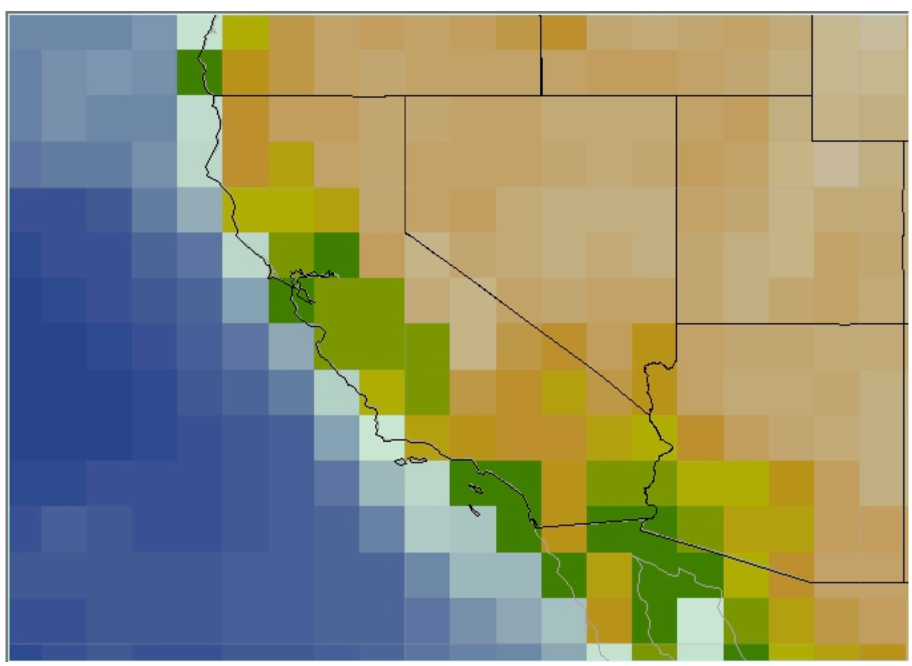


Figure It Out

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 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.

Activity 7.2: Identifying Zones

Overview:

In this activity, you will identify the different kinds of movement zones at your earth structure and then around your plate. You will also predict which direction the plate is moving.

Procedure:

1. **Group the earth structures of the class into different types of zones.** You have read descriptions of the different types of movement zones and decided what type(s) of movement is happening at your earth structure. Is everyone in the same groups as in the last activity? If teams moved, why did they move?

2. **Identify the types of zones that are around your plate.** In your earth structure teams, you will use earthquake and volcano data in *MyWorld* to analyze earthquake and volcano data for the boundaries around your plate. You should capture a map of your plate with both earthquake and volcano data plotted and then label the different types of zones.

3. **Label the types of zones that are around your plate map.** Use the Three Page World Map of your plate you drew at the end of Lesson 5. Use the symbols recommended in the zone descriptions to identify the different types of zones around your plate.

4. **How is your plate moving?** Based on the data you just analyzed, how is your plate moving? What direction is it moving? How do you know? Draw arrows on your plate map (Three Page Map from Lesson 5) to show the direction the whole plate is moving. Draw similar arrows on your class plate map as well so the class can discuss your predictions.

5. **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 needs to come to some consensus about the direction the plates are moving. Go back to the data if you need to verify and discuss patterns in the data.

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?

Activity 7.3: Depth of Earthquakes

Overview:

In Activity 7.1, you learned that deep earthquakes happen at subduction zones. In this lesson you will look at some depth data of earthquakes to help you explain and identify subduction zones. You will also read about the differences in oceanic and continental crust.

Procedure:

1. **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"?

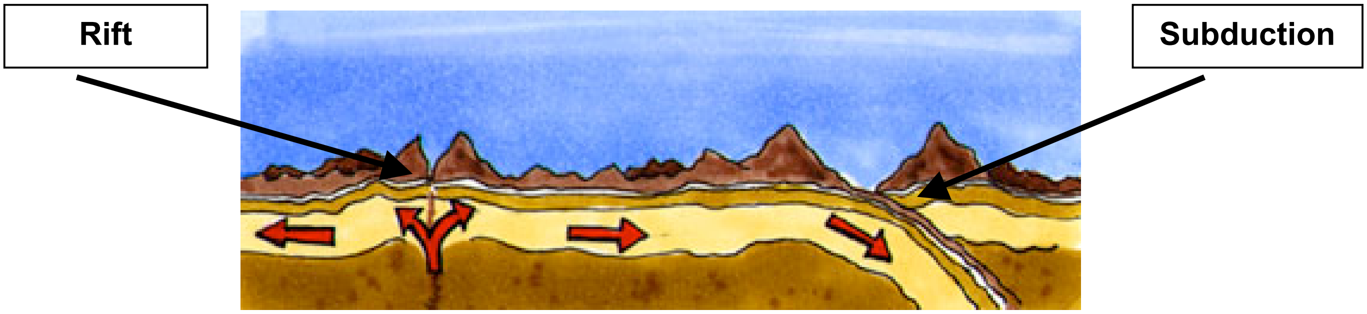
2. **Read *Is All Crust the Same?*** and answer the Figure It Out questions that follow to help you explain why some crust subsides and other crust bends when the plates collide.

