Geology of Devils Tower

Lesson Plans

- Use with the **Devils Tower** module.
- Use with the **Devils Tower** worksheets.

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Geologic Setting

Standards

National Science Education Standards Grades K-4

- Earth and Space
  - *Changes in the Earth and Sky*
    - The surface of the Earth changes. Some changes are due to slow processes, such as erosion and weathering, and some changes are due to rapid processes, such as landslides, volcanic eruptions and earthquakes.

- Science as Inquiry
  - *Understanding about scientific inquiry*
    - Plans and conducts simple investigations.

- Science and Technology
  - *Understanding about science and technology*
    - People have always had questions about their world. Science is one way of answering questions and explaining the natural world.

Overview

Devils Tower is part of the Black Hills, which are dome mountains. Dome mountains are formed when the rocks of Earth's crust are pushed upward. The layers of sedimentary rock above the uplifted dome are eroded away. In this activity students use clay to model the formation of a dome mountain. This demonstration also allows them to see the age of the sediment layers as they become exposed.

Materials

- Four colors of clay or dough to represent the layers of sedimentary rock. (See recipe below if needed.)

- Groups of students will need about a fourth of a cup of each color.

- Plastic knife for each group.

Procedure

1. Flatten out each color to a similar size.

2. Stack the layers of clay sandwich style.

3. Discuss the age of the layers (i.e., the oldest at the bottom with the youngest on top).

4. Make a slight dome with the layers so that they don't stick to the table.

5. Using their hands, have students push toward the center from all sides. The clay should dome upward.

6. Using the plastic knife cut the top inch from the dome to reveal the layers. The oldest clay should show in the center.

Recipe for soft dough

2 cups flour
1 cup salt
1 Tablespoons alum
2 cups boiling water
2 tablespoons baby oil
Food coloring

Mix dry ingredients. Add water and oil. Mix well. Color as desired. Stores a long time in baggies.

Results

Deposits of mud, silt, or sand form horizontal layers of sedimentary rocks like the layers made in your activity. Pressure within the Earth push the rock layers for millions of years until they dome. Erosion caused by wind, water, ice, and plants cause change. Old mountains such as the Black Hills show the effects of dome building, that is, you find the oldest rocks in the center and the youngest rocks on the edges. This is represented when you removed the top from your dome to reveal the age of the layers.

Discussion Questions

1. What did the clay represent?

2. What force was represented by your hands?

3. How is erosion involved?

4. How are domed mountains different from volcanoes?

Web Sites of Interest

http://www.ugs.state.ut.us/education/tc/tc0399.htm
http://earthnet.bio.ns.ca/english/activities/landforms/activity15.html
http://intranet.canacad.ac.jp/groups/grade_8/mssciexemp/vol/mountains/index.html
http://www.sdnhm.org/fieldguide/fossils/timeline.html
http://www.ucmp.berkeley.edu/education/explorations/tours/geotime/gtpage9b.html

Igeneous Rocks

Standards

National Science Education Standards Grades K-4

- Earth and Space
  Properties of Earth materials
  Earth materials are solid rocks and soils, water, and the gases of the atmosphere. The varied materials have different physical and chemical properties, which make them useful in different ways, for example, as building materials, as sources of fuel, or for growing the plants we use as food. Earth materials provide many of the resources that humans use.

- Science as Inquiry
  Abilities necessary to do scientific inquiry
  Communicate investigations and explanations in a spoken or drawn and written format.

- Science and Technology
  Understanding about science and technology
  Scientists and engineers often work in teams with different individuals doing different things that contribute to the results.

Overview

Devils Tower is made of igneous rock. That means it cooled and crystallized from magma (molten rock). Textures of igneous rock include phaneritic, aphanitic, porphyritic, glassy, vesicular, and fragmental.

- Phaneritic texture is coarse with grains that are large enough to see with the naked eye. An example of a phaneritic texture would be granite.
- Aphanitic texture is fine with grains that are too small to be seen with the naked eye for example basalt.
- Porphyritic texture has crystals that can be seen with the naked eye embedded in a matrix of smaller crystals, which cannot be seen with the naked eye.

Overview (continued)

The igneous rock in Devils Tower is called a "phonolite." It is rich in sodium. It has a texture with large feldspar crystals and small pyroxene crystals. Phonolite porphyry is unusual because it is only found in Wyoming, Montana, and West Africa. It contains feldspar but no quartz.

