THE Geologic COLUMN OF MISSOURI

VOLUME 3, ISSUE 1 Summer 2008

DNR photo by Jerry D. Vineyard and David Hoffman

Aerial view of Elephant Rocks State Park.

Igneous Rocks

The Volcanic Stone of Missouri

The St. Francois Mountains of southeast Missouri are known for their exposures of 1.5 to 1.2 billion year old igneous rocks. These exposures are remarkably fresh and unaltered, and are unique within the mid-continent region of the United States. The area also gives a rare glimpse into rocks that are formed by the most violent volcanic eruptions known on the earth. Consequently, geologists come from around the world to study them.

The igneous rocks are core features in some of Missouri's most spectacular scenery and popular state parks, including Johnson's Shut-Ins, Elephant Rocks and Taum Sauk Mountain. Each of these parks owes its unique character to the igneous rocks and to the geologic processes that have formed and shaped them.

The rocks have also provided a livelihood for generations of Missourians. Early mining of iron and granite in the St. Francois Mountains led to the development of settlements and towns, and was often the impetus behind the development of infrastructure in the region. Today, this region is still a major producer of mineral products.

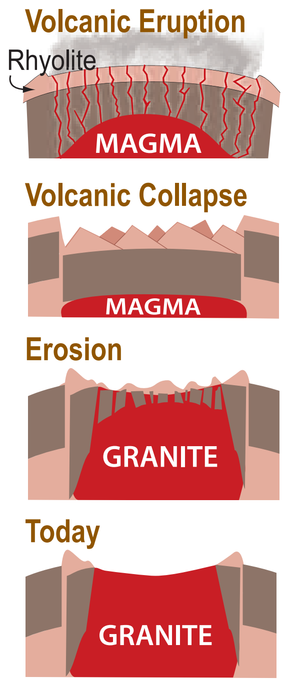
MISSOURI
DEPARTMENT OF NATURAL RESOURCES
Division of Geology and Land Survey

Missouri's Volcanic Past

Approximately 1.4 billion years ago, southeast Missouri was a landscape dominated by volcanic calderas, some of which were up to 15 miles in diameter. These calderas were different from volcanoes active today in places like Hawaii. Instead, they more closely resembled the Yellowstone caldera, which today, is the largest dormant volcano in the United States. Unlike "typical" volcanoes, calderas do not erupt from one main vent or develop a large cone-shaped mountain. Instead, magma (molten rock) from an underlying chamber moves upward under pressure and erupts lava from multiple vents in a series of smaller eruptions. Over time, the pressure in the magma chamber builds to the point that the overlying rock cannot withstand the pressure and a giant eruption occurs, forming a crater miles in diameter. Layers of volcanic rock form thousands of feet thick.

Large calderas such as these generally erupt rhyolite (see Granites and Rhyolites), a volcanic rock that is very high in silica, a compound comprised of the elements silicon and oxygen. The higher the silica content in a magma, the more viscous, or thick, will be the lava. Viscous magmas tend to hold more volcanic gas and therefore erupt explosively. Rhyolite calderas produce the most violent eruptions of any type of volcano on earth.

Formation of a Caldera Volcano



Volcanic Eruption: Pre-existing rock is pushed upward and fractured by magma in the chamber below. Rhyolite ash and lava erupt to the surface.

Volcanic Collapse: After eruptions, the overlying rocks collapse into the mostly emptied magma chamber.

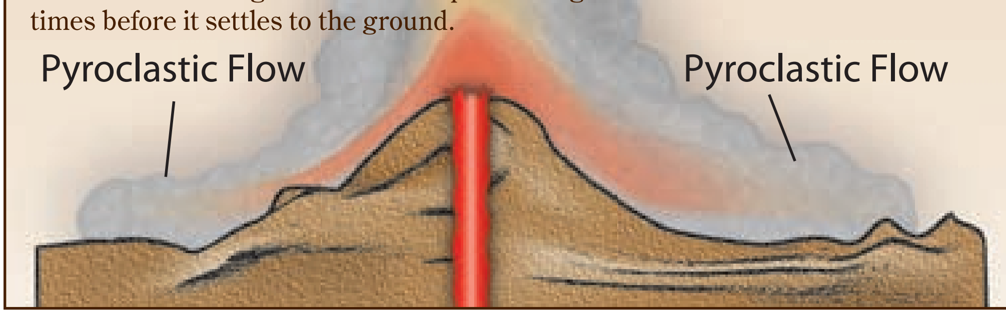
Erosion: As the caldera becomes extinct, remaining magma cools into granite. Overlying igneous rocks slowly begin to erode.

