

When I think of volcanoes, I think of...

▪ Yellowstone Caldera

Yellowstone is like a breath chest in that is always moving up and down, inflating and deflating. This is due to volcanic activity, but also due to underground water sources as well as gasses.

Food for Thought: A core sample of the Great Salt Lake would show volcanic ash and lava deposits from both of Yellowstone's previous major explosions, showing the massive reach of such a force of energy.



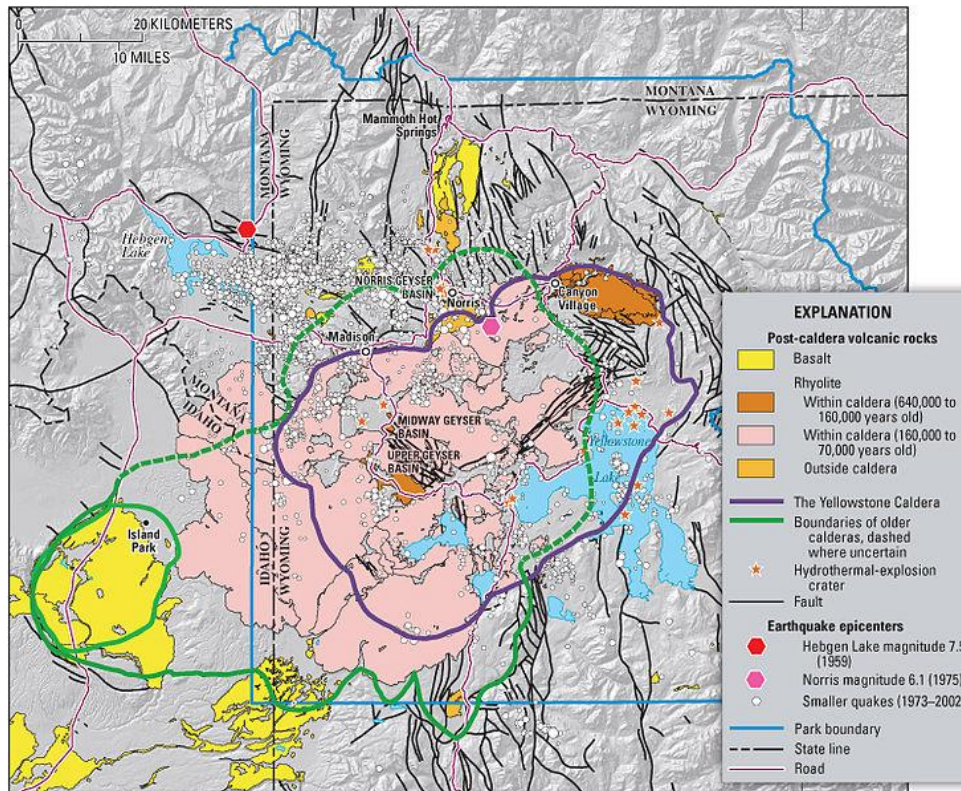
The Yellowstone Caldera is the volcanic caldera located in Yellowstone National Park in the United States, sometimes referred to as the Yellowstone Supervolcano. The caldera is located in the northwest corner of Wyoming, in which the vast majority of the park is contained. The major features of the caldera measure about 34 by 45 miles (55 by 72 km).

Yellowstone lies over a hotspot where light, hot, molten mantle rock rises toward the surface. While the Yellowstone hotspot is now under the Yellowstone Plateau, it previously helped create the eastern Snake River Plain (to the west of Yellowstone) through a series of huge volcanic eruptions. The hotspot appears to move across terrain in the east-northeast direction, but in fact the hotspot is much deeper than terrain and remains stationary while the North American Plate moves west-southwest over it.

Over the past 18 million years or so, this hotspot has generated a succession of violent eruptions and less violent floods of basaltic lava. Together these eruptions have helped create the eastern part of the Snake River Plain from a once-mountainous region. At least a dozen of these eruptions were so massive that they are classified as supereruptions. Volcanic eruptions sometimes empty their stores of magma so swiftly that they cause the overlying land to collapse into the emptied magma chamber, forming a geographic depression called a caldera. Calderas formed from explosive supereruptions can be as wide and deep as mid- to large-sized lakes and can be responsible for destroying broad swaths of mountain ranges.

