Classroom Activities

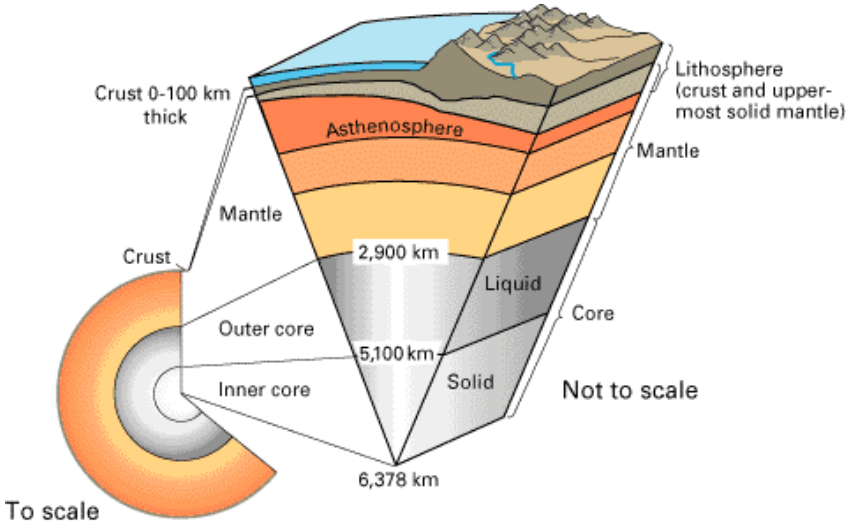
Introduction and A Rocky Paradox: Plate Tectonics/Mountain Building

Subjects

Supercomputers, simulation, modeling, plate tectonics, Rocky Mountains, seismology

Background

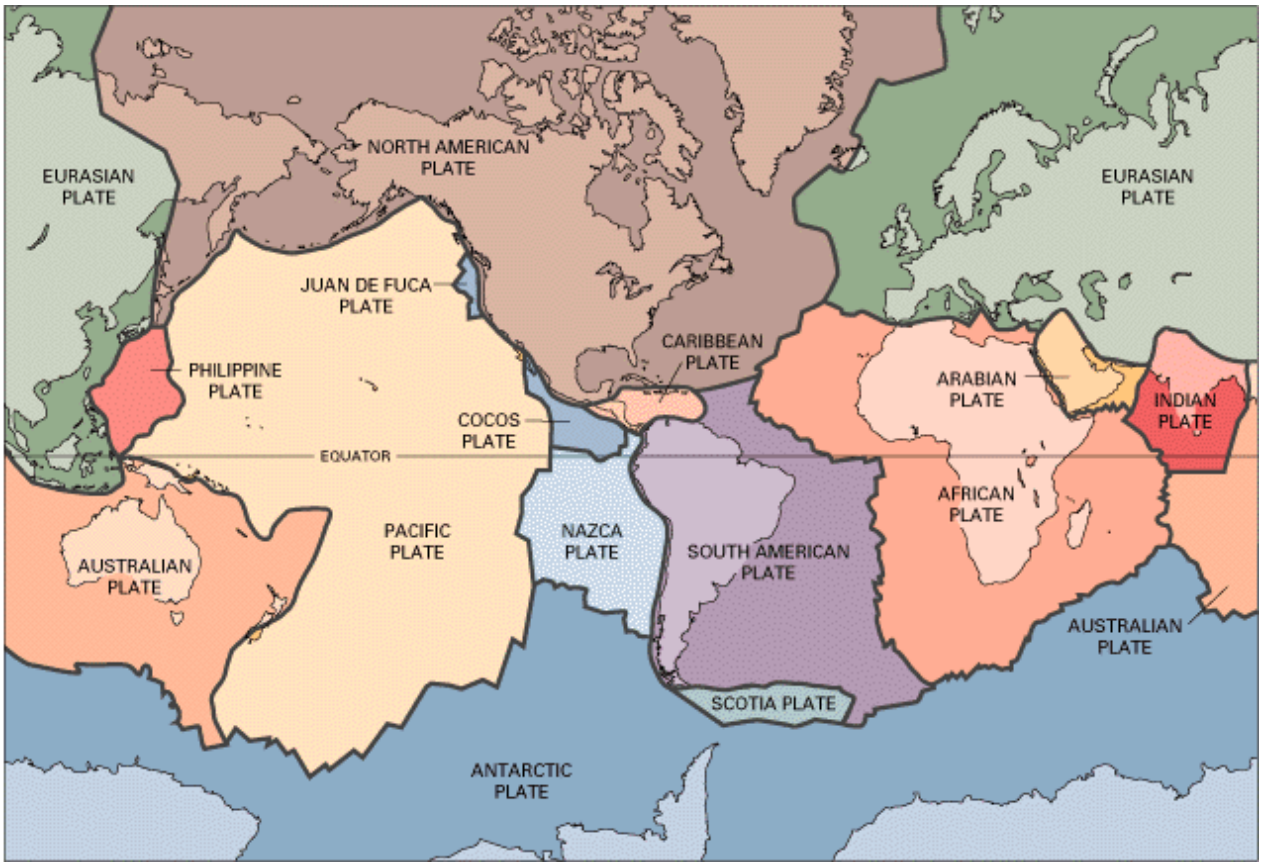
The solid Earth consists of several layers. The outermost layer is the solid crust on which we walk. The crust is about 35 kilometers thick under the continents. The crust is the thinnest layer of the Earth. The lithosphere below the crust is solid and consists mainly of materials more dense than crustal rocks. The total thickness of the lithosphere is about 100 kilometers. The mantle is a very thick shell with a thickness of 2,900 kilometers. The mantle behaves like something hard or solid and is the thickest layer. The outer core is about 2,200 kilometers thick. The outer core behaves as a liquid. The inner core behaves as a solid and is 1,200 kilometers thick. Temperatures increase as you go deeper into the Earth.



