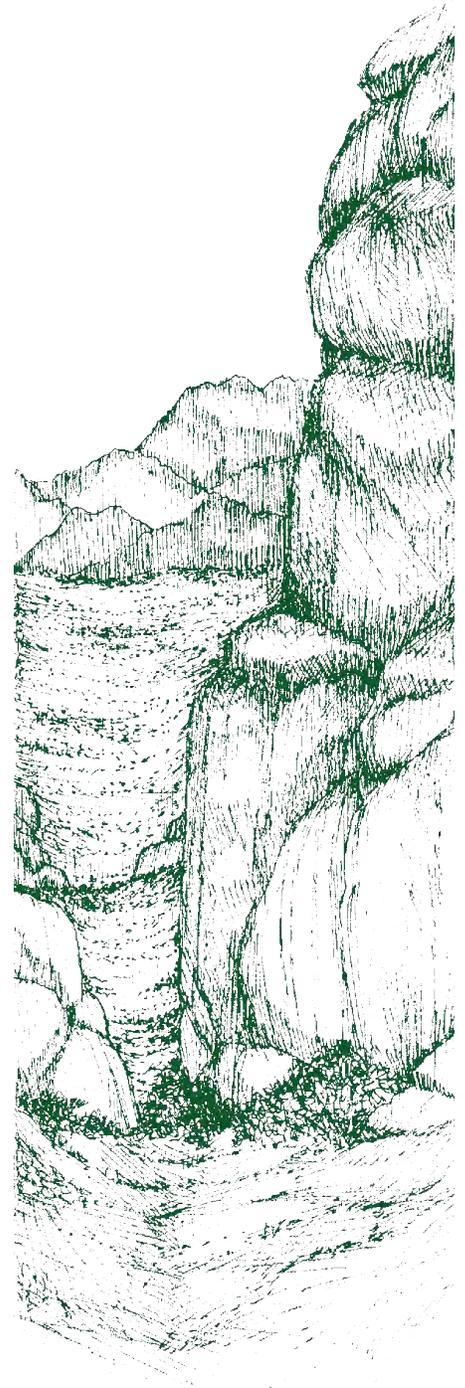


# GEOLOGY

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Far from being static, the geology of Earth is dynamic, in constant motion and change. The crust is a puzzle made up of *tectonic plates*, shifting against one another over a molten layer of *magma*. During the changing relationship of the plates, Earth's crust has undergone compression and stretching, creating vast breaks in the surface known as *faults*. Periods of mountain building uplifted the great mountain chains of the world. Since the Precambrian Era, the Mojave Desert has experienced many different phases over almost incomprehensible time periods.

(See the Fun Facts chart in this unit)



# GEOLOGY

All three families of rock are evident in the Mojave Desert — *igneous*, *sedimentary*, and *metamorphic*. The earliest rock, related to the metamorphic *gneiss* and *schist* at the bottom of the Grand Canyon, has little exposure in the Mojave, but can be seen at Saddle Island in Lake Mead National Recreation Area (NRA) and parts of Death Valley National Park (NP). Changed from pre-existing rock by immense temperature and/or pressure (without melting), this metamorphic rock is ancient — from the Precambrian Era, formed about 1.6 to 1.8 billion years ago.

## Once Upon A Time

It is hard to imagine that during the Paleozoic Era (570 – 225 million years ago) much of the American Southwest was covered by shallow seas. However, fossil impressions of marine creatures in limestone and dolomite reveal the ancient beginnings of many sedimentary rocks. Throughout this period, fluctuating seas deposited thousands of feet of sediment, then retreated, exposing these layers to erosion. Different layers of marine deposits can be seen in banded mountains throughout the desert.

During the Mesozoic Era (225 – 65 million years ago) mountains were uplifted, revealing the Paleozoic layers. Evaporating bodies of water left behind salt (halite), calcium (gypsum), and many other evaporates that have been mined by humans for hundreds of years for industrial and domestic use. Rivers and transient streams carried great amounts of eroded material into the lowlands.

