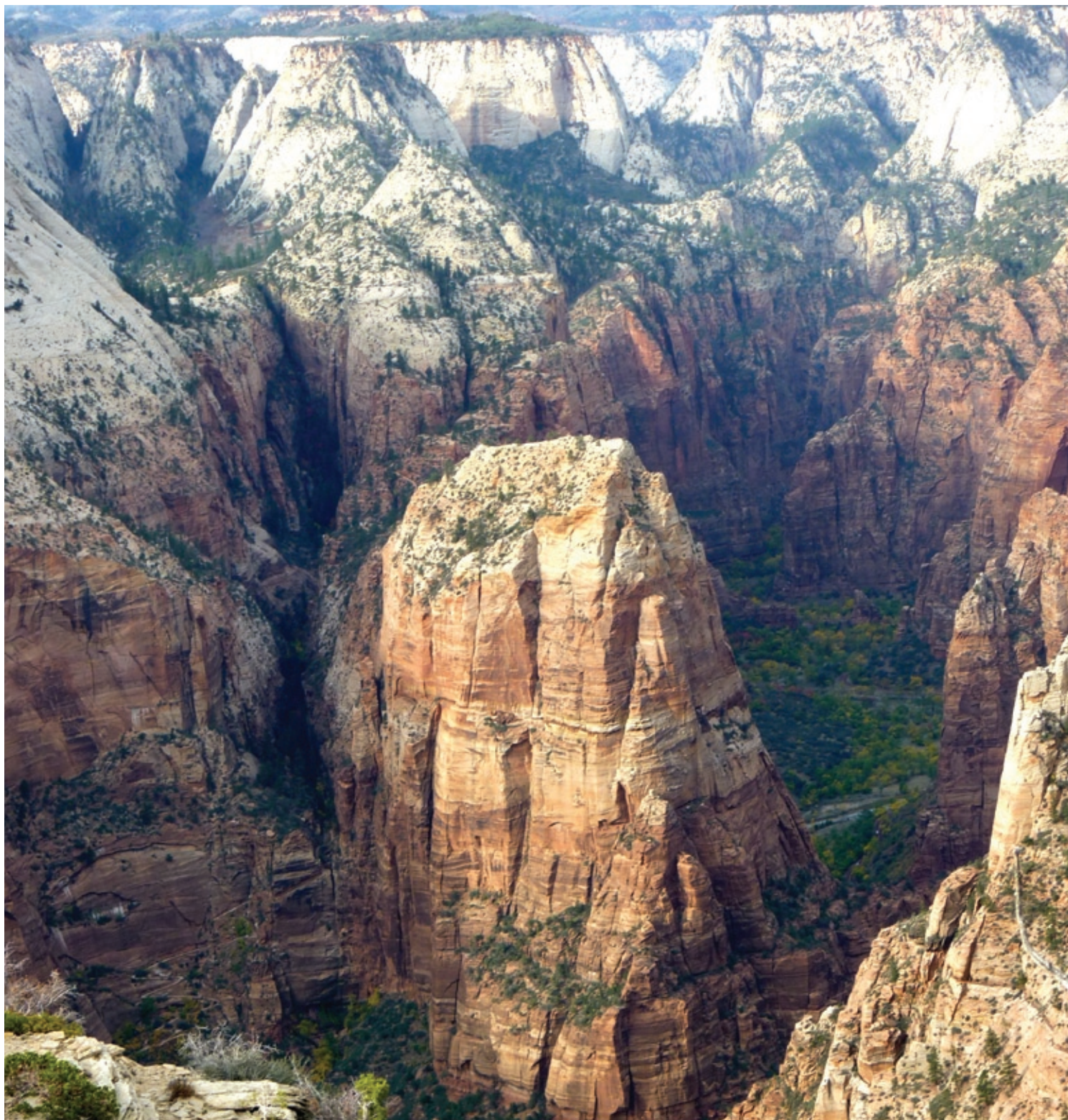




# Changing Landscapes

## *Fifth Grade Pre- and Post-Visit Activity Guide*



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Zion National Park  
Springdale, Utah 84767

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**Landslides, flashfloods and earthquakes continue to play a role in shaping Zion National Park.**

### Core Connections

Utah Core Curriculum  
Fifth Grade Science

Standard 2: Students will understand that volcanoes, earthquakes, uplift, weathering, and erosion reshape Earth's surface.

Objective 1: Describe how weathering and erosion change Earth's surface.

