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Devils Postpile National Park

Geologic Story



Columns of the Devils Postpile. Photo by Wymond W. Eckhardt, NPS.

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Introduction

The Devils Postpile is a fine example of columnar basalt. Until recently, it was thought to have been formed about one million years ago. Current studies suggest that the Devils Postpile was formed less than 100,000 years ago when a cooling lava flow cracked into multisided columns. Other well-known examples of columnar-jointed lava are the Giant's Causeway in Ireland and Fingal's Cave in Scotland. The Palisades of New Jersey along the Hudson River and the columns at San Miguel Regla, Mexico, are noteworthy, but are less well known. Other occurrences are

found throughout the world, but well-developed columns are not abundant.

Some details of the geologic origin of the Devils Postpile are not completely clear, but enough is known to reconstruct much of the story. To understand the geologic setting of the Postpile, we must go back hundreds of millions of years; to a time when sands and muds were being deposited in a vast sea that covered southeastern California and parts of adjoining states.

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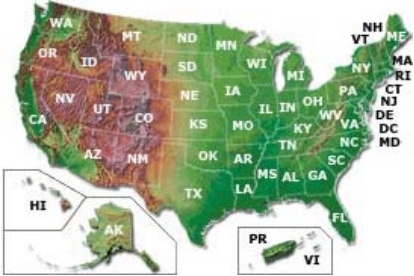
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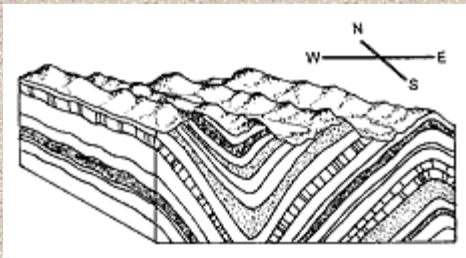
Devils Postpile National Park Geologic Story

Origin of the Sierra Nevada

About 150 million years ago, in the Jurassic period of geologic time, the sediments that had been deposited in the sea and later compressed into sedimentary rocks began to be lifted above sea level. Then began a time of explosive volcanic eruptions that spewed forth vast quantities of lava and volcanic ash, deeply burying the sedimentary rocks. The layered sedimentary and volcanic rocks were then deformed and, in many places, folded intricately, changing or metamorphosing them into tougher, very resistant metamorphic rocks. Examples of these metamorphic rocks can be seen at Minaret Summit and along the road descending to Agnew Meadow.



Devils Postpile view. Photo by Wymond W. Eckhardt, NPS.

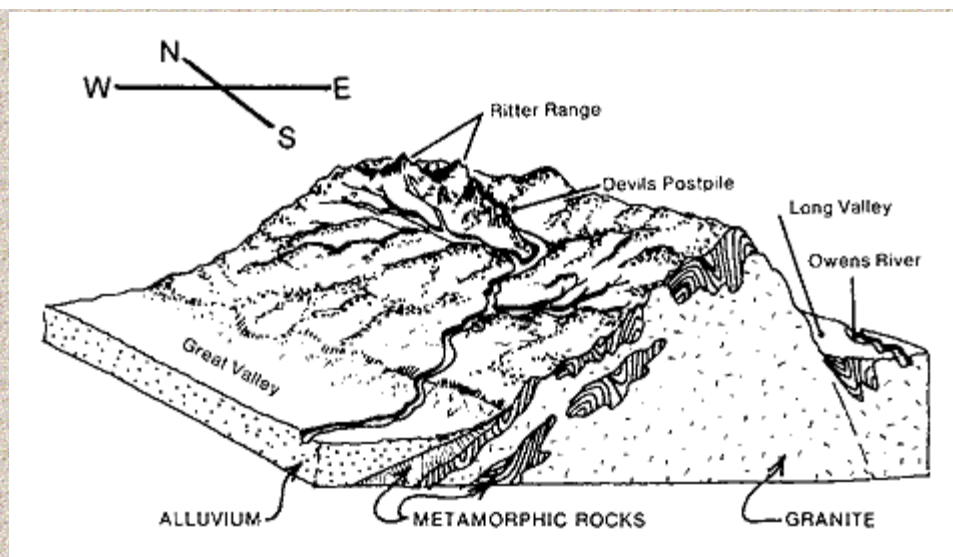


Layers of sedimentary and volcanic deposits were compressed into rocks. These rock layers were then strongly squeezed and folded. Erosion caused more resistant layers to stand out as ridges. Streams carved valleys in softer layers.

Concurrent with the folding and deformation of the layered rocks, molten rock bodies were intruded into these rocks under conditions of great heat and high pressure deep below the Earth's surface; some of this molten rock, or magma, reached the surface to form new volcanoes. This intrusive activity ended about 80 million years ago, in the Cretaceous period. The molten rock cooled slowly and in time solidified into the granite core of the Sierra Nevada.

The episode of deformation, intrusion, and volcanic eruption ended in the formation of a mountain range that can be considered an ancestral Sierra. Erosion followed, and by the end of Cretaceous time, about 60 million years ago, most of the older volcanic and metamorphic rocks had been worn away, exposing the granite core of the range. The area had a low relief compared to

the mountains of today and posed little obstacle to streams draining westward from the interior of the continent.



San Joaquin River Drainage - More resistant rocks caused the river to flow south through the monument before turning west toward the Great Valley.