Earth's inner furnace
Source: http://observe.arc.nasa.gov/nasa/earth/tectonics/Tectonics2_and_a_quarter.html

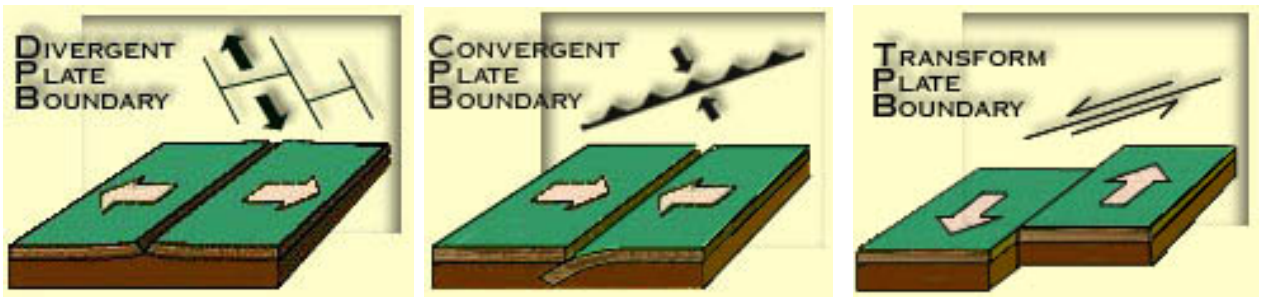
A tectonic plate is a massive section of the Earth's crust (lithosphere) that "rides" upon the asthenosphere, a hot, semiplastic layer of the planet. Plates are moved on the asthenosphere by convection currents. These plates move independently, sometimes colliding, sometimes sliding against each other. The Earth's surface is broken into 10 to 12 major plates and many smaller minor plates. These plates, each about 100 kilometers (60 miles) thick, move relative to one another an average of a few centimeters a year.

Plate tectonics is the branch of science that deals with the process by which rigid plates move across hot, more deformable material. It has helped to explain much in global-scale geology, including the formation of mountains and the distribution of earthquakes and volcanoes.



Major tectonic plates of the world
Source: http://geology.er.usgs.gov/eastern/plates.html

Three types of movement are recognized at the boundaries between plates: convergent, divergent, and transform-fault.



Three types of faults
Source: http://observe.arc.nasa.gov/nasa/earth/tectonics/Tectonics3.html

A divergent fault is a boundary between two plates where the plates are moving away from each other. Magma from deep within the Earth pushes its way up, forcing the plates apart. As two plates pull apart, rock below partially melts to produce magma that rises and fills the gap. This process can create seafloor spreading.