Objective 2: Explain how volcanoes, earthquakes, and uplift affect Earth's surface.

Objective 3: Relate the building up and breaking down of Earth's surface over time to the various physical land features.

## Introduction

### Theme

The Earth's surface is a dynamic system that is constantly changing due to weathering, erosion, earthquakes, volcanoes, and uplift.

### Focus

The activities focus on relationship between geologic processes and changes on the Earth's surface.

### Pre-Visit Activities

1. Earth's Power Punches – Students view a presentation of digital images showing the forces that shape the Earth's surface. Then students view images from Zion and determine which geologic forces have contributed to the landscapes shown. Finally, students discuss which landscapes were formed slowly and which were formed quickly.
2. Rock On Zion! – Students will learn how Zion was formed and evaluate how weathering and erosion contributed to the formation of the rock layers and subsequent carving of the canyon.
3. Then and Now – Students will explore what the area surrounding Zion might have been like during past geologic times when each layer was formed. By creating posters, the students depict Zion during past geologic times and compare with the park today.

### Post-Visit Activities

1. Map Minds - Using a topographic map of Zion, students identify geological features (e.g., valleys, canyons, buttes, mesas) and describe changes resulting from erosion.
2. It Happened Here! - Students draw on the knowledge they have gained about geologic events to invent a specific event and imagine themselves in it.
3. Future Forecasters - During this activity students reflect on what they have learned, assess their knowledge, and predict future changes to the landscape of southwestern Utah in 100 million years.

## Background

Zion National Park is located along the edge of a region called the Colorado Plateau. Uplift, tilting, and the erosion of rock layers formed a feature called the Grand Staircase, a series of colorful cliffs stretching between Bryce Canyon, Zion, and the Grand Canyon.

Zion has spectacular geology. The arid climate and sparse vegetation expose bare rock and reveal the park's geologic history. Evidence of deposition (sedimentation), lithification, uplift, weathering, erosion, tectonics, and volcanic activity make the park a showcase for changing landscapes.

### Deposition (Sedimentation)

Zion National Park was a relatively flat basin near sea level 275 million years ago, near the coast of Pangaea, the land area believed to have once connected nearly all of the earth's landmasses together. As sands, gravels, and muds eroded from surrounding mountains, streams carried these materials into the basin and deposited them in layers. The sheer weight of these accumulated layers caused the basin to sink, so that the top surface always remained near sea level. As the land rose and fell and as the climate changed, the depositional environment fluctuated from shallow seas to coastal plains to a massive desert of windblown sand. This process of sedimentation continued until over 10,000 feet of material accumulated.

### Lithification

Mineral-laden waters slowly filtered through the compacted sediments. Iron oxide, calcium carbonate, and silica acted as cementing agents, and with pressure from overlying layers over long periods of time, transformed the deposits into stone. Ancient seabeds became limestone; mud and clay became mudstones and shale; and river sand and sand dunes became sandstone. Each layer originated from a distinct source and so differs in thickness, mineral content, color, and eroded appearance.

### **Tectonics and Uplift**

In an area from Zion to the Rocky Mountains, tectonic forces deep within the Earth pushed the surface up creating the Colorado Plateau. This was not chaotic uplift, but slow vertical hoisting of huge blocks of the crust. Zion's elevation rose from near sea level to as high as 10,000 feet above sea level. Uplift is still occurring.

For many millions of years, portions of the Pacific Plate (oceanic crust) subducted beneath the thicker, more buoyant North American Plate (continental crust). This subduction formed mountains and volcanoes along the west coast, and led to the formation of the Rocky Mountains. Later, changes in plate geometry led to the end of subduction along much of the West Coast (although subduction continues today in the Pacific Northwest). Instead of being pushed together, the plates began to slide sideways (lateral motion), as is seen today in California's San Andreas Fault. This lateral motion stretched portions of western North America; creating a region called the Basin & Range. Western-most Utah is part of the eastern edge of the Basin & Range province, where stretching

continues today along active faults like the Hurricane and Wasatch Faults. Despite the mountain building and stretching that occurred in the surrounding areas, the Colorado Plateau rose to its high elevation with little deformation.

### **Erosion**

The uplift of the Colorado Plateau gave the streams greater cutting force in their descent to the sea. The park's location on the western edge of this uplift caused the streams to tumble off the plateau, flowing rapidly down a steep gradient. These streams began eroding and cutting into the rock layers, forming deep and narrow canyons.