The oldest identified caldera remnant straddles the border near McDermitt, Nevada-Oregon, although there are volcanoclastic piles and arcuate faults that define caldera complexes more than 60 km (37 mi) in diameter in the Carmacks Group of southwest-central Yukon, Canada, which is interpreted to have formed 70 million years ago by the Yellowstone hotspot. Progressively younger caldera remnants, most grouped in several overlapping volcanic fields, extend from the Nevada-Oregon border through the eastern Snake River Plain and terminate in the Yellowstone Plateau. One such caldera, the Bruneau-Jarvis caldera in southern Idaho, was formed between 10 and 12 million years ago, and the event dropped ash to a depth of one foot (30.48 cm) 1,000 miles (1,600 km) away in northeastern Nebraska and killed large herds of rhinoceros, camel, and other animals at Ashfall Fossil Beds State Historical Park.

Within the past 17 million years, 142 or more caldera-forming eruptions have occurred from the Yellowstone hotspot.



The loosely defined term 'supervolcano' has been used to describe volcanic fields that produce exceptionally large volcanic eruptions. Thus defined, the Yellowstone Supervolcano is the volcanic field which produced the latest three supereruptions from the Yellowstone hotspot. The three super eruptions occurred 2.1 million, 1.3 million, and 640,000 years

ago, forming the Island Park Caldera, the Henry's Fork Caldera, and Yellowstone calderas, respectively. The Island Park Caldera supereruption (2.1 million years ago), which produced the Huckleberry Ridge Tuff, was the largest and produced 2,500 times as much ash as the 1980 Mount St. Helens eruption. The next biggest supereruption formed the Yellowstone Caldera (640,000 years ago) and produced the Lava Creek Tuff. The Henry's Fork Caldera (1.2 million years ago) produced the smaller Mesa Falls Tuff but is the only caldera from the Snake River Plain-Yellowstone (SRP-Y) hotspot that is plainly visible today.

Non-explosive eruptions of lava and less-violent explosive eruptions have occurred in and near the Yellowstone caldera since the last supereruption.^{[10][11]} The most recent lava flow occurred about 70,000 years ago, while a violent eruption excavated the West Thumb of Lake Yellowstone around 150,000 years ago. Smaller steam explosions occur as well; an explosion 13,800 years ago left a 5 kilometer diameter crater at Mary Bay on the edge of Yellowstone Lake (located in the center of the caldera). Currently, volcanic activity is exhibited via numerous geothermal vents scattered throughout the region, including the famous Old Faithful Geyser, plus recorded ground swelling indicating ongoing inflation of the underlying magma chamber.

The volcanic eruptions, as well as the continuing geothermal activity, are a result of a great cove of magma located below the caldera's surface. The magma in this cove contains gases that are kept dissolved only by the immense pressure that the magma is under. If the pressure is released to a sufficient degree by some geological shift, then some of the gases bubble out and cause the magma to expand. This can cause a runaway reaction. If the expansion results in further relief of pressure, for example, by blowing crust material off the top of the chamber, the result is a very large gas explosion.

▪ Craters of the Moon

Craters of the Moon National Monument and Preserve is a U.S. National Monument and National Preserve in the Snake River Plain in central Idaho. It is along US 20 (concurrent with US 93 & US 26), between the small towns of Arco and Carey, at an average elevation of 5,900 feet (1,800 m) above sea level. The protected area's features are volcanic and represent one of the best-preserved flood basalt areas in the continental United States.



The Monument was established on May 2, 1924. In November 2000, a presidential proclamation by President Clinton greatly expanded the Monument area. The National Park Service portions of the expanded Monument were designated as Craters of the Moon National Preserve in August 2002. It lies in parts of Blaine, Butte, Lincoln, Minidoka, and Power counties. The area is managed cooperatively by the National Park Service and the Bureau of Land Management (BLM).

The Monument and Preserve encompass three major lava fields and about 400 square miles (1,000 km²) of sagebrush steppe grasslands to cover a total area of 1,117 square miles (2,893 km²). All three lava fields lie along the Great Rift of Idaho, with some of the best examples of open rift cracks in the world, including the deepest known on Earth at 800 feet (240 m). There are excellent examples of almost every variety of basaltic lava as well as tree molds (cavities left by lava-incinerated trees), lava tubes (a type of cave), and many other volcanic features.

Past

Between 15,000 and 2,000 years ago, the Craters of the Moon Lava Field formed during eight major eruptive periods. During this time the Craters of the Moon lava field grew to cover 618 square miles. The Wapi and Kings Bowl lava fields formed contemporaneously about 2,200 years ago.

