Volcanoes

by
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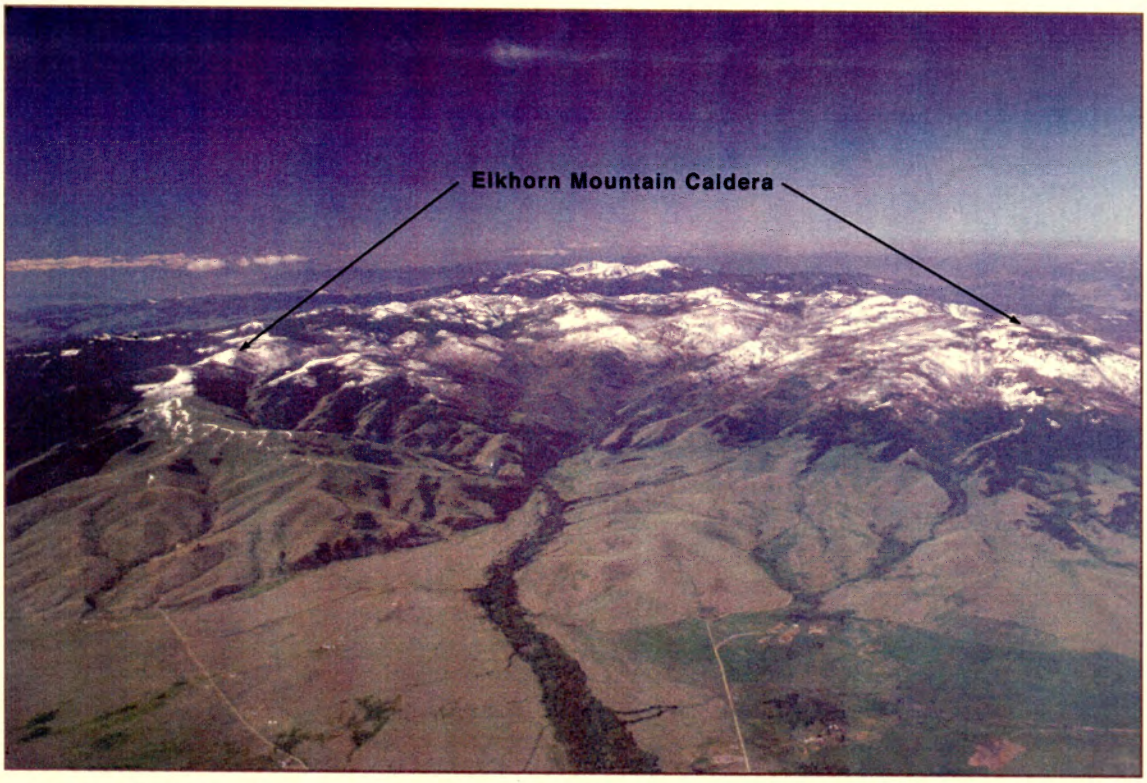
December 2002



You are looking southward at an eroded caldera that collapsed to form the northern end of the Elkhorn Mountains more than 65 million years ago.

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Volcanoes

Volcanoes come in all sizes and shapes, controlled largely by the composition of the lava. Lavas that contain about 50 percent or less of silica are classified as basalts and tend to be hot and fluid. Their lavas can flow long distances on gentle slopes to form large shield volcanoes. If the lava is highly gas-charged, it may explode at the surface to form cinder cones. Those that contain 65% or more silica are classified as rhyolites and tend to be thick and viscous. They tend to form thick, steep-sided flows and domes right over the vent. When the lava is highly gas-charged, they are extremely explosive. All that remains after an eruption may be just a gigantic hole in the ground. Their highly gas-charged fragmental lavas can cover huge areas as the explosions discharge the lava at high velocity, and the gas may continue to blow the lava apart as it travels across the ground. In between basalts and rhyolites are the andesites. They build the huge, steep, super volcanoes made of alternating viscous lava flows and fragmented lava blown out during explosive episodes. The alternating layers make the volcano unstable and prone to sudden collapse. The resulting volcanic mudflows, lahars, travel rapidly, like a slurry of concrete, to form a wide apron of overlapping mudflows at the base of the volcano.