In this activity students will use texture definitions from above to sort pictures into the three bulleted categories and write brief explanations to support their thinking.

Materials

- Copies of rock photographs (color if possible.)
- Definition cards (see example)
- Paper
- Pencil

Before the Activity

1. Determine student partners.

2. Print out a set of definition cards for each group.

3. Print out a set of rock photographs for each group.

Procedure

1. Read and discuss texture definition cards.

2. Provide photo cards.

3. Have partners sort photos under the three definitions.

4. Support their thinking in a written explanation.

5. Share results with class.

Web Sites of Interest

http://geology.csupomona.edu/alert/igneous/texture.htm
http://www.dc.peachnet.edu/~pgore/geology/geo101/igneous.htm
http://volcano.und.edu/vwdocs/vwlessons/lessons/Igrocks/Igrocks5.html

Formation

Standards

National Science Education Standards Grades K-4

- Science and Technology
  - *Abilities of technological design*
    - Communicate a problem, design, and solution

- Science as Inquiry
  - *Communicate investigations and explanations*
    - Communicate, critique, and analyze their work and the work of other students. This communication might be spoken or drawn and written.

Overview

Devils Tower's geologic history centers around three hypotheses. All of them use the following concept. The tower was formed about one mile underground as molten rock moved toward the surface, cooled, and hardened. The tower became exposed slowly as erosion removed the softer surrounding rock. The following are current theories of formation:

- Volcanic Neck: The tower represents the underground conduit or plumbing system that led upwards to a volcano. The conduit became plugged and that plug is what is observed today. Any evidence for volcanic activity has since eroded away. This is an exciting interpretation!

- Laccolith: The tower was once part of a mushroom-shaped lens of rock. Therefore, the tower was probably much larger than it is today and may even have extended to the Missouri Buttes. There are many laccoliths in the area including Sundance Mountain. At the turn of the 20th century this theory was very fashionable amongst geologists.

- Stock: The tower likely never erupted and was not much bigger or different in shape from what we observe today. This is the simplest explanation.

In this activity, students will select one of the theories and attempt to construct a three dimensional model to represent it such as a diorama, box-sculpture, paper-mâché, clay, or salt dough model.

Materials

- Various art materials
- Labeled diagram showing a stock, volcanic neck, and laccolith

Procedure

- Explain to students who have chosen the **volcanic neck** that they need to explain what has happened to the rest of the volcano in a short caption that will accompany their model.
- Explain to students who have chosen the **laccolith** that they need to explain what has happened to the rest of the mushroom shaped laccolith in a short caption that will accompany their model.
- Explain to students who have chosen the **stock** that they need to represent the change that has occurred as erosion removed the softer surrounding rock and the tower became exposed. They need to explain that process in a short caption that will accompany their model.
- Conclude activity with a sharing session.

Web Sites of Interest

http://volcano.und.edu/vwdocs/vwlessons/lessons/Igrocks/Igrocks5.html
http://formontana.net/2a.html
http://www.rockware.com/support/casestudies/sierra_blanca.pdf
http://www.lpl.arizona.edu/~jrich/work/whiteoaks.pdf

Structure

Standards

National Science Education Standards Grades K-4

- Science and Technology
  - *Understanding about science and technology*
    - People have always had questions about their world. Science is one way of answering questions and explaining the natural world.

- Science as Inquiry
  - *Abilities to do scientific inquiries*
    - Communicate investigations and explanations in a spoken or drawn and written format.

  - *Properties of Objects and Materials*
    - Objects have many observable properties, including size, weight, shape, color, temperature, and the ability to react with other substances.

- Earth and Space
  - *Changes in Earth and Sky*
    - The surface of the Earth changes. Some changes are due to slow processes, such as erosion and weathering, and some changes are due to rapid processes, such as landslides, volcanic eruptions, and earthquakes.

Overview

The structure of Devils Tower includes columnar jointing. Columnar joints are common in lava flows, drying lake beds, and drying mud. Some columns of the tower are 600 feet (183 m) tall and 15 feet (4.6 m) in diameter making it one of the largest and tallest examples. It occurs in homogenous substances as they shrink at just the right speed. The shrinking causes cracks to form and intersect to form roughly hexagonal shapes. The phonolite in the tower shrank as it cooled causing the cracks and forming the columns. Another National Monument that lends itself well for comparison is Devils Postpile.