Grain by grain the Virgin River has carried away several thousand feet of rock that once lay above the highest layers visible today. On average, the Virgin River transports one million tons of sediment per year. The rate varies dramatically with the flow of the river, with the vast majority of sediment transport occurring during floods. When the river is low and clear, very little sediment is moving, and much of the transport involves minerals dissolved in the water.



**Bridge Mountain Zion National Park.**

The Virgin River is still excavating. Upstream from the Temple of Sinawava, in The Narrows, the river cuts through Navajo Sandstone, creating a slot canyon. At the Temple of Sinawava, the river has reached the softer Kayenta Formation below. Water erodes the shale, undermining the overlaying sandstone and causing it to collapse, widening the canyon. As the plateaus continue to rise, the basins drop, and the river cuts, Zion Canyon is expanding upstream at a rate of about 10 miles of lateral movement every million years.

### **Volcanic Activity**

Volcanic vents, created as a result of the weakening of the Earth's crust during tectonic events, allowed lava flows and cinder cones to form. Cinder was piled several hundred feet high in classic cone shapes and lava flowed into valleys. Cinder cones and black basalt flows are visible west of Rockville and on the Kolob Terrace.

### **Fractures and Faults**

Fractures and their control of canyon erosion are one of the most striking features of the canyons of the Virgin River. The fractures (not faults because there is no displacement) exert a strong influence on the erosion of smaller canyons in the Navajo Sandstone.

These fractures are believed to have formed due to tectonic compression and extension forces. The fractures form perpendicular to the direction of the compression and extension. The dominant fracture direction in Zion is roughly north-south. There are also fracture sets that are east-west (Kolob Canyons) and northeast-southwest (Kolob Terrace and Hop Valley).

While the straight north-south canyons on either side of Checkerboard Mesa are controlled by large fractures, the criss-cross fractures on its surface are of a more recent origin. The horizontal banding is the result of differential weathering of the crossbedded sandstone, while the vertical cracks are thought to be the result of freeze/thaw cycles at the surface of the rock.

## **Pre-Visit Activities**

### **1. Earth's Power Punches**

**Duration:** 1 Hour

**Location:** Indoors

**Key Vocabulary:** blind arch, butte, cinder cone, erosion, earthquake, geologic processes, mesa, rock layers, uplift, volcanoes, weathering

#### **Objectives**

By the end of the activity, students will be able to a) name three Earth processes that shape the landscape, b) name two Earth processes that have helped to change the landscape at Zion, c) name which Earth processes have occurred quickly and which have occurred slowly.

#### **Method**

Students view a presentation showing geologic processes that contribute to changing landscapes. Applying their knowledge to Zion, students view images and identify evidence of geologic forces such as weathering, erosion, earthquakes, volcanoes, and uplift.

#### **Background**

The Earth's surface constantly changes due to weathering, erosion, earthquakes, volcanoes, and uplift. At Zion National Park evidence of these processes is observed in the water and wind carved rocks, uplifted geologic layers, volcanic flows, cinder cones, mesas, blind arches, and other landforms.

#### **Materials**

- Utah State Geological Survey presentation of Landscapes located at [http://geology.utah.gov/teacher/ppt/utah\\_landforms.ppt](http://geology.utah.gov/teacher/ppt/utah_landforms.ppt)
- Zion National Park landscape images located at <http://www.nps.gov/zion/forteachers/loader.cfm?csModule=security/getfile&PageID=541853>



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“Grain by grain the Virgin River has carried away several thousand feet of rock that once lay above the highest layers visible today.”

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### Suggested Procedures

Show the Utah State Geological Survey Landscapes presentation and read the accompanying notes for each slide.

At the conclusion of the presentation ask the students to think about the Earth changing processes that were discussed. Show each of the Zion landscape images and ask the students to name which Earth process they think were at work to create the landscape in each image. Have the students write down a list of Earth changing processes for two or three of the images.

Ask the students to determine which processes can occur quickly (minutes/hours) and which occur over a long period of time (years to millions of years). Have students discuss their results with the class and describe the processes they investigated. Ask the students to describe how they came up with their determination of the time it took for each process to occur.

## 2. Rock On Zion!

**Duration:** 1 Hour

**Location:** Indoors

**Key Vocabulary:** chemical weathering, deposition, erosion, lithification, mass wasting, mechanical weathering, plateau, rock cycle, uplift

### Objectives

By the end of the activity, students will be able to a) explain how Zion Canyon was formed, b) explain how weathering and erosion has contributed to the formation of the rock layers and c) describe how the Virgin River carved Zion Canyon.