Is All Crust the Same?

You know that the thin layer of the earth is called the crust. This crust is not all the same. There are two different types of crust: oceanic and continental. These two types of crust are made of different types of rock and therefore have different densities.

As the name already suggests, **oceanic crust** is below the oceans. Though this is not true of all oceanic crust, most of it is found under the oceans. Oceanic crust, at 6-11 km (4-7 miles) thick, is very thin compared to the continental crust. Most of the rifts of the world are part of these thin oceanic plates, so the crust here is young compared to the rocks of the continental crust. Rocks of the oceanic crust are not older than 200 million years, and some of the rock of this crust was born yesterday. Magma at these rifts comes from deep in the mantle. This magma is dark, thin, and dense. It flows easily out of cracks in the crust and cools off quickly in the cold ocean. The magma of the oceanic crust also consists of different materials than the continental crust. The molten material from Earth's mantle is rock that is low in silica, such as basalt. Basalt rock is very fine and has gritty grains. It comes from deeper parts of the crust and mantle.

Continental crust is what we think of when we think of Earth's land. Continental crust is thick and less dense than the oceanic crust. The continental crust is an average of 30 to 40 km (20 to 25 miles) thick, but at the Himalayas the crust is about 70 km (45 miles) thick. The continental crust is older than the oceanic crust. Some rocks are 3.8 billion years old. The molten material that is added to the crust on the continents in most cases comes from the destruction of the plates at subduction zones. This is rock that is high in silica, like granite. The continental crust "floats" on top of the oceanic crust. The oceanic crust is denser so it dives under the continental crust when the two kinds of crust meet.



http://www.mos.org/oceans/planet/change.html

http://www.imige.biz/slovensky/en/belt.html

New oceanic crust is formed at the mid-ocean ridge where the plates rift. However, this crust is destroyed when it reaches the continental crust and subsides. At that point, it goes back into the mantle where it is again heated and melted. This process is very similar to the conveyor belt at the grocery store. Like the picture at the left, the conveyor belt moves in one direction and goes under (subduction zone) and then comes back up (rift zone). The Earth's crust is continuously recycled.

Figure It Out

1. Compare oceanic crust to continental crust.

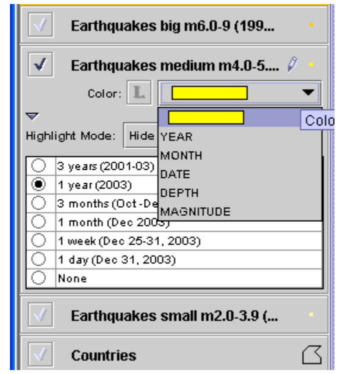
2. Is the plate your earth structure is part of primarily oceanic crust or continental crust?

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.

5. **Where would you expect to find deep earthquakes**? Choose a few places that you expect to find deep earthquakes and mark them with a rectangle on a *Small World Map* worksheet.

Compare the depths of earthquakes using *MyWorld.* Take your *Small World Map* worksheet to the computer with you.



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 maps. The globe shape is also the best representation of what the data really looks like. When using the globe projection, the best way to get around is with the Re-Center Tool. The point you click will become the center of the view.

7. **Check the places you expected to see deep earthquakes**. Does this data support the idea that these places are subduction zones? Mark the places where you found deep earthquakes. Hint: If you are having trouble seeing the data, hide the Continents Layer.

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 there is a subduction zone. Explain how the data supports that location.

Reflection Questions

What types of movement zones are happening at your earth structure? Describe the data you have to support that idea.

Activity 7.4: Volcano Types Data

Overview:

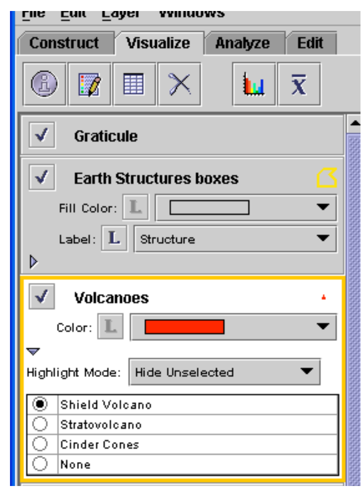
You will look at patterns in volcano types data to help you explain what is happening at your earth structure and plate boundaries.

