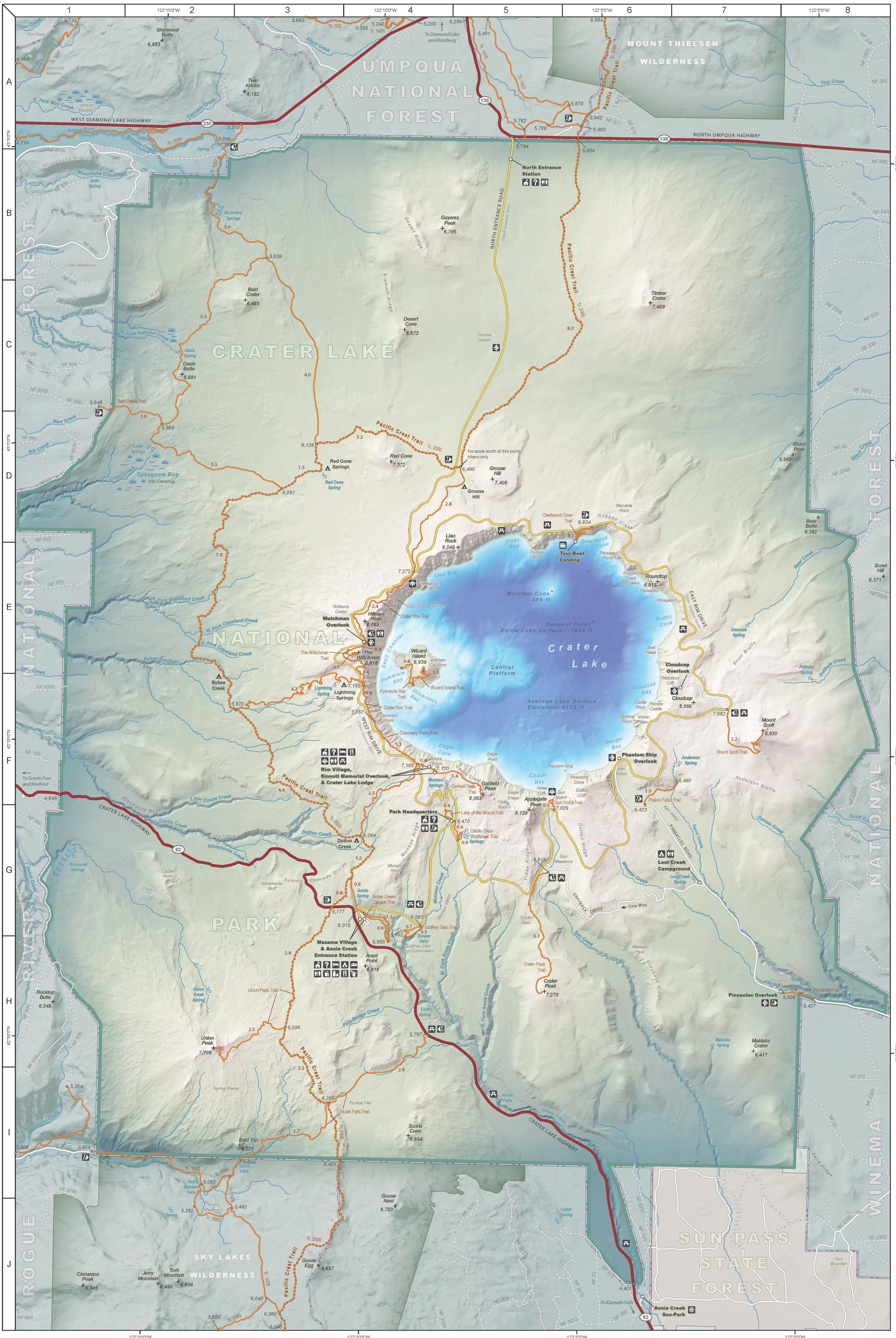


CRATER LAKE NATIONAL PARK

Crater Lake National Park, encompassing 286 square miles in the High Cascades of southern Oregon, contains one of North America's geologic wonders. The seemingly placid central icon of the park, Crater Lake, formed following a catastrophic eruption of Mount Mazama approximately 7,700 years ago. Crater Lake, which occupies a large caldera, has a surface area of 20.6 square miles and attains a maximum depth of 1,943 feet, making it the deepest lake in the United States.

In 1902 Crater Lake was designated the United States' sixth national park. The park features a 33-mile road around the rim of the crater that has several spectacular views of the lake. This road is popular with cyclists in the summer and snowshoers and cross-country skiers in the winter. There are over 85 miles of trails within the park that offer both short day hikes and longer backcountry routes. The Pacific Crest National Scenic Trail traverses the park for about 32 miles. Scheduled boat tours of the lake depart from Cleetwood Cove in the summer.