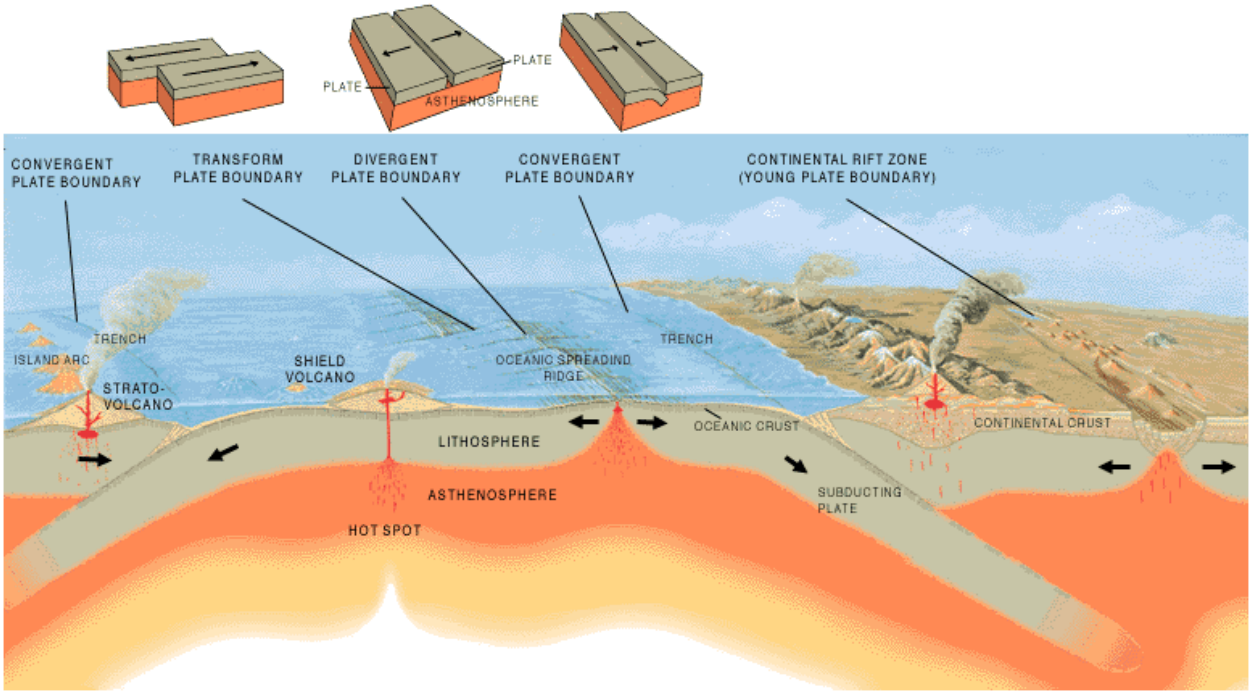


Plate boundary interactions
Source: http://pubs.usgs.gov/publications/text/Vigil.html

A boundary where two plates collide is known as a convergent fault. There are three types of convergent faults: Oceanic crust colliding with oceanic crust (O-O), oceanic crust colliding with continental crust (O-C), and continental crust colliding with continental crust (C-C). At convergent boundaries, plates move toward each other and collide. Where an oceanic plate collides with a continental plate, the more dense oceanic plate tips down and slides beneath the continental plate forming a deep ocean trench (a long, narrow, deep basin.) An example of this type of movement, called subduction, occurs at the boundary between the oceanic Nazca Plate and the continental South American Plate. Where continental plates collide, they form major mountain systems such as the Himalayas.

A transform fault occurs where two plates are sliding past each other. These boundaries are often hazardous areas to live in, since they are prone to earthquakes. Earthquakes can happen at these faults when the plates "stick" together, causing a buildup of pressure. When the pressure becomes too much, the plate can slip, releasing a lot of energy. This energy can cause an earthquake. The San Andreas Fault zone is an example of this type of boundary.

The processes that produce mountain belts are called orogenesis. Mountain belts are typically formed by plate tectonic activity, specifically continental collision. Orogeny is the variety of processes that result in mountain formation.

Lesson Plan

Objectives

Students will

> Describe and draw Earth's geological layers from the inner core to the outer continental crust.
> Explain the process of orogenesis using drawings and simulations from plate tectonics theory.
> Use a bar graph to describe the relative thickness of each of the Earth's geologic layers.
> Create a clay model of divergent, convergent, and transform fault plate boundaries.

Engage:

1. Locate and display pictures of Nepal and its people (many are available online).
2. Scenario: Consider that you are a citizen of Nepal. Scientists tell you that your country will "cease to exist" physically and literally in 10 million years. What can this mean? Can this be true, and if so how can it be prevented? How can you or scientists explain this eventual disappearance of your homeland? What tangible evidence can support this claim?
3. Students can work in groups of three to four to discuss the real-world problem. They can use any resources available to discern plausible answers. One Internet source is: http://www.pbs.org/wgbh/nova/everest/earth/birth.html
4. Follow up with whole-group sharing. Have students make connections between the dynamic changing Earth and its effect upon human life.