Procedure:

1. **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.

2. **What type of volcano would you expect to find at each of the zones?** Where would you expect to find stratovolcanoes? Where would you expect to find shield volcanoes? On your *Small World Map* worksheet, mark where you would expect to find stratovolcanoes with a red rectangle, shield volcanoes with a blue rectangle, and cinder cone volcanoes with a yellow rectangle.

3. **Compare the location of different types of volcanoes.** Take your *Small World Map* worksheet to the computer.
   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 the best representation of what the data really looks like.
   f. **Use the volcano type selections to analyze the volcano data pattern**:
      - Where are the stratovolcanoes? Mark these in red.
      - Where are the shield volcanoes? Mark these in blue.
      - Wher are the cinder cone volcanoes? Mark these in yellow.



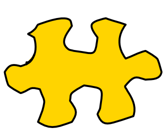


Figure It Out

1. Where do stratovolcanoes occur? Where do 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?

Reflection Question

What types of movement zones are happening at your earth structure? Describe the data you have to support that idea.

Activity 7.5: What is Happening at Your Earth Structure?

Overview:

In this final activity, you will summarize your evidence and explain the changes that are happening at your earth structure.

Procedure:

1. **Read the letter from NESS outlining what they would like you to put in your final report.**

National Earth Structure Survey
111 E. Old Trench Road
Washington D.C. 20005

Dear Junior Scientists:

We are very excited about the progress you have made and the patterns you have found. Junior Science Assistants have been keeping us informed of your work and ideas. We would like to look at the work that you have done and share it with others in the science community. We really look forward to seeing your analysis of the data. There is much debate in the science community about how to analyze the data for a process that takes place over such long periods of time.

In your report, please include your identification of the boundary zones and the direction you think the plate is moving. We would also like to know what you think is happening at each earth structure. [This seems a little vague.] Please describe the process causing the changes at your earth structure. We'd like to see your supporting evidence as well ast your analysis of that supporting evidence.

We are also preparing for further study, so we are interested in what questions you still have about the processes of Earth's crust.

It has been a pleasure working with you, and we look forward to your future work.

Keep Rocking and Rolling,

Dr. Seismic P. Wave

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2. **Decide what do you need to do.** Here are some notes about pieces you have already started to meet the expectations of Dr. Seismic P. Wave.

Plate boundary and zone identification and direction movement	Three Page Map from Activity 7.1 Data with notes
Description of process at earth structure	Diagram and description started in Activity 7.1 Data maps of earth structure with notes

3. Discuss with your teacher and the class how each team is going to present their reports for NESS: Display board, computer presentation, report, etc.

4. To check your findings before you send them on to NESS, **the class will meet in small groups to share their reports**. While you are listening to the other groups, look for:
   - explanations that are clearly supported with evidence
   - explanations that contradict your explanations
   - accurate descriptions of the supporting evidence (analyzing accurately and with "enough" data)

   You should also give the other groups feedback. The class can determine what kinds of feedback should be given. One possibility is to look for multiple types of supporting evidence: earthquake, volcano, topography, anecdotal, earthquake depth, and volcano type

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.

WHAT'S THE POINT?

You 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.

You have done your part to contribute to the collective knowledge of the community. You have successfully participated in developing scientific explanations of the processes changing the Earth's crust; you did so by analyzing data. You looked at much data and analyzed it and have some explanations to contribute to the scientific community. Congratulations!

Apply What You Know

Assessment Activity

National Earth Structure Survey
111 E. Old Trench Road
Washington D.C. 20005

Dear Junior Science Team:

We have been very impressed with your hard work and explanations of the process changing the crust of the Earth. Part of the mission of NESS is to share our knowledge with local communities so they can better prepare for catastrophic earthquakes and volcanic eruptions.

Some of the Junior Science Team members have sent in articles describing volcanic or earthquake activity in their areas. They would like to know why these events are happening. How do you explain what is the process causing these changes? And, what evidence can they share with their community to support your explanation? The team members that submitted the articles will be putting together presentations and reports to take to their local communities. We need you to do the preliminary data gathering and analysis.

We look forward to your contributions.

Keep Rocking and Rolling,

Dr. Seismic P. Wave

Read the articles and the other materials sent by some of the Junior Science Team members.

Your task is to describe the process that is changing and shaping the crust at these places. Below is a list of what the junior scientists would like you to include in your letter so that they can prepare a report for their community.

- **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.**