Prominent geologic features in the park include Wizard Island (E4, F4), Phantom Ship (F6), Pumice Castle (F6), Llao Rock (E4-5), Devils Backbone (E4), The Pinnacles (H7-8), and Mount Scott (F7). These well-known rock exposures reveal important clues about the volcanic past of Mount Mazama and future eruptive activity at Crater Lake (caldera).

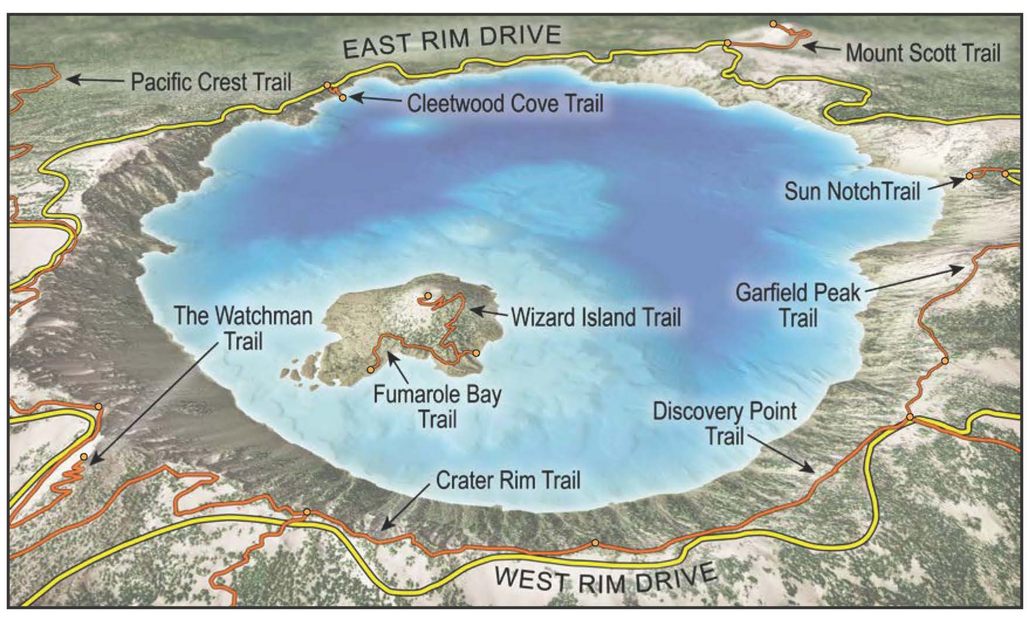
CLIMATE (Source: NPS)

The climate of Crater Lake National Park is exemplified by cool summers and moist winters with heavy snowfall. The High Cascades receive a large amount of precipitation, mainly in the form of snow in the winter months, when weather fronts move eastward from the Pacific Ocean and run up against this imposing mountain range. Crater Lake National Park headquarters receives on average 67 inches of annual precipitation including over 500 inches of annual snowfall. The majority of snowfall occurs from November through March and the park averages a spring snowpack over 120 inches deep. Temperatures (Fahrenheit) measured at the park headquarters peak in July and August, with average highs in the 60s and 70s and lows in the 40s. The coldest temperatures occur in December and January, with average highs in the 30s and lows in the teens. Weather in the Cascade Range can change quickly; it is strongly advised to be prepared for these changes and to check current conditions before traveling.

Please contact the National Park Service (http://www.nps.gov/crla/) for current information regarding National Park Service rules, regulations, and trail conditions.

Devil's Backbone and Llao Rock — Devils Backbone (E4) is a 1,000-foot long andesite dike that stretches from the crater rim to the lake. The dike was a feeder conduit for a pre-caldera vent and lava flow that erupted 40,000 to 50,000 years ago. Llao Rock (E4-5) is a large mass of rhyodacite that towers almost 2,000 feet above the northwest corner of the lake. The flows and related pyroclastic deposits at Llao Rock are part of a volcanic episode that preceded the caldera-forming eruption of Mount Mazama by just 200 to 100 years.

Phantom Ship — Phantom Ship (F6) is a 500-foot-long island in the lake that can take on a ghostly character depending on the time of day and the viewing angle. Phantom Ship is an erosionally resistant remnant of andesite and dacite lava flows that erupted from the vicinity of Phantom Cone (F6) in the southeast part of the caldera around 400,000 years ago.



Lidar-derived perspective view looking toward the northeast over Crater Lake. See main map for trail segment mileage.

LIDAR

The maps contained in this guide include terrain imagery created using lidar data. The lidar data were collected from a light aircraft carrying a highly accurate laser scanner. The scanner makes over 100,000 measurements each second to build up a three-dimensional "point cloud" model of vegetation, structures and the surface of the Earth. A computer sorts the points, separating those that measure the ground from those that measure trees and buildings. Images derived from these sets of points can then be merged with aerial photography and other forms of digital map data to create imagery.