Explore:

1. Have students use the Pre-viewing Activities to review and access prior knowledge. Review the vocabulary.
2. Introduce the Video Viewing Questions. Ask students to complete the questions while watching the video and check their answers with a partner after viewing.
3. Show the video "Journeys through Earth and Space," Introduction and A Rocky Paradox.
4. Discuss controversial answers to the Video Viewing Questions.
5. Have students read the Background for this story. Students will complete Activities 1, 2, 3, and 4. Activities 3 and 4, which model the three types of fault boundaries, may be done as a demonstration or in groups.
6. Have students complete Activity 5.

Explain:
Students will apply knowledge to answer the following questions:
1. What is the energy source that moves the Earth's plates? Is this an example of convection, conduction, radiation, or a combination of these? Explain.
2. Why does the Earth's inner core (4300 degrees C) have solid properties while the cooler outer core (3700 degrees C) is liquid?
3. What is the Mohorovicic Discontinuity, and why is it important to us in understanding the composition of the Earth?
4. Respond to Analysis Questions in Activity 5.

Evaluate:
Replay the video, "Journey through Earth and Space," A Rocky Paradox.
Students will write a one- to two-page essay describing in detail: "How did the Rocky mountains form and why are they so far inland from the Pacific Coast of the United States?" Do you think the Rocky Mountains have completed their formation? Defend your answer.

Extend: Technology
Use the following Web site:
Quakes and Plates
http://edmall.gsfc.nasa.gov/inv99Project.Site/Pages/trl/inv1-1.html
Students can complete an online activity that will show how tectonic plate movement is related to regions of earthquakes.

Activity Reading Level: Flesch-Kincaid: 7.5

National Standards (Science Content)
Grades 9-12

Scientific Inquiry-Content Standard A:
Abilities Necessary to do Scientific Inquiry
- Use technology and mathematics to improve investigations and communications.
- Formulate and revise scientific explanations and models using logic and evidence.
- Communicate and defend a scientific argument.

Earth and Space Science-Content Standard D:
Energy in the Earth System
- The outward transfer of Earth's internal heat drives convection circulation in the mantle that propels the plates comprising Earth's surface across the face of the globe.

The Origin and Evolution of the Earth System
- Interactions among the solid Earth, the oceans, the atmosphere, and organisms have resulted in the ongoing evolution of the Earth system.

Science and Technology-Content Standard E:

Understandings about Science and Technology

- Scientists in different disciplines ask different questions, use different methods of investigation, and accept different types of evidence to support their explanations.
- Science often advances with the introduction of new technologies.

Science in Personal and Social Perspectives-Content Standard F:

Natural and Human-Induced Hazards

- Normal adjustments of Earth may be hazardous for humans.

History and Nature of Science-Content Standard G:

Nature of Scientific Knowledge

- Scientific explanations must meet certain criteria. First and foremost, they must be consistent with experimental and observational evidence about nature, and must make accurate predictions, when appropriate, about systems being studied.
- Because all scientific ideas depend on experimental and observational confirmation, all scientific knowledge is, in principle, subject to change as new evidence becomes available.

Additional References

On the Move: Continental Drift and Plate Tectonics
http://kids.earth.nasa.gov/archive/pangaea/

Plate Tectonics
http://scign.jpl.nasa.gov/learn/plate.htm

Plate Tectonics/Plate Types
http://observe.arc.nasa.gov/nasa/earth/tectonics/Tectonics1.html

What on Earth is Plate Tectonics
http://wrgis.wr.usgs.gov/docs/parks/pltec/pltec1.html

Major Tectonic Plates of the World
http://geology.er.usgs.gov/eastern/plates.html

Activities and Teaching Suggestions for Plate Tectonics
http://www.volcanoworld.org/vwdocs/vwlessons/plate_tectonics/part1.html

Printable World Map.
http://www.abcteach.com/Maps/world.htm

NASA Observatorium Teacher's Guides: Plate Tectonics
http://observe.arc.nasa.gov/nasa/education/teach_guide/tectonics.html