Today: The rhyolite has eroded, exposing the large granite body at the surface. The harder rhyolite forms knobs.

Lava vs. Ash

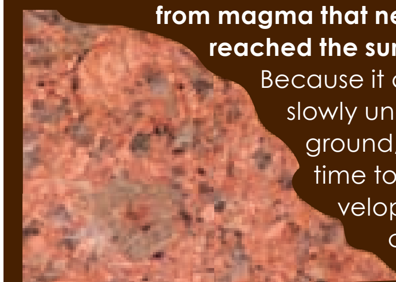
When many people think of volcanic eruptions, they picture lava flows. While some of the volcanic rocks in Missouri are lava flows, most of them are a type called ash flow tuffs, similar to those formed by the Mt. St. Helens eruptions in the early 1980s. Ash-flows occur when the lava explodes so forcibly that it comes out in small droplets that immediately harden into fine, gritty pieces of rock, called volcanic ash. The ash is mixed with hot volcanic gases that are also part of the eruption. This mixture of ash and hot gases flows like a liquid down the side of the volcano, and is called a pyroclastic flow. Pyroclastic flows can move at speeds of up to 100 miles per hour, and may be near 1,800 degrees Fahrenheit. The ash is so hot that it welds together when it falls to the ground, forming a solid rock. This is the type of eruption that destroyed the Roman cities of Pompeii and Herculaneum, except that the eruptions from Missouri's volcanoes are estimated to have been more than 100 times larger.

Other volcanic rocks in Missouri are called ash-fall tuffs. These igneous rocks form when smaller eruptions occur. The volcanic ash is blown up into the air, but does not contain as much volcanic gas as when a pyroclastic flow is unleashed. The ash falls to the ground, or is blown by winds before being deposited. Volcanic ash that is blown high into the atmosphere can go around the Earth several times before it settles to the ground.

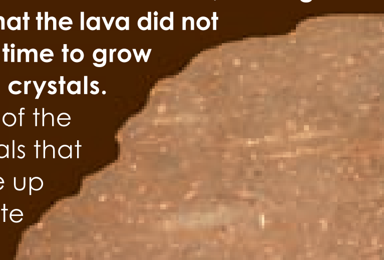


Granites and Rhyolites

Granite is the most common igneous rock type at depth in Missouri, but it makes up very little of the exposed rock in the St. Francois Mountains. Most of the outcrops are a volcanic rock called rhyolite. While the two rocks look very different, they have essentially the same chemical composition and are made up of the same minerals. **Granite was formed from magma that never reached the surface.** Because it cooled slowly underground, it had time to develop large crystals of the minerals quartz, feldspar and mica. **Rhyolite, on the other hand, erupted from a volcano, cooling so fast that the lava did not have time to grow large crystals.** Most of the crystals that make up rhyolite are so small that one needs a microscope to see them.



Close-up of Missouri red granite



Close-up of Missouri rhyolite

Because the mineral grains are larger, granite in the St. Francois Mountains weathers and erodes faster than rhyolite. Therefore, areas with granite bedrock are often very low knobs or lowlands. Rhyolite is much more resistant to weathering, and makes up most of the steep, high knobs that form the St. Francois Mountains.

Other igneous rocks found in the St. Francois Mountains include trachyte, diorite and syenite. These look very much like rhyolite, except they are black or near black in color. They contain less quartz and feldspar than rhyolite, and more minerals that are dark in color that contain high amounts of iron and magnesium. They are exposed in only a few places, but weather (and form knobs) like rhyolite.

A Moment in Time

Iron Mountain is located in St. Francois County and was originally given in 1797 to James Pratt, a settler of great influence in the Upper Louisiana territory, as part of a land grant by the Spanish government. At the time, the mountain was believed to be entirely iron ore. In 1836, the property was conveyed to the Missouri Iron Company, which began mining the site. The first mining was of ore exposed at the surface, but operations soon changed to underground mining. Iron Mountain was mined almost continuously by various companies from 1836 until 1966, when the M.A. Hanna Company made the decision to cease iron mining operations at the site. Several years before this date, the company began processing piles of unmineralized igneous rock, called waste rock, which was left over from the iron mining for use as aggregate, or crushed stone. Today, the site still produces igneous rock once considered waste from the mining operation as aggregate, making it the oldest continually mined property in the United States. The hoist for the underground workings and many of the original buildings remain on the site, preserved by the current and past operators as a living piece of Missouri's history.

DNR photo by Art Hebrank

Headframe, buildings and water tanks from the Iron Mountain mine, which began mining in 1836.