These lidar data have a vertical absolute accuracy of ±2 inches for flat and horizontal surfaces. Slopes have greater vertical inaccuracies. Map elevations within Crater Lake National Park are lidar-derived and may differ from previously published elevations. The remaining elevations are from the USGS. See the legend for relevant elevation symbols.

The Oregon Department of Geology and Mineral Industries (DOGAMI) has been collecting lidar data in Oregon since 2004. The goal is to cover the entire state as funding for data collection becomes available. Funding comes through the Oregon Lidar Consortium, which is a wide-ranging partnership of government agencies that pool funds through DOGAMI.

You can learn more about lidar and view lidar images of other parts of Oregon at www.OregonGeology.org and www.OregonGeology.org/dogamilidarviewer/.

NATIONAL PARK TRAILS

Trail Name	Round Trip Mileage	Map Location
Annie Creek Canyon	2.1	G4, H4
Bert Creek	3.1	C1-2, D1-2
Castle Crest Wildflower	0.4	G5
Cleetwood Cove	2.1	C6
Crater Peak	6.3	G5, H5
Crater Rim (One-Way, Rim Village to Merriam Point)	6.7	E4, F4
Discovery Point (From Rim Village)	3.4	F4
Fumarole Bay	1.6	E4, F4
Garfield Peak (From Rim Village)	2.8	F4-5
Godfrey Glen	1.2	G4, H4
Lady of the Woods	0.4	G4
Mount Scott	4.5	F7
Pacific Crest (One-Way, Within Crater Lake N. P.)	32.3	A6 at top to I3 at bottom
Pinnacles	1.3	H8
Plaikni Falls	1.9	F6-7
Stuart Falls	11.0	H4, I3-4
Sun Notch	0.5	F5, G5
Union Peak	10.7	G3, H2-3
The Watchman (From Watchman Overlook)	1.9	E4
Wizard Island	2.4	E4, F4

LEGEND

Highway
National Park Primary Route
Improved Road
Unimproved Road
Trail
Pacific Crest National Scenic Trail
2.2 Lidar-Derived Trail Segment Mileage
National Park
National Forest
Wilderness Area
State Forest
126 Oregon State Highway
NF 210 Forest Service Road

6,517 Lidar-Derived Elevation (feet)
5,936 U. S. Geological Survey Elevation (feet)
4,945 Trail Elevation (feet)
Information
Entrance Station / Park Headquarters
Restrooms
Trailhead
Campground
Backcountry Camp Site
RV Camping
Picnic Area
Lodging
Showers
Gas Station
Dining
Food
Viewpoint
Tour Boat Landing
Sno-Park

Scale 1: 63,360
0 0.5 1 1.5 2 Miles
0 0.5 1 1.5 2 Kilometers
Map coordinates in degrees, minutes, seconds

N MN 15° 2013 Magnetic Declination

GEOLOGY

Introduction

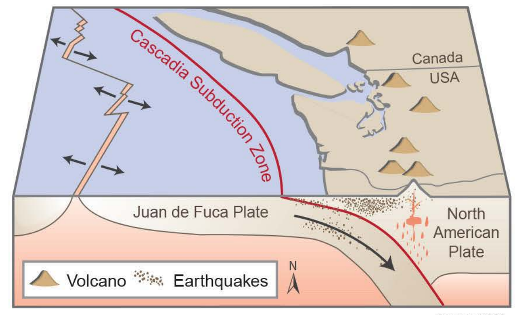
The area encompassed by Crater Lake National Park is underlain by a variety of volcanic rocks that record more than 500,000 years of complex volcanism in this part of the Cascade volcanic arc. Early eruptions in this area built an imposing volcanic mountain known as Mount Mazama. Mount Mazama, constructed of overlapping shield and composite volcanoes, is estimated to have attained an elevation of about 12,000 feet. At its zenith, the mountain was also mantled by a number of glaciers, as indicated by U-shaped valleys cut into the remaining lower flanks of the volcano. Many of these cutoff U-shaped valleys can be seen today around the rim of Crater Lake at places such as Kerr Notch (F6) and Sun Notch (F5).

About 7,700 years ago, Mount Mazama cataclysmically erupted and collapsed, leaving the 5-mile-wide caldera that Crater Lake occupies today. The caldera-forming eruption has been followed by sporadic volcanic activity, some of which formed new topographic features, such as Wizard Island (E4, F4). The caldera has also been half-filled by a lake that reaches a maximum depth of 1,943 feet. Signs of past volcanic activity can be seen throughout Crater Lake National Park in the many creatively named volcanic landforms. While these features give us clues to the region's tumultuous volcanic past, they also remind us that the volcano may erupt again and pose threats to human activity.

Phantom Ship (F6) is made up of the oldest exposed rock in the Crater Lake caldera (about 400,000 years old). This 175-foot-tall island is composed of remnants of altered but highly resistant andesite and dacite lava flows that predate Mount Mazama.