Geology: Plate Tectonics
http://www.ucmp.berkeley.edu/geology/tectonics.html

Plate Tectonics: Looking at Our Ever-Changing Planet
http://www.gsfc.nasa.gov/gsfc/service/gallery/fact_sheets/earthsci/earth.htm

Plate T-48: Himalayan Front and Tibetan Plateau
http://daac.gsfc.nasa.gov/DAAC_DOCS/geomorphology/GEO_2/GEO_PLATE_T-48.HTML

Plate T-11: Appalachian Mountains
http://daac.gsfc.nasa.gov/DAAC_DOCS/geomorphology/GEO_2/GEO_PLATE_T-11.HTML

Credits

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Introduction and A Rocky Paradox: Plate Tectonics/Mountain Building

Pre-viewing Activities

Questions

What are the geological layers of the Earth?

Where is the Earth's mantle? Draw an illustration to depict the Earth's layers.

The Rocky Mountains are 1,500 kilometers (1,000 miles) inland from the Pacific coast. How do you suppose they formed so far inland?

How do you think a computer could help answer this question?

Vocabulary to Know

Convergent Plate Boundaries
Core (Inner and Outer)
Crust (Continental and Oceanic)
Divergent Plate Boundaries
Lithosphere
Mantle
Mohorovicic Discontinuity
Plate Tectonics
Transformational Plate Boundaries

Video Viewing Questions

1. What is NASA using to tackle questions such as the inland position of the Rocky Mountains?

2. Two things supercomputers can do include:
   a. _____
   b. _____

3. What is ESS? How is it different from Earth Science?

4. Describe the Earth's mantle.

5. What forms and drives tectonic plates?

6. How far inland are the Rocky Mountains from the Pacific coast of the U.S.?

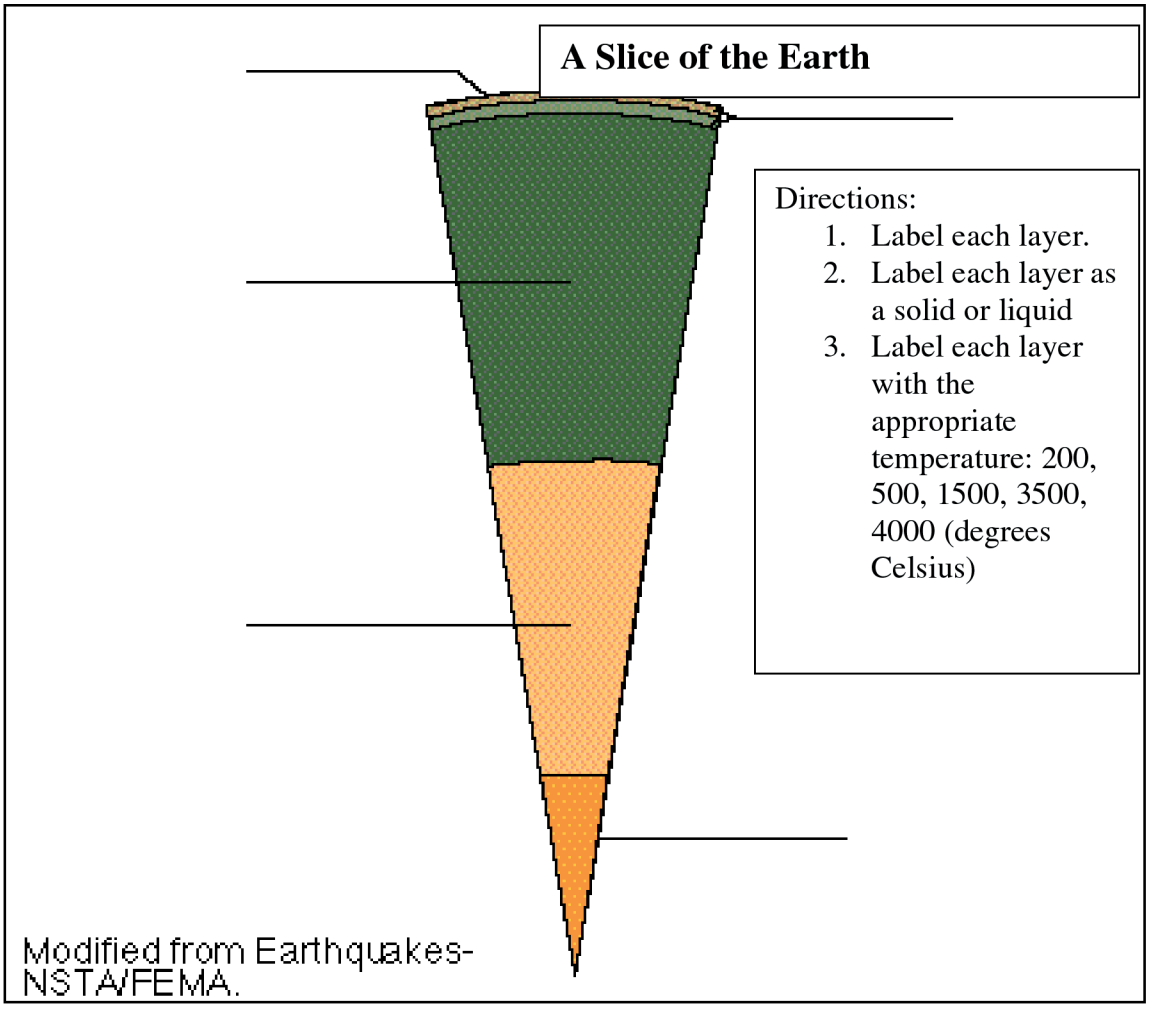
7. Which tectonic plates were involved in the formation of the Rocky Mountains?