St. Francois Mountains

The history of the St. Francois Mountains began when repeated rhyolite ash-flows, ash-falls and lava eruptions cooled and solidified on the surface. This process lasted for at least several hundred million years. When the magma chambers emptied after large eruptions, the overlying rock would fracture and collapse. Large blocks of rhyolite would tilt and slip against one another. Magma chambers refilled and the calderas erupted many times. At the same time, granites intruded into the pre-existing rock and solidified below the surface. The total thickness of the granite and rhyolite sequence is not known, but is easily tens of thousands of feet.

Eventually, the underlying magma cooled and the calderas became inactive. The igneous rocks eroded, forming a mountainous topography. Geologists estimate that as much as 6,000 feet of igneous rock may have been eroded to form the range of knobs and hills that we call the St. Francois Mountains. The calderas themselves were also eroded, so that today we see only the roots of the once giant calderas.

Roughly 520 million years ago, the Ozark region was lowered due to continental movement. Seas inundated the area and began to deposit sedimentary rocks — first beach-like deposits of sandstone and then limestone and dolomite. The seas advanced and retreated many times, burying the St. Francois Mountains under layers of sediment that lithified, or hardened, into sedimentary rocks.

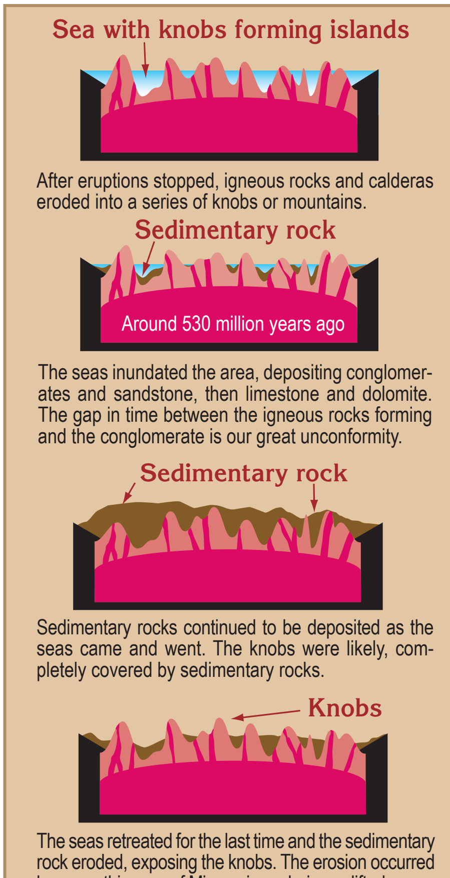
Recently, in geologic terms, the Ozark region has been uplifted due to pressure on the tectonic plate that carries the North American continent. The uplift led to increased erosion, removing the sedimentary rocks from the core of the St. Francois Mountains. The same rugged topography that we see exposed in just a few counties in southeast Missouri lies buried under hundreds to thousands of feet of sedimentary rock throughout the Ozarks. As the area continues to be slowly uplifted, more of the buried mountain range will be exposed at the surface.

Young and Old

When rocks are removed by erosion and the erosional surface is then covered by younger rocks, unconformities occur. Unconformities represent gaps in the geologic record similar to pages missing from the middle of a book.

In the St. Francois Mountains, there are numerous places where a person's hand can span rocks that bracket 900 million years of missing geology — a period of time that represents more than one-fifth of the geologic history of the Earth.

Fossils are often useful indicators of the age of rocks. Igneous rocks, however, do not contain fossils, because they either formed deep underground or were too hot for any life to survive their placement on the earth's surface. Instead, radioactive isotopes are used to date igneous rocks. Radioactive elements, such as uranium, naturally decay. This decay occurs at a known rate. Geologists find the percentage of atoms that have experienced decay and use this as a clock to tell how long it has been since the rock formed. This is how we know that the igneous rocks in the St. Francois Mountains are 1.5 to 1.2 billion years old.



After eruptions stopped, igneous rocks and calderas eroded into a series of knobs or mountains.

The seas inundated the area, depositing conglomerates and sandstone, then limestone and dolomite. The gap in time between the igneous rocks forming and the conglomerate is our great unconformity.

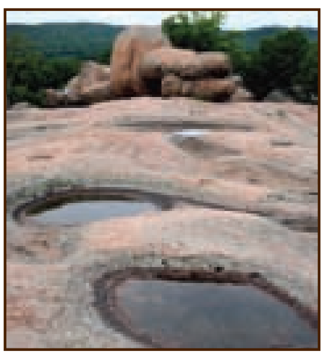
Sedimentary rocks continued to be deposited as the seas came and went. The knobs were likely, completely covered by sedimentary rocks.