Cascade Volcanoes

Crater Lake is located in the southern part of the Cascade Range, a north-south trending mountain range extending from southern British Columbia to northern California. The glacier-covered volcanic peaks of the Cascades commonly stand a mile or more above the surrounding landscape, making them distinctive among mountains in the contiguous United States. These volcanoes are generally isolated from each other, allowing individual peaks to visually dominate the landscape for 50 to 100 miles in every direction. The chain of volcanoes that makes up the Cascade Range is the result of long-lived plate tectonic interactions in the region. The Cascade volcanoes form a volcanic arc that lies to the east of and parallel to the offshore Cascadia subduction zone, where the Juan de Fuca plate and the North American plate collide at rates of 1 to 4 inches per year. As the eastward moving Juan de Fuca plate plunges, or "subducts," beneath the westward moving North American plate, mantle rocks melt above the subducting plate at a depth of about 25 miles. The resulting pockets of magma may ascend through weak zones such as fractures and faults. Magma that reaches shallow parts of the Earth's surface may erupt explosively (pyroclastic eruptions) or may ooze quietly (lava flows) depending on magma chemistry, gas content, temperature, and pressure conditions.

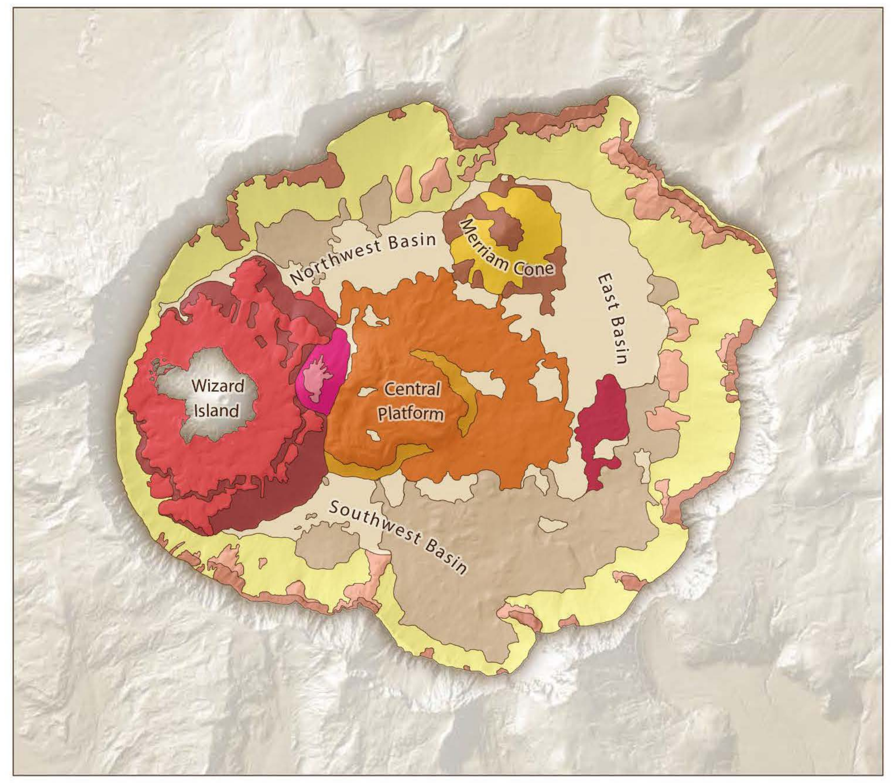


Source: USGS

Tuff spires preserved in The Pinnacles (H7-8, reverse side) are formed in pyroclastic flow deposits related to the 7,700-year-old cataclysmic eruption that formed Crater Lake caldera. The Pinnacles are the hollow cores of fumaroles; vents formed by escaping volcanic gases through ash and pumice deposits. As these areas erode, the harder, cemented cores of these fumaroles remain, forming the rocky spires of The Pinnacles.

The type of volcano produced by an eruption is generally controlled by the silica content of the lava it erupts. Silica or silicon dioxide is the same chemical compound that occurs naturally as quartz. Lava with low silica content is relatively fluid and can spread out over large distances to produce a very broad volcanic cone, or shield volcano, whereas lava with intermediate and higher silica content is more viscous and tends to accumulate around the volcanic vent and produce a steep volcanic cone. The tall volcanic peaks in the Cascades are predominantly composed of lavas with an intermediate composition called andesite and dacite. In addition to being more viscous, lavas of this type have a tendency to trap gas. This trapped gas can produce violent explosions as the molten rock nears the surface and pressure decreases. The released gas propels lava and preexisting rock into the air, producing pyroclastic (literally "fire fragments") material. Because volcanoes of intermediate silica composition can produce both lava flows and explosive eruptions, they are typically composed of alternating layers, or strata, of these materials. Volcanoes built by these eruptions are called composite volcanoes.