Basalts

Basalt crystallizes from magma that has risen through the crust from the earth's upper mantle. It tends to be hot, thin, and fluid. Often, it accumulates in shallow magma chambers in the crust before erupting at the surface. While it is accumulating in the shallow chamber, it may absorb elements and minerals from the walls of the chamber to become more silicious. Its lighter fractions rise to the upper part of the chamber where the highly gas charged magma exerts more and more pressure against the overlying crust until it explodes to the surface. Expanding gases blow the magma apart and pulverize rock lining the vent to send ash clouds high into the atmosphere. Sometimes, high-speed ground-hugging surges plaster hot ash and mud on the surrounding countryside. Bright red fire fountains spew gas-charged lava from a few feet to several thousand feet above the vents. The lava that rains down from the fire fountains flows downhill away from the vent in molten streams and fingers. The surfaces of the fingers crust over to form lava tubes that can conduct molten lava within them for miles with little loss in temperature. If the magma loses much of its gas before arriving at the surface, it may accumulate in a lava lake whose level fluctuates with pulses in the eruption to overflow, subside, or discharge into lava tubes.

Explosive eruptions typically produce cinder cones made of loose and porous piles of ash, cinders, lapilli, and bombs, collectively known as tephra. Because the tephra is so permeable, little gully development takes place on the cones until the material weathers enough to form a soil. Most basaltic cinder cones are less than several hundred feet in height, perhaps because by the time they have grown that high, most of the highly explosive, gas-charged lava has been expended. If the rising magma has access to large volumes of water, the eruptions are even more explosive as the water flashes to steam. In steam-permeated tephra, silica is leached from the minerals and reprecipitated as cement between the particles as they accumulate, to form a rock called tuff. Because of the powerful explosions, cones made of tuff have larger craters than cinder cones, and runoff quickly incises gullies into their soft impermeable flanks.

Hot, plastic clots of lava that fall from the margins of fire fountains splat and weld themselves together around the vent to form spatter cones.

Quiet effusions of lava build up shield volcanoes around vents as their lava lakes overflow. Because basaltic lava flows so readily, the slopes of shield volcanoes tend to be gentle. When the magma withdraws and the eruption stops, a pit crater or pit caldera is left at the top of the shield. Calderas are distinguished from craters in being larger, more than one mile in diameter.