### Method

After viewing images of landforms in Zion National Park and discussing the rock cycle images, students will evaluate how weathering and erosion have contributed to the formation of the rock layers and subsequent carving of the canyon.

### Background

Evidence of weathering and erosion can be observed at the park. Weathering and erosion are often confused. According to the



Winter runoff carving the landscape of Zion.



U.S. Geological Survey, weathering involves two processes that often work together to decompose rocks. No movement is involved in weathering.

Chemical weathering involves a chemical change in at least some of the minerals within a rock. Mechanical weathering involves physically breaking rocks into fragments without changing the chemical make-up of the minerals within it. Weathering is a surface or near-surface process.



Erosion occurs as soon as a rock particle (loosened by one of the two weathering processes) moves. Mass wasting is simply movement down slope due to gravity. Rock falls, slumps, and debris flows are all examples of mass wasting.

### Materials

- Images of the rock cycle, geologic layers (unlabeled student version and labeled teacher key) and Earth changing processes located at <http://www.nps.gov/zion/forteachers/loader.cfm?csModule=security/getfile&PageID=541856>

### Suggested Procedures

1. Write the word “weathering” on the board. Then write the word “erosion” on the board. Ask the students to think of some of the things that might make weathering happen such as water and ice, wind, chemicals. Then ask the students to think of some things such as water, wind, glaciers that erode (move) the weathered materials. Ask the students to think about which of these processes might have carved Zion.
2. Show the rock cycle image and have the students explain how they think the cycle works. Ask them if the park was always a canyon or if it has changed over time. How have the processes shown in the rock cycle impacted Zion?



**Weathering and erosion create beautiful scenery including arches, slot canyons and patterns.**

3. Go through the images of four steps of the rock cycle that have helped to shape Zion, including sedimentation, lithification (compaction and cementation), uplift, and erosion.
4. Show the unlabeled image of the geologic layers at Zion and see if the students can explain why there are different geologic layers and how they might have been deposited. How did weathering and erosion play a role? Then show the image with the layers labeled and discuss the observed differences in color, slope and, texture between layers.
5. Ask the students to synthesize their ideas and describe how the fine particles of rock were deposited over millions of years. Students should recognize that the layers are different because different types of rocks and sand were deposited at different times as the environment changed.
6. Show the remaining images portraying geologic processes. Explain that over several million years, the Virgin River weathered and eroded the rock layers and made it possible for us to see them. The river once flowed at the top of a flat plateau but has carved through the rock layers to its current level.
7. Ask the students how the canyon is likely to change as the Virgin River continues to weather and erode the sedimentary rock layers.



One can observe several rock layers when viewing the Towers of the Virgin.

### 3. Then and Now

**Duration:** 1 Hour

**Location:** Indoors

**Key Vocabulary:** basalt flow, Carmel Formation, Chinle Formation, geologic processes, Kaibab Limestone, Kayenta Formation, Navajo Sandstone, Moenave Formation, Moenkopi Formation, paleoenvironment, Temple Cap Formation

#### **Objectives**

By the end of the program, students will be able to a) analyze images of some of Zion's rock layers, b) view and discuss images of the Zion region as its various layers were deposited, and c) create posters showing what the park looks like today and what it looked like when one of its layers was deposited.

#### **Method**

After analyzing the rock layers of Zion, students connect the geologic layers to paleoenvironments. The activity concludes with creation of posters showing the students' depictions of Zion during past geologic times compared to today.

#### **Background**

Students will explore what the area might have been like during past geologic time when each geologic layer at Zion was formed. The layers, from oldest to youngest are briefly described below.

The Kaibab Formation (limestone) is the oldest exposed formation in the park where it occurs in small outcrops at the Kolob Canyon area of the park. (It can also be seen in the Hurricane Cliffs). It was deposited when a shallow tropical sea covered the area and it contains fossils of ancient marine animals. The Moenkopi Formation was deposited in a coastal flood plain environment of streams and tidal flats, and consists of reddish brown siltstones and mudstones with gray gypsum- rich shale and limestone beds. Above the Moenkopi Formation is the Chinle Formation, a mauve, gray and white shale. During Chinle time, a large river system flowed through the area, bringing large coniferous trees and volcanic ash which





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Studying the present landscape can give us clues to the past.

eventually led to formation of petrified wood. The overlying Moenave Formation, consisting of reddish-brown siltstones and shales, was deposited by streams and lakes.