Pumice Castle (F6), the colorful formation exposed on the eastern rim of the caldera, is made up of layers of welded and nonwelded air-fall pumice and ash. These pyroclastic deposits and related dacitic lavas erupted east of the caldera around 70,000 years ago.



Adapted from USGS

Lake Bottom Geology of Crater Lake

Within a few hundred years after the cataclysmic eruption and collapse of Mount Mazama, volcanic activity in the newly formed caldera produced several volcanic landforms: Wizard Island, Merriam Cone, and the Central Platform. Of these, only Wizard Island currently appears above the water surface. In addition, a rhyodacite dome formed about 4,800 years ago east of Wizard Island. Several areas of landslides and debris flows blanket the lake bed, and around the edge of the lake Mount Mazama rock and pre-Mazama rock are also exposed.

Approximate age: 7,700 years to present

- Sediment gravity flow deposits
- Talus and debris-flow deposits
- Landslide and debris-avalanche deposits

Approximate age: 4,800 years

- Rhyodacite lava and breccia

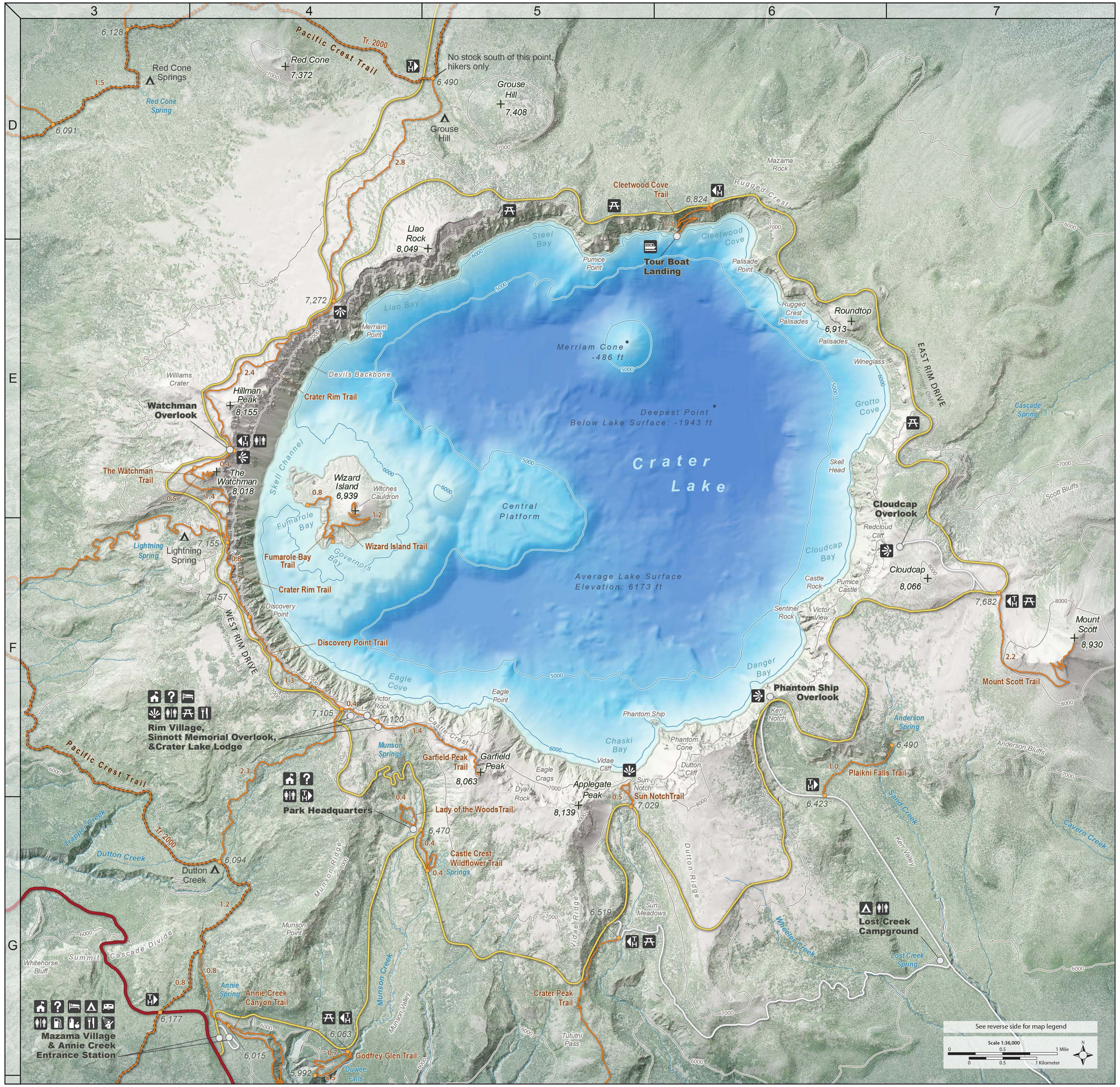
Approximate age: 7,700-6,950 years

- Wizard Island andesite, lava and breccia
- Merriam Cone andesite, lava and breccia
- Central Platform andesite, lava and breccia
- East Basin andesite