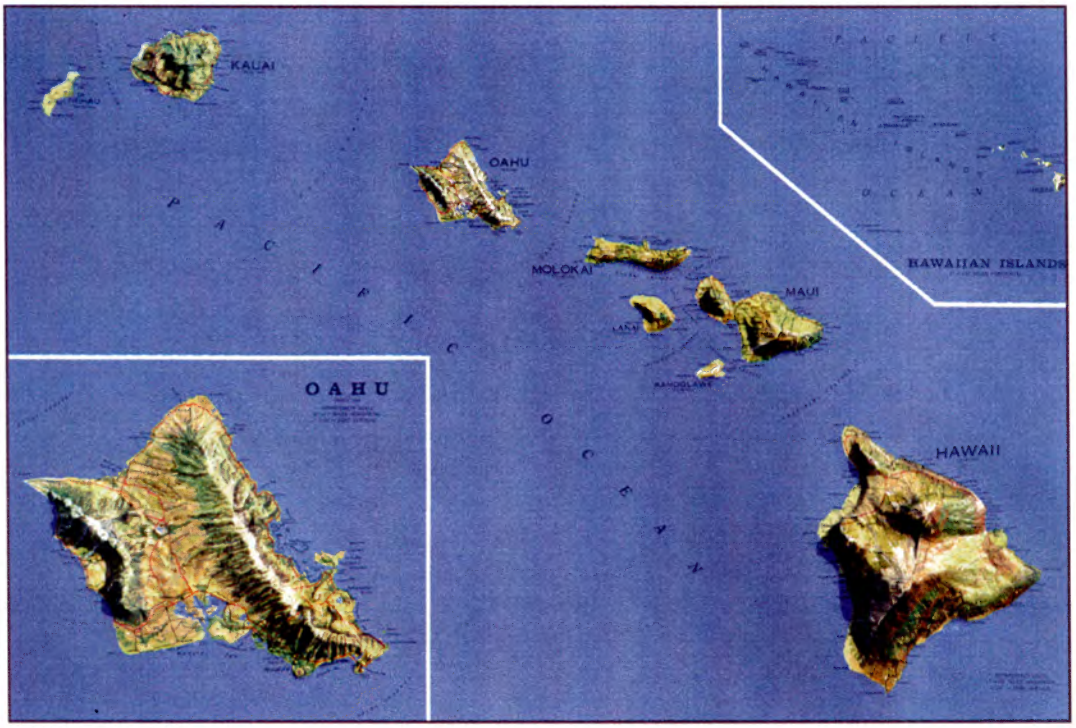
Characteristic features and structures produced by basaltic volcanism are illustrated in this booklet by photos taken in Hawaii, Iceland, and New Zealand.

Andesites & Rhyolites

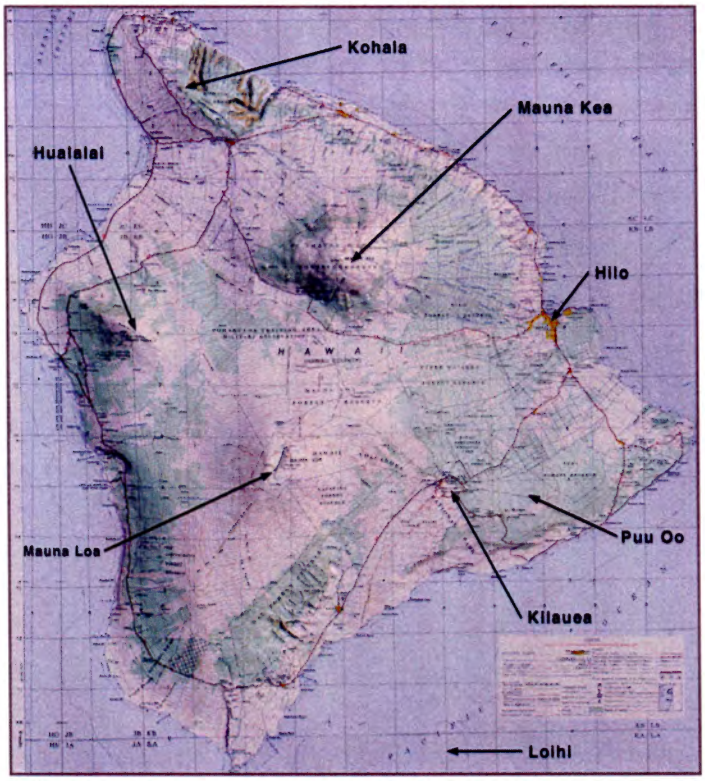
Rhyolite magmas contain the greatest percentage of silica, are the thickest, most viscous, and can be the most explosive of the rock melts. Andesites are intermediate in character between rhyolites and basalts.