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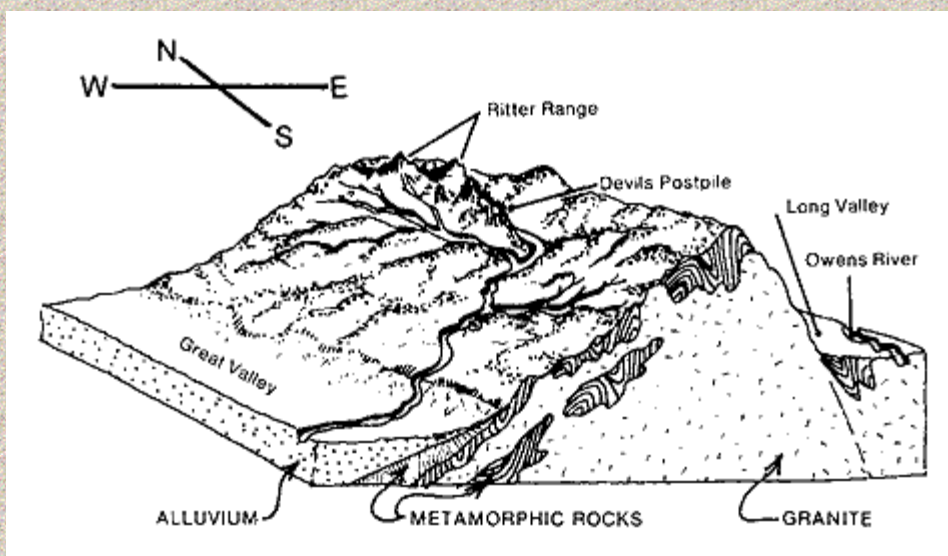
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Renewed Uplift and Stream: Incision

About 25 million years ago, this lowland area began to be uplifted and tilted toward the southwest, a construction which would eventually lead to the present Sierra Nevada. As the rate and amount of southwest tilt increased, the gradients of streams flowing southwest also increased and the faster flowing streams cut deeper and deeper canyons. At that time the steep eastern Sierra Nevada escarpment had not yet formed. The main trunk of the San Joaquin River then had its headwaters perhaps as far east as Nevada, flowing in a channel that crossed what is now the Sierran crest north of Minaret Summit. Within the growing mountain range the specific course of the river was controlled by differing hardness of the bedrock as well as by the tilt of the range. For example, the highly resistant metamorphic rocks of the Ritter Range proved a great obstacle to the southwestward flow of the river and forced it to flow southeastward and then south through the Devils Postpile area. South of the Postpile the river finally was able to swing southwest across the less resistant granite at the south end of the Ritter Range.



The Sierra Nevada rose and tilted along a long normal fault that follows the western edge of the Owens Valley.

About 3 million years ago the river channel north of Minaret Summit was filled by lava flows- reddish- colored, layered rocks visible on the slope above the road descending to Agnew Meadows. This blocked the former channel and isolated the present San Joaquin drainage basin from the area east of the crest. Also about this time the Long Valley-Mono Lake area began to lag behind as the present range continued to rise and the growth of the east-facing Sierra Nevada escarpment further blocked any renewal of a trans-Sierra San Joaquin River. The Sierra Nevada

continues to rise today.

During the Pleistocene epoch, or ice age, glaciers, fed by heavy snowpacks, descended slowly through the old stream-cut canyons, deepening and widening them. Ice accumulated on the east slope of the Ritter Range and flowed down the valley of the Middle Fork of the San Joaquin River several times, shaping the valley to near its present form. These glaciers, carving cirques back into the highly jointed, but resistant, rocks of the Ritter Range sculptured the magnificent Minarets and Matterhorn-like peaks of the range crest.

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Devils Postpile National Park Geologic Story

Rocks of Devils Postpile Formed

Although the rocks of the Devils Postpile formed during the ice age, the Postpile owes its origin to geologic processes initiated earlier. These rocks are but one manifestation of widespread volcanic activity in this part of the Sierra Nevada that began more than three million years ago and has continued to the present. Perhaps born of the same underlying cause as the volcanism, contemporaneous large-scale fault movements created the steep eastern front of the Sierra Nevada; volcanic activity was greatest along or adjacent to the eastern escarpment. Long Valley, from the headwaters of Owens River to Lake Crowley, is a giant volcanic caldera. Mammoth Mountain- a massive volcanic dome- has grown on the caldera margin.

Less than 100,000 years ago, basalt lava, which was to become the Devils Postpile, erupted in the already glaciated valley of the Middle Fork of the San Joaquin River. The age of volcanic rocks can be estimated by study of the radioactive decay of elements in the rocks. Previous estimates for the age of the Postpile basalt, ranging from about 600,000 years to nearly a million years, are now thought to be seriously in error. Although an exact age for the Postpile flow still is not known, we believe that an age of less than 100,000 years, based on radiometric age determinations on rocks thought to be correlative, is more reasonable.

The Postpile lava reached the surface in the vicinity of the Upper Soda Springs Campground at the north end of Pumice Flat (see map on page 14). Across the San Joaquin River from the campground, rust-colored basalt cinders- products of explosive eruptions- rest upon granite bedrock and are probably the remains of a volcanic cinder cone, similar to the Red Cones southeast of the Monument. Two basalt dikes- tabular bodies of solidified lava- can be seen cutting upward through the cinder pile; when molten, these dikes may have been feedervents for lava flows. We do not know how extensive the lava outpourings were, because most of the basalt has been removed by combined glacial and stream erosion, but we can piece together some minimum figures from the scattered outcrops that remain. Lava filled the valley from side to side for a distance of at least three miles, from Pumice Flat south to the Devils Postpile, and in the vicinity of the Postpile the lava was probably more than 400 feet deep.

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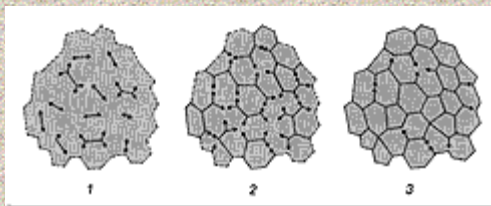
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Devils Postpile National Park Geologic Story

Genesis of the Posts

The lava flow that became the Devils Postpile was very fluid and remained molten almost throughout while it pooled in the valley of the San Joaquin River. Because its top was exposed to air and its bottom to underlying cooler granite bedrock, the flow cooled to solid rock inward from these surfaces. The flow shrank, too, because virtually all liquids occupy less space when frozen, or solidified.



1. Surface cracks started when the tension caused by the shrinkage of cooling was greater than the strength of the lava.

2. As cracks reached about 10 inches in length, they branched, thus forming angles of approximately 120° which provided the greatest stress relief.

3. Each new crack branched again when it obtained the critical length and together with other similar cracks formed an irregular polygonal pattern.

Ideal conditions, existing within the cooling lava, allowed surface cracks to deepen which resulted in the formation of the long columns.