Most of the spectacular scenery seen at Zion is due to the Jurassic Kayenta Formation and Navajo Sandstone. The Kayenta Formation was deposited in a river and floodplain environment and consists of a reddish-brown, interbedded sandstone, siltstone and shale. The Navajo Sandstone, which makes up the large cliffs of Zion, was deposited when the entire Colorado Plateau region (and beyond) turned into a vast sand dune desert. Shifting winds blew sand into dunes, resulting in the cross-bedding patterns seen in the rock today. The Jurassic Temple Cap Formation, a tan to gray sandstone, is exposed on higher plateaus of Zion, most notably on top of The West Temple. Younger Jurassic and Cretaceous formations are located at Zion's highest elevations.

Pleistocene volcanic rocks are exposed in the western part of the park. They were formed from tectonic activity that produced cinder cones and basalt flows on mesa tops.

**Materials**

- Image of the park's rock layers, geologic cross-section, and paleoenvironments illustrations located at <http://www.nps.gov/zion/forteachers/loader.cfm?csModule=security/getfile&PageID=541864>

**Suggested Procedures**

1. Show the students the image of the geologic layers at Zion. Explain that each of the layers was deposited as part of many rock cycles. How many different layers can they count? How many different colors do they see in the layers? Why do they think the layers look different from each other?
2. Show the geologic cross-section and name each layer and the time period that it was formed.

3. Explain that the climate and landscape of southwestern Utah was very different when each of the canyon's layers was forming. Show the students the illustrations of the paleoenvironments during different geologic times. Explain that the past environments shown on the illustrations became the major layers of the canyon.

4. Referring to the geologic layers in the photos and the description of each paleoenvironment, ask the students to imagine what the area looked like at those times. Ask the students to think about the types of animals and plants that might have lived in the area at that time, and compare and contrast their descriptions with the habitats in Zion today.

5. Form groups of students and assign each group one of the geologic layers shown on the cross-section. Make sure each layer is assigned at least once in the classroom. Have students draw posters illustrating the questions listed below. They should also write captions describing them.

- What does the park look like today and why does it look this way? (Students draw a picture on one half of the poster, and describe it with a caption.)
- What did the Zion area look like when the students' assigned layer was being deposited, including the plants and animals? (Students draw a second picture on another part of the poster)

6. Have students share their posters with the class and describe the layers they investigated.

# Post-Visit Activities

## 1. Map Minds

**Duration:** 1 Hour

**Location:** Indoors

**Key Vocabulary:** cinder cone, contour line, erosion, topographic map, uplift

### Objectives

After this activity, students will be able to: a) use a simple topographic map, b) name two geological features on a map, and c) describe map features that were created through weathering and erosion.

### Method

Using a topographic map of the park, students identify geological features (e.g., canyons, mesas, cinder cones) and describe changes that have occurred through erosion (e.g., wind, gravity, running water).

### Background

Topographic maps consist of contour lines that show elevation differences of the land surface. Each contour line connects points on the Earth's surface that have the same elevation. Where contour lines are closely spaced, the terrain is steep. The more closely

spaced the lines, the steeper the slope. Conversely, gentle ground slopes are portrayed by contours spaced widely apart. Landforms can be identified on topographic maps. In this activity, mesas, cinder cones, and canyons will be identified.

### Materials

- Crayons or colored pencils
- Mesa topographic features maps (student and teacher version)
- Volcano topographic features maps (student and teacher version)
- Zion Canyon topographic map
- All topographic maps located at <http://www.nps.gov/zion/forteachers/loader.cfm?csModule=security/getfile&PageID=541580>

### Suggested Procedure

1. Teacher Preparation - Study the geologic features on the teacher versions of two topographic maps (linked under Materials above). In dry climates like southern Utah, rocks can erode into mesas and buttes. The Mesa Map shows two flat-topped plateaus bordered on all sides by steep cliffs. Mesas get smaller as their cliffs erode and become small, flat-topped hills called buttes. This map also shows contour lines close to each other representing a steep slope or cliff.



Evidence of uplift and erosion can be observed at Zion National Park .



The Volcano Map shows contour lines spaced further apart that represent a gentle slope. On the Volcano Map the Earth's hot mantle has pushed magma up in places and erupted lava to form a small volcano or cinder cone. The volcano map also shows drainages or canyons with water (washes, rivers) that have a blue line in-between branches of contour lines that represent the surrounding canyon walls.

