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Yellowstone Caldera

Yellowstone Caldera, also known as the **Yellowstone Plateau Volcanic Field**, is a Quaternary caldera complex and volcanic plateau spanning parts of Wyoming, Idaho, and Montana. It is driven by the Yellowstone hotspot and is largely within Yellowstone National Park. The field comprises four overlapping calderas, multiple lava domes, resurgent domes, crater lakes, and numerous bimodal lavas and tuffs of basaltic and rhyolitic composition, originally covering about 17,000 km^2 (6,600 sq mi).

Volcanism began 2.15 million years ago and proceeded through three major volcanic cycles. Each cycle involved a large ignimbrite eruption, continental-scale ash-fall, and caldera collapse, preceded and followed by smaller lava flows and tuffs. The first and also the largest cycle was the Huckleberry Ridge Tuff eruption about 2.08 million years ago, which formed the Island Park Caldera. The most recent supereruption, about 0.63 million years ago, produced the Lava Creek Tuff and created the present Yellowstone Caldera. Post-caldera eruptions included basalt flows, rhyolite domes and flows, and minor explosive deposits, with the last magmatic eruption about 70,000 years ago. Large hydrothermal explosions also occurred during the Holocene.

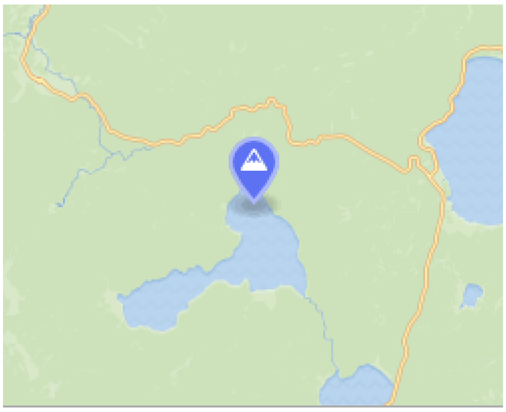
From 2004 to 2009, the region experienced notable uplift attributed to new magma injection. The 2005 docudrama *Supervolcano*, produced by the *BBC* and the *Discovery Channel*, increased public attention on the potential for a future catastrophic eruption. The Yellowstone Volcano Observatory monitors volcanic activity and does not consider an eruption imminent. Imaging of the magma reservoir indicates a substantial volume of partial melt beneath Yellowstone that is not currently eruptible.

Yellowstone Caldera	

The northeastern part of Yellowstone Caldera, with the Yellowstone River flowing through Hayden Valley and the caldera rim in the distance

Highest point	
Elevation	9,203 ft (2,805 m)
Coordinates	44°24′N 110°42′W

Geography



Location	Yellowstone National Park, Wyoming, United States
Parent range	Rocky Mountains
Topo map	USGS Yellowstone National Park
Geology	
Rock age	2,150,000–70,000 years
Volcanic field	Yellowstone Plateau
Last eruption	70,000 years ago
Climbing	
Easiest route	Hike/auto/bus

Geology

The Yellowstone Plateau Volcanic Field lies at the eastern end of the Snake River Plain and disrupts the continuity of the Laramide orogenic belt, which formed during the Late Cretaceous.[1] From about 53 to 43 million years ago, this area experienced significant andesitic volcanism exceeding 29,000 km^3 (7,000 cu mi) in total volume, forming the Absaroka Volcanic Supergroup. Prominent peaks such as Mount Washburn and Eagle Peak are eroded remnants of these earlier stratovolcanoes.[2] Before the formation of the Yellowstone Plateau, the Teton Range and Madison Range were likely structurally continuous, as were the Red Mountains and Gallatin Range.[3]

Current Yellowstone volcanism is not a continuation of Laramide tectonism or the Absaroka volcanic province.[3] Instead, it is the most recent part of a linear age-progression of rhyolitic complexes along the Snake River Plain, extending at least 16 million years to the McDermitt caldera complex.[4] Large rhyolitic tuff supereruptions occurred at these older eruptive centers.[5][6] One is the 12.1 million-year-old Ibex Hollow Tuff from the Bruneau-Jarbidge volcanic field in southern Idaho, burying herds of Nebraska mammals under volcanic ash.[7] Older volcanics proposed to be part of this hotspot track include the 56 million-year-old Siletzia oceanic plateau and the 70 million-year-old Carmacks Group.[8][9]