Present and Future

This region is experiencing basin and range type faulting, which is stretching or pulling apart the crust. The Lost River Range north of the town of Arco provides good evidence that these forces are still active. In 1983 these forces caused a magnitude 6.9 earthquake, during which Mount Borah rose about 1 foot and the Lost River Valley in that vicinity dropped about 8 feet. On the Eastern Snake River Plain, rather than producing mountain ranges, the tensional forces have caused decompression melting, which results in dike emplacement and periodic eruption of molten rock onto the surface. As long as these forces continue to act, more eruptions will eventually occur. The recurrence interval for eruptive activity

in the Craters of the Moon Lava Field averages 2,000 years and it has been more than 2,000 years since the last eruption. The constancy of most recent lava output rates suggests that slightly over one cubic mile of lava will be erupted during the next eruption period. In the past, eruptions in the Craters of the Moon Lava Field have generally shifted to the segment of the Great Rift with the longest repose interval. Therefore, the next eruptive period is expected to begin along the central portion of the Great Rift in the Craters of the Moon Lava Field, but may well propagate to the northern part of the monument in the proximity of the loop road. Initial flows, based on past performance, will probably be relatively non-explosive and produce large-volume pahoehoe flows. Eruptions from potential vents on the northern part of the Great Rift may be comparatively explosive and may produce significant amounts of tephra (airfall material ejected from a volcano), destroy cinder cones by both explosion and collapse, and build new ones.

Until the next eruption, ongoing -but subtle- changes continue to affect the geology of Craters of the Moon. These environmental factors include gravity, weather, as well as other natural and human caused effects on this volcanic landscape.

▪ Devils Tower

Devils Tower (Lakota: Mathó Thípila ("Bear Lodge") or Ptehé Ĝí ("Brown Buffalo Horn") (Arapaho: Wox Niiinon is an igneous intrusion or laccolith in the Black Hills near Hulett and Sundance in Crook County, northeastern Wyoming, above the Belle Fourche River. It rises dramatically 1,267 feet (386 m) above the surrounding terrain and the summit is 5,114 feet (1,559 m) above sea level.

Devils Tower was the first declared United States National Monument, established on September 24, 1906, by President Theodore Roosevelt. The Monument's boundary encloses an area of 1,347 acres (545 ha).

The site is also considered Sacred to the Lakota and other tribes that have a connection to the area. Hundreds of parallel cracks make it one of the finest traditional crack climbing areas in North America. In recent years, about 1% of the Monument's 400,000 annual visitors climb Devils Tower, mostly using traditional climbing techniques.

Devils Tower rises above the surrounding grassland and Ponderosa pine forests like a rocky sentinel. Northern Plains tribes have worshipped near this remarkable geologic formation for thousands of years. Fur trappers, explorers, and settlers alike were awed by the tower's majesty. In 1906, President Theodore Roosevelt established Devils Tower as our nation's first national monument. Many have gazed at the Tower and wondered, "How did this amazing formation form?"



The Stage is Set

Most of the landscape surrounding Devils Tower is composed of sedimentary rocks. These rocks are formed from broken or dissolved fragments of other rocks and are usually deposited by water or wind.

The oldest rocks visible in Devils Tower National Monument were laid down in a shallow inland sea. This sea covered much of the central and western United States during Triassic time, 225 to 195 million years ago. This dark red sandstone and maroon siltstone, interbedded with shale, can be seen along the Belle Fourche River. Oxidation of iron rich minerals causes the redness of the rocks. This rock layer is known as the Spearfish Formation.

Above the Spearfish formation is a thin band of white gypsum, called the Gypsum Springs formation. Gypsum is an important mineral resource commonly used in making drywall. This layer of gypsum was deposited during the Jurassic time, 195 to 136 million years ago.

Seas retreated and returned. Gray-green shales deposited offshore in deep marine environments were interbedded with fine-grained sandstones, limestones, and sometimes thin beds of red mudstone. These rock layers, called the Stockade Beaver member, are part of the Sundance Formation—also of Jurassic age.

The Hulett Sandstone member, also part of the Sundance formation, is a yellow, fine-grained sandstone deposited on an ancient beach. Resistant to weathering, it forms the nearly vertical cliffs that encircle the Tower itself.

Seas retreated and advanced; landforms developed and eroded. New sediments were deposited. Approximately 50 to 60 million years ago, during Tertiary time, pressures within western North America climaxed, uplifting the Rocky Mountains and the Black Hills. At this time or shortly after, magma (molten rock) welled up toward the surface of the earth, intruding into the already existing sedimentary rock layers.

The Tower is Formed: An Ongoing Debate

Geologists agree that Devils Tower was formed by the intrusion (the forcible entry of magma into or between other rock formations) of igneous material. What they cannot agree upon is how that process took place and whether or not the magma reached the land surface.

Numerous ideas have evolved since the official discovery of Devils Tower. Geologists Carpenter and Russell studied Devils Tower in the late 1800s and came to the conclusion that the Tower was indeed formed by an igneous intrusion. Later geologists searched for more detailed explanations.