Approximate age: 7,700 years and older

- Mount Mazama andesite and dacite
- Pre-Mazama rocks, undivided

Wizard Island (E4, F4) is a cinder cone that forms the upper part of a large andesitic lava platform that resides below the surface of Crater Lake in the western edge of the caldera. The andesitic lavas and cinder cone erupted within a few hundred years after the eruption and collapse of Mount Mazama. The summit of the island is about 760 feet above the lake surface, is 2,500 feet above the adjacent caldera floor, and has a crater 90 feet deep.

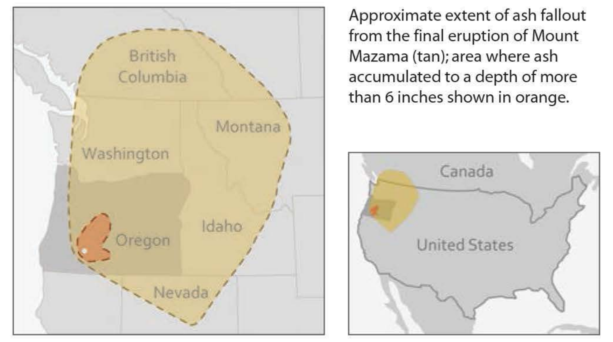


ERUPTIVE HISTORY

Mount Mazama

The eruptive history of Crater Lake started about 420,000 years ago with the eruption of Mount Scott (F7). Several overlapping shield and composite volcanoes formed over the next few hundred thousand years, forming what is now referred to as Mount Mazama. About 30,000 years ago, the magma became more silica rich. Explosive eruptions and thick lava flows resulted. Redcloud Cliff (F6) and Grouse Hill (D5) were two of the silica-rich flows that erupted between 30,000 and 25,000 years ago. About 7,900 years ago an eruption that created the ash, pumice, and lava that compose Llao Rock (E4-5) occurred. Eruptions built up until approximately 7,700 years ago with the cataclysmic eruption and collapse of Mount Mazama: the largest known eruption in the Cascade Mountains.

Mount Mazama's final eruption began at one vent on the mountain's northeast side, where a cloud of ash and pumice was sent 30 miles into the atmosphere. This cloud was blown northeastward, and layers of ash were deposited as far away as British Columbia. So much magma was ejected from the volcano that the summit began to collapse. When the collapse started, cracks opened up around the flanks of the volcano, and pyroclastic flows were sent down all sides of the mountain. When the eruption came to an end, a caldera 5 miles wide and nearly 1 mile deep remained.

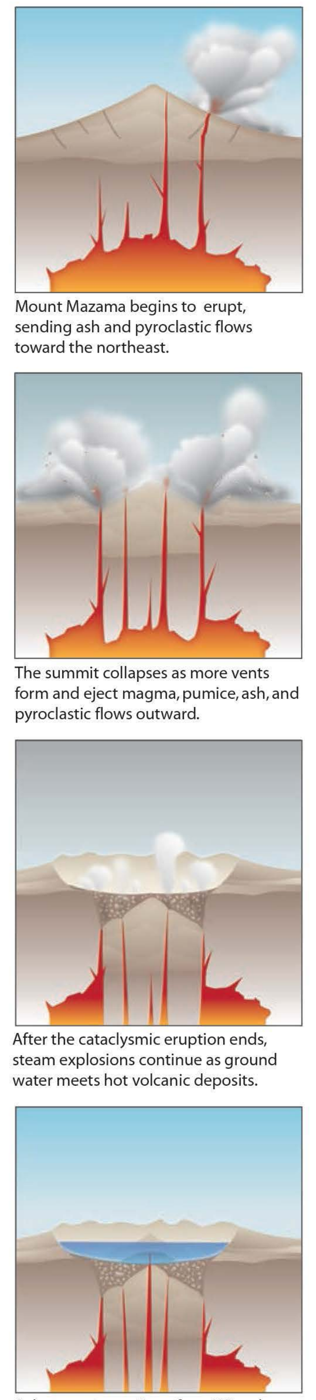


Approximate extent of ash fallout from the final eruption of Mount Mazama (tan); area where ash accumulated to a depth of more than 6 inches shown in orange.

The Caldera

Within 750 years following the collapse of Mount Mazama, eruptions in the caldera created new landforms, all of which except Wizard Island (E4, F4) are now underwater. While the caldera began to fill with rainwater and snowmelt, eruptions created what is now Wizard Island, the Central Platform (E5, F5), and Merriam Cone (E5). Crater Lake's water volume was limited by porous rock in the northeast wall of the caldera, which now serves as a drain and water level regulator for the lake. The last volcanic eruption at Crater Lake occurred about 4,800 years ago with the growth of an underwater rhyodacite dome on the eastern flanks of Wizard Island. Several large landslides have also added sediment to the lake bottom over the years.