The cause of the northeastward progression of volcanism is debated. Some models invoke only upper-mantle processes, such as mantle pushed upward by the leading edge of the subducting Farallon plate,[10] slab rollback,[11] a propagating rift,[12] or mantle convection driven by abrupt changes in thermal layer thickness at the continent–ocean boundary.[13] A proposed lower-mantle origin suggests a fragment of the subducting Farallon slab penetrated the 660 km (410 mi) discontinuity, pushing up the lower mantle and triggering melting of water-rich transition zone beneath the western United States.[14] Alternatively, a long-lived mantle plume rooted at the core–mantle boundary has been proposed. The plume erupted the Columbia River Basalt Group and is now feeding the Yellowstone hotspot.[15] Seismic tomography has revealed a 350 km (220 mi) wide, cylindrical thermal anomaly extending from the deepest mantle to just beneath Yellowstone, supporting the mantle plume origin.[16] In this model, the North American Plate moves southwest at about 2.2 cm (0.87 in) per year over the relatively stationary plume, creating the observed age-progression of eruptive centers.[17]

Structure of calderas

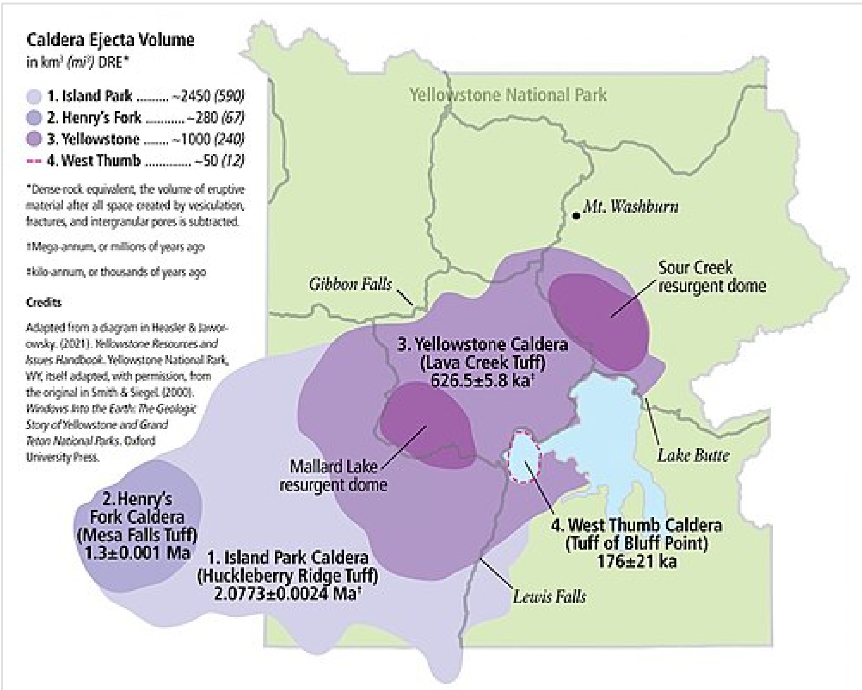
The northern and eastern extent of the first-cycle caldera are unknown due to burial, although it likely reached into the third-cycle caldera, perhaps east of the Central Plateau.[18] The Huckleberry Ridge Tuff in the Red Mountains is interpreted as thick intracaldera fill of the Island Park Caldera,[19] and Big Bend Ridge at the southwestern edge of the volcanic plateau is inferred to be part of its caldera wall.[19] A fault along the Snake River and Glade Creek, bounding the northern end of Teton Range and Huckleberry Ridge, is also thought to be part of the Island Park ring-fault.[20] It is not known whether any of the first-cycle caldera segments was resurgent.[21]

The second-cycle caldera is known as the Henry's Fork Caldera. Thurmon Ridge at the northwestern edge of the volcanic plateau is inferred to be its northern caldera wall.[22] The fault along Big Bend Ridge was reactivated, collapsing again during the second-cycle caldera formation.[19] Although basalt flows bury its southern and eastern boundary, a positive gravity anomaly indicates a circular caldera about 19 km (12 mi) in diameter, with its southern boundary in the middle of the Island Park basin.[22]

Robert L. Christiansen inferred that the Yellowstone Caldera is a compound caldera comprising two partially overlapping ring-fault zones, centered on the resurgent Mallard Lake dome and Sour Creek dome.[23] The southwest boundary is unconstrained due to post-caldera rhyolite burial, but he proposed that the south flank of Purple Mountain and the Washburn Range, along with the west flank of the Absaroka Range, mark the caldera boundary on the north and east sides.[24] Lewis Falls, Lake Butte, and Flat Mountain Arm of Yellowstone Lake are also part of the Yellowstone caldera rim.[25] However, the purported Sour Creek ring-fault zone and the location of the eastern caldera boundary have been challenged. More recent field mappings suggest the eastern ring-fault lies west of Sour Creek dome, closely following the Yellowstone River.[26][27]

The most western portion of Yellowstone Lake is the elliptical 6 km × 8 km (3.7 mi × 5.0 mi) West Thumb Basin, which includes one of the lake's deepest areas. It is interpreted as a fourth caldera, formed by a third-cycle post-caldera explosive eruption.[28]

Eruption history



Yellowstone sits on top of four overlapping calderas (U.S. National Park Service).