As the solidifying lava shrank, tensional stresses developed in response. Those stresses operating in a vertical direction simply caused the mass to settle in response to gravity, but those oriented in horizontal directions were relieved only by cracking of the solidifying rock.

Columnar joints or cracks are formed as a lava flow cools and shrinks under certain conditions that allow the flow to crack into long vertical columns ideally tending toward a hexagonal cross section. Uniform cooling conditions tend to promote the development of columnar joints, but the degree of homogeneity of the solidifying lava is probably more important. It can be shown mathematically that the surface of a homogeneous medium should be divided by a crack system defining regular hexagons when it is subjected to uniform shrinkage because a hexagonal system provides the greatest relief with the fewest cracks.

Regular hexagons are rare, because in natural lava flows, cooling stresses in rocks are never completely uniform, and therefore the columns are generally bounded by curved cracks forming irregular-shaped polygons with

variable numbers of sides. Cooling conditions are never ideal at the surface of a flow, but as cooling, solidification, and cracking proceed from the surface of a flow into its interior, a point may be reached where the shrinkage forces may be uniform enough for irregular jointing to give way to the formation of columnar joints.

In higher parts of the Devils Postpile flow, remnants of which may still be seen in the general area, jointing is irregular or poorly columnar. In lower parts, where cooling was more uniform, nearly perfect columns formed. These are now exposed by erosion as the Devils Postpile. We see in the Postpile only the lower part of the lava flow.

Columns have an average diameter of 2 feet and a maximum diameter of 3 1/2 feet; some are 60 feet long. The columns have various numbers of sides, as indicated by a sample of 200 posts: 4 sides, 2%; 5 sides, 37%, 6 sides, 55%, 7 sides, 5%. A few columns have only three sides.

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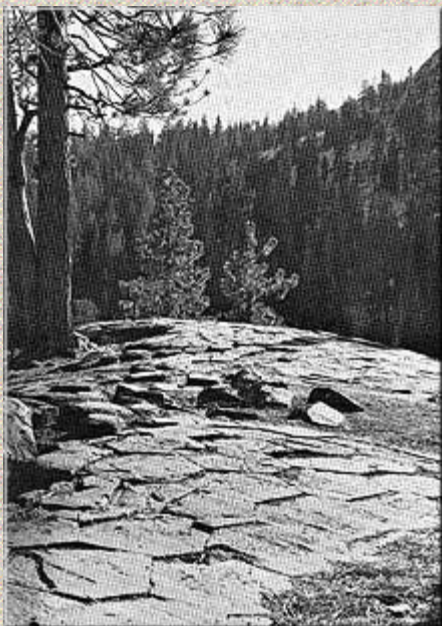
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Devils Postpile National Park Geologic Story



Exposed ends of columns on top of the Postpile.

The Postpile is Exposed

The glaciers that flowed down the valley of the Middle Fork of the San Joaquin River eroded most of the lava flows from the area. Although these slow-moving bodies of ice were large and powerful, they did leave a few remnants of the original lava flows. On the remnant known as the Devils Postpile, the glaciers cut a vertical face, exposing the interior of the flow and the sides of the columns. In the 10,000 years since the last glacier left, numerous columns have spalled from the face of the cliff, creating a talus pile of broken posts.

Other lava columns, less spectacular than those of the Devils Postpile, are found in several places within or near the Monument. Most of the exposures clearly indicate the direction of ice flow since they have steep downstream- that is, down-glacier -slopes with gentle upstream slopes. When glaciers move over fractured rock, the plucking action on the downstream side of the rock outcrop is much greater than the grinding action of ice

overriding the upstream side, so that the downstream slopes are commonly precipitous.

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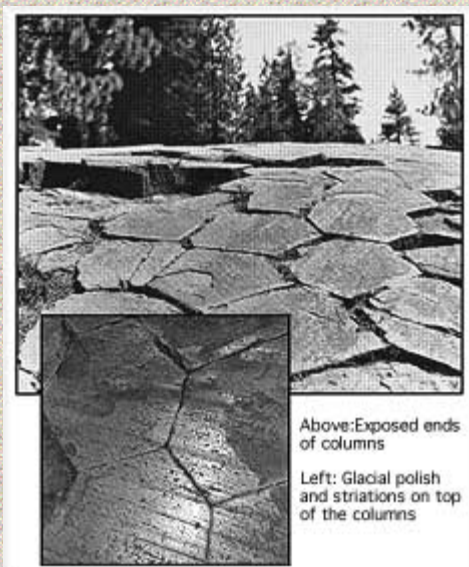
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Devils Postpile National Park Geologic Story



Photos by Wymond W. Eckhardt, NPS.

Top of the Postpile

A hike to the top of the Postpile reveals not only a cross section of the posts, but interesting effects of the ice- the polished and scoured tops of the rock columns. The polygonal column-ends are exposed like a tiled floor, and exhibit shining surfaces where the ice polished them with fine silt; parallel striations and grooves show where the glacier dragged rocks across them.

When the last glacier melted away, nearly all of the upper surfaces of the exposed rock in the Monument must have exhibited glacial polish. Now, however, weathering and subsequent erosion have removed almost all of the original polished surfaces, and only patches such as those on top of the Devils Postpile remain. (in such a context, the regulation prohibiting the collection of rock specimens in the National Monument becomes especially meaningful. Without realizing

it, collectors could remove the most dramatic proof that a glacier rode over the top of the Devils Postpile, thus, not only destroying scientific evidence but detracting from the understanding and enjoyment of future visitors).

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Devils Postpile National Park Geologic Story

Curved Columns

Most of the columns in the Devils Postpile diverge from the vertical as though tilted and some are even curved as if they had been bent. Under ideal conditions, the long dimensions of basalt columns develop at right angles to the cooling surfaces. If a lava flow is homogeneous in chemical composition, of uniform thickness, and has level top and bottom cooling surfaces, then, theoretically, the flow cools uniformly into vertical columns. All of these factors were not fulfilled in the Devils Postpile flow, however, causing irregularities in cooling and consequently producing curved posts with various number of sides.