Mount Mazama and the Formation of Crater Lake (Adapted from USGS)



Mount Mazama begins to erupt, sending ash and pyroclastic flows toward the northeast.

The summit collapses as more vents form and eject magma, pumice, ash, and pyroclastic flows outward.

After the cataclysmic eruption ends, steam explosions continue as ground water meets hot volcanic deposits.

Subsequent eruptions form Wizard Island. The caldera fills with water, creating Crater Lake.

Volcanic Deposits and Hazards

Source: USGS

LAVA FLOWS and DOMES Lava is molten rock that flows onto the Earth's surface. Lava flows move downslope away from a vent and bury or burn everything in their paths. Lava domes form when lava piles up over a vent.

PYROCLASTIC FLOWS Pyroclastic flows are high speed avalanches of hot rock, gas, and volcanic ash that are formed by the collapse of lava domes or eruption columns. They can move up to 100 miles per hour and have temperatures to 1,500 °F. They are lethal, burning, burying, or asphyxiating all in their paths.

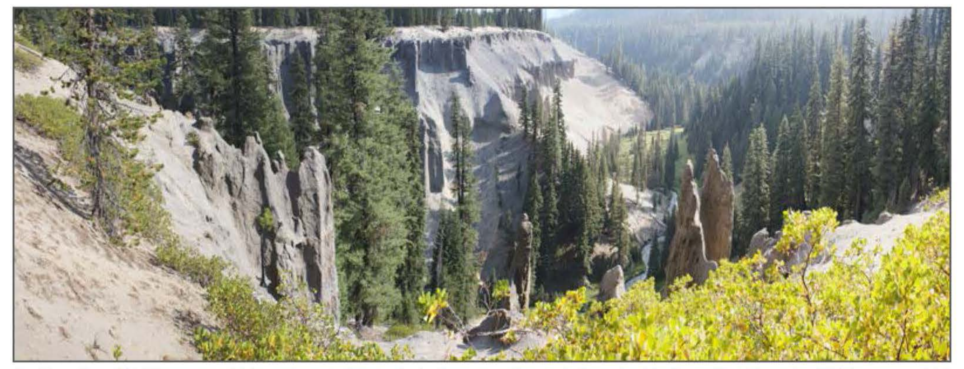
TEPHRA Explosive eruptions blast lava fragments (tephra) and gas into the air. Tephra can also be carried aloft in billowing volcanic ash clouds above pyroclastic flows. Large fragments fall to the ground close to the volcano, but smaller fragments (volcanic ash) can travel hundreds to thousands of miles downwind.

DEBRIS AVALANCHES and LAHARS Debris avalanches are rapidly moving landslides of rock, soil, and overlying vegetation, snow, or ice. They can bury or smash objects in their path. All or some portion of debris avalanches can transform into lahars. Lahars are fast-moving slurries of rock, mud, and water that move down river valleys. They can bury, move, or smash objects in their path. Lahars form when pyroclastic flows melt snow or ice, or by the transformation of debris avalanches, or by mobilization of loose debris on the flanks of volcanoes.

FUTURE VOLCANIC ACTIVITY

Given its long record of volcanic activity, Crater Lake will likely erupt again. Because the most recent activity was on the lake floor in the caldera, the floor will most likely be the region of renewed eruption. Shallow eruptions in the lake could produce violent explosions and pyroclastic surges that could eject rock, ash, and hot gases outside the caldera, possibly even miles away. Cataclysmic eruptions, such as the one that caused Mount Mazama's ultimate collapse, are rare. Landslides and earthquakes are also potential hazards in this area, due to the West Klamath Lake Fault Zone, which crosses the region. A large regional earthquake, up to magnitude 7.0 (Richter scale), is possible. However, events of this magnitude occur infrequently.

Staff at the Oregon Department of Geology and Mineral Industries and the USGS Cascades Volcano Observatory study the risks, assess the vulnerabilities to a volcanic eruption, and work to mitigate the effects of the volcanic hazards.