A total of 6,500 km^3 (1,600 cu mi) of rhyolite and 250 km^3 (60 cu mi) of basalt were emplaced over three volcanic cycles between about 2.15 million and 0.07 million years ago.[29] Each cycle lasted roughly three-quarters of a million years. The sequence of events in each cycle is similar: a catastrophic rhyolitic ash-flow sheet and caldera collapse, preceded and followed by eruptions of rhyolitic lavas and tuffs and basaltic eruptions near the caldera margin.[30] Ash-flow sheets account for more than half of the total volcanic volume of the Yellowstone Plateau.[31]

First-cycle

The first-cycle lasted from about 2.15 million to 1.95 million years ago, spanning approximately 200 kyr.[32] The only known pre-collapse rhyolitic unit is the Rhyolite of Snake River Butte, located just north of Ashton and dated at 2.1398 ± 0.0035 million years,[33] roughly 60–70 kyr before the caldera-forming Huckleberry Ridge Tuff.[34] Its vent lies near the eventual first-cycle caldera margin close to the Big Bend Bridge.[18] Additional rhyolite flows may have erupted along the incipient ring-fault,[18] but the pre-collapse rhyolite history likely spans no more than ~70 kyr.[34] Another pre-collapse unit is the 60 to 70 m (200 to 230 ft)-thick Junction Butte Basalt on the northeastern margin of the plateau,[18] dated at 2.16 ± 0.04 million years.[35] The Overhanging Cliff basalt is a flow of this unit.[18]

The first-cycle caldera-forming event was the eruption of the Huckleberry Ridge Tuff at 2.0773 ± 0.0034 million years ago, during transitional magnetic polarity.[36] Its thickness exceeds 1 km (0.62 mi) in the Red Mountains area.[37] The initial Plinian phase deposited up to 2.5 m (8.2 ft) of fallout ash at Mount Everts before transitioning to ash-flow tuff.[38][39] Early Plinian activity was intermittant, sourced from multiple vents, probably lasted a few weeks and evacuated about 50 km^3 (12 cu mi) of magma from four magma bodies,[40] triggering caldera collapse at the onset of transition to ash-flow.[41][40] The ash-flow tuff is a composite sheet consisted of three intermittent members, with a total magma volume of about 2,450 km^3 (590 cu mi).[38] Member A likely vented from the plateau's central area[38] and tapped nine magma bodies.[40] After a hiatus of a few weeks or more,[41] the most voluminous Member B erupted from north of Big Bend Ridge.[42] After another extended break of years to decades,[41] part of the Member A magmatic system was rejuvenated to feed Member C.[41] The least voluminous Member C might have source area near the Red Mountains, where it is about 430 m (1,410 ft) thick.[43] Some outcrops of Member A and Member C have been misidentified as Member B, complicating volume estimates of individual ash-flow unit.[44] Glen A. Izett estimated that an additional 2,000 km^3 (480 cu mi) of ash was dispersed as fallout across North America.[45] Tephra fallout from this event is known as the Huckleberry Ridge ash bed (formerly "Pearlette type B"). Its area covered exceeds 3,400,000 km^2 (1,300,000 sq mi).[46]. It is widely distributed and has been identified in the Pacific Ocean at Deep Sea Drilling Project Site 36, about 1,600 km (990 mi) from Island Park Caldera,[47] as well as in the Humboldt and Ventura basins of coastal California,[48] near Afton in Iowa, Benson in Arizona, and Campo Grande Mountain in Texas.[49]

One lava flow near the Sheridan Reservoir[50] and two flows at the north end of Big Bend Ridge[51] are post-collapse rhyolites of the first-cycle volcanism. The Sheridan Reservoir Rhyolite, dated at 2.07 ± 0.19 million years,[50] if vented from the Island Park ring-fracture, required a flow distance of at least 20 km (12 mi).[52] Its volume is estimated to exceed 10 km^3 (2.4 cu mi).[53] The other two flows, the Blue Creek flow and the overlying Headquarters flow, have a combined volume of 10–20 km^3 (2.4–4.8 cu mi)[54] and erupted respectively at 1.9811 ± 0.0035 million years and 1.9476 ± 0.0037 million years ago.[33]