Andesites tend to build large stratovolcanoes by explosive eruptions of ash, as air falls and ash flows, followed by effusions of viscous lava that pour over the edges of the vent. As the eruption subsides, lava that is too gas-depleted and cold to flow forms a dome (tholoid) over the vent. The cones tend to be unstable because thick massive flows rest at steep angles on layers and lenses of ash that may be altered and weakened by circulating hot acid water. Aided by melting of glaciers and torrential rains that accompany eruptions, parts of these volcanoes tend to collapse into gigantic mudflows. Hot and cold mudflows interbedded with air-fall ash, ash flows, and pyroclastic flows are the dominant deposits forming aprons of debris around andesite volcanoes. A pyroclastic flow is an ash flow that contains chunks of landslide debris and blown-apart volcano. Ash flows tend to range from being unstratified and unsorted to being poorly stratified and poorly sorted. Air-fall ash tends to be stratified and sorted, and may contain pisolites, ash hailstones. Mudflows contain a variety of debris in an unsorted and unstratified mass. Hot mudflows are stained red from the oxidation of iron minerals by the hot water and steam.

Rhyolite magmas are responsible for some of the largest and most explosive eruptions. The highly gas-charged magma initially explodes as it rises in a pipe or fissure, spreading air-fall ash over the countryside as it enlarges the vent. As the vent grows larger, the magma rises faster, exploding as it travels over the ground as ash flows at velocities generally exceeding 100 miles per hour. Their high speed and rapid-fire expulsion spreads them into sheets of ash that fill valleys and overtop divides. If they are hot enough, the glass shards in them weld together to form a welded tuff. Ash from the upper parts and far ends of the ash-flow clouds may spread as air fall wherever winds take it around the globe. Repeated eruptions from a central vent build a gently-sloping cone of air fall ash interbedded with welded and nonwelded ash flows, an ignimbrite shield. Expulsion of huge volumes of ash empties the magma chamber, and the top of the cone collapses into a caldera. Gas-depleted magma may pond within the caldera, and later intrusion of residual magma into the caldera may elevate part of the caldera into a resurgent dome. Lava may erupt as thick rhyolite flows and as volcanic domes. Rhyolite flows may break up into breccias rich in obsidian fragments that cooled rapidly as the lava broke apart over the tops and steep fronts of the viscous flows.



The Pacific Ocean crust is sliding northwestward over a mantle plume that builds islands of basalt, the oldest at the northwest end of the chain, the youngest at the southeast end. Active eruptions occur on the southeastern part of the Big Island of Hawaii and off its southeastern coast on Loihi, a submarine volcano.