Educational research conducted by Mid-Continental Regional Education Laboratory advocates comparisons as highly effective ways of learning and attaching meaning to new material. The following activity uses internet resources and a graphic organizer to promote a comparison of Devils Tower in Wyoming to Devils Postpile in California. The organizer can be modified to include various characteristics to fit the needs of the classroom. It may be expanded to include language or research objectives by assigning written reports.

Materials

http://www.nps.gov/deto/
http://www.nps.gov/deto/geology.htm
http://wrgis.wr.usgs.gov/docs/wgmt/parks/detoproj/detoproj.html
http://www.nps.gov/depo
http://www.nps.gov/depo/pphtml/nature.html
http://www.nps.gov/depo/pphtml/naturalfeatures.html
http://www.nps.gov/depo/depo_nr/geology/geology.htm
http://www.nps.gov/depo/depo_nr/geology/postpiles.htm
http://www2.nature.nps.gov/geology/parks/depo/index.htm
http://geology.wr.usgs.gov/docs/usgsnps/depo/dpgeol1.html
http://geology.wr.usgs.gov/docs/usgsnps/depo/dpgeol14.html
http://geology.wr.usgs.gov/docs/usgsnps/depo/dpgeol11.html
http://geology.wr.usgs.gov/docs/usgsnps/depo/dpgeol5.html
http://geology.wr.usgs.gov/docs/usgsnps/depo/dpgeol4.html
http://geology.wr.usgs.gov/docs/usgsnps/depo/dpgeol6.html
http://geology.wr.usgs.gov/docs/usgsnps/depo/dpgeol7.html
http://geology.wr.usgs.gov/docs/usgsnps/depo/dpgeol8.html

- Printed copy of the graphic organizer (see attached example)

- Teacher resources:
  http://www.cr.nps.gov/history/online_books/berkeley/effinger1/effinger1e.htm
  http://www.cr.nps.gov/history/online_books/berkeley/effinger1/effinger1f.htm
  http://www.cr.nps.gov/history/online_books/berkeley/effinger1/effinger1h.htm

- Possible graphic organizer responses

Before theActivity

- Run graphic organizers for each of your students or student teams.

- Access each of the above sites and print if internet availability is limited.

- Introduce the graphic organizer and discuss possible responses under each characteristic.

- If language or research objectives are included, outline the expectations and format to be used.

Characteristics	Devils Tower	Devils Postpile	Similar	Different
Location State Mt. range River system				
Size of area Size of column				
Age Epoch				
Structure Shape				
Created by				
Type of rock				
Method of change				

Lesson Four

Characteristics	Devils Tower	Devils Postpile	Similar	Different
Location				
State	Northeast Wyoming	Southeastern California		X
Mt. range	Black Hills	Sierra Nevada Mountains		X
River system	Belle Fourche River	San Joaquin River		X
Size of area	1,347 acres	798 acres		X
Size of column				
	600 feet tall	60 feet high		X
	15 feet across	2 to 3 ½ feet across		X
Age	50 million years ago	Less than 100,000 years ago		X
Epoch	Eocene			X
Structure	Columnar jointing	Columnar jointing	X	
	Rough hexagonal shapes	Hexagonal shapes	X	
		55% are hexagonal		X
Shape	Exposed on the sides	Exposed on top and side		X
	Some curved	Some curved	X	
Created by	Volcanic activity	Volcanic activity	X	
	Magma flow	Lava flow		X
Type of rock	Igneous Rock	Igneous Rock	X	
	Phonolite porphyry	Basalt fine grained		X
	Large feldspar crystals	Large feldspar crystals	X	
	Pyroxene			X
	Intrusive (meaning formed under Earth's surface)	Extrusive (meaning formed on Earth's surface)		X
Method of change	Cooled slowly	Cooled slowly	X	
	Shrinking caused cracks	Shrinking caused cracks	X	
	Erosion	Erosion	X	
	Water	Water	X	
	Wind	Glacier		X
	Gravity	Gravity	X	
	Freeze-thaw cycle	Freeze-thaw cycle	X	
	Plants	Earthquake		X
	Talus at base	Talus at base	X	