The exceptional aspect of the Devils Postpile is not that some columns are curved, but that in places the lava was homogeneous enough and had a cooling rate uniform enough to have produced many columns so long and regular.



*Curved columns. Photo by
Wymond W. Eckhardt, NPS.*

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Devils Postpile National Park Geologic Story

Other Volcanic Rocks In and Near the Monument

Not all of the volcanic rock in the Monument area belongs to the Postpile basalt flow, although much of it has been grouped into a single geologic unit on most published maps of the area. This has led to confusion both as to the composition of the Postpile flow (called andesite on some maps) and as to its source (said to be Mammoth Pass in some reports). Recent studies have given us a better understanding of the variation in rock types and the complex relationships between the different volcanic units. Individual volcanic units previously grouped with the Postpile flow, but here considered separately, are: andesite of Mammoth Pass; rhyodacite of Rainbow Falls; and basalt of The Butresses (basalt of the Devils Postpile is the youngest unit; the others are listed in order of increasing age).

Lava that erupted from a vent near Mammoth Pass once was thought to be part of, and indeed the source of, the Postpile basalt. This was simply because this lava was erupted from an obviously higher elevation and cascaded into the Middle Fork valley toward the Postpile. The Mammoth Pass rock, however, is andesite, a rock with somewhat more silica than basalt, and resulted from a separate volcanic event. In appearance the andesite lacks the small, but visible, crystals of feldspar that characterize the Postpile basalt.

The oldest volcanic unit formerly included with the basalt of the Devils Postpile is a basalt that makes up The Butresses, southwest of the Postpile. In appearance this basalt superficially resembles the Postpile basalt, but the abundant visible crystals are mostly pyroxene rather than feldspar, a subtle but important difference between the two rock types. The basalt of The Butresses was erupted from one or more vents west of the Monument and flowed eastward into the Middle Fork valley.

A totally different type of volcanic rock that occurs near the Monument is a pyroclastic rock or welded-tuff. This tuff formed from volcanic ash that was hot and plastic when it fell and fused into a generally cohesive mass. Exposures of this tuff can be seen behind the old ranger cabin east of Reds Meadow. At this locality the tuff has columnar joints, but the columns are nearly horizontal rather than vertical. The exact source of the volcanic ash is not known, but it is probably related to the extensive deposits of the Bishop Tuff, a welded tuff that erupted from the Long Valley caldera, and can be seen in road cuts near Tom's Place on Highway 395.

The most recent volcanic event in the Devils Postpile area, the only one younger than that which produced the Postpile flow, built the Red Cones about one and one-half miles southeast of the Monument. The two basalt cinder cones, with well-preserved summit craters, illustrate what the eroded pile of cinders near the Upper Soda Springs Campground might once have looked like. A basalt lava flow that issued from the base of the southern cone extends down Crater Creek to within one mile of the Middle Fork, perhaps similar to the way that the Postpile flow might have issued from the ancient cinder cone that once existed near the Upper Soda Springs

Campground. The Red Cones and their lava flow are so well preserved because they are less than 10,000 years old, and thus escaped the powerful excavating force of glacial erosion that so drastically modified the older volcanic rocks.

Pumice, a frothy volcanic glass, is a porous lightweight material of pastel shades that covers the ground at various places in the area. Its unweathered, loosely compacted nature indicates it was deposited recently. This pumice was formed in postglacial time when molten rock of high silica content and abundant dissolved gasses erupted from the Mono and Inyo Craters northeast of the Monument.

The recency of the Red Cones and widespread blanket of pumice, the presence of hot springs here and to the east, and the recent volcanic eruptions and earthquakes in Long Valley provide dramatic evidence that volcanoes in this region cannot be labeled "extinct." Within the framework of geologic time, which we tend to think of in terms of millions of years, the dormancy of local volcanism is a barely measurable pause that might, at any time, be abruptly terminated by the onset of new eruptions.

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Devils Postpile National Park Geologic Story

Distribution of Volcanic Rocks of Devils Postpile and Vicinity

images on the way.



DISTRIBUTION OF VOLCANIC ROCKS DEVILS POSTPILE NATIONAL MONUMENT AND VICINITY

Geology by DAVID W. CLOW and KENNETH R. COLLUM, 1983

Modified from N. K. HUBER and C. D. RINEHART and R. P. KOEPPEN.

Base map by U.S. Geological Survey.

EXPLANATION

- Undifferentiated surface deposits, including: pumice, stream deposits, recent organic soils.
- Basalt of the Red Cones. Unglaciaded red cinder Cones and lava flows.
- Basalt of the Devils Postpile. Dark gray, fine-grained basalt flow, with abundant feldspar crystals.
- Andesite of Mammoth Pass. Light gray to dark gray, fine-grained andesite, with minor feldspar and pyroxene crystals.
- Rhyodacite of Rainbow Falls. Light gray, fine-grained rhyodacite, with minor oxyhornblende crystals. Exhibits horizontal to semi-horizontal platy weathering fractures. Some dense, black, columnar-jointed outcrops.
- Tuff of Reds Meadow. Similar to Bishop Tuff. Buff, ash-flow rhyolite exhibiting welding of pumice with abundant quartz, feldspar, and rock fragments.
- Basalt of The Buttresses. Dark gray basalt, with abundant olivine crystals, and minor pyroxene. Crude columnar jointing.
- Contact, as mapped by Clow and Collum (1983).
- Contact, volcanic units as mapped by Huber and Rinehart (1965; 1967).
- - Monument boundary.