The climate became even more arid than it is today, expanding great belts of sand dunes. Jurassic winds carried the sand, creating the *cross-bedding patterns*

still evident in the Aztec sandstone found in Red Rock Canyon National Conservation Area (NCA), Valley of Fire State Park, and Lake Mead NRA. It continues into Arizona and Utah where it is called Navajo sandstone. Red, beige, and even white, this sandstone has a propensity for fanciful erosion by wind and water. Spectacular arches can be formed. Beehives, goblins, and castles appear to the human imagination in other rock formations.

The beginning of the Cenozoic Era (65 million years ago – present) heralded another tectonically active period. Several different types of faulting deformed the layers of sediment and the metamorphic rock beneath. Normal faults produced vertical lifting and dropping, while strike-slip faults shifted blocks laterally. Thrust faults folded older layers over younger deposits, producing miles of horizontal displacement. This topsy-turvy construction can be seen at the Keystone Thrust Fault at Red Rock Canyon NCA and in the Muddy Mountains of Lake Mead NRA.

## Magma On The Move

Along with the faulting, volcanic activity increased across the landscape. Igneous rock is derived from molten layers of magma beneath the Earth's crust. Under great pressure, the magma rises towards the surface through weak points such as faults.

If the molten rock solidifies before reaching the surface, it is intrusive, forming *tabular sills*, *dikes*, and large bodies called *plutons*. These rocks are large-grained from slow cooling. Erosion of less resistant surface rock exposes the plutonic formations. Plutonic rock can be seen all over the Mojave Desert, and Joshua Tree National Park has especially

fantastic examples.

Extrusive igneous rock is magma that reaches the surface, in the form of lava and explosive material. Ash, cinder, *lapilli*, and *volcanic bombs* are violently expelled by volcanoes and vents when lava is very thick and filled with gas. *Cinder cones*, *calderas*, and *stratovolcanoes* are formed in this way. *Shield volcanoes* are formed by less viscous lava. Extrusive igneous rock is usually fine-grained from cooling quickly on the surface.

The most recent period of volcanic activity in the Mojave Desert occurred only three thousand years ago and was centered at the Ubehebe Crater in Death Valley NP. The hot springs in Black Canyon at Lake Mead NRA and the cinder cones and lava flows found in the Mojave National Preserve (NPRES) are reminders of this active period.

## Shake, Rattle, And Roll

For Mojave Desert residents earthquakes are active reminders of the Earth's dynamic nature. An earthquake is a shaking of the Earth caused by the release of energy as rock suddenly breaks or shifts under stress. Although earthquakes can happen anywhere, most occur along tectonic plate margins and are associated with faults.

The Mojave Desert lies near the boundary between the Pacific and North American plates. As these plates slide past each other stress is created, forcing rocks to break along faults. A magnitude 7.6 earthquake, centered in the western Mojave Desert, rattled a wide area on June 28, 1992. It was the largest to strike California in forty years and was also the world's largest earthquake for 1992. Aftershocks from this quake were felt for many years.

## Whittling The Earth

In this arid region of little precipitation and sparse vegetation, *erosion* is a major process shaping the desert. Water can seep into the smallest crack and percolate between grains of stone. Acids, minerals, and gases are carried in solution to react with the rock, causing chemical alterations such as *oxidation* of iron and manganese which produces many hues of red and purple.

The rain that does come is often in torrential thunderstorms that carry large amounts of debris through washes, forming *alluvial fans* below the mountains and filling in the desert basins. Wind also distributes material, molding sand dunes, such as those found at the Kelso Dunes in the Mojave NP, and abrading landforms into sculptural shapes, like the arches at Valley of Fire. Gravity continually draws material downward, forming aprons of *talus* debris along the skirts of the mountains.

Erosion is not always a natural process. Human activities, such as overgrazing, deforestation, construction, and water diversion, are recorded on the land. Bicycles, off-road vehicles, and indiscriminate blazing of new trails destroy the protective layer of *desert pavement* and promote erosion of fragile desert soils. Removal of even seemingly unimportant rocks spoils the experience for others and is illegal in National Park Service areas.

The fascinating rock formations of the Mojave Desert are inviting, but be careful when climbing. Many people are injured or killed in climbing accidents every year. Explore and enjoy the desert safely and sanely.

## GLOSSARY

**alluvial fan** — a fan-shaped deposit formed where streams issue from the mountains onto the lowlands.

**caldera** — a large depression typically caused by collapse or ejection of the summit area of a volcano.

**cinder cone** — a small volcano built primarily of rock fragments ejected from a single vent.

**cross-bedding pattern** — layers inclined at a steep angle to the horizontal, characteristic of sand dunes and river deltas.

