National Park Service

Zion National Park

Landscapes: Past, Present, and Future

Exploring How Landscapes Change Over Millions of Years

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Contents


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Today's rocks in Zion National Park are the product of millions of years of geologic processes and different environments.

Introduction

This guide contains background information about how geologic processes and changes over millions of years continually shape the landscape, and directions for three activities that will help students better understand how these processes are still at work in Utah. This guide is specifically designed for fifth grade classrooms, but the activities can be modified for students at other levels.

Theme

The Earth's surface is a dynamic system that changes with the activity of volcanoes, earthquakes, erosion, and other geologic processes.

Focus

The activities focus on relationship between long-term geologic processes and changes on the Earth's surface that have happened in the past, that are still occurring today, and will continue to occur in the future.

Activities

Landscapes: Past

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.

Landscapes: Present

Using a topographic map of Zion, students identify geological features (e.g., valleys, canyons, buttes, mesas) that are present in Zion today.

Landscapes: Future

During this activity students predict future changes to the landscape of southwestern Utah in 100 million years.

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.

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 and Range. Westernmost Utah is part of the eastern edge of the Basin and 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.

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.

Landscapes: Past

Duration
1 hour

Location
Indoors

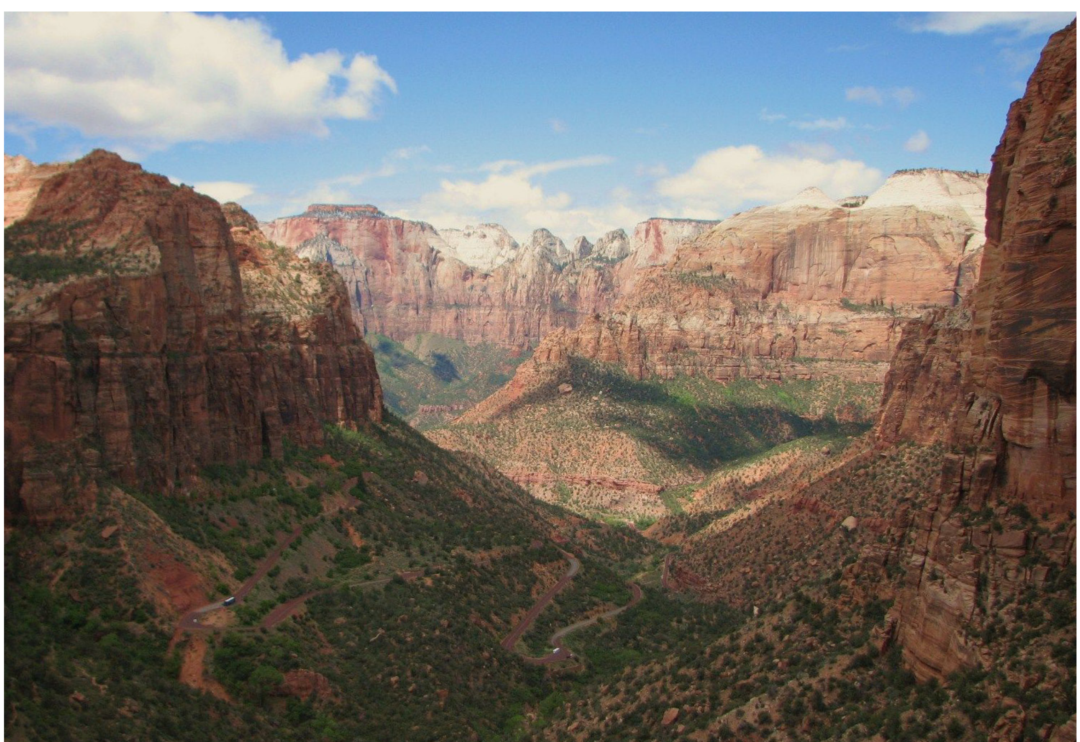
Key Vocabulary
geologic processes, paleoenvironment, Kaibab Limestone, Moenkopi Formation, Chinle Formation, Moenave Formation, Kayenta Formation, Navajo Sandstone, Temple Cap Formation

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
There are seven distinct rock layers in Zion National Park which all were deposited at different times and from different paleoenvironments.

The Kaibab Formation (limestone) is the oldest exposed formation in the park where it occurs in small outcrops at the Kolob Canyons 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 eventually led to formation of petrified wood. The overlying Moenave Formation, consisting of reddish-brown siltstones and shales, was deposited by streams and lakes.



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Many of Zion's different rock layers are visible in the main canyon including the Temple Cap Formation, Navajo Sandstone, Kayenta Formation, and the Moenave Formation.


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Close up on the Moenave Formation.

Petrified rock in the Chinle Formation.