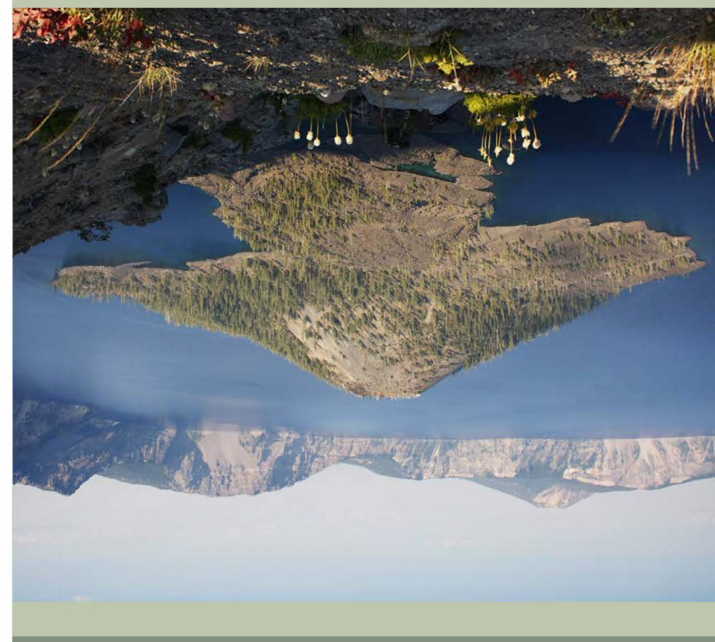
Godfrey Glen (G4, H4, reverse side), southeast of Crater Lake, has many fins and pinnacles (similar to The Pinnacles [H7-8, reverse side] area) that are the hollow cemented cores of fumaroles. In this area, Munson Creek has eroded through the ash and pumice, leaving only the resistant formations behind.

NPS AND NFS CONTACTS

Crater Lake National Park	Umpqua National Forest	Rogue River-Siskiyou National Forest
P.O. Box 7	Supervisor's Office	3040 Biddle Road
Crater Lake, OR 97604	2900 NW Stewart Parkway	Medford, OR 97504
(541) 594-3000	Roseburg, OR 97471	(541) 618-2200
http://www.nps.gov/crla/	(541) 957-3200	http://www.fs.usda.gov/rogue-siskiyou/
	http://www.fs.usda.gov/umpqua/	

Oregon Department of Geology and Mineral Industries

CRATER LAKE
GEOLOGIC GUIDE and RECREATION MAP



CRATER LAKE GEOLOGIC GUIDE AND RECREATION MAP

As part of the public education program at the Oregon Department of Geology and Mineral Industries, we are pleased to provide this guide to the Crater Lake region. The topographic maps shown in this guide are based on lidar technology — a new, highly accurate way to map the ground surface. Learn more about how DOGAMI is mapping Oregon with lidar by visiting our web site, **www.OregonGeology.org**.

Vicki S. McConnell, Oregon State Geologist

ACKNOWLEDGMENTS

Cartography: Daniel E. Coe, DOGAMI
Photographs: Daniel E. Coe, Lina Ma, DOGAMI
Text: Jason D. McClaughry, Daniel E. Coe, DOGAMI

Plate Tectonics and Volcanic Deposits and Hazards diagrams modified from:
Gardner, C.A., Scott, W.E., Major, J.J., and Pierson, T.C., Mount Hood—history and hazards of Oregon's most recently active volcano: U.S. Geological Survey Fact Sheet 060-00, 3 p. http://pubs.usgs.gov/fs/2000/fs060-00/

Mount Mazama Ash diagram adapted from:
Williams, H., and Goles, G., 1968, Volume of the Mazama ash-fall and the origin of Crater Lake Caldera, in Andesite Conference Guidebook, Dole, H.M., and Newhouse, C.J., eds.: Oregon Department of Geology and Mineral Industries Bulletin 62, p. 37-41.

Mount Mazama and the Formation of Crater Lake diagrams adapted from:
Klimasauskas, E., Bacon, C.R., and Alexander, J., 2002, Mount Mazama and Crater Lake: growth and destruction of a cascade volcano: U.S. Geological Survey Fact Sheet 092-02, 4 p.

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Bacon, C.R., and Lanphere, M.A., 2006, Eruptive history and geochronology of Mount Mazama and the Crater Lake region, Oregon: Bulletin of the Geological Society of America, v. 118, no. 11-12, p. 1331-1359. doi: 10.1130/B25906.1

Harris, S.L., 2005, Fire mountains of the West: the Cascade and Mono Lake volcanoes, 3rd ed.: Missoula, Mont., Mountain Press, 454 p.

Lake Bottom Geology of Crater Lake map references:
Bacon, C.R., Gardner, J.V., Mayer, L.A., Buktenica, M.W., Dartnell, P., Ramsey, D.W., and Robinson, J.E., 2002, Morphology, volcanism, and mass wasting in Crater Lake, Oregon: Geological Society of America Bulletin, v.114, p. 675-692.

Base map data references:
Robinson, J.E., 2012, High-resolution digital elevation dataset for Crater Lake National Park and vicinity, Oregon, based on LiDAR survey of August-September 2010 and bathymetric survey of July 2000: U. S. Geological Survey Data Series 716. http://pubs.usgs.gov/ds/716/

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Charles R. Bacon and Joel E. Robinson, U.S. Geological Survey, and Chris Wayne, U.S. National Park Service, provided helpful comments in the preparation of this map.

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