2. Use the student topographic features maps (linked under Materials above) to enable students to discover and visualize the features described above. On the mesa map, have the students find and label the mesas, and an example of a steep slope.
3. On the volcano map, ask the students to find and label the small volcano called Crater Hill and the 4600-foot contour line that surrounds the crater. Ask the students to color between each of the heavier contour intervals (spaced every five contours) with a different color between each heavier line. Discuss spacing between contours and how spacing shows steep or gentle slopes.
4. Have students relate the building up and breaking down of the Earth's surface to the landforms they identified. Following are examples of questions you might ask.

Mesa Map:

- What might cause a mesa to form? [uplift and erosion]
- Why is the slope gentler at the base of mesas? [deposition; erosion and weathering break the rocks down and the material is deposited at the base, different rock types.]

Volcano Map:

- What landform does a river create? [canyon]
- How long did it take for the different geologic events to create the various landscapes that you see on the volcano map?

5. Continue by using the canyon topographic map (linked under Materials above). On this topographic map, have students:

- Identify trails (dashed black lines)
- Find and name two high peaks (e.g., Bridge Mt., Beehive Peak)
- Identify cliffs -very closely spaced contour lines on the majority of the map.
- Find gentle slopes - largely spaced contour lines (e.g., Sand Bench Trail, South Campground)

6. Relate the build up and break down of the Earth's surface to the Zion area.

Ask students:

- Where might uplift have occurred?
- Where is deposition occurring?
- Where is weathering and erosion occurring?
- What would likely happen if the area were to be uplifted even more?

7. Have students write a paragraph describing how the area would look if there were no mountain uplift, weathering, or erosion. Ask a few students to share their paragraphs and justify their answers.

## 2. It Happened Here!

**Duration:** 1 to 2 hours

**Location:** Indoors

**Key Vocabulary:** erosion, eyewitness, Hurricane Fault, landslide, scientist,

### Objectives

After this activity, students will be able to: a) describe a single event from three perspectives, b) name two geological features, and c) describe map features that were created through landscape changes.

### Method

Students draw on the knowledge they have gained about geologic events to invent a specific event and imagine themselves in it.



NPS/AODRIENNE FITZGERALD

**A display of the rock layers present at Zion National Park.**

### **Background**

The contrast of experiencing an event from different perspectives helps students understand diverse viewpoints. By taking on the role of news reporter, students explore facts related to the event. As scientists, students appreciate the importance of scientific observation and data collection, and as eyewitnesses students explore emotional responses to events.

### **Materials**

- Writing paper and pens
- Student copies of writing guide (three types)
- Classroom computers
- Images of Earth changing processes that occurred near Zion National Park located at <http://www.nps.gov/zion/forteachers/loader.cfm?csModule=security/getfile&PageID=541867>

### **Suggested Procedure**

1. Show the images to review the kind of landscape changes that can be caused by weathering and erosion, landslides, rock falls, floods, earthquakes, small volcanoes and lava flows. Tell students that they are

going to draw on the knowledge they already have about the geologic events to invent a specific event and imagine themselves in it. Distribute copies of the writing guides and ask each student to note the date and time of their changing landscape event, the location, how much damage it caused, and other basic information at the top of the writing guide.

2. Now tell students that each will write about his or her hypothetical geologic event from three different points of view: that of a news reporter, a scientist, and an individual directly affected by the quake. Each of the three accounts will describe the same landscape-changing event, but the styles of the three will vary.
3. News Reporter—a short, concise article describing the who, what, where, and when of the landscape-changing event and providing information the public needs.



4. Scientist—a scientific account stating what is objectively known about the landscape-changing event: its causes, its effects, its magnitude and/or intensity, and the likelihood of its recurrence, if known.
5. Eyewitness—a personal letter to a friend telling about being in a landscape-changing event. This will describe what happened to the student, to the area in which the student was, to others that might have been with the student at the time of the event. Have students describe what they had done before the event to be prepared, how effective their preparations were, what life was like in the two weeks following the event, and what they would do differently in preparation for the next event.
6. Tell students to feel free to make up information, quotations, etc., but to keep the basic facts consistent from one essay to another. However, since in real life compositions of the second and third type are likely to be written later than news accounts, some discrepancies in details are to be expected.

#### Evaluation

Ask students to talk about the experience of writing the accounts.