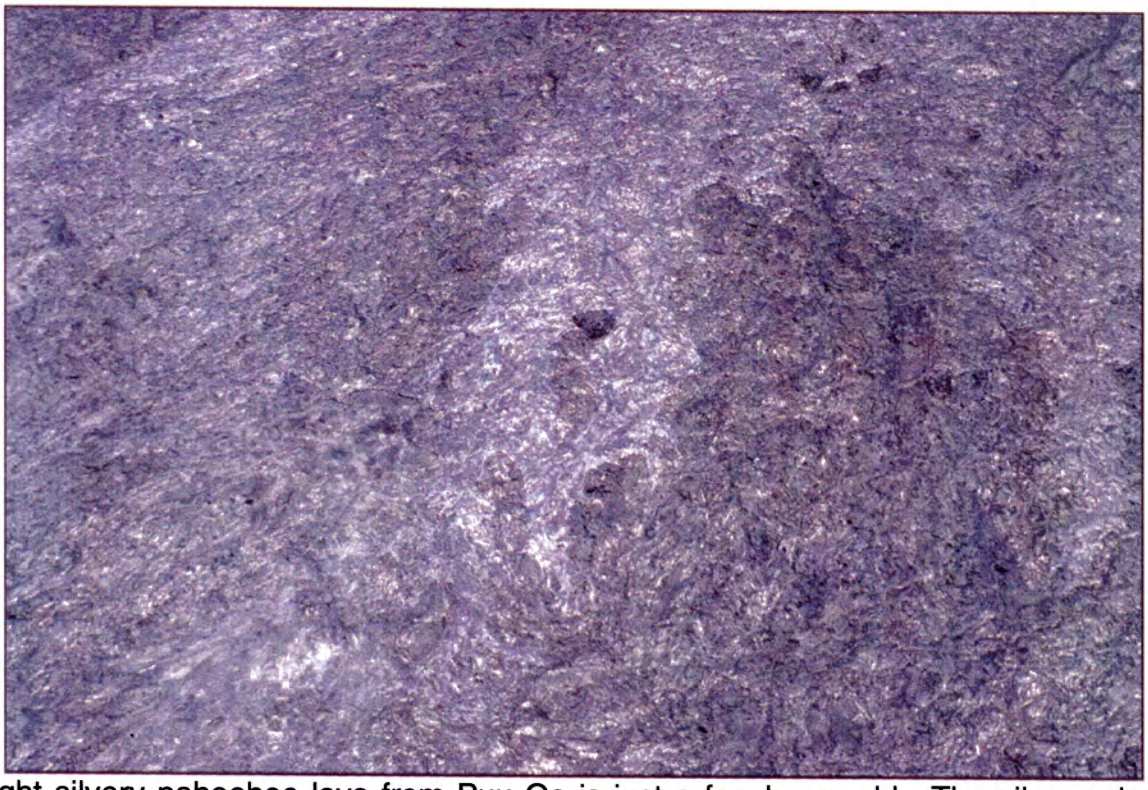
Recent volcanic activity has been concentrated at Puu Oo along a rift that extends eastward from Kilauea, though the Kilauea caldera, Mauna Loa, and perhaps Hualalai remain threats to erupt. Kohala's last eruption was about 100,000 years ago; that of Mauna Kea about 4500 years ago, and that of Hualalai in 1801. Mauna Loa has erupted 40 times since 1832, the last one in 1950. Kilauea caldera, formed in 1790, has erupted more than 20 times since 1924, but many episodes lasted only a day or two.

Halemaumau is a pit crater on the floor of Kilauea caldera that was greatly enlarged by steam explosions in 1924. "Bathtub rings" mark several temporary floors of the pit crater since then. The pit crater overflowed its western edge briefly in 9/74, and that lava subsided to form the present floor, part of which, on the right, has subsided a bit more. Fire fountains formed spatter cones during a 14 hour eruption on April 30, 1982 along an extension of the southwest rift on the floor of Kilauea caldera.

Keanakako'i ash blew out as pyroclastic surges and ash flows interspersed with air falls during the 1790 eruption that formed Kilauea caldera. Powerful explosions emptied the magma chamber and foundered a series of coalesced lava shields that filled an earlier caldera. Subsequent lavas from elsewhere in Kilauea's caldera cascaded into the southwest rift over the ash exposed by the rift. The cycle of caldera filling and collapse may continue with Kilauea as its next victim. View SW along the rift.

Puu Oo erupted in cycles from 1/83 to 7/86 with fire fountains that lasted about 13 hours followed by about 26 days of quiet. The eruptions then moved eastward along the rift until early 1991 when that vent, Kupaianaha, plugged and they returned to Puu Oo. Collapse of the cone's walls has enlarged the vent. Picture 7/17/95.

A thin crust of cracked lava covers the lava lake in Puu Oo's enlarged crater. The lava alternately erupts in low fire fountains, as shown here, and then subsides into underlying lava tubes. The level of the lava lake rises and falls as activity waxes and wanes, and lava occasionally overflows the crater lip in the foreground. Picture 1/8/98.



Bright silvery pahoehoe lava from Puu Oo is just a few hours old. The silver color is characteristic of basalt that has just formed a skin over the lava. As it cools and oxidizes, it turns darker. Picture 7/17/95.