Continue to *Summary of Glacial and Volcanic History*
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Devils Postpile National Park Geologic Story

Summary of Glacial and Volcanic History

The intertwining of glacial and volcanic events in the valley of the Middle Fork of the San Joaquin River is reasonably clear, but some events must be based upon inference derived from data obtained elsewhere in the Sierra Nevada. From our present knowledge we can summarize the glacial and volcanic history of the Devils Postpile region as follows (listed in order of decreasing age):

1. The oldest volcanic rock in the vicinity of the Monument is believed to be the basalt now exposed at The Buttresses, although its exact age is not known.
2. The valley of the Middle Fork of the San Joaquin River was glaciated, probably more than once, prior to about 760,000 years ago.
3. Deposition of the tuff near Reds Meadow about 760,000 years ago was concurrent with extensive volcanic activity that created the Long Valley caldera and produced the Bishop Tuff.
4. Stream erosion, perhaps aided by another glaciation, removed much of the tuff from the central part of the valley.
5. Rhyodacite lava erupted from vents just downstream from the present site of the Postpile and flowed southward beyond Rainbow Falls.
6. Andesite lava erupted near Mammoth Pass and cascaded into the Middle Fork valley.
7. Less than 100,000 years ago basalt now exposed at the Devils Postpile erupted north of Pumice Flat and flowed out to cover, at the very least, several square miles of the valley floor.
8. Stream and glacial erosion again removed much of the accumulated volcanic rock from the Middle Fork valley. The last glaciation, which ended about 10,000 years ago, produced the Polish and striations visible on the top of the Devils Postpile.
9. The Red Cones and their associated lava flow were formed sometime after the last glacier vanished from the valley.
10. Pumice erupted from the Inyo and Mono Craters and covers the area as a surface deposit.

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Devils Postpile National Park Geologic Story

Other Geologic Features

Other interesting geologic features of the Monument include glacial erratics and mineral springs.



Glacial erratic perched on bedrock slope.

Glacial erratics are boulders carried by ice from points upstream. They have been deposited in many places within the Monument, but are most abundant on the high granite hills and ridges west of the Middle Fork of the San Joaquin River. Many of the erratics are different from the rocks they now rest upon, and some are composed of metamorphic rock which occurs only north of the Monument. The erratics of metamorphic rock tell us that the ice carried them south from a distant source.

Mineral springs- some of them hot- occur within or near the National Monument. They are further manifestations of the recency of local volcanic activity. One cold, highly-carbonated spring flows out on a gravel bar on the west side of the Middle Fork of the San Joaquin River in Soda Springs Meadow, about one-tenth of a mile north of the Devils Postpile. Such springs often occur where gasses and water vapor are driven upward from hot areas deep in the Earth and combine with ground water near the surface to produce mineralized springs. At Soda Springs, iron present in solution in the acidic water oxidizes on exposure to the atmosphere and has stained the river gravel in the vicinity a reddish brown. A hot spring issues forth at Reds Meadow, just east of the Monument, further attesting to the continuing volcanic activity in the area.

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Devils Postpile National Park Geologic Story

Rainbow Falls

At Rainbow Falls the Middle Fork of the San Joaquin River drops 101 feet over a cliff of volcanic rock that is somewhat different from the rock making up the Devils Postpile. Although the rock is locally massive or poorly jointed, as that near the top of the falls, it is generally characterized by nearly horizontal, thinly-spaced joints giving the rock a platy appearance. This rock is the rhyodacite of Rainbow Falls. While there is glacial polish on the top of the massive volcanic rock and the cliff at the falls is similar in appearance to glacially sculptured lee slopes, the cliff was not formed by ice.

After the last glacier melted, the Middle Fork of the San Joaquin River flowed downstream from the Devils Postpile in a channel close to The Buttresses and about 1,500 feet west of its present channel. The old channel can still be traced northward from its junction with the present river at the first bend downstream from Rainbow Falls. Another old channel is nearby, but it is not cut as deeply and, therefore, was probably not occupied as long.

When the Middle Fork flowed in these older channels, it cut through the lava flows down to granite, leaving a cliff for its eastern bank. Then, some distance upstream, its waters were diverted eastward. The river left its bed to follow its present path until it returned to its old channel by cascading down the cliff it had cut earlier, thus forming the predecessor of today's Rainbow Falls but more than 500 feet west of the present falls.

As the Middle Fork cascaded over its former bank, its water eroded into the softer platy rock at the base and undercut the harder massive rock above, causing it to cave in. The cliff has thus retreated 500 feet or more upstream to the present location of Rainbow Falls. Normally, streams tend to erode channels with uniform gradients, bevelling off and eventually eliminating irregularities such as waterfalls. Rainbow Falls is an exception, however, because of the two, unequally hard, horizontal rock layers in its cliff. It is like Niagara Falls in this respect, for Niagara has a similarly hard rock layer at the top of its cliff and is being undercut in the same fashion.



***Rainbow Falls- Middle Fork
San Joaquin River, 101 feet
high.***

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Devils Postpile National Park Geologic Story

Recent Changes



In postglacial time the Devils Postpile has changed greatly. The huge talus pile of broken posts is evidence that the lava columns extended many feet in front of the present face after the last glacier melted. The prying action of water freezing in the cracks between the columns has probably been responsible for most of the fallen posts. The present rate of falling is sporadic and uncertain. A 1909 photograph showed three of the columns leaning far ahead of others in the formation. These were separated from nearby vertical columns by as much as 12 inches at the top. Although they appeared ready to fall, these three familiar leaning columns did not topple even during the strong earthquakes in the summer of 1952.

During May of 1980, intense earthquake swarms occurred at an epicentral site about two miles southeast of the community of Mammoth Lakes. This eastern Sierra community and the surrounding area were shaken by an unprecedented series of earthquakes that included four of a Richter magnitude of 6.0 within a 48-hour period. Lesser earthquake swarms accompanied by sporadic tremors continued throughout the summer of 1980. During this period the very familiar leaning columns tumbled down. Numerous other columns in the formation were cracked, and today rest precariously on their severed bases. Small earthquakes continue to contribute to the mechanical weathering process of the Postpile formation- columns continue to fall at an unpredictable rate.

Columns that have fallen recently can be detected by looking for lighter shades of newly-exposed unweathered rock surfaces on the downed columns.

These very familiar leaning columns fell on August 7, 1980.

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While this site is under development, this page will act as an index to Devils Postpile National Monument's geology web pages and resources. Please feel free to let us know what you think at the e-mail link below.

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A Geologic Wonder

Established in 1911 by presidential proclamation, Devils Postpile National Monument protects and preserves the Devils Postpile formation, the 101-foot high Rainbow Falls, and pristine mountain scenery. The formation is a rare sight in the geologic world and ranks as one of the world's finest examples of columnar basalt. Its columns tower 60 feet high and display an unusual symmetry.