- Did you feel you had enough information to do the job in each case?
- Did some of you wish you knew more? Is there anything specific you'd like to find out?
- Was one point of view more comfortable than the others? Were some accounts easier to write?
- Discuss the validity of the different points of view. Emphasize that each kind of account is valuable in its own right.
- Ask students to share how landscape changing events might impact Zion National Park in the future.
- Ask students to explain how some landscape-changing events might occur quickly like an earthquake but that other events like the creation of new rock layers from deposition of sediments (rock pieces) might take millions of years.

### 3. Future Forecasters

**Duration:** 1 Hour

**Location:** Classroom with a cleared space or outdoors

**Key Vocabulary:** tectonic plates, paleoenvironment

#### Objectives

After completing this activity, students will be able to a) predict future landscapes at Zion based on the understanding of geologic processes, b) use performance skills to describe the proposed landscape at Zion National Park 100 million years in the future, and c) draw posters of Zion's proposed landscape 100 million years in the future.

#### Method

Watch the video of the tectonic changes in the past and predicted changes in 100 million years. Tell students that they are going to draw on the knowledge that they already have about the geologic events to draw pictures and then film a movie of them describing the landscape of southwestern Utah 100 million years in the future.

#### Background

This post-visit activity is designed help students reflect on what they have learned, assess their knowledge, and predict future changes to the landscape of southwestern Utah in 100 million years.

#### Materials

- Drawing paper and color markers, pencils and pens
- Classroom computers
- Download or view You Tube Video showing historical evolution of tectonic plates through 100 million years in the future <http://www.youtube.com/watch?v=uGcDe4xVD4&NR=1&feature=fvwp>

### Suggested Procedure

Watch the video. Then watch it again and pause it on the final scenes showing the position of the North American tectonic plate where Utah is located 100 million years in the future. Ask the students:

- Where is the approximate location of southwestern Utah on the map?
- Does it look like the area is underwater or very near an ocean inlet?
- What kind of fossils will we find in the 100 million year layer?
- After the landscape changes in another 200 million years, what do you imagine it will look like?

Have the students draw pictures of the landscape of southwestern Utah based on the landscape predicted in the video animation. Have the students use their imagination and add plants and animals to the future landscape. Once the students have completed their pictures, have them share the drawings with the class.

### Evaluation

Ask students to talk about the experience of thinking about the future landscape of southwestern Utah in 100 million years.

- How will people adapt over millions of years as the landscape changes and southwestern Utah is eventually underwater?
- Do you think people will still be here?
- Are there both fast and slow changes that occur in the landscape? Name three fast geologic processes and three slow processes of landscape change.
- If such drastic landscape changes happen naturally over millions of years, why is it still necessary for us to take care of the present landscapes and environment?

## Glossary

**basalt flow:** lava flow of molten rock from the Earth's interior.

**Basin and Range:** type of topography that is characterized by a series of tilted fault blocks forming ridges or mountains and broad, intervening basins or valleys.

**bedrock:** the solid rock underlying all soil, sand, clay, gravel, and loose material on the Earth's surface.

**blind arch:** a curved structure created by natural geological forces causing rock to fall away, with a rock face behind so there is no window through the arch.

**butte:** a steep-sided hill with a flat top, often standing alone in an otherwise flat area. A butte is smaller than a mesa.

**cementation:** the process in which the spaces between loose particles are filled with a hardening or bonding agent. This is one form of lithification.

**Chinle Formation:** a rock layer consisting of a conglomerate and brightly colored shales, limestones, volcanic ashes, and thin sandstones of various compositions. Characteristic features are picturesque erosion forms and petrified wood.

**cinder cone:** a steep, conical hill of volcanic fragments that accumulates around and downwind from a volcanic vent.

**Colorado Plateau:** a large uplifted plateau roughly centered on the four corners region (Utah, Arizona, Colorado, and New Mexico) of the southwestern United States.

**compaction:** the process by which overlying rock layers or sediments compress the spaces between underlying particles. This is one form of lithification.

**contour line:** an imaginary line that joins points of equal elevation on the surface of the land above or below a reference surface, such as mean sea level. Contours make it possible to measure the height of mountains, depths of the ocean bottom, and steepness of slopes.

**crater:** a pit or hole in the ground created by an explosion or the impact of a meteorite.

**deposition:** the geological process by which material is added to a landform or land mass.



**earthquake:** the result of a sudden release of energy in the Earth's crust that creates seismic waves.

**erosion:** the movement of weathered materials by natural processes.

**extrusive rock:** rock produced by molten lava that flows onto the surface of the Earth (also called volcanic rock).

**eyewitness:** someone who has knowledge about a dramatic event through seeing it firsthand.

**fault:** the boundary between two rock sections that have been displaced relative to each other.

**fold:** a bend in a layer of rock.

**fossil:** the mineralized or otherwise preserved remains or traces (such as footprints) of animals, plants, and other organisms.