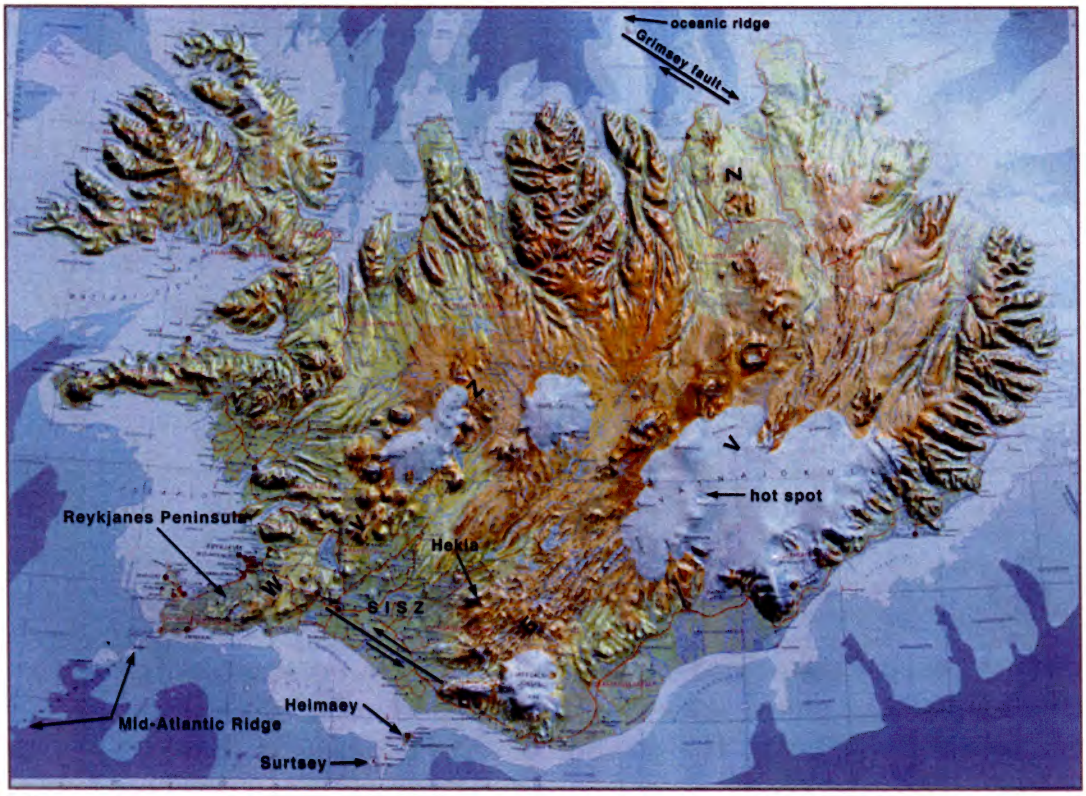
Steam rises through holes in the roof of a lava tube that drains the lava lake in Puu Oo. The steam oxidizes and stains the walls of Puu Oo red and yellow. Picture 12/31/2000.

Skylights in the roof of a lava tube reveal the molten lava flowing toward the sea from Puu Oo. Picture 1/8/98

Molten lava drops over the old sea cliff from the mouth of its lava tube and into another lava tube to then enter the sea in a cloud of steam. Picture 1/8/98.

Lava congealed around a tree trunk as the tree trunk ignited and burned out to leave a mold of the tree in a lava flow at Kilauea.