In 1907, scientists Darton and O'Hara decided that Devils Tower must be an eroded remnant of a laccolith. A laccolith is a large, mushroom-shaped mass of igneous rock which intrudes between the layers of sedimentary rocks but does not reach the surface. This produces a rounded bulge in the sedimentary layers above the intrusion. This idea was quite popular in the early 1900s when numerous studies were done on a number of laccoliths in the Southwest.

Other ideas have suggested that Devils Tower is a volcanic plug or that it is the neck of an extinct volcano. Although there is no evidence of volcanic activity - volcanic ash, lava flows, or volcanic debris - anywhere in the surrounding countryside, it is possible that this material may simply have eroded away.

The simplest explanation is that Devils Tower is a stock—a small intrusive body formed by magma which cooled underground and was later exposed by erosion.

The magma which formed Devils Tower cooled and crystallized into a rock type known as phonolite porphyry. It is a light to dark-gray or greenish-gray igneous rock with conspicuous crystals of white feldspar. Hot molten magma is less dense and occupies more volume than cool hardened rock. As the rock cooled, it contracted, forming hexagonal (and sometime 4-, 5- and 7-sided) columns separated by vertical cracks. These columns are similar to those found at Devil's Postpile National Monument in California but those at Devils Tower are much larger.

The Tower is Uncovered

Until erosion began its relentless work, Devils Tower was not visible above the overlying sedimentary rocks. But the forces of erosion, particularly that of water, began to wear away the soft sandstones and shales above and around the Tower. The much harder igneous rock of the Tower survived the onslaught of erosional forces, and the gray columns of Devils Tower began to appear above the surrounding landscape.

As rain and snow continue to erode the sedimentary rocks surrounding the Tower's base, and the Belle Fourche River carries away the debris, more of Devils Tower will be exposed. But at the same time, the Tower itself is slowly being eroded. Rocks are continually breaking off and falling from the steep walls. Rarely do entire columns fall, but on remote occasions, they do. Piles of rubble, broken columns, boulders, small rocks, and stones, lie at the base of the Tower, indicating that it was, at some time in the past, larger than it is today.

Eventually, at some time far in the future, even Devils Tower itself will erode away!

▪ **Mount Fuji**

Mount Fuji, located on Honshu Island, is the highest mountain in Japan at 3,776.24 m (12,389 ft). An active stratovolcano, that last erupted in 1707–08, Mount Fuji lies about 100 kilometers (62 mi) south-west of Tokyo, and can be seen from there on a clear day. Mount Fuji's exceptionally symmetrical cone, which is snow-capped several months a year, is a well-known symbol of Japan and it is frequently depicted in art and photographs, as well as visited by sightseers and climbers. It is one of Japan's "Three Holy Mountains" along with Mount Tate and Mount Haku; it is a Special Place of Scenic Beauty, a Historic Site, and has been submitted for future inscription on the World Heritage List as a Cultural (rather than Natural) Site.



Geology

Mount Fuji is located at the triple junction where the Amurian Plate, the Okhotsk Plate, and the Philippine Sea Plate meet. Those plates form the western part of Japan, the eastern part of Japan, and the Izu Peninsula respectively.

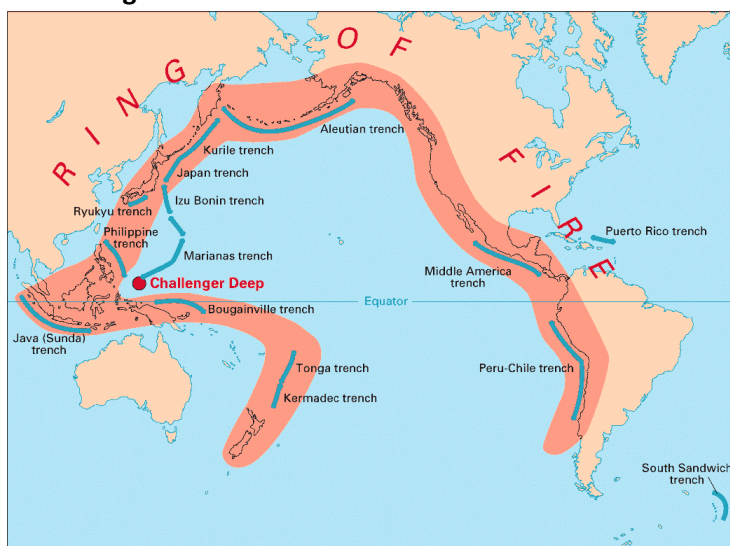
Scientists have identified four distinct phases of volcanic activity in the formation of Mount Fuji. The first phase, called Sen-komitake, is composed of an andesite core recently discovered deep within the mountain. Sen-komitake was followed by the "Komitake Fuji," a basalt layer believed to be formed several hundred thousand years ago. Approximately 100,000 years ago, "Old Fuji" was formed over the top of Komitake Fuji. The modern, "New Fuji" is believed to have formed over the top of Old Fuji around 10,000 years ago.