8. What types of plates were these: convergent, divergent, or transformational? How do you know that?

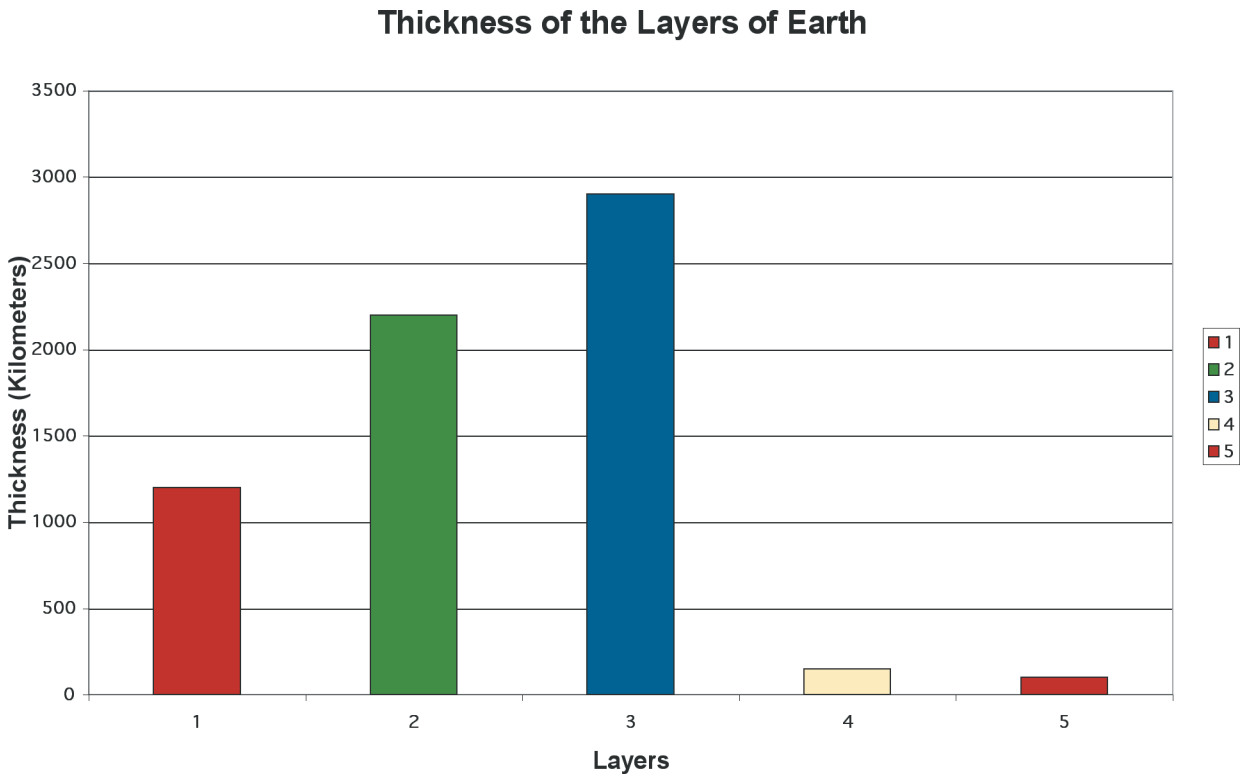
9. What caused the crust to "bob up" or upwell?