Erosion

Standards

National Science Education Standards Grades K-4

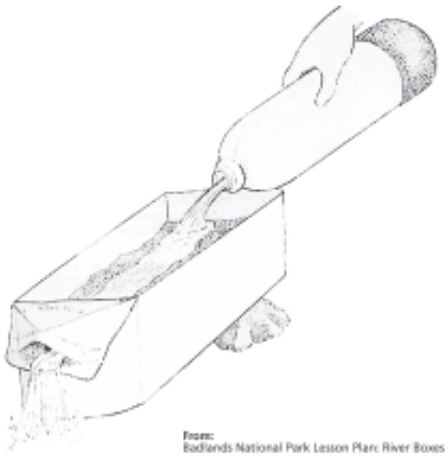
- Earth and Space
  - *Changes in the Earth and Sky*
    - The surface of the Earth changes. Some changes are due to slow processes, such as erosion and weathering, and some changes are due to rapid processes, such as landslides, volcanic eruptions and earthquakes.

- Science as Inquiry
  - *Understanding about scientific inquiry*
    - Plans and conducts simple investigations.
  - *Abilities necessary to do scientific inquiry*
    - Communicate investigations and explanations in a spoken or drawn and written format.

Overview

About 5 million years ago Devils Tower was most likely underground covered by a relatively flat area. Because the land was rising, erosive forces began to carry away rock in large quantities. Devils Tower was exposed as the paleo-Belle Fourche River carried away softer sedimentary rock. The tower was exposed from the top down. Thousands of years of weathering have impacted the tower even though it is considerably harder than the sedimentary rocks surrounding it. Wind, water, plants, and the freeze/thaw cycle have combined with gravity (mass wasting) to help erosion.

Activity One - Water Erosion



From:
Badlands National Park Lesson Plan: River Boxes

Materials for each group

- 1/2 gallon cardboard milk carton
- 2 liter bottle
- Sand to fill the carton
- Scissors
- Glue/rubber cement
- Rock about the size of a 9volt battery
- Water

Procedure

The day before

1. Use scissors to cut the side panel of the milk carton under the spout leaving the spout intact.
2. Have students glue or cement the rock in the carton at the end opposite the spout.

To start the activity

1. Have each group take their carton, sand, and 2 liter bottle filled with water and go outside since the activity can be messy.
2. Lay the milk carton on its side with the cut out panel facing up.
3. Instruct groups to fill their carton with sand covering the cemented rock, patting it down firmly in place.
4. Position the cartons on varying degrees of slant to simulate a flowing river. The lower end of the carton will be the open spout end. So that when water is poured at top it will flow over the surface of the soil and out the spout.
5. Have one student pour water slowly at the top of the carton so the water can run down the sand. The student needs to pour slowly and at a constant speed so as not to flood the carton.
6. Students are to observe changes taking place including the path cut and the depth of the river bed.
7. Direct another student to pour larger amounts of water and have students describe changes taking place. Are they seeing signs of erosion?
8. Continue pouring water until the cemented rock is exposed. (A demonstration pan may be optional.)
9. Students need to be able to verbalize how this activity relates to the erosion at Devils Tower.

Activity Two - Wind Erosion

Materials for each group

- Newspaper
- Dry sand
- Jar lid

Procedure

1. Place the lid on the center of the newspaper.

2. Fill the lid with the sand.

3. Blow gently on the sand, increasing the breath strength until sand is being moved from the lid.

4. Continue blowing for 5 to 10 seconds.

5. Compare the sand on the paper to that in the lid by rubbing your finger over it. Which is finer? Why?

6. Have students discuss how the activity relates to erosion at Devils Tower.

Activity Three - Freeze/Thaw Cycle

Materials for demonstration

- 1 quart jar with lid
- Water
- Towel

Procedure

1. In front of the class, fill the jar full with water and seal it with the lid.

2. Wrap the towel around the jar and freeze it overnight.

3. Have students predict what will happen.

4. Unwrap the jar in front of the class and ask for their observations. What happened to the jar? (The water expanded as it froze forcing the glass to crack.)

5. How does this activity relate to erosion at Devils Tower? (The discussion should reveal that in nature the same thing happens when rain water gets inside the cracks and holes of rocks.)