**geology:** the science and study of the solid earth and the processes by which it is shaped and changed.

**geologic processes:** a scientific term used to describe the internal and external forces that shape the physical makeup of the Earth.

**geologic time scale:** used by geologists and other scientists to describe the timing and relationships between events that have occurred during the history of Earth.

**geomorphology:** geologic study of the configuration and evolution of land forms.

**igneous rock:** rock produced by the cooling and solidification of magma, either on or below the Earth's surface.

**intrusion:** the pushing up of magma into pre-existing rocks.

**intrusive rock:** rock produced by the cooling of magma deep beneath the Earth's surface (also called plutonic rock).

**Kaibab Formation:** a rock layer consisting of limestone and containing marine fossils.

**Kayenta Formation:** a rock layer that was deposited in a river and flood-plain environment and consists of a reddish-brown, interbedded sandstone, siltstone and shale.

**landslide:** the downslope movement, under gravity, of masses of soil and rock material; includes a wide range of ground movement, such as rockfall, slump, and debris slide.

**lava:** magma that emerges onto the surface of the Earth.

**lithification:** the processes in which sediments become solid rock.

**lithosphere:** the outer crust of the Earth, which is broken into seven large rigid plates and several smaller ones.

**lithospheric plates:** a massive, irregularly shaped slab of solid rock, generally composed of both continental and oceanic lithosphere (also called tectonic plates); part of plate tectonics.

**magma:** molten rock deep within the Earth.

**mass wasting:** a general term for the downslope movement of soil and rock under the force of gravity.

**mesa:** (Spanish and Portuguese for "table") an elevated area of land with a flat top and sides that are usually steep cliffs. It takes its name from its characteristic table-top shape and is larger than a butte.

**metamorphic rock:** rock that has undergone change as a result of intense heat and pressure.

**Moenave Formation:** a rock layer consisting of reddish-brown siltstones and shales, deposited by streams and lakes.

**Moenkopi Formation:** a rock layer deposited in a coastal flood plain environment of

streams and tidal flats, consisting of reddish brown siltstones and mudstones with gray gypsum rich shale and limestone beds.

**Navajo Sandstone:** the rock layer which makes up the large cliffs of Zion; it was deposited when the entire Colorado Plateau region (and beyond) turned into a vast sand dune desert. Shifting winds blew sand into dunes, resulting in the cross-bedding patterns seen in the rock today.

**normal fault:** a break in the Earth where tension pulls rocks apart and one block slides down relative to the other block.

**paleoenvironment:** the past environment of an area during a given period of its history.

**plate tectonics:** theory of geology that has been developed to explain the observed evidence for large scale motions of the Earth's lithosphere.

**plateau:** also called a high plain or tableland, is an area of high elevation land, usually consisting of relatively flat terrain.

**relative age:** the age of a rock in comparison to other rocks.

**rock cycle:** interrelated sequence of events by which rocks are initially formed, altered, destroyed, and reformed as a result of magmatism, erosion, sedimentation (or deposition), lithification, and metamorphism.

**scientist:** in a broad sense is one engaging in a systematic activity to acquire knowledge. In a more restricted sense, a scientist is an individual who uses the scientific method.

**sedimentary rock:** rock produced from particles deposited by wind, water, ice, or chemical reactions.

**sediment:** finely divided solid material, ex: sand, gravel, mud.

**subduction:** a geologic process in which one edge of a crustal plate descends below another.

**subsidence:** sinking or downward settling of the Earth's surface.

**thrust fault:** occur in a compressional environment, where rocks are squeezed together and one block is forced upward (and possibly over) relative to another.

**topographic map:** a representation of the Earth, or part of it, showing the shape of the Earth's surface with contour lines. It also includes symbols that represent such features as streets, buildings, streams, and vegetation.

**uplift:** a geological process most often caused by plate tectonics which increases elevation.

**volcano:** an opening, or rupture, in a planet's surface or crust, which allows hot, molten rock, ash and gases to escape from below the surface.

**weathering:** decomposition of rocks, soils, and their minerals by chemical or physical processes. Chemical weathering involves a chemical change in at least some of the minerals within a rock. Mechanical weathering involves physically breaking rocks into fragments without changing the chemical make-up of the minerals within it.

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