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Features



Reds Meadow Shuttle Bus

The mandatory shuttle bus into the Reds Meadow Valley and Devils Postpile National Monument allows visitors to experience the area safely.

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Did



After the Rainbow Fire in 1992, many of the trees died. The hollows of these trees and logs are now home to sleeping bears in the area. The hollows also provide homes for many birds.

Bring Devils Postpile Into Your Classroom!

From field trips to classroom visits to distance learning opportunities, many curriculum based opportunities await educators and their students.

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101 feet. This is a great day hike from the ranger station.

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View of Mt. Shuksan, North Cascades National Park. Photo by R. Tabor, USGS

USGS Geology in the Parks

Welcome! From the swirling sands of Mojave National Preserve's Kelso Dunes to the brief, fiery growth of Sunset Crater Volcano, our National Parks preserve the showcases of our nation's rich geological heritage. We invite you to explore a few of these very special places with us.

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About this site

This new site is produced as a collaborative effort of the US Geological Survey and National Park Service. We are adding, updating, and expanding weekly. Provisional pages that are under review are posted with an **UNDER CONSTRUCTION** banner.

Our presentation is structured to inform and entice virtual and future park visitors with a non-technical approach to geology. We hope that everyone from middle-school age and up will find something of interest. Information is presented at a variety of technical levels. All of our 'entry' pages including the first page of any topic, including field trip stops, is presented at the most basic level. If you're interested in more detail, simply work your way through each site and you'll find that our presentation becomes increasingly specialized and uses more technical language. We have also included lots of material specifically aimed at park interpreters and educators.

Most scientific terms are highlighted as

- [Joshua Tree](#) -
Earthquake!
- [Devils Postpile](#)
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links. Clicking on the term will take you to our [glossary](#) or other page that explains the term or concept. The glossary provides simplified definitions for technical terms. Many terms also have their own '*more details*' links to pages with illustrations and/or more information.

We have organized our pages into two categories, general geology topics and individual parks. As you can see by browsing through some of the buttons to the right, there are several sites that cover the basics: plate tectonics, rocks and minerals, and the like. These offer the key introductory information you need to get started.

Several sites are dedicated to the unique geologic history and resources of specific parks. When you visit these sites, you'll notice that their style and content varies. Each of these sites is jointly developed by park interpreters and USGS staff, therefore each one reflects the unique visitor make-up, resources, and of course, personality of that park and its staff.

For the 'experts' we are developing technical resource pages for each park that includes a list of geologic and topographic maps, technical literature citations, and other pertinent information for geology aficionados.

You'll also find education resource pages for several parks. These will eventually include interpreter's geology manuals, field trip guides, lessons, and any other materials of use to educators and NPS interpreters.

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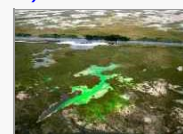
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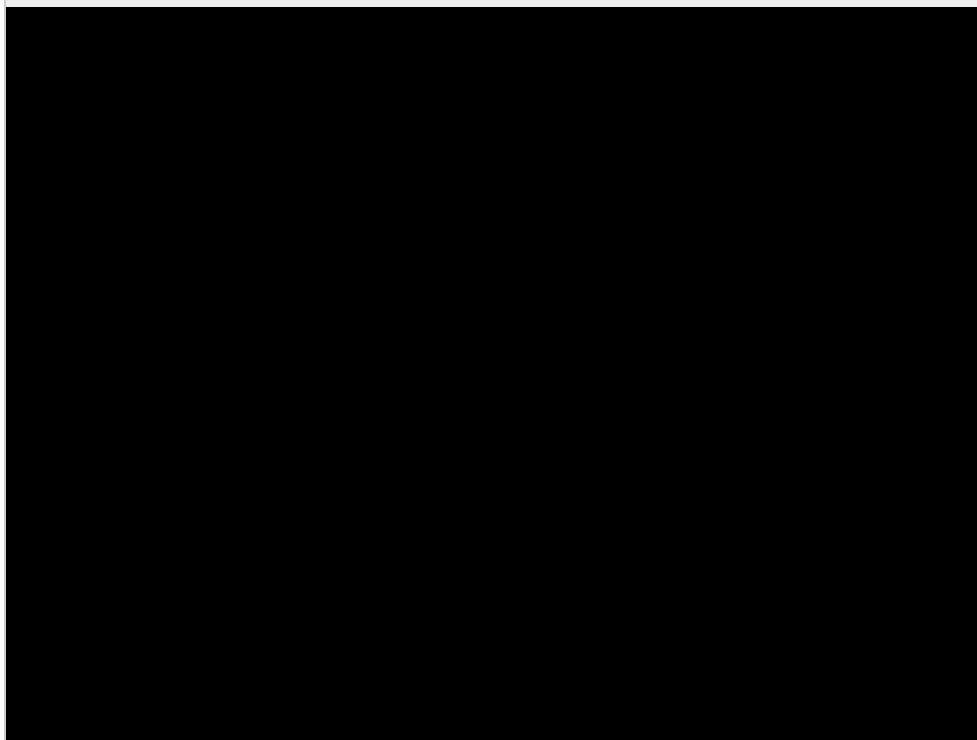
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TESNAR Program: CSAs



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Jeff Cordova:

This is all part of the TASNAR program. It's a program run by the USGS, and it's basically trying to teach tribes technology. It's important for tribal water resource managers to develop rating curves at stream-flow gaging stations for all ranges in a stream flow. Often due to the flashy nature of high flow events, and the lack of bridges or cable ways at existing tribal stream gages, the slope area method is often used to calculate the discharge of high flow events. The USGS is working with tribes to develop rating curves for the entire range of flows at tribal stream gages using the Continuous Slope Area method or CSA method. Using the Continuous Slope Area method technicians can calculate the entire flood hydrograph, using the data collected by the CSA's

Details

Title: TASNAR Program: CSAs

Description:

TESNAR stands for the Technical training in Support of Native American Relations, and is a program run by the USGS to foster cooperation between tribes and the USGS by providing them with the tools and training to manage their tribal resources, such as water. As shown here, training in the Continuous Slope Area Method can help tribes a great deal, by providing data when their low-flow gages have been compromised by a high-flow events.