The volcano is currently classified as active with a low risk of eruption. The last recorded eruption was the Hōei eruption which started on December 16, 1707 (Hōei 4, 23rd day of the 11th month) and ended about January 1, 1708 (Hōei 4, 9th day of the 12th month) during the Edo period. The eruption formed a new crater and a second peak (named Hōei-zan after the Hoei era) halfway down its side. Fuji spewed cinders and ash which fell like rain in Izu, Kai, Sagami, and Musashi. Since then, there have been no signs of an eruption. In the evening of March 15, 2011, there was a magnitude 6.2 earthquake at shallow depth a few kilometers from Mount Fuji on its southern side. But according to the Japanese Meteorological Service there was no sign of any eruption.

Current eruptive danger

Following the 2011 Tōhoku earthquake and tsunami much attention was given to the volcanic reaction of Mt. Fuji. In September 2012, mathematical models created by the National Research Institute for Earth Science and Disaster Prevention suggested that the pressure in Mount Fuji's magma chamber could be at 1.6 megapascals higher than it was in 1707. This was commonly reported in the media to mean that an eruption of Mt. Fuji was imminent. However, since there is no known method of measuring the pressure of a volcano's magma chamber, such research is only speculative. The other indicators mentioned, such as active fumaroles and recently discovered faults, are typical occurrences at this type of volcano.

▪ Ring of Fire



The Ring of Fire is an area where a large number of earthquakes and volcanic eruptions occur in the basin of the Pacific Ocean. In a 40,000 km (25,000 mi) horseshoe shape, it is associated with a nearly continuous series of oceanic trenches, volcanic arcs, and volcanic belts and/or plate movements. The Ring of Fire has 452 volcanoes and is home to over 75% of the world's active and dormant volcanoes. It is sometimes called the circum-Pacific belt or the circum-Pacific

seismic belt.

About 90% of the world's earthquakes and 81% of the world's largest earthquakes occur along the Ring of Fire. Also, many of the world's volcanoes are located here. The next most seismic region (5–6% of earthquakes and 17% of the world's largest earthquakes) is the Alpide belt, which extends from Java to Sumatra through the Himalayas, the Mediterranean, and out into the Atlantic. The Mid-Atlantic Ridge is the third most prominent earthquake belt.

The Ring of Fire is a direct result of plate tectonics and the movement and collisions of lithospheric plates. The eastern section of the ring is the result of the Nazca Plate and the Cocos Plate being subducted beneath the westward moving South American Plate. The Cocos Plate is being subducted beneath the Caribbean Plate, in Central America. A portion of the Pacific Plate along with the small Juan de Fuca Plate are being subducted beneath the North American Plate. Along the northern portion, the northwestward-moving Pacific plate is being subducted beneath the Aleutian Islands arc. Farther west, the Pacific plate is being subducted along the Kamchatka Peninsula arcs on south past Japan. The southern portion is more complex, with a number of smaller tectonic plates in collision with the Pacific plate from the Mariana Islands, the Philippines, Bougainville, Tonga, and New Zealand; this portion excludes Australia, since it lies in the center of its tectonic plate. Indonesia lies between the Ring of Fire along the northeastern islands adjacent to and including New Guinea and the Alpide belt along the south and west from Sumatra, Java, Bali, Flores, and Timor. The famous and very active San Andreas Fault zone of California is a transform fault which offsets a portion of the East Pacific Rise under southwestern United States and Mexico. The motion of the fault generates numerous small earthquakes, at multiple times a day, most of which are too small to be felt. The active Queen Charlotte Fault on the west coast of the Haida Gwaii, British Columbia, Canada, has generated three large earthquakes during the 20th century: a magnitude 7 event in 1929; a magnitude 8.1 in 1949 (Canada's largest recorded earthquake); and a magnitude 7.4 in 1970.

▪ **Mount Rainier**

Mt. Rainier is the most significant threat of continental U.S. active volcanoes.

Mount Rainier National Park encompasses 235,625 acres on the west-side of the Cascade Range, and is located about 100 kilometers (50 miles) southeast of the Seattle-Tacoma metropolitan area. Mount Rainier National Park is approximately 97 percent wilderness and 3 percent National Historic Landmark District and receives approximately 2 million visitors per year.



