CRATER LAKE

by

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Crater Lake lies inside the top of an ancient volcano called Mount Mazama. This ancient volcano is one in a north-south chain of huge cones built during the last few millions of years along the crest of the Cascade Range, stretching about 600 miles from Lassen Peak in California northward to Mount Garibaldi near Vancouver, British Columbia. Other conspicuous volcanoes in the chain include Mounts Shasta, Jefferson, Hood, Saint Helens, Adams, Rainier, and Baker.

About 80 million years ago, in what geologists call the Late Cretaceous epoch, most of western Oregon, including the present site of the Cascade Range, lay beneath the Pacific Ocean. Earth movements then uplifted the land, shifting the coast westward to the present western foothills of the Cascade Range. Volcanic eruptions began about 50 million years ago, and they have continued at intervals down to historic times. The lavas and ashes discharged by the early eruptions over a period of more than 40 million years accumulated in some places to a thickness of more than 2 miles. They can now be seen all along the western slopes of the Cascade Range as well as in various parts of central and eastern Oregon. Strangely enough no high mountains were formed by these vast piles of volcanic rocks, for the underlying floor sank as fast as the rocks accumulated. Thus redwood forests continued to grow in eastern Oregon until about 10 million years ago. There was no mountain range like the present Cascades to check rain-laden winds from the ocean from spreading far inland. Subsequently, the ancient lavas and ashes were upheaved to produce the original Cascade Range, and ever since the rich flora on the wet slopes to the west has contrasted with the desert flora on the plateau to the east.

During the uplift and after, many north-south cracks opened beneath the present summit of the Cascade Range. Countless eruptions of fluid, wide-spreading flows of basaltic lava from these cracks gradually built a chain of coalescing "shield volcanoes", shaped like giant, overturned saucers, and not unlike those now active on the island of Hawaii. By the close of the Pliocene epoch about 2 million years ago, the crest of the Cascade Range had become a high plateau capped by many of these gently sloping shields.

During the following Pleistocene epoch, that is to say during the last Ice Age, most of the Cascade volcanoes became more explosive. The lavas they erupted, changing gradually in composition from basalt to andesite, became more viscous and therefore could not spread as far from their sources as did those of the earlier shield volcanoes.

Hence, the broad, low shields were partly or entirely buried beneath steeper sided volcanic cones. Some of these cones were deeply eroded by glaciers so that the hard fillings of their central feeding pipes now stand out as summit pinnacles, like miniature Matterhorns. Among such eroded cones are Union Peak, 7 miles southwest of the lake, and Mount Thielsen, 12 miles north of the lake.

Mount Mazama, the volcano that enclosed Crater Lake, began to grow about a million years ago, while the neighboring Union Peak and Mount Thielsen volcanoes were in their dying stages of activity. It rose from a foundation of older volcanic rocks between 5,000 and 6,000 feet above sea level, and it probably attained a maximum elevation of more than 12,000 feet. At no time was it merely a single cone; the central, highest cone always had several smaller, parasitic cones on its sides. The volcano grew almost entirely by eruption of andesitic lavas and ashes from closely spaced vents, and while it grew, glaciers advanced and retreated on its flanks may times. Clear evidence of glaciation can be seen on the walls of Crater Lake, particularly on the northern wall and on the eastern wall near Redcloud Cliff, where layers of volcanic rock alternate with layers of silt, sand, gravel, and boulders laid down by ancient glaciers and by the rivers which they fed. The last glaciers, moving slowly down the sides of the volcano, polished, grooved, and scratched the lava surfaces in their path, as can be seen in many places along the rim of Crater Lake. The glaciers also carved deep U-shaped canyons on the slopes of the volcano, such as those responsible for Sun and Kerr Notches on the crater rim. And as the glaciers melted they left irregular piles or moraines of bouldery debris on the floors of the valleys, such as may be seen, for example, in Munson Valley between Park Headquarters and the crater rim.

When the glaciers reached their maximum size, about 25,000 years ago, some of them were more than 1,000 feet thick, and some spread down the mountainsides for distances of 10 to 17 miles. Except for a few narrow ridge-crests, the entire volcano was sheathed in a mantle of ice.

Later, while the glaciers were making their final slow retreat and were confined to the bottoms of the canyons on the upper slopes of the volcano, a semi-circular line of parasitic volcanoes developed on the northern side of Mount Mazama, about 5,000 feet below the summit, along what is now the northern rim of Crater Lake. Many thick flows of lava issued from this northern arc of vents, among them the andesites that formed the Watchman and Hillman Peak, and the glassy dacites that form Llao Rock, the Cleetwood Cove flow, and the great V-shaped Redcloud Cliff. The feeding pipes of all these lavas are to be seen on the walls of Crater Lake. Many cones of red and black basaltic cinders erupted on the lower flanks of the mountain at approximately the same time the northern arc of vents was active, and several large dome-shped hills of andesite and dacite lava were formed close to the eastern foot of Mount Mazama. Explosions of dacite pumic also took place from craters near the summit.