Location: Tucson, AZ, USA

Date Taken: 8/8/2013

Length: 1:57

Video Producer: [Ashley Foxx](#) , U.S. Geological Survey

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sensors once the flood waters have receded.

With a traditional Standard Slope Area method we are only getting data for the one point in time that the water levels are highest. CSA's continually record data so that we have a good record of the entire hydrograph and not just the peak.

It is critically important that the channel geometry is known, at each cross section, at each sensor in the CSA reach. When CSA sensors are installed, each cross section is surveyed so that the dimensions of the channel at each sensor are known.

These CSAs were installed as redundant sensors, in sites that already have low flow gaging stations. The CSAs piggyback off

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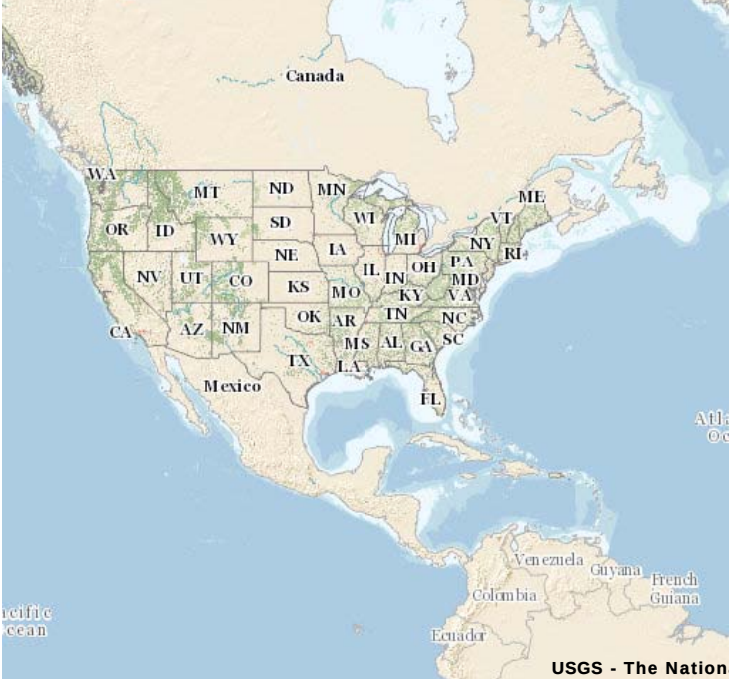
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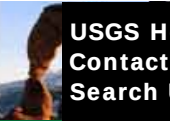
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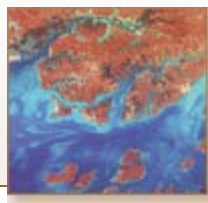
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[Natural Hazards Mission Programs & Activities](#)

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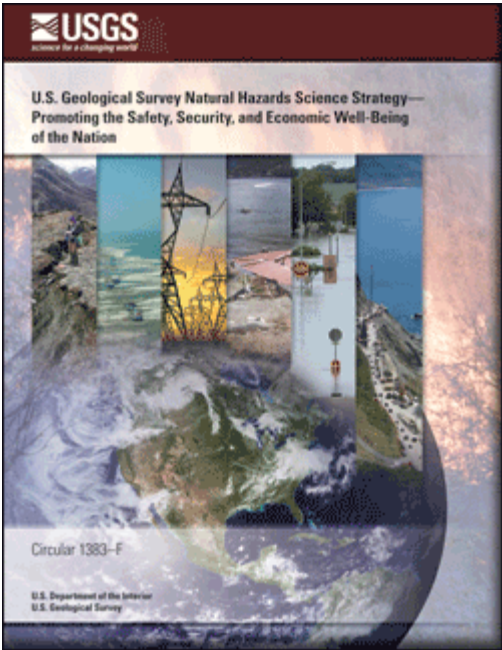
Natural Hazards

Every year in the United States, natural hazard events threaten lives and livelihoods, resulting in deaths and billions of dollars in damage. The USGS works with many partners to monitor, assess, and conduct targeted research on a wide range of natural hazards so that policymakers and the public have the understanding they need to enhance preparedness, response and resilience.

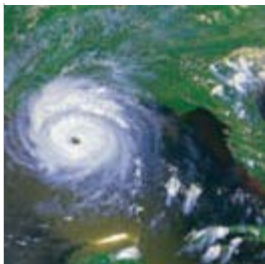
In 2010, the USGS realigned its organizational structure around the missions identified in the [USGS Science Strategy](#). The Natural Hazards Mission Area includes six science programs: [Coastal & Marine Geology](#), [Earthquake Hazards](#), [Geomagnetism](#), [Global Seismographic Network](#), [Landslide Hazards](#), and [Volcano Hazards](#). Through these programs, the USGS provides alerts and warnings of geologic hazards and supports the warning responsibilities of the National Oceanic and Atmospheric Administration (NOAA) for geomagnetic storms and tsunamis. The Coastal and Marine Geology Program supports all the missions of the USGS, characterizing and assessing coastal and marine processes, conditions, change and vulnerability.

The Natural Hazards Mission Area is responsible for coordinating USGS response following disasters and overseeing the bureau's [emergency management](#) activities. The mission area coordinates long-term planning across the full USGS hazards science portfolio, including activities funded through many other programs across the bureau, including floods, hurricanes and severe storms, and wildfires.

The future direction of the USGS hazards mission is guided by the recently released [USGS Natural Hazards Science Strategy](#), which was developed by a team of USGS scientists with considerable input from partners and the public. This document is part of a broader USGS [science strategy](#) planning process across all our missions.



Natural Hazards Mission Area Programs & Activities	
Coastal and Marine Geology	Earthquake Hazards
CMGP conducts research on the changes to the coastal and marine environment that	The Earthquake Hazards Program is part of the National Earthquake Hazards Reduction Program

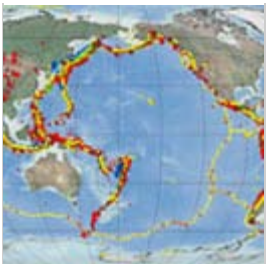


impact lands, lives and livelihoods, and vulnerable ecosystems;

providing science to inform decisions that ensure safe and resilient coastal communities and sustainable use and protection of marine resources. Supporting the Natural Hazards mission, CMGP conducts research on marine geohazards including earthquakes, tsunami, and submarine landslides and on coastal change hazards from erosion, hurricanes and other extreme storms, and sea-level rise.