At 14,410 feet, Mount Rainier is the most prominent peak in the Cascade Range. It dominates the landscape of a large part of western Washington State. The mountain stands nearly three miles higher than the lowlands to the west and one and one-half miles higher than the adjacent mountains. It is an active volcano that last erupted approximately 150 years ago.

The park is part of a complex ecosystem. Vegetation is diverse, reflecting the varied climatic and environmental conditions encountered across the park's 12,800-foot elevation gradient. Approximately 58 percent of the park is forested, 23 percent is subalpine parkland, and the remainder is alpine, half of which is vegetated and the other half consists of permanent snow and ice. Forest ages range from less than 100 years old on burned areas and moraines left by receding glaciers to old-growth stands 1,000 or more years. Some alpine heather communities have persisted in the park for up to 10,000 years.

Species known or thought to occur in the park include more than 800 vascular plants, 159 birds, 63 mammals, 16 amphibians, 5 reptiles, and 18 native fishes. The park contains 26 named glaciers across 9 major watersheds, with 382 lakes and 470 rivers and streams and over 3,000 acres of other wetland types. Of these vertebrates, there are 4 federally listed threatened or endangered species known to occur in the park, including 3 birds and 1 fish. Four other species historically occurred in the park, but their present status is unknown including: gray wolf, grizzly bear, Canada lynx, and Chinook salmon.

▪ Crater Lake

Crater Lake is a caldera lake located in the south-central region of the U.S. state of Oregon. It is the main feature of Crater Lake National Park and famous for its deep blue color and water clarity. The lake partly fills a nearly 2,148-foot (655 m) deep caldera that was formed around 7,700 (\pm 150) years ago by the collapse of the volcano Mount Mazama. There are no rivers flowing into or out of the lake; the evaporation is compensated for by rain and snowfall at a rate such that the total amount of water is replaced every 250 years.



On June 12, 1853, John Wesley Hillman was reportedly the first person of European descent to see what he named "Deep Blue Lake" in Oregon. The lake was renamed at least three times, as Blue Lake, Lake Majesty, and finally Crater Lake.

Crater Lake is known for the "Old Man of the Lake", a full-sized tree which is now a stump that has been bobbing vertically in the lake for more than a century. The low temperature of the water has slowed the decomposition of the wood, hence the longevity of the bobbing tree.

While having no indigenous fish population, the lake was stocked from 1888 to 1941 with a variety of fish. Several species have formed self-sustaining populations. Since 2002, one of the state's regular-issue license plate designs has featured Crater Lake. The commemorative Oregon State Quarter, which was released by the United States Mint in 2005, features an image of Crater Lake on its reverse.

Geology

Mount Mazama, part of the Cascade Range volcanic arc, was built up mostly of andesite, dacite, and rhyodacite over a period of at least 400,000 years. The caldera was created in a massive volcanic eruption that led to the subsidence of Mount Mazama around 5700 BC: about 50 cubic kilometers (12 cubic miles) of rhyodacite was erupted in this event. Since that time, all eruptions on Mazama have been

confined to the caldera.

Lava eruptions later created a central platform, Wizard Island, Merriam Cone, and other, smaller volcanic features, including a rhyodacite dome that was eventually created atop the central platform. Sediments and landslide debris also covered the caldera floor.

Eventually, the caldera cooled, allowing rain and snow to accumulate and eventually form a lake. Landslides from the caldera rim thereafter formed debris fans and turbidite sediments on the lake bed. Fumaroles and hot springs remained common and active during this period. Also after some time, the slopes of the lake's caldera rim more or less stabilized, streams restored a radial drainage pattern on the mountain, and dense forests began to revegetate the barren landscape. It is estimated that about 720 years was required to fill the lake to its present depth of 594 m. Much of this occurred during a period when the prevailing climate was less moist than at present.

Some hydrothermal activity remains along the lake floor, suggesting that at some time in the future Mazama may erupt once again

▪ **Sunset Crater**

Sometime between 1040 and 1100, a series of eruptions—the only eruptions in the Southwest indisputably witnessed by local peoples — brought the dormant San Francisco Volcanic Field back to life. Earthquakes, thunderclaps, and fire bombs shook the ground. Billowing ash, falling cinders, and forest fires blackened both the landscape and the daytime sky, while at night, the horizon glowed fiery red. When the field again grew quiet, a classic example of a cinder cone, Sunset Crater Volcano, loomed over a dramatically altered land of lava flows and cinders.