Second-cycle

After ~500 kyr of quiescence,[55] a new magmatic system formed north of Big Bend Ridge. It erupted the Bishop Mountain Flow at 1.4578 ± 0.0016 million years and the Tuff of Lyle Spring at 1.4502 ± 0.0027 million years.[56] The Bishop Mountain Flow is a rhyolite with an exposed volume of about 23 km^3 (5.5 cu mi) and reaches a thickness of 375 m (1,230 ft) along the inner caldera wall. The Tuff of Lyle Spring is a 1 km^3 (0.24 cu mi), composite ash-flow sheet consisting of two cooling units.[57] Both eruptions appear to have originated from an isolated, highly evolved local magma chamber distinct from the second-cycle magma source.[51] Tiffany A. Rivera et al. (2017) suggest these two eruptions should not be assigned to the second cycle but instead represent the separate Lyle Spring magmatic system.[55] The next pre-collapse rhyolite eruption is the Green Canyon Flow in the north of Big Bend Ridge, with a mapped volume of about 5 km^3 (1.2 cu mi), dated at 1.2989 ± 0.0009 million years.[56] Its age is indistinguishable from that of the subsequent Mesa Falls Tuff, but the Henry's Fork Caldera fracture truncates the Green Canyon Flow, indicating it predates the second-cycle caldera.[58]

The second-cycle caldera-forming eruption was the Mesa Falls Tuff, dated at 1.3001 ± 0.0006 million years.[59] Its exposed thickness exceeds 150 m (490 ft) on Thurmon Ridge, though it is likely much thicker within the caldera.[51] During the initial Plinian phase, about 5 m (16 ft) of ash and pumice were deposited around the Ashton area, while much of the vitric ash dispersed to more distant regions, as inferred from the high crystal content of the local deposit. This airfall is overlain by a 1 m (3.3 ft) pyroclastic surge layer also enriched in crystals.[60] A single cooling unit of ash-flow tuff followed, covering about 2,700 km^2 (1,000 sq mi) with an estimated volume of 280 km^3 (67 cu mi).[51] The Mesa Falls ash bed (formerly "Pearlette type S") is the distal ash-fall of this eruption, found in Brainard and Hartington in Nebraska, and in the southern Rocky Mountains of Colorado.[49]

Post-collapse eruptions included the Moonshine Mountain dome[61] and five rhyolite domes collectively known as the Island Park Rhyolite.[22] The Moonshine Mountain dome, with an estimated volume of 2.5 km^3 (0.60 cu mi), erupted at 1.3017 ± 0.0019 million years.[56] While its age is indistinguishable from the Mesa Falls Tuff, field evidence indicates it formed after the collapse of the Henry's Fork Caldera.[61] The dome's magma source is likely the same region that supplied the Bishop Mountain Flow.[62] The Island Park Rhyolite comprises five bodies: Silver Lake dome, Osborne Butte dome, Elk Butte dome, Lookout Butte dome, and Warm River Butte dome.[22] These domes collectively have a total volume of 1–2 km^3 (0.24–0.48 cu mi).[54] All five erupted within a few centuries, around 1.2905 ± 0.0020 million years, during a single eruptive episode.[63] While Lookout Butte is located on the rim of Big Bend Ridge caldera wall, the vents for the other four domes align along a northwest-trending, structurally controlled linear vent zone about 30 km (19 mi) long and no more than 7 km (4.3 mi) wide.[64]

Third-cycle

Pre-collapse third-cycle silicic rocks are broadly divided into the Mount Jackson Rhyolite and the Lewis Canyon Rhyolite,[65] which vented along what later became the ring-fracture zone of the third-cycle caldera.[66] The earliest known lava in this cycle is the Wapiti Lake flow of the Mount Jackson group, dated at 1.2187 ± 0.0158 million years,[67] exposed near the Grand Canyon of the Yellowstone and likely vented near Wapiti Lake.[68] Another flow, the Moose Creek Butte flow (1.1462 ± 0.0022 million years), also belongs to the Mount Jackson group.[69] Although younger than the Island Park Rhyolite, its geochemical similarity has led some researchers to propose it as a second-cycle post-collapse eruption.[70] Pumice of an unknown tuff unit at Broad Creek has an age range from 0.948 ± 0.016 million years to 1.11 ± 0.02 million years.[71] Later Mount Jackson eruptions include the Flat Mountain Rhyolite (0.929 ± 0.034 million years)[72] and the Harlequin Lake flow (0.8300 ± 0.0072 million years).[67] The Lewis Canyon Rhyolite group contains lavas dated to 0.8263 ± 0.0184 million years,[67] though Robert L. Christiansen suggests they could be late-stage first-cycle eruptions.[73] A recently discovered ash-flow unit is dated to 0.796 million years.[74] An explosive eruption deposited pumiceous fallout near Harlequin Lake,[65] which is immediately overlain by the Mount Haynes lava (0.7016 ± 0.0014 million years).[67] An ash bed from a Yellowstone eruption was deposited in the Great Salt Lake approximately 0.7 million years ago.[75] The age of the Big Bear Lake flow is uncertain, but it lies beneath the third-cycle caldera-forming Lava Creek Tuff.[65] Additional Mount Jackson flows may be buried within the Yellowstone caldera, inferred from intracaldera topography.[73]