- [Coastal Change](#)
- [Tsunamis](#)

[Monthly Newsletter - Soundwaves](#)



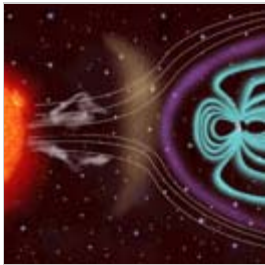
(NEHRP), a four-agency partnership led by the National Institute of

Standards and Technology (NIST). Earthquakes pose significant risk to 75 million Americans in 39 States. The USGS provides research and information products for earthquake loss reduction, including hazard and risk assessments, comprehensive real-time earthquake monitoring, and public outreach.

- [Earthquake Map](#)
- [Real-time RSS Feeds](#)
- [Earthquake Notification Service](#)
- [Did You Feel It?](#)

["Earthquake Hazards – A National Threat" Fact Sheet](#)

[Geomagnetism](#)



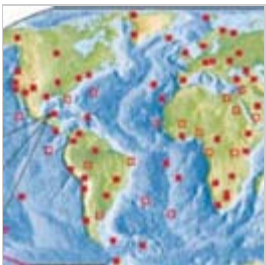
The mission of the Geomagnetism Program is to monitor the Earth's magnetic field. Using ground-based observatories, the Program provides continuous records of

magnetic field variations covering long timescales; disseminates magnetic data to various governmental, academic, and private institutions; and conducts research into the nature of geomagnetic variations for purposes of scientific understanding and hazard mitigation.

- [Real-time Data](#)

["Monitoring the Earth's Magnetic Field" Fact Sheet](#)

[Global Seismographic Network](#)



The Global Seismographic Network (GSN) is a permanent digital network of state-of-the-art seismological and geophysical sensors connected by a

telecommunications network. The GSN provides near-uniform, worldwide monitoring of the Earth, with over 150 modern seismic stations distributed globally. The GSN was formed in partnership among the USGS, the National Science Foundation (NSF) and the Incorporated Research Institutions for Seismology (IRIS).

- [Station Status](#)

[The Global Seismographic Network Fact Sheet](#)

[Landslide Hazards](#)

The mission of the Landslide Hazards Program is to

[Volcano Hazards](#)

The Volcano Hazards Program advances the scientific



provide information that leads to the reduction of losses from landslides and increase in public safety through improved understanding of landslide hazards and strategies for hazard mitigation. The USGS conducts landslide hazard assessments, pursues landslide investigations and forecasts, provides technical assistance to respond to landslide emergencies, and engages in outreach activities.

- [Advisories](#)
- [Real-time Monitoring](#)

["Landslide Hazards – A National Threat" Fact Sheet](#)
["Wildfire Hazards – A National Threat" Fact Sheet](#)



understanding of volcanic processes in order to lessen the harmful impacts of volcanic activity. The USGS monitors active and potentially active volcanoes, assesses their hazards, responds to volcanic crises, and conducts research on how volcanoes work. The USGS also issues warnings of potential volcanic hazards to responsible emergency-management authorities and to the populace affected.

- [Current Alerts for U.S. Volcanoes](#)

["Volcano Hazards – A National Threat" Fact Sheet](#)

[Science Applications for Risk Reductions \(SAFRR\) Project](#)



The SAFRR project focuses on building partnerships to improve the use of natural hazards information from the USGS, to identify needs and gaps, and to develop new products that increase the use of USGS science by emergency managers and community decisionmakers in order to promote greater resilience to natural hazards. SAFRR evolved from the Multi-Hazards Demonstration Project in Southern California, which has developed interdisciplinary, science-based products that deliver information that starts with the hazard and carries through to impacts on the community.

- [USGS Natural Hazards Risk Reduction Project Goes National](#)

[USGS Emergency Management](#)



The USGS Natural Hazards Mission Area has been given responsibility for overseeing the bureau's emergency management activities. This function includes the USGS Hazard Response Executive Committee, which provides executive direction, oversight, and support to USGS managers in responding to major hazard events. During incidents of national significance, the USGS provides support to certain National Response Framework emergency support functions.

- [USGS Emergency Management](#)

Additional USGS Hazards Science Activities

[Astrogeology](#)



The Astrogeology Science Center serves the nation, the international science community, and the general public in the pursuit of new knowledge about our Solar

System. The program has participated in analyzing data from numerous missions to planetary bodies, assisting in finding potential landing sites for exploration vehicles, mapping our neighboring planets, moons, and asteroids, and conducting research to better understand the geologic processes operating on these bodies.

- [Gazetteer of Planetary Nomenclature](#)
- [PILOT - Planetary Image Locator Tool](#)

[Floods and Droughts](#)



The USGS is the Nation's primary provider of information on water. The bulk of the USGS activities related to floods and droughts are carried out through

programs within the Water Mission Area. Web portals make it possible to view current water conditions and where floods and droughts are occurring.

- [USGS Flood Information](#)
- [Current Conditions](#)
- [FloodWatch](#) | [DroughtWatch](#)
- [Interactive Flood Map](#)

["Flood Hazards – A National Threat" Fact Sheet](#)

[Wildfire Hazards](#)



The USGS carries out a wide range of wildfire-related science activities that span multiple USGS mission areas, including landscape ecology studies, geospatial support

for fire response, burned area hydrology, and post-fire debris flow warnings.

- [GEOMAC](#)
- [EROS Fire Science Activities](#)
- [Satellite Data Applications for Fire Science](#)
- [LANDFIRE](#)
- [Post-wildfire Debris Flow Hazards](#)
- [Fire Ecology](#)
- [Ash Contamination from Wildland-Urban Interface](#)
- [Wildfire and changing vegetation dynamics](#)

["Wildfire Hazards – A National Threat" Fact Sheet](#)

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