**desert pavement** — a surface of pebbles and cobbles exposed by winds and sheet wash that protects the finer material beneath, a desert crust.

**dike** — a long, narrow, cross-cutting mass of *igneous rock* intruded a fissure in older rock. Dikes are often oriented vertically.

**erosion** — processes that fragment, dissolve, and remove rock and related material: wind, water, gravity.

**fault** — a fracture or fracture zone in Earth's crust along which there has been movement of the sides relative to one another.

**gneiss** — a *metamorphic rock* where intense pressures and temperatures have caused minerals to segregate giving the rock a banded appearance.

**hoodoo** — a pillar of rock left by *erosion*.

**igneous rock** — a rock formed by the crystallization of molten *magma*.

**lapilli** — small, stony particles ejected from a volcano.

**lava** — molten rock that makes it to Earth's surface.

**magma** — naturally occurring molten

rock containing water and gases, found beneath Earth's crust.

**Maar volcano** — volcano formed by a steam explosion caused when groundwater meets magma

**metamorphic rock** — a rock changed by great temperature, pressure, stress, and/or chemical changes, usually at depth in the crust, from pre-existing rocks (either *igneous* or *sedimentary*).

**oxidation** — the process of combining chemically with oxygen, producing an oxide.

**pluton** — a structure resulting from the crystallization of *magma* beneath Earth's surface.

**schist** — a *metamorphic rock* that readily splits into parallel layers and has a platy or scaly appearance.

**sedimentary rock** — a rock formed of sediments deposited by wind, water (conglomerates, sandstone, shale), or precipitation (limestone, gypsum, salt).

**shield volcano** — a broad, gently sloping volcano built from fluid lavas.

**stratovolcano** — a volcano with steep sides, built up by different layers of explosive cinder and ash, with occasional lava flows.

**tabular sill** — an *igneous* body intruded parallel to the layering of pre-existing rock. Most sills are horizontal.

**talus** — an accumulation of rock debris, usually at the base of a cliff.

**tectonic plate** — one of the geological structures making up Earth's crust. Related to the deformation of the crust by faulting and folding.

**volcanic bomb** — a streamlined rock fragment ejected from a volcano while molten.

# GEOLOGY

## Activity 1

### Deep Time

**OBJECTIVE:** Demonstrate the relative distance of events in time.

**MATERIALS:** Adding machine paper tape (at least forty feet), crayons, Span of Time chart on page 5.

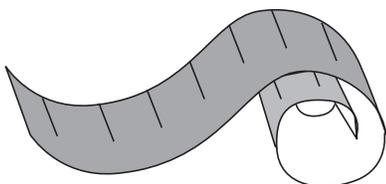
**SUBJECTS:** Art, math, science.

**SKILLS:** Application, computation, drawing.

**METHOD:**

1. Find a space about forty feet in length.
2. Assign one person to represent the beginning of the Earth and have them pull out the paper tape. Lay the tape on the ground.
3. Assign each person an event on the Span of Time chart and have them pace out the distance to their assigned event.
4. Starting with the beginning of the Earth, have each student call out their event and how long ago it occurred.
5. Have students draw a picture to represent their assigned event at the length of tape that represents that date in time. (Note that modern events have occurred in such a tiny part of recent history compared with the rest of time that it would be difficult to include all the events on this tape.)

**EXTENDING THE EXPERIENCE:** Try a larger format outside, using twine instead of tape. Using the same format, make a time line for human history.



## Activity 2

### Dunes And Hoodoos

**OBJECTIVES:** List different ways rock can be eroded. Describe the *erosion* that occurs from these processes.

**MATERIALS:** Blow dryer, empty ice tray, flat plate, rain or a sprinkler, sand, small block the same height as the tray, three quarters.

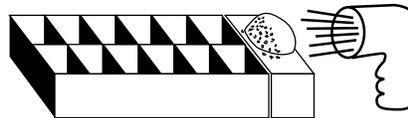
**SUBJECTS:** Art, language arts, science.