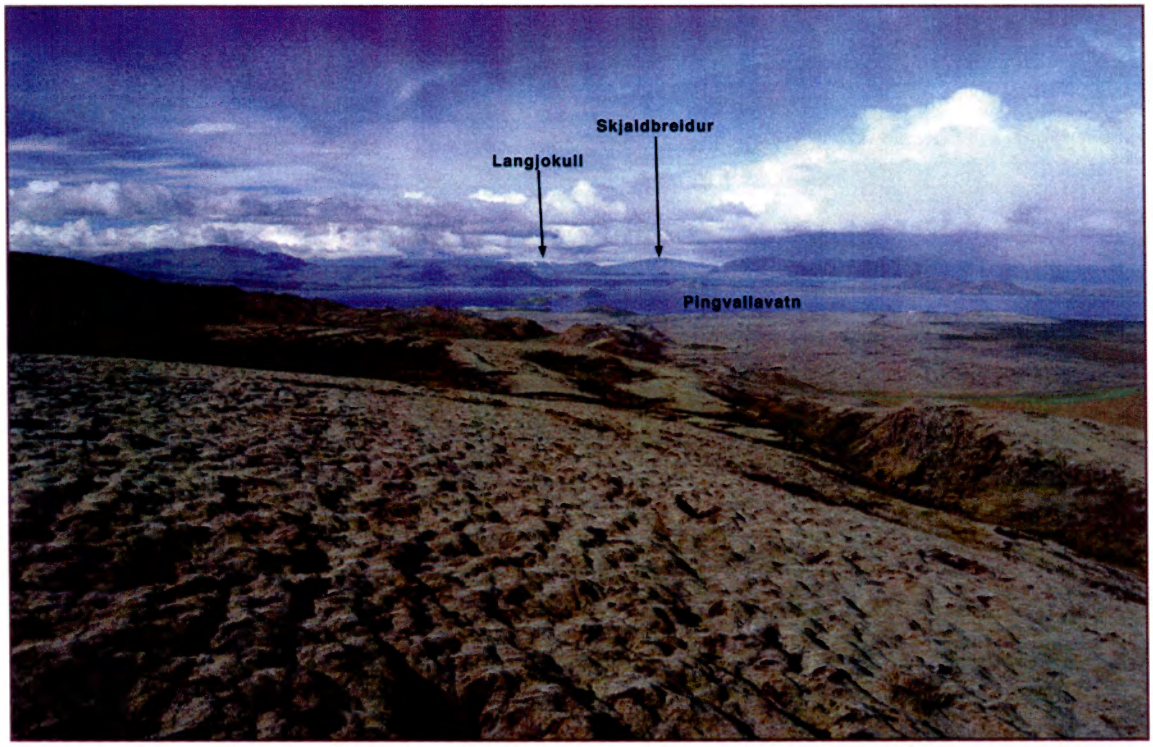
Lava that formed a temporary pond congealed around trees as the trees burned out. The lava pond then drained to leave the hardened lava around the burned out trees. The upward flare of the lava at the tops of the lava trees marks the maximum depth of the lava pond that formed from a July, 1974 fissure eruption west of Lua Manu pit crater along Chain of Craters Road in Kilauea's caldera.



Iceland is a hot spot, a mantle plume, along the Mid-Atlantic Ridge. The ridge enters Iceland at the southwestern tip of Reykjanes Peninsula. A series of short north-south fault scarps forms the South Iceland Seismic Zone (SISZ) that extends from the base of Reykjanes Peninsula to Hekla volcano. The SISZ is probably the surface expression of a transform fault system, shown diagrammatically, that connects the Western Volcanic Zone (WVZ) to the Eastern Volcanic Zone (EVZ). A possible interpretation is that the Mid-Atlantic Ridge is attempting to migrate westward off the hot spot, but the hot spot weakens the crust to shift the locus of the ridge to east-central Iceland. North of Iceland, the Grimsey fault system may be the surface expression of a transform fault that offsets the EVZ back to its original oceanic ridge location.

During the last Ice Age, before 13,000 years ago, all of Iceland was covered by an ice sheet that extended out onto the shallow continental shelves around the island. Continued volcanism under the ice produced many unique volcanoes whose lower flanks are made of pillow lavas that grade upward into hyaloclastites that may be capped by lava flows if the volcano managed to emerge above the ice.

The oldest rocks in Iceland are marine sediments that date from 16 million years ago. the Eastern Volcanic Zone dates from 3 to 4 million years ago, and the Western Volcanic Zone had its origin somewhat before that. The WVZ's latest eruption occurred offshore along the Mid-Atlantic Ridge in 1926. Lava last erupted on Reykjanes Peninsula in 1340, and magma heats geothermal areas to the present time.