The seas retreated for the last time and the sedimentary rock eroded, exposing the knobs. The erosion occurred because this area of Missouri was being uplifted.

Elephant Rocks

The granite boulders in Elephant Rocks State Park are not only beautiful and enjoyable, but are also a textbook example of weathering granite. The granite formed thousands of feet below the surface, but has been uplifted and exposed by erosion. Cracks formed in the granite when it cooled, and stresses caused by the uplift led to greater fracturing of the rock. When the granite was exposed at the surface, water and ice began to widen the fractures and erode the granite. The granite at the surface became a series of oblong blocks. The corners and edges of the blocks became rounded due to weathering and chemical reactions of the rock with water and air. Eventually, the rounded blocks became the huge isolated boulders, or "elephants," that are sitting on the granite outcrop.

The basins, often called "birdbaths," that are near the "elephants" were originally shallow depressions that could accumulate water. The combined chemical reaction between the granite and the water, as well as continual freezing and thawing, continues to cause the granite to fragment and weather, gradually deepening and widening the basins.


DNR photo by Bill Duley

Numerous birdbaths in the granite at Elephant Rocks State Park.

Minerals and Mining

The unique geology in the St. Francois Mountains led to the formation of numerous mineral deposits. The location of the deposits, in turn, affected settlement in the area and the area's history. Names like Ironton, Iron Mountain and Graniteville reflect the mineral products around which those communities were founded. Metals like iron, copper and manganese and stone products from rhyolite and granite have been produced from this region for centuries.

"Granite has a long history of use as a building stone, and is found in houses around the state and in buildings from California to Massachusetts."

Iron was the primary mineral commodity produced from igneous rocks. The exposed St. Francois Mountains, as well as the igneous rocks still buried beneath the sedimentary rocks, host a world class iron ore district. Iron metal was first produced in 1815, when surface veins of magnetite (iron oxide) were mined on Shepherd Mountain, near Ironton. The surface iron mines at Iron Mountain and Pilot Knob were also developed in the first half of the 19th century. The first iron furnace west of the Mississippi River was constructed near Ironton at this time as well. The iron was shipped by wagon to St. Louis and other river ports. This eventually proved too costly, and led to construction of the St. Louis and Iron Mountain Railroad, completed in 1858. It later became the Missouri Pacific Railroad, one of the major rail systems in the nation.


DNR photo

An example of a granite quarry, near Graniteville.

Iron production continued in Missouri until 2001, when Pea Ridge, the last operating underground iron mine in the United States, ceased production. The mine is located approximately 16 miles southeast of the town of Sullivan. Iron from Pea Ridge was used for steel production, coal desulfurization, high-density concrete and iron pigments. Large reserves of high-grade iron ore still remain underground in Missouri's igneous rocks, giving the state the potential to return to a position as a major iron producer.

Granites and rhyolites are also mineral commodities produced in Missouri. Missouri granite has a long history of use as a building stone, and is found in houses around the state and in buildings from California to Massachusetts. Graniteville granite, found at and near Elephant Rocks State Park, was used extensively in St. Louis for cobblestone streets, buildings at Washington University and for Eads Bridge. Graniteville granite is also in the Illinois and Iowa statehouses and the Missouri Governor's Mansion. Rhyolite is also quarried, and today, is used to make the granules found on roofing shingles.

Rock Types

All rocks found on and in the earth can be divided into three main types. **Igneous rocks** are rocks that form by the cooling and solidification of molten rock. **Sedimentary rocks** like limestone and sandstone form either by precipitation from water or by the erosion of other rocks and redeposition and cementing of the eroded grains. **Metamorphic rocks**, which are rare in Missouri, form when the minerals and textures of a rock are changed by extreme heat or pressure.

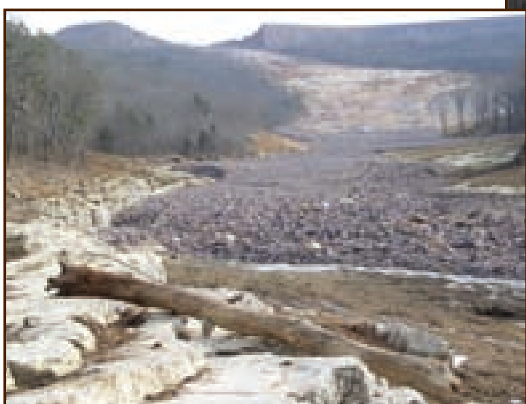
Igneous rock **Sedimentary rock** **Metamorphic rock**

Fascinating Geology Revealed

In December 2005, a hydropower reservoir facility located on top of Proffit Mountain in rural Reynolds County failed. The event affected Johnson's Shut-Ins State Park and water quality and aquatic habitat in the East Fork of the Black River as well as in downstream sections of the Black River.