A long interval of quiet followed. The glaciers retreated still farther up on the mountainsides until only three tongues extended below the present rim of Crater Lake for a mile or so, one passing through Kerr Notch, a se cond through Sun Notch, and a third down Munson Valley as far as Park Headquarters. As the glaciers retreated, forests spread upward in their wake. Trees three feet or more in diameter grew along what is now the south rim of the lake.

During this long spell of calm, the liquid magma in the feeding chamber of Mount Mazama, perhaps 2 or 3 mile underground, was slowly crystallizing. Heavy crystals sank in the liquid while gases rose toward the top of the chamber. In this way a relatively light, gas-rich liquid containing only a few crystals came to overlie a heavier liquid containing less gas but charged with abundant crystals. In bried, gas-rich dacite magma poor in crystals came to overlie gas-poor basaltic magma crowded with iron-rich minerals. The stage was set for the cilmactic outbursts that were to destroy the top of Mount Mazama and in doing so produce the colossal basin that holds Crater Lake.

Characteristically, the gas pressure was at its greatest during the initial stages of these culminating eruptions. Hence the dacite magma that was first discharged was blown high above the mountaintop as fine, incandescent spray that fell to earth as fragments of frothy white pumice, mostly of sand size or even finer. As the eruptions continued and the gas pressure diminished, the size of most of the falling fragments of pumice increased, and the winds veered northeast, toward the present city of Bend. Some of the fine pumic has recently been identified as far away as Alberta, Canada, and much of it must have risen into the stratosphere to cause brilliant sunrises and sunsets all over the Northern Hemisphere. The total area covered by falling pumice was more than 350,000 square miles, and no less than 5,000 square miles were buried to a depth of 6 inches, as shown on the map below. All of eastern Oregon and eastern Washington, blanketed by white pumice, must have had a wintry aspect, as if covered by a heavy fall of snow. How long these high-pressure initial eruptions lasted cannot be told with certainty, but by comparison with the famous eruptions of Krakatoa in Indonesia in 1883, perhaps they lasted no more than a few months or years.

The eruptions then changed radically in character. When the upper, gas-rich layers of the feeding chamber had been discharged, the lower layers of dacite liquied foamed to the surface. Part of the liquid continued to be blown high above the volcano producing showers of pumice, but most of it rose only a short distance, foaming over the rims of the craters and then avalanching down the mountainsides as glowing pumice fragments, often moving at speeds of more than 50 miles an hour. Some of the avalanches rushed down the old U-shaped glacial valleys; those that emptied into the valley of the Rogue River did not stop until they had traveled 35 miles, even though much of their path lay through dense forests. North and east of the volcano where there were no deep canyons to confine the avalanches, they spread in wide sheets, some pouring into Klamath Marsh while others swept by the present site of Chemult with such speed that they traveled 25 miles from their source, across a plateau and even uphill. Such was the mobility of these incandescent, turbulent avalanches that lumps of pumice 14 feet in diameter were carried for a distance of 20 miles.

Shortly before the discharge of glowing avalanches ended, the lower levels of the feeding chamber were tapped, so that white sheets of dacite pumice were buried in places by avalanches of darker basaltic scoria very rich in crystals, still visible on the walls of the canyon of Annie Creek, or even more clearly, at the Pinnacles on Sand Creek. Finally, after a few weak, dying explosions, the great eruptions ceased. All of the wooded glacial canyons on the slopes of Mount Mazama had been utterly devastated, choked to depths of 300 feet or so by deposits of hot pumice and scoria, which continued to give off acid fumes for many years. Each canyon had been changed to a "Valley of Ten Thousand Smokes", like the one formed in Alaska in 1912 when a green valley was similarly filled by glowing avalanches of pumice. Even more dramatic was the change in the form of Mount Mazama. The high, ice-clad peak, long a familiar landmark to the Indians, had vanished, and in its place was an awesome pit, a caldron between 5 and 6 miles wide and 4,000 feet deep, on the bottom of which were countless fumaroles and boiling pools. For miles in all directions, the dreary wastes of pumice and scoria were made still more desolate by the charred ruins of the former forests.

Seventeen cubic miles of the mountaintop had disappeared. How did it happen? Surely the volcano had not simply "blown its top". Had the peak been demolished by explosions, enormous volumes of coarse, blocky debris would be found along the rim of Crater Lake and stretching thence for many miles. There is no sign of such debris; in many places, indeed, ice-scratched surfaces of lava are still exposed along the rim of the caldera, and elsewhere the old lavas of the volcano are thickly covered by pumice.