Cross-bedding patterns in Navajo Sandstone tell a story of shifting winds and enormous sand dunes.

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

- Landscapes: Past images

Suggested Procedures

1. Show the students the image of the geologic layers at Zion. 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. Then show the image with the layers labeled and discuss the observed differences in color, slope and, texture between layers. 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. 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.

3. Explain that each of the layers was deposited as part of many rock cycles over millions of years. Show the geologic cross-section and name each layer and the time period that it was formed.

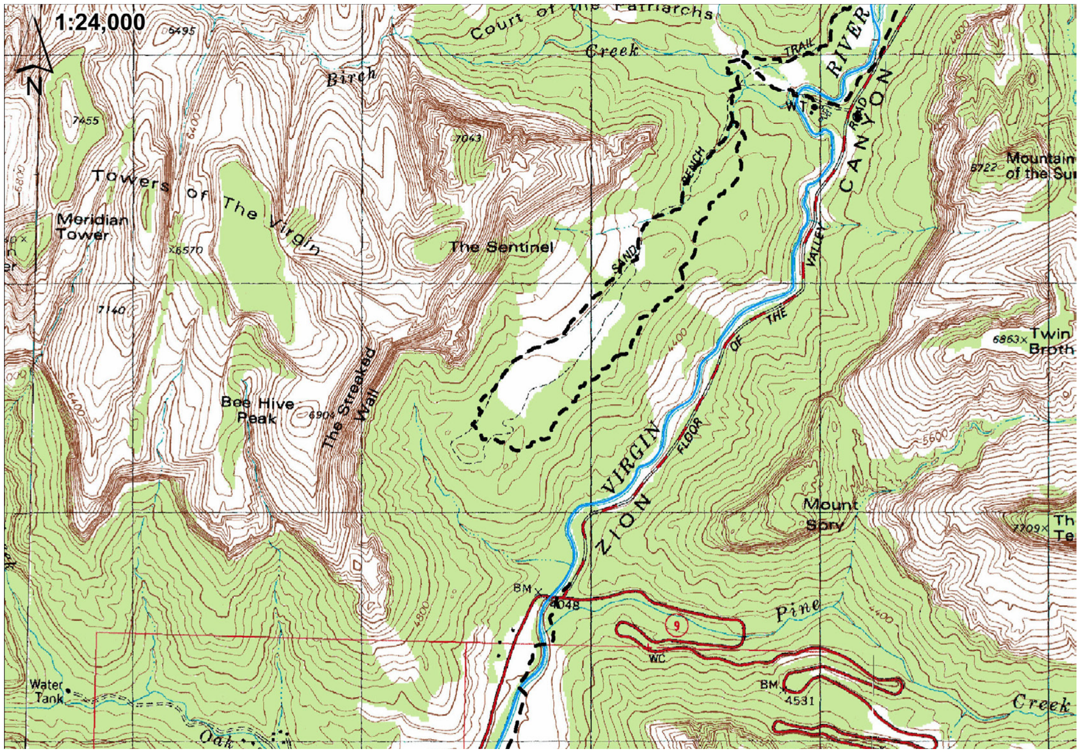
4. Explain that the climate and landscape of southwestern Utah was very different when each of the park's rock layers was forming. Show the students the illustrations of the paleoenvironments during different geologic times. Explain that the past environments shown on the illustrations became the major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

5. 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.

6. 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.

7. Have students draw posters illustrating a) what the park looks like today and why it looks this way and then b) what the Zion area looked like when the students' assigned layer was being deposited, including the plants and animals. After drawing both pictures on their poster, students should also write captions describing them.

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



Topographic map section of the lower canyon area of Zion National Park.

Landscapes: Present

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 present in Zion National Park today (e.g., canyons, mesas, cinder cones) and describe changes that have occurred through geologic events.

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.

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.

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.

Materials

- Landscapes: Present images
- Zion Canyon topographic map
- Crayons or colored pencils
- Mesa topographic features maps (student and teacher version)
- Volcano topographic features maps (student and teacher version)

Suggested Procedure

1. 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.

2. On the volcano map, ask the students to find and label the small volcano called Crater Hill and the 4,600-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.

3. 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?

4. 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).

5. 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?

6. 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.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What will Zion National Park look like in 100 million years? Only time will tell.

Landscapes: Future

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 describe 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 YouTube video showing historical evolution of tectonic plates through 100 million years in the future http://www.youtube.com/watch?v=uGcDed4xVD4&NR=1&feature=fvwp

Suggested Procedure
1. 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?

2. Have the students draw maps and 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.

3. 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

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.

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 such as a volcanic eruption, or from 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).

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 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.

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.

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.

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.

topographic map: a representation of the Earth, or part of it, showing the shape of the Earth's surface with contour lines.

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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