**SKILLS:** Analysis, comparing, description, evaluation, predicting, oral and written communication.

**METHOD:** Students can predict what they think will happen in each experiment. They can write and draw what happens after each experiment and compare the results to their predictions.

**WIND:**

1. At the end of an empty ice tray, place a block that is the same height as the tray.



2. Mound approximately  $\frac{1}{2}$  cup of sand on the block.
3. Use a blow dryer to blow the sand across the ice tray.
4. Note the shape the pile takes as the sand blows away.
5. Note the different sizes of sand grains in the tray. What size made it the farthest?

**WHAT HAPPENED AND WHY?**

Wind transports and deposits sand. Because of their lighter weight, small grains will go the farthest. The different shapes that sand dunes take depend on the speed and direction of the

wind. A crescent with its horns pointing downwind is a barchan dune, common in all deserts.

**WATER:**

1. Make a mound of sand (two inches deep in the center) on a flat plate.



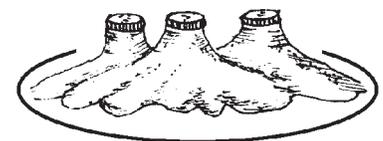
2. Place three quarters on top, about one inch apart.



3. Place out in the rain or make your own with a sprinkler from above.

4. Note what happens to the sand.

**WHAT HAPPENED AND WHY?**



The quarters act like very hard rocks on less resistant stone. A cap rock protects the layers beneath from erosion so that *hoodoos*, pinnacles, and other strange shapes are made.

**EXTENDING THE EXPERIENCE:** Ask students to look for evidence of erosion in their neighborhoods. It can involve an entire mountain or just a square inch.

## THE SPAN OF TIME

(INDOOR) LENGTH FROM PRESENT	(OUTDOOR) LENGTH FROM PRESENT	YEARS AGO	EVENTS
38 feet	254 yards	4.57 billion	Earth begins
29 feet	194 yards	3.5 billion	Life on Earth begins
25 feet are abundant	167 yards	3 billion	First fossils form; algae, fungi, and bacteria
4.5 feet	31 yards	550 million	Jellyfish, sponges, and worms are abundant
3.75 feet	25 yards	450 million	First primitive fish
40 inches	22 yards	400 million	Earliest land plants (ferns and mosses)
35 inches	19 yards	350 million	Earliest land animals (amphibians)
31 inches	17 yards	310 million	First reptiles
27 inches	15 yards	270 million	Reptiles abundant and well developed
24.5 inches	14 yards	245 million	Age of Dinosaurs begins
18 inches	10 yards	180 million	Flowering plants develop
16 inches	9 yards	160 million	Birds evolve; dinosaurs abound
7 inches	4 yards	70 million	Modern birds develop
6 inches	11 feet	65 million	Dinosaurs extinct; Age of Mammals begins
5 inches	8 feet	50 million	Mammals and birds abundant
4 inches	7 feet	40 million	First elephants
.5 inches	10 inches	5 million	First humans
.15 inches	3 inches	1.5 million	Beginning of Pleistocene and Ice ages
.001 inch	.02 inch	10,000	End of the most recent Ice Age
.0002 inch	.004 inch	1,915*	Mt. Vesuvius erupts in Pompeii
.0001 inch	.0015 inch	779*	Magna Carta signed in 1215
.00002 inch	.0004 inch	218*	Declaration of Independence signed in 1776

Indoor Scale: .1 inch = 1 million years  
Outdoor Scale: 2 inches = 1 million years

\* Years ago calculated from 1994

# GEOLOGY

## Activity 3

### Mystery Minerals

**OBJECTIVES:** List four tests used in geology to identify rocks and minerals. Identify limestone by using a test.

**MATERIALS:** Magnifying glasses, pennies, rock and mineral samples (limestone, dolomite, graphite, hematite, pyrite, gypsum, quartz, etc.), steel files or scissors, unglazed white porcelain tiles, vinegar.

**SUBJECTS:** Language arts, science.

**SKILLS:** Analysis, classification, comparison, computation, observation, writing.

**METHOD:**

**1.** Have students keep a log, recording results and observations. For each sample, perform these tests:

**Test One:** Observe the color of the mystery sample. Color is important in identification.

**Test Two:** Observe how the sample reflects light. This is called its luster. Is it dull, metallic, resinous, glassy, pearly, silky, or diamond-like?