Sedimentary Rocks

Standards

National Science Education Standards Grades K-4

- Earth and Space
  - *Changes in the Earth and Sky*
    - The surface of the Earth changes. Some changes are due to slow processes, such as erosion and weathering, and some changes are due to rapid processes, such as landslides, volcanic eruptions and earthquakes.
  - *Properties of Earth materials*
    - Soils have properties of color and texture, capacity to retain water, and ability to support the growth of many kinds of plants, including those in our food supply.

- Science as Inquiry
  - *Understanding about scientific inquiry*
    - Plans and conducts simple investigations.
  - *Abilities necessary to do scientific inquiry*
    - Communicate investigations and explanations in a spoken or drawn and written format.

Overview

Sedimentary rocks dominate the northeastern corner of Wyoming. Much of the rock within Devils Tower National Monument is sedimentary, making up the oldest and youngest formations. Mostly sandstones and siltstones, they were deposited by shallow seas that covered the area 250 to 160 million years ago. The red rocks are locally called the "Spearfish Formation" and the yellowish rocks are called the "Hulett Sandstone." These rocks contain fossils and pure gypsum. The Belle Fourche River meanders allowing for erosion and deposits. Names of grain sizes are gravel (< 2mm), sand (1/16 to 2mm), and mud (< 1/16 mm). Conglomerate and breccia are composed of gravel. Sandstone is composed of sand. Shale and mudstone are composed of mud.

Activity One

Sedimentary rocks vary from fine-grained mudstones to widely varying conglomerates. The types of sediments that form these rocks come together in different environments. Fine-grained sediments need time to settle out of solution while course-grained material will resist moving even in active stream channels.

Remember, however, that after the sediments settle, they still must be joined together before being called a sedimentary rock!

Materials for each group

- 3 jars with cover/lid
- Bag of pebbles (about ¾ cup)
- Bag of sand (about ¾ cup)
- Bag of silt (about ¾ cup)
- Water
- Newspaper or paper towel
- Hand lens

Procedure

1. Have each group spread their three sediment samples out on a newspaper or paper towel to examine the content with hand lens.
2. Construct a group list of what was found in each sample.
3. Carefully fill each jar about half full with:
Jar 1 – pebbles
Jar 2 – sand
Jar 3 – silt
4. Add water to jar leaving about an inch at the top.
5. Secure lids and carefully shake each jar. Check lids before shaking.
6. Set each jar down and watch for ten minutes, taking notes of what happens in each jar every 2 minutes during that time.
7. Place jars in an undisturbed area overnight.
8. The next day, have students take notes on what they see in each jar and draw an image of the sediment in each jar. Be careful not to disturb the contents.

Discussion Questions

1. What do you observe when the sediment settles in Jar 1? Jar 2? Jar 3?
2. What do you observe about the differences in settling?
3. What do you observe about the texture of sediment in each jar?
4. What do you observe about the water?
5. How does this relate to what we know about sedimentary rocks?

Activity Two

Sediment rock is formed when various materials (such as sand, mud, seashells, pebbles, and pieces of igneous or metamorphic rock) are joined together. The method of bonding these different materials together determines how solid the rock will be.

Materials for each group

- Mixing bowl
- Sand (various textures optional)
- Epsom salt
- Spoon
- Cup
- Water
- Small paper cup

Procedure

1. Mix one cup of water and 1/2 cup of Epsom salt in a mixing bowl.

2. Stir until most of the salt dissolves.

3. Place about 1 inch of sand into a small paper cup.

4. Add enough salt solution to just cover the sand.

5. Mix well.

6. Let the mixture stand until dry (about 2 or 3 days).

7. Cut off the paper.

8. Observe the rock.

9. Have groups share.

Discussion Questions

1. Where is the salt?

2. How does it hold the sand together?

3. How do the textures of each groups differ?

Web Sites of Interest

http://volcano.und.nodak.edu/vwdocs/vwlessons/lessons/Sedrocks/Sedrocks1.html
http://www.fi.edu/fellows/fellow1/oct98/create/sediment.htm
http://library.thinkquest.org/J002289/snacks.html (This is a cooking activity that makes a layer cookie.)

Other Experiment Options

http://wow.osu.edu/Geology/sedrocks.htm
http://www.bbc.co.uk/education/rocks/rockcycle/expsix.html