Today Sunset Crater Volcano National Monument protects 3040 acres representing the Colorado Plateau's most recent volcanic eruption. It is the youngest, least-eroded cinder cone in the San Francisco Volcanic Field. Much of the ground surface is covered by lava flows or deep volcanic cinder deposits; at first glance, the landscape still appears stark and inhospitable. But look again - within the dramatic geologic features are small islands of pine and aspen trees, desert shrubs, and wildflowers. These provide small but unique habitats for wildlife as well. Slowly but surely, life returns.

▪ **Lake Taupo, New Zealand**

Lake Taupo is a lake situated in the North Island of New Zealand. With a surface area of 616 square kilometres (238 sq mi), it is the largest lake by surface area in New Zealand, and the second largest freshwater lake by surface area in geopolitical Oceania after Lake Murray (Papua New Guinea).

Lake Taupo lies in a caldera created by a supervolcanic eruption which occurred approximately 26,500 years ago. According to geological records, the volcano has erupted 28 times in the last 27,000 years. It has ejected mostly rhyolitic lava, although Mount Tauhara formed from dacitic lava.

The initial event 26,500 years ago is the largest eruption and is known as the Oruanui eruption. It ejected an estimated 1170 cubic kilometres of material and caused several hundred square kilometres of surrounding land to collapse and form the caldera. The caldera later filled with water, eventually overflowing to cause a huge outwash flood.

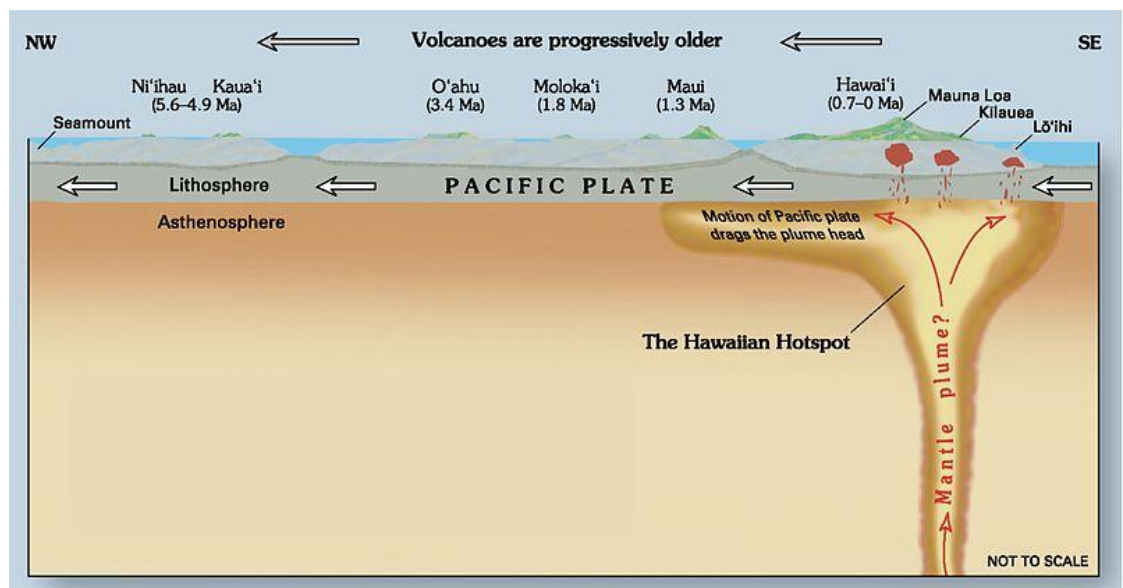
Several later eruptions occurred over the millennia before the most recent major eruption, which is traditionally dated as about 180 CE from Greenland ice-core records. Tree ring data from two studies suggests a later date of 232 CE \pm 5. Known as the Hatepe eruption, it is believed to have ejected 100 cubic kilometres of material, of which 30 cubic kilometres was ejected in the space of a few minutes. This was one of the most violent eruptions in the last 5000 years (alongside the Tianchi eruption of Baekdu at around 1000 and the 1815 eruption of Tambora), with a Volcanic Explosivity Index rating of 7; and there appears to be a correlation, to within a few years, of a year in which the sky was red over Rome and China. The eruption devastated much of the North Island and further expanded the lake. The area was uninhabited by humans at the time of the eruption, since New Zealand was not settled by the Māori until about 1280. Possible climatic effects of the eruption would have been concentrated on the southern hemisphere due to the southerly position of Lake Taupo. Taupo's last known eruption occurred around 30 years later, with lava dome extrusion forming the Horomatangi Reefs, but that eruption was much smaller than the 180 CE eruption.