By far the greater part of the material blown out during the climactic eruptions was fresh magma emptied from the chamber beneath the volcano. The volume of materail that fell in showers during the early stages amounts to about 3-1/2 cubic miles, of which only a very small proportion consists of bits of old lava torn from the top of Mount Mazama; the rest consists of frothy fragments of pumice and their included crystals. The volume of the glowing avalanches of white pumice and dark basaltic scoria amounts to about 8 cubic miles. Perhaps 15 to 20 percent of this volume is made up of fragments from the old mountaintop; the remainder represents fresh magma from the underlyin g reservoir. Weak, dying explosions added about a quarter of a mile to the total volume. All told, approximately 12 cubic miles of material were discharged, and, as at Krakatoa in 1883, it was principally the rapid escape of enormous volumes of fresh magma which, by draining the feeding reservoir, caused the top of the volcano to collapse.

But it cannot have been only the eruption of magma that brought about the great engulfment. Approximately 17 cubic miles of Mount Mazama disappeared while only about 12 cubic miles of material erupted. Approximately one-tenth of the missing 17 cubic miles of the volcano was blown away in fragments; and, if one takes into account the bubbles in the fragments as they now lie on the ground, the volume of liquid and crystals erupted from the reservoir was considerably less than 10 cubic miles. One seems forced tp conclude that the volume of Mount Mazama that collapsed into the depths was very much more than the volume of magma that was erupted. It is probable, therefore, that during or just before the great eruptions, part of the reservoir was drained by injection of magma into cracks in the walls or by withdrawal in some other fashion. It was by a combination of underground drainage and explosive eruptions that the reservoir was drained sufficiently to cause its roof to cave in, carrying with it the entire top of Mount Mazama. And no doubt the collapse took place very rapidly, possibly within a few days, as it did in Krakatoa in 1883.

The collapse was eccentric with respect to the former top of Mount Mazama, for the top lay well to the south of the center of Crater Lake; that is why the southern wall of the lake is much higher than the northern counterpart. It was the presence of the semi-circular line of weakness, represented by the northern arc of vents, that caused this eccentric collapse.

When did these dramatic events take place? Judging by the lengths of the glaciers on Mount Mazama immediately before the great eruptions, and by a study of pollen in peat deposits overlying some of the pumice deposits, it had been calculated tentatively that Crater Lake was formed between 4,000 and 7,000 years ago. When the radiocarbon method of dating developed, tests revealed that charcoal logs within the glowing avalanche deposits were burned 6,600 years ago. This, then, is the age of Crater Lake. Discovery of obsidian tools, spear throwers, sandals, and other artifacts beneath the pumice to the north and east of Crater Lake indicates that Indians must have witnessed the destruction of Mount Mazama.

After a quiet period of unknown duration, eruptions began anew, but now they were confined to the floor of the caldera (the geologic term for a large circular volcanic depression). A detailed bathymetric survey of Crater Lake, made by the U. S. Coast and Geodetic Survey in 1959 (shown below) shows a cone, almost a mile wide and 1,300 feet high, not far from the northern wall. This has been named the Merriam Cone, and samples dredged from its sides show that it is built of andesitic cinders. An extensive flat area, including the deepest part of the lake (322 fathoms or 1,932 feet) adjoins this submerged cone; perhaps it was formed when a lava flow was erupted from the base of the cone. The angle of the slope of the cone suggests that these eruptions took place above water, when Crater Lake was extremely shallow.

After Merriam Cone had been formed, activity moved to the western part of the caldera, and another large cone of andesitic cinders developed, ultimately forming Wizard Island. Many flows of andesitic lava were discharged from fissures on the flanks of this cone, the last of them after the explosions of cinders had ended. The longest flows spread eastward for about 2 miles (as may be seen on the map), and at one place, not far from Wizard Island, a small conical hill of dacite lava rises above them. This hill consists of dacite lava similar to that forming Llao Rock, but whether it was erupted before or after the andesitic lavas is still undetermined.

The oldest trees on Wizard Island are reported to be about 800 years of age; the final eruptions within Crater Lake may therefore have taken place less than 1,000 years ago. Today there are no hot springs or hot gas vents within or near the lake to suggest that any magma remains underground, but whether Mount Mazama is dead or merely dormant we cannot say.

Crater Lake is the deepest body of fresh water in the United States, and its water is of exceptional purity. It was formed almost entirely by infalling rain and snow, springs and cascades from the walls contributing relatively little to its volume. The level of the lake varies only slightly with the seasons, being highest during the early summer when the snows are melting fastest, and lowest at the end of the season. Otherwise, the amount of water added every year keeps pace with that lost by evaporation and by percolation through the walls.