The climatic ash-flow eruption of the third cycle was the Lava Creek Tuff, dated at 0.6260 ± 0.0026 million years,[34] during a glacial–interglacial transition in the Marine Isotope Stage.[76] This composite tuff sheet consists of at least two members, distinguishable by a widely occurring welding intensity decrease between them,[77] and represents a total ash-flow volume of about 1,000 km^3 (240 cu mi).[78] Member A likely erupted south of Purple Mountain, where it reaches its greatest thickness of 430 m (1,410 ft) and exhibits maximum welding.[78] The Purple Mountain to Gibbon Canyon segment of caldera wall collapsed after the emplacement of Member A but before it completely cooled.[79] A 20–30 cm (7.9–11.8 in) loose crystal ash unit separates Member A from Member B, indicating a break in the eruption sufficiently long for cooling of thick ash-flows.[80] A 3 m (9.8 ft) thick pumiceous ash-fall deposit underlies Member B and probably marks its initial phase.[80] Member B ash-flows extends radially outward along paleovalleys and more extensive plateau segments. The eruptive center for Member B appears to be situated farther east compared to that of Member A.[81] However, this simplistic eruptive sequence has been challenged.[26] An additional 40 m (130 ft) ash-flow unit (informally named unit 2) has been identified, venting from around Bog Creek. Unit 2 erupted some decades after Member A had cooled[82] and overlies tuff fragments from Member A.[74] Two additional rhyolite ash-flow units (unit 3 and unit 4) have been recognized, erupting from a vent near Stonetop Mountain and are previously undocumented parts of the Lava Creek Tuff.[83] An unknown welded tuff underlying Member B at Flagg Ranch, not attributed to Member A, was emplaced shortly before the initial ashfall of Member B and is considered part of the early Lava Creek eruption.[84] Rather than having the simple structure of just two ignimbrite sheets, the Lava Creek Tuff may consist of multiple ash-flow lobes from distinct magma bodies.[74] The ash fallout from the Lava Creek Tuff eruption is known as the Lava Creek ash bed (formerly "Pearlette type O"),[49] covering an area exceeding 3,000,000–4,000,000 km^2 (1,200,000–1,500,000 sq mi).[46] Perkins and Nash (2002) estimated that the volume of this ash bed is greater than 500 km^3 (120 cu mi).[85] It has been identified in the Gulf of Mexico,[86] near Regina, Saskatchewan,[87] in Ventura, California,[88] and in Viola Center, Iowa.[49]