Underwater hydrothermal activity continues near the Horomatangi vent, and nearby geothermal fields with associated hot springs are found north and south of the lake, for example at Rotokawa and Turangi. These springs are the site of occurrence of certain extremophile micro-organisms, that are capable of surviving in extremely hot environments.

The volcano is currently considered to be dormant rather than extinct.

▪ Hawaiian Hot Spots

The Hawaii hotspot is a volcanic hotspot located near the namesake Hawaiian Islands, in the northern Pacific Ocean. One of the most well-known and heavily studied hotspots in the world, the Hawaii plume is responsible for the creation of the Hawaiian – Emperor seamount chain, an over 5,800 kilometres (3,600 mi) long chain of volcanoes, four of which are active, two of which are dormant, and more than 123 of which are extinct, many having since been ground beneath the waves by erosion as seamounts and atolls. The chain extends from south of the island of Hawai'i to the edge of the Aleutian Trench, near the eastern edge of



Russia.

While most volcanoes are created by geological activity at tectonic plate boundaries, the Hawaii hotspot is located far from nearby plate boundaries; the classic hotspot theory, first proposed in 1963 by John Tuzo Wilson, proposes that a single, fixed mantle plume builds volcanoes that then, cut off from their source by the movement of the Pacific Plate, become increasingly inactive and eventually erode below sea level over millions of years. According to this theory, the nearly 60° bend separating the Emperor and Hawaiian segments of the chain was caused by a sudden shift in the movement of the Pacific Plate. In 2003, fresh investigations of this irregularity led to the proposal of a mobile hotspot theory, suggesting that hotspots are mobile, not fixed, and that the 47 million year old bend was caused by a shift in the hotspot's motion rather than the plate's.

- **Aviation Risk**

Defining Volcanic Ash

Volcanic ash is a product of explosive volcanic eruptions and is the finest grade of ejected solid debris at source, defined as being of (equivalent) diameter less than 2 mm]. It is generally accepted that ash in clouds downwind of an eruption will always be composed of much smaller particles than this with equivalent diameters of less than 0.1 mm. Such particles can rise to the higher levels of the plume at the site of the eruption and remain in suspension at prevailing ambient air densities. The upper winds transport the particles away to eventual dispersal in an 'ash cloud'. Ash clouds typically form above FL200, but the lower limit of the initial cloud depends on both the height of the volcanic vent and the vigour with which material is ejected from it. Visible emissions are often dominated by vast white clouds of steam, especially when a vent is beneath an ice cap as often occurs in Iceland. Steam clouds continuously emitted during an eruption often mask ash emissions which almost always occur in intermittent bursts.

Volcanic ash in the immediate vicinity of the eruption plume is of an entirely different particle size range and density to that found in downwind dispersal clouds which contain only the finest grade of ash.

Volcanic ash usually contains more than 50% silica. Silica is extremely hard and has a melting point in the region of 1100 °C. It is the potential for abrasion and for melting and re-solidifying within the high by-pass jet turbines which power modern jet transport aircraft which is the origin of the damaging effect of ash encounters on aircraft.

The Effects of Ash Cloud Encounters on Aircraft

Whilst there are a number of potential effects of volcanic ash encounters on aircraft, the ones that warrant serious attention are those affecting aircraft engines. These effects are attributable almost entirely to the dominant silica particles. Their extreme hardness means that they have an abrasive effect on any surface impacted at a significant relative speed and this includes the interior of aircraft engines. However, their more significant characteristic as far as aircraft engines are concerned is the fact that their melting point is well below the core temperatures nowadays typically sustained in high by-pass jet engines running at above flight idle thrust. Ingested silicate ash melts in the hot section of the engine and then fuses onto the high pressure turbine blades and guide vanes. This drastically reduces the throat area and both static burner and compressor discharge pressures rapidly increase and cause engine surge. Transient and possibly terminal loss of thrust can occur in the most severe cases[4] with a successful engine re-start only possible if clear air can be regained.

The ash loading at which this process affects normal engine operation is not established beyond the awareness that relatively high ash densities must exist. Whether this silica-melt risk remains at the much lower ash densities characteristic of downstream ash clouds is currently unclear.

What makes this matter of extreme importance is that since this sequence may interfere with the normal function of aircraft engines and perhaps cause them to run down completely, a similar effect can be anticipated on all the engines on an aircraft. This is therefore a serious safety hazard which invites preventive risk management strategies in line with other comparable aviation risks.

Abrasion damage to aircraft engines caused by ash impact, whilst not affecting their continued normal function, cannot be repaired and will permanently reduce their operating efficiency thereafter. However, this is an economic issue rather than a safety one and establishing what knowledge would better inform the management of that economic risk is not the primary focus of this article.