Introduction and A Rocky Paradox: Plate Tectonics/Mountain Building

Activity 1: A Slice of the Earth



Activity 2: Graph Interpretation



1. Match each bar with the appropriate layer. Choose from the list below.

_____ Crust
_____ Inner core
_____ Lithosphere
_____ Mantle
_____ Outer core

2. How thick is each layer (in kilometers)?

_____ Inner core
_____ Outer core
_____ Mantle
_____ Lithosphere
_____ Crust

3. What have you learned about the thickness of the layers of Earth? Summarize your findings in complete sentences.

Activity 3: Faults

Transform fault

You can simulate a transform fault by placing your hands side-by-side and sliding one forward. Each hand represents a tectonic plate.

1. Describe in your own words what happens in a transform fault. Give an example of this type of a plate boundary.

Divergent fault

Use your hands again to simulate a divergent fault. Just place your hands together and then separate one hand away from the other (left and right).

2. Describe in your own words what happens in a divergent fault.

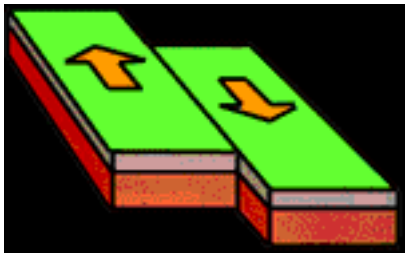
Convergent fault

Use your hands once more to simulate a convergent fault. Place your hands side-by-side. Now push one hand against the other. Allow them to push together and rise up in the center where they touch.

3. What does this uprising represent in terms of geology and plate tectonics?
4. Describe in your own words what happens in a convergent fault.

Activity 4: Clay Modeling

Use three different colors of modeling clay to create models of each type of fault: transform, divergent, and convergent. Models should look something like this example of a transform fault. Why are there three layers represented? Are there ALWAYS three layers involved in plate movement? Explain.



Activity 5: Mapping

1. Read the background material.
2. Use an atlas world relief map or an Internet site to find and name the major mountain systems. Identify and list at least eight of these.

Major Mountain Systems

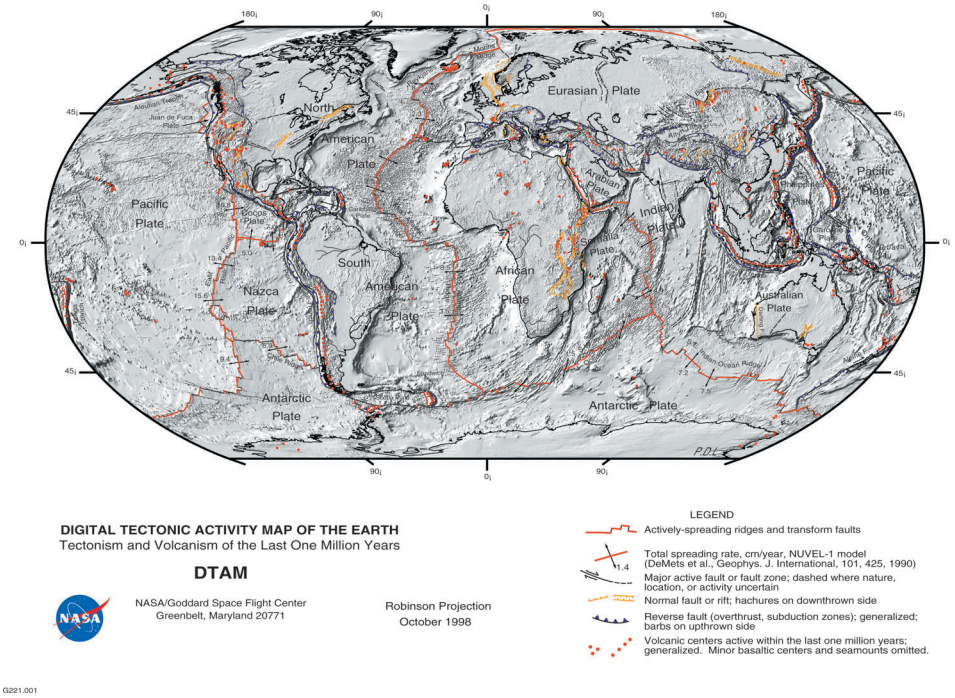
a.
b.
c.
d.
e.
f.
g.
h.