Post-collapse rhyolites

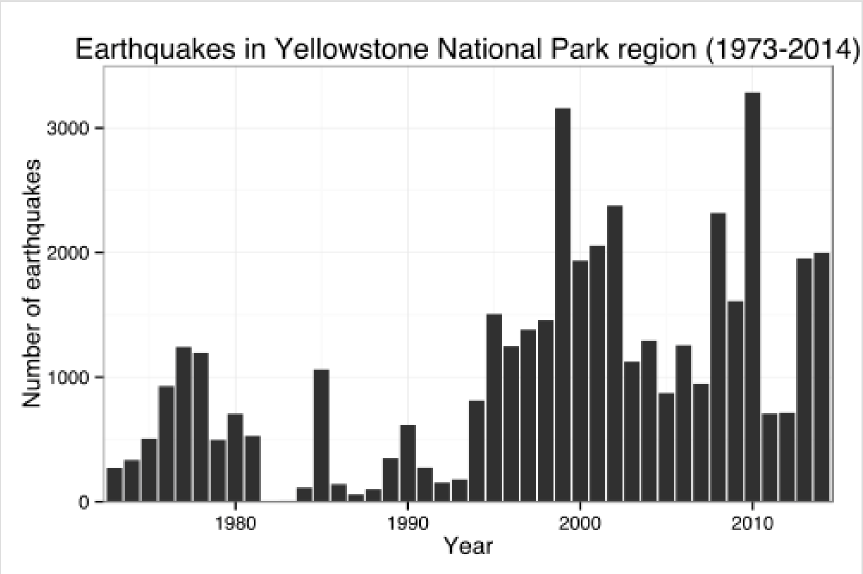
Post-collapse rhyolites likely erupted shortly after the Lava Creek Tuff.[89] The subaerial post-collapse silicic rocks are collectively referred to as the Plateau Rhyolite,[90] which primarily consists of lava flows.[89] Plateau Rhyolite is divided into three intracaldera members—Upper Basin Member, Mallard Lake Member, and Central Plateau Member—and two extracaldera members—Obsidian Creek Member and Roaring Mountain Member.[91] It is likely that rhyolitic pumice and ash were erupted during the opening of vents for each of these lava flows.[89] The earliest intracaldera rhyolite, the East Biscuit Basin Flow of the Upper Basin Member, is dated to 0.635 ± 0.014 million years, followed by felsic lithic clasts of an unknown unit (0.6 ± 0.02 million years) in Yellowstone Lake,[92] and the North Biscuit Basin Flow (0.580 ± 0.040 million years).[93] The earliest extracaldera rhyolite is the Riverside Flow (0.5258 ± 0.0033 million years) of the Roaring Mountain Member,[94] broadly contemporaneous with the Middle Biscuit Basin Flow (0.527 ± 0.028 million years).[93] Two ash-flow tuff units of the Upper Basin Member include the 35 m (115 ft)-thick Tuff of Uncle Tom's Trail[91] and the 230 m (750 ft)-thick Tuff of Sulphur Creek[95], the latter dated at 0.479 ± 0.02 million years.[96] Tuff of Sulphur Creek is at least 13 km^3 (3.1 cu mi).[97] These tuffs were deposited on the north flank of the Sour Creek dome.[91] The Canyon lava flows of the Upper Basin Member erupted immediately after the Tuff of Sulphur Creek, as the ash-flow was still hot at the time of emplacement.[98] Both the Tuff of Sulphur Creek and Canyon flows originated from a vent near Fern Lake.[98] The two tuffs and Canyon flows have a combined magma volume of 40–70 km^3 (9.6–16.8 cu mi).[54] The Dunraven Road Flow (0.486 ± 0.042 million years) of the Upper Basin Member overlies the Canyon flows[98] and may have had an extracaldera vent.[99] The Cougar Creek lava dome of the Roaring Mountain Member erupted 0.358 ± 0.002 million years north of the caldera.[100] Four additional lava flows of the Obsidian Creek Member—Willow Park dome, Apollinaris Spring dome, Gardner River complex, and Grizzly Lake complex—erupted between 0.326 ± 0.002 million years and 0.263 ± 0.003 million years,[100] in the vicinity of Norris Geyser Basin northward toward Mammoth Hot Springs.[101] The South Biscuit Basin Flow of the Upper Basin Member erupted 0.257 ± 0.009 million years ago.[93] The Scaup Lake Flow of the Upper Basin Member is dated to 0.244 ± 0.009 million years,[93] while the Landmark dome of the Obsidian Creek Member is 0.226 ± 0.006 million years.[100]

Non-explosive eruptions of lava and less-violent explosive eruptions have occurred in and near the Yellowstone caldera since the last supereruption.[102][103] The most recent lava flow occurred about 70,000 years ago, while a violent eruption excavated the West Thumb of Lake Yellowstone 174,000 years ago. Smaller steam explosions occur as well. An explosion 13,800 years ago left a 5 km (3.1 mi) diameter crater at Mary Bay on the edge of Yellowstone Lake (located in the center of the caldera).[104] 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.

Hazards

Earthquakes

Volcanic and tectonic actions in the region cause between 1,000 and 2,000 measurable earthquakes annually. Most are relatively minor, measuring magnitude 3 or weaker. Occasionally, numerous earthquakes are detected in a relatively short period of time, an event known as an earthquake swarm. In 1985, more than 3,000 earthquakes were measured over a period of several months. More than 70 smaller swarms were detected between 1983 and 2008. The USGS states these swarms are likely caused by slips on pre-existing faults rather than by movements of magma or hydrothermal fluids.[106][107]



Incidence of earthquakes in Yellowstone National Park region (1973–2014)[105]

In December 2008, continuing into January 2009, more than 500 earthquakes were detected under the northwest end of Yellowstone Lake over a seven-day span, with the largest registering a magnitude of 3.9.[108][109] Another swarm started in January 2010, after the Haiti earthquake and before the Chile earthquake. With 1,620 small earthquakes between January 17, 2010, and February 1, 2010, this swarm was the second-largest ever recorded in the Yellowstone Caldera. The largest of these shocks was a magnitude 3.8 that occurred on January 21, 2010.[107][110] This swarm subsided to background levels by

February 21. On March 30, 2014, at 6:34 AM MST, a magnitude 4.8 earthquake struck Yellowstone, the largest recorded there since February 1980.[111] In February 2018, more than 300 earthquakes occurred, with the largest being a magnitude 2.9.[112]

Volcanoes

The Lava Creek eruption of the Yellowstone Caldera, which occurred 640,000 years ago,[113] ejected approximately 1,000 cubic kilometres (240 cu mi) of rock, dust and volcanic ash into the atmosphere. It was Yellowstone's third and most recent caldera-forming eruption.