**Test Three:** Add a few drops of vinegar to the sample. Observe through a magnifying glass. Does it fizz? If it does, it is a carbonate rock such as limestone or dolomite. The acidic vinegar is reacting with the rock to produce carbon dioxide gas.

**Test Four:** Streak the rock on a tile. What color is the streak mark? Is it the same as the rock? Example: pyrite is a brassy yellow, but its streak is greenish black.

**Test Five:** Try to scratch the surface of the rock with your fingernail, a penny, and a steel file or scissors. This demonstrates the relative hardness for each sample. Compare with the scale

below. The Mohs scale of hardness runs from 1 (softest) to 10 (hardest):

- |     |                        |
|-----|------------------------|
| 1   | TALC                   |
| 2   | GYPSUM                 |
| 2.5 | FINGERNAIL             |
| 3   | CALCITE                |
| 3.5 | PENNY                  |
| 4   | FLUORITE               |
| 5   | APATITE                |
| 6   | FELDSPAR               |
| 6.5 | STEEL FILE OR SCISSORS |
| 7   | QUARTZ                 |
| 8   | TOPAZ                  |
| 9   | CORUNDUM               |
| 10  | DIAMOND                |

**2.** Have students tabulate their results and compare the different samples. Although they might not be able to identify each sample exactly, these tests help classify various rocks.

**EXTENDING THE EXPERIENCE:** Have students compare their results with those in a geology text.

## Activity 4

### Oxidation

**OBJECTIVES:** Describe the changes of a metal during *oxidation*. List what chemicals can speed up oxidation.

**MATERIALS:** Four iron or steel nails, four shallow dishes, distilled water, salt, vinegar, (optional: four pennies).

**SUBJECTS:** Art, language arts, science.

**SKILLS:** Analysis, application, comparison, drawing, evaluation, observation, prediction, writing.

**METHOD:**

**1.** Place an iron or steel nail in each of four shallow dishes. Students can predict what they think is going to happen to each nail.

**2.** Pour two tablespoons of distilled

water each over three of the nails. Leave the fourth one dry.

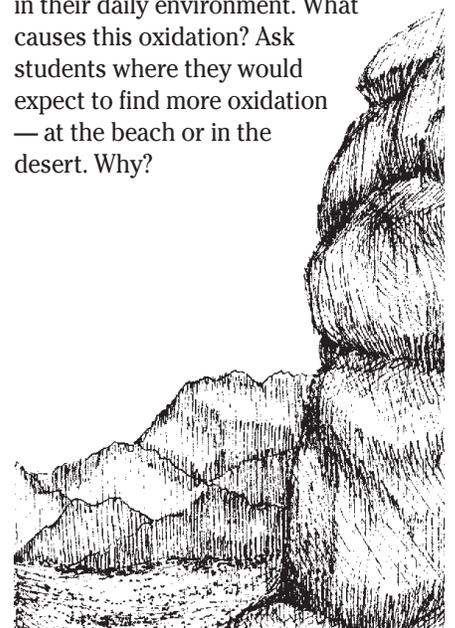
**3.** Sprinkle a tablespoon of salt each over two of the wet nails.

**4.** Pour a tablespoon of vinegar over one of the salty, wet nails.

**5.** Have students keep a log predicting what they think will happen to each nail. Record observations in writings and drawings. Observe and compare the nails every day for a week. Optional: Repeat 1-5, but use pennies instead of nails.

**WHAT HAPPENED AND WHY?** When left in contact with the air, metals can bind with oxygen. Oxidation, or rusting, creates the many bright colors that can be seen in desert rocks and soils. Salts, water, and acids help speed up the process. Oxygen combines with iron to form a reddish-brown iron oxide called hematite or, in more extreme cases, a yellowish-colored rust called limonite. The salt will react with copper to produce copper chloride.

**EXTENDING THE EXPERIENCE:** Have students look for examples of oxidation in their daily environment. What causes this oxidation? Ask students where they would expect to find more oxidation — at the beach or in the desert. Why?



## Fun Facts — THE GEOLOGIC CALENDAR

Absolute dates were added quite recently, long after the calendar had been established using relative dating techniques. The Precambrian accounts for more than eighty-five percent of geologic time.