3. Use a sheet of acetate (transparency film) to trace the major tectonic plates of the world. Make sure that this is the same size as a world map you will use in the next step of this activity.
4. Overlay a geophysical or political map of the world with the tectonic plates tracing.
5. Label the plate boundaries on the overlay in the following way:

D–divergent
T–transform
C–convergent
To convergent add:
OO–oceanic with oceanic (your label should look like this, C-OO)
OC–oceanic with continental crust
CC–continental crust with continental crust.

Analysis Questions (Refer to the previous USGS map and the following NASA map.)

1. Name four major mountain ranges that might have been formed by colliding plates.
2. Using the atlas, locate the Zagros Mountains in southern Iran, where the Arabian Plate is impacting the Iranian Plate. Sketch and describe what is happening.
3. Which plate is forming the Andes Mountains on the west side of South America?
4. What plates were involved in forming the Rocky Mountains?
5. Why are the Rocky Mountains so far inland? Describe what happened.



Digital tectonic activity map of the Earth
Source: http://denali.gsfc.nasa.gov/dtam/dtam/

Introduction and A Rocky Paradox: Plate Tectonics/Mountain Building

Educators' Answer Key

Pre-viewing Activities

Questions

The three basic Earth layers are the crust, mantle, and core. (The Background material adds the lithosphere between the crust and mantle and divides the core into the outer core and the inner core.)

The mantle is the middle layer of the Earth. A drawing of concentric circles labeled with crust, mantle, and core might work well at this stage, depending on what the students have learned so far.

Although students would not be aware of it before watching the video or learning from another source, the tectonic plate that formed the Rocky Mountains did not sink until it had traveled 1,500 kilometers from the Pacific coast.

A computer can help answer the question by simulating the geological processes in detail.

Video Viewing Questions

1. Supercomputers
2. Process observations into a motion picture, solve equations that describe realities seen and unseen.
3. Earth and Space Sciences. It is different because it includes space phenomena such as the Sun.
4. The mantle is the middle layer of the Earth.
5. Tectonic plates are formed when rock cools off at the top of the mantle. The plates are driven by the flow of rock (motions) in the mantle.
6. 1,500 kilometers, or 1,000 miles
7. Farallon Plate and North American Plate
8. Convergent. The plates came together.
9. The Farallon Plate settling to the bottom of the mantle.

Additional background on Video Viewing Question 9: As the Farallon Plate moved eastward, the North American Plate moved westward above it. The lower crust of the North American Plate was relatively soft, and as this plate moved westward some of the lower crust tended to lag behind and pile up in front of where the Farallon Plate was sinking (subducting). There was a significant thickening of the crust in this region. Eventually, plate motion in the Pacific Ocean changed so that the Farallon Plate ceased to grow anymore, and the plate completely sank into the mantle. This subduction caused the thickened crust to bob up like a cork to produce the Rocky Mountains.

Activity 1: A Slice of the Earth

From top to bottom, the labels, matter states, and temperatures are as follows:

Crust	Solid	200 degrees C
Lithosphere	Solid	500 degrees C
Mantle	Solid	1500 degrees C
Outer core	Liquid	3500 degrees C
Inner core	Solid	4000 degrees C

Activity 2: Graph Interpretation

1. 5 = Crust, 1 = Inner core, 4 = Lithosphere, 3 = Mantle, 2 = Outer core

2. 1,200 km = Inner core, 2,200 km = Outer core, 2,900 km = Mantle, 100 km = Lithosphere, 35 km = Crust

Activity 5: Mapping

2. Major Mountain Systems

Alps (Europe)
Andes Mountains (South America)
Appalachian Mountains (North America)
Atlas Mountains (Africa)
Brazilian Highlands (South America)
Carpathian Mountains (Europe)
Cascade Range (North America)
Great Dividing Range (Australia)
Himalaya Mountains (Asia)
Rocky Mountains (North America)
Tian Shan (Asia)
Transantarctic Mountains (Antarctica)
Ural Mountains (Asia, Europe)
Zagros Mountains (Asia)

Analysis Questions

1. All of the Major Mountain Systems listed above qualify, plus chains such as the Sierra Nevada (North America) that formed when the Farallon Plate first sank beneath the North American Plate.
2. The Arabian Plate is colliding with the Iranian Plate, pushing the Zagros Mountains slowly upward.
3. Nazca Plate
4. Farallon Plate and North American Plate
5. The Rocky Mountains are so far inland because the Farallon Plate scraped along the bottom of the North American Plate for 1,500 kilometers before sinking to the bottom of the mantle.