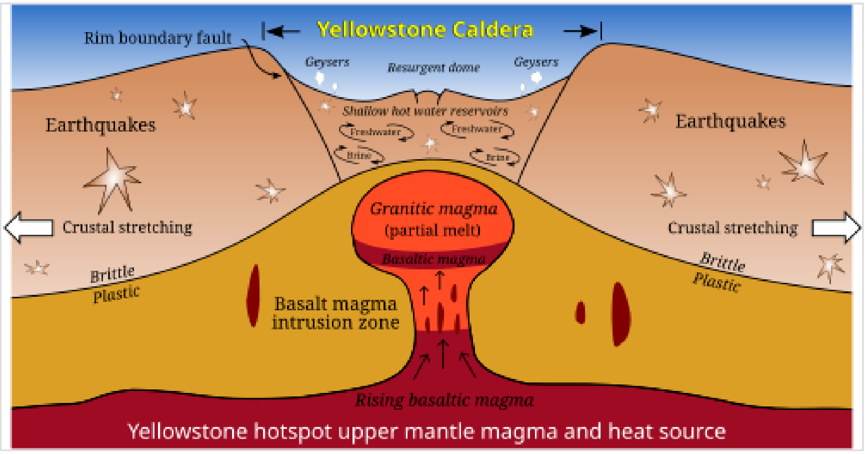


Diagram of the Yellowstone Caldera

Geologists closely monitor the elevation of the Yellowstone Plateau, which has been rising as quickly as 150 millimetres (5.9 in) per year, as an indirect measurement of changes in magma chamber pressure.[114][115][116]

The upward movement of the Yellowstone caldera floor between 2004 and 2008—almost 75 millimetres (3.0 in) each year—was more than three times greater than ever observed since such measurements began in 1923.[117] From 2004 to 2008, the land surface within the caldera moved upward as much as 8 inches (20 cm) at the White Lake GPS station.[118][119] In January 2010, the USGS stated that "uplift of the Yellowstone Caldera has slowed significantly"[120] and that uplift continues but at a slower pace.[121] USGS, University of Utah and National Park Service scientists with the Yellowstone Volcano Observatory maintain that they "see no evidence that another such cataclysmic eruption will occur at Yellowstone in the foreseeable future. Recurrence intervals of these events are neither regular nor predictable." This conclusion was reiterated in December 2013 in the aftermath of the publication of a study by University of Utah scientists finding that the "size of the magma body beneath Yellowstone is significantly larger than had been thought". The Yellowstone Volcano Observatory issued a statement on its website stating:

> Although fascinating, the new findings do not imply increased geologic hazards at Yellowstone, and certainly do not increase the chances of a 'supereruption' in the near future. Contrary to some media reports, Yellowstone is not 'overdue' for a supereruption.[122]

Media reports were more hyperbolic in their coverage.[123]

A study published in *GSA Today*, the monthly news and science magazine of the Geological Society of America, identified three fault zones where future eruptions are most likely to be centered.[124] Two of those areas are associated with lava flows aged 174,000–70,000 years ago, and the third is a focus of present-day seismicity.[124]

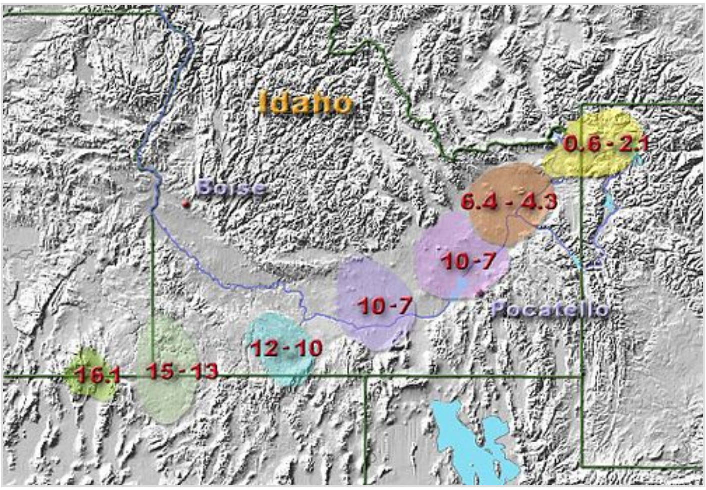
In 2017, NASA conducted a study to determine the feasibility of preventing the volcano from erupting. The results suggested that cooling the magma chamber by 35 percent would be enough to forestall such an incident. NASA proposed introducing water at high pressure 10 kilometers underground. The circulating water would release heat at the surface, possibly in a way that could be used as a geothermal power source. If enacted, the plan would cost about $3.46 billion. Brian Wilcox of the Jet Propulsion Laboratory observes that such a project could incidentally trigger an eruption if the top of the chamber is drilled into.[125][126]