The flood scar revealed a dramatic exposure of the igneous and sedimentary bedrock that make up the west flank of Proffit Mountain. The hillside provides a unique geologic workshop for current and future generations of geologists, geology students and to anyone interested in the geologic history of this unique region.

The division has supported efforts to understand the failure mechanism for the reservoir and the geologic and geophysical limitations for the safe rebuild of a new pumped storage facility. New geologic drill hole information was collected and used in conjunction with archived data. Support was also provided for assessment and repair of the environmental damage related to the event. The division has also provided geologic expertise for interpretative displays within Johnson's Shut-Ins State Park.



The flood scar is slightly more than 1.5 miles in length from the reservoir to the former bed of the East Fork of the Black River.

The flood scar left behind after approximately 1.3 billion gallons of water rushed down the side of the Proffit Mountain, exposing igneous bedrock.

Archiving Geologic Data

A mission of the Division of Geology and Land Survey is to archive geologic data of different types and to make this information available for inspection by geologic professionals and the public. The division archives include everything from paper information to rock samples. The McCracken Core Library contains more than 2.5 million feet of drill core from around the state. The drill cores vary from surficial materials collected for earthquake hazard and glacial material studies to deep drill cores that enhance our understanding of the igneous rocks that are buried under thick layers of sedimentary rock. The drill cores are used to explore for ore deposits, for geologic mapping, hydrologic and environmental studies, and academic purposes. Core samples are an important scientific and economic resource that would be very expensive or impossible to duplicate. Maintaining a core library greatly increases the department's ability to provide technical assistance and geologic information to those who develop, market, manage or regulate the state's energy, land, and water resources.

DNR photo by Mark Gordon

The Division also archives information about past mining activity in Missouri. Part of this archive contains historic mine maps. The maps show surface and underground mines that produced commodities including: iron, lead, zinc, limestone and sandstone, among others.

Web Sites

Taum Sauk State Park
www.mostateparks.com/taumsauk.htm

Johnson's Shut-Ins State Park
www.mostateparks.com/jshutins.htm

Elephant Rocks State Park
www.mostateparks.com/elephantrock.htm

Elephant Rocks Fact Sheet
www.dnr.mo.gov/pubs/pub683.pdf

Publications

RI-64. Geology of the Precambrian St. Francois Terrane, Southeastern Missouri, (Contribution to Precambrian Geology No. 8), by Eva B. Kisvarsanyi, 58 p., 9 figs., 10 tbls., 1:250,000-scale map, 1981.

RI-67. Guidebook to the Geology and Ore Deposits of the St. Francois Mountains, Missouri, (Contribution to Precambrian Geology No. 9), by Eva B. Kisvarsanyi, Arthur W. Hebrank, and Richard F. Ryan, 119 p., 75 figs., 8 tbls., 1981.

OFM-83-160-MR. Geologic Map of Exposed Precambrian Rocks in the Iron Mountain Lake Quadrangle, Missouri, www.dnr.mo.gov/geology/sitemap/rolla/ro8301.htm

OFM-83-161-MR. Geologic Map of Exposed Precambrian Rocks in the Wachita Mountain (Fredericktown NW¼) **Quadrangle, Missouri,** (Contribution to Precambrian Geology No. 11), by M.E. Bickford and J.R. Sides, 1:24,000

OFM-83-162-MR. Geologic Map of Exposed Precambrian Rocks in the Lake Killarney Quadrangle, Missouri, (Contribution to Precambrian Geology No. 12), by J.R. Sides, 1:24,000.

These and other publications may be purchased from the Missouri Department of Natural Resources' Division of Geology and Land Survey. To order, contact the publications desk at: 573-368-2125 or 1-800-361-4827, or use our online form at: www.dnr.mo.gov/geology/adm/publications/MapsOrder.htm. For additional information visit our Web site: www.dnr.mo.gov/geology/.

THE Geologic COLUMN

Published by the

Missouri Department of Natural Resources
Division of Geology and Land Survey

Joe Gillman
Director and State Geologist
Division of Geology and Land Survey

Bill Duley
Deputy Director and Assistant State Geologist
Division of Geology and Land Survey

Cheryl Seeger
Contributing Author

Hylan Beydler
Division Information Officer

Mark Gordon
Layout and Graphics

MISSOURI DEPARTMENT OF NATURAL RESOURCES
Division of Geology and Land Survey
P.O. Box 250, Rolla, MO 65402-0250

THE Geologic COLUMN OF MISSOURI