According to analysis of earthquake data in 2013, the magma chamber is 80 km (50 mi) long and 20 km (12 mi) wide. It also has 4,000 km^3 (960 cu mi) underground volume, of which 6–8% is filled with molten rock. This is about 2.5 times bigger than scientists had previously imagined; however, scientists believe that the proportion of molten rock in the chamber is too low to allow for another supereruption.[127][128][129]

In October 2017, research from Arizona State University indicated prior to Yellowstone's last supereruption, magma surged into the magma chamber in two large influxes. An analysis of crystals from Yellowstone's lava showed that prior to the last supereruption, the magma chamber underwent a rapid increase in temperature and change in composition. The analysis indicated that Yellowstone's magma reservoir can reach eruptive capacity and trigger a super-eruption within just decades, not centuries as volcanologists had originally thought.[130][131]

Hydrothermal explosions

The volcanic eruptions, as well as the continuing geothermal activity, are a result of a great plume of magma located below the caldera's surface. The magma in this plume contains gases that are kept dissolved by the immense pressure under which the magma is contained. 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 chain 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.



Path of the Yellowstone hotspot over the past 16 million years

Studies and analysis may indicate that the greater hazard comes from hydrothermal activity which occurs independently of volcanic activity. Over 20 large craters have been produced in the past 14,000 years, resulting in such features as Mary Bay, Turbid Lake, and Indian Pond, which was created in an eruption about 1300 BC.

In a 2003 report, USGS researchers proposed that an earthquake may have displaced more than 77 million cubic feet (2,200,000 m^3; 580,000,000 US gal) of water in Yellowstone Lake, creating colossal waves that unsealed a capped geothermal system and led to the hydrothermal explosion that formed Mary Bay.[132][133]

Further research shows that very distant earthquakes reach and have effects upon the activities at Yellowstone, such as the 1992 7.3 magnitude Landers earthquake in California's Mojave Desert that triggered a swarm of quakes from more than 800 miles (1,300 km) away, and the 2002 7.9 magnitude Denali fault earthquake 2,000 miles (3,200 km) away in Alaska that altered the activity of many geysers and hot springs for several months afterward.[134]

In 2016, the USGS announced plans to map the subterranean systems responsible for feeding the area's hydrothermal activity. According to the researchers, these maps could help predict when another eruption occurs.[135]

Cultural significance

IUGS geological heritage site

In respect of it being "well-known for its past explosive volcanic eruptions and lava flows as well for its world class hydrothermal system", the International Union of Geological Sciences (IUGS) included "The Yellowstone volcanic and hydrothermal system" in its assemblage of 100 geological heritage sites around the world in a listing published in October 2022. The organization defines an IUGS Geological Heritage Site as "a key place with geological elements and/or processes of international scientific relevance, used as a reference, and/or with a substantial contribution to the development of geological sciences through history".[136]

See also

Volcanoes portal

United States portal

- Iceland hotspot and Iceland plume
- Lake Taupō
- Lake Toba
- Long Valley Caldera, Valles Caldera, La Garita Caldera
- Toba catastrophe theory

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External links

- Media related to Yellowstone Caldera at Wikimedia Commons
- The Snake River Plain and the Yellowstone Hot Spot (http://volcano.oregonstate.edu/oldroot/volcanoes/volc_images/north_america/yellowstone.html)
- Yellowstone Volcano Observatory (https://volcanoes.usgs.gov/yvo/)
  - FAQ relating to the supervolcano (https://volcanoes.usgs.gov/yvo/about/faq/faqsupervolcano.php)
- *Supervolcano documentary (https://www.bbc.co.uk/sn/tvradio/programmes/supervolcano/programme.shtml)* from BBC
- *Interactive: When Yellowstone Explodes (http://ngm.nationalgeographic.com/2009/08/yellowstone/yellowstone-interactive) Archived (https://web.archive.org/web/20110705142900/http://ngm.nationalgeographic.com/2009/08/yellowstone/yellowstone-interactive) July 5, 2011, at the Wayback Machine* from National Geographic
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- The Yellowstone magmatic system from the mantle plume to the upper crust (https://www.science.org/doi/10.1126/science.aaa5648) (46,000 km3 magma reservoir below chamber)
- Inside Yellowstone's Supervolcano (https://web.archive.org/web/20160416061209/http://www.nationalgeographic.com/magazine/2016/05/yellowstone-national-parks-supervolcano-animation), National Geographic