The moss-covered pahoehoe lava in the foreground flowed over this area 10,000 years ago from Skjaldbreidur shield volcano as part of a 17 cubic km eruption of primitive mantle-derived high Mg lava. The graben holding Pingvallavatn (lake) initially formed after these massive post-glacial flows and continues to subside in response to crustal extension.

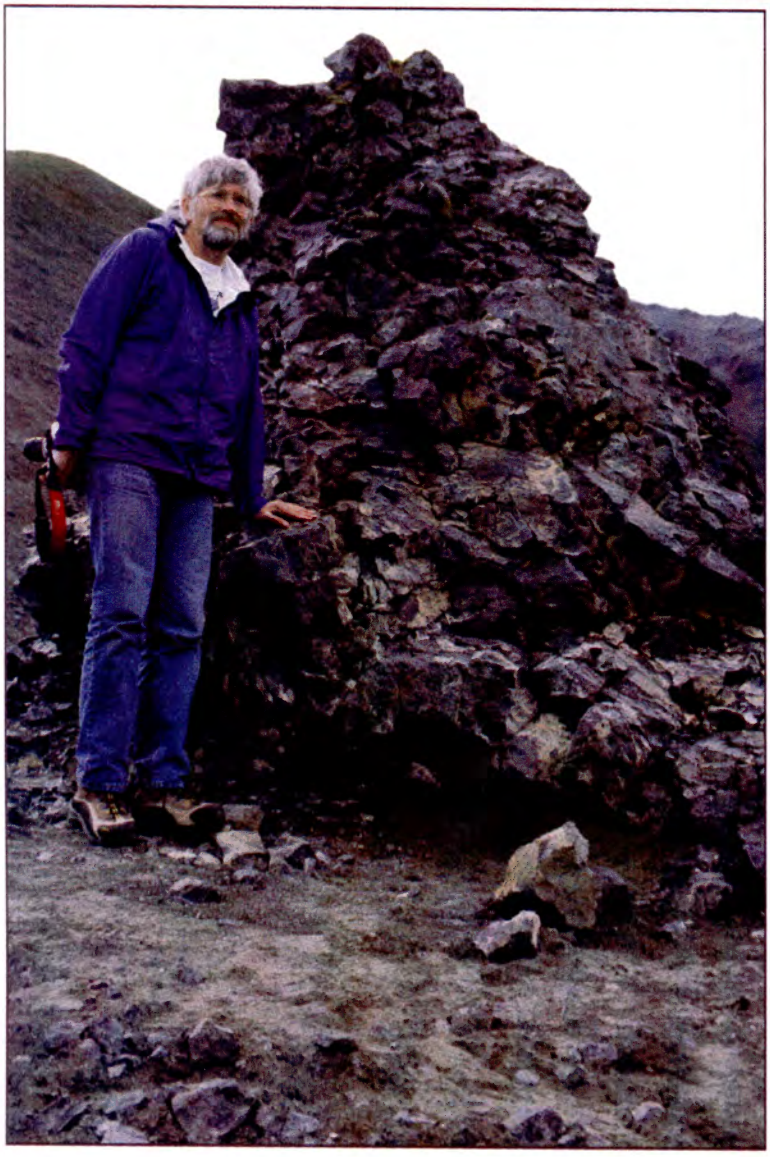
Hrutfell is a table mountain formed along a fissure by a subglacial eruption. Basaltic lava capping the mountain extruded as the volcano emerged from the ice. Its height is a measure of the thickness of the ice sheet.

Blafell table mountain erupted in mid-Pleistocene and has eroded to expose dipping layers of pillow basalt at its base.

Pillows inflated as molten basalt extruded under water that pooled above the volcano and below the glacial ice. For pillows to form, the basalt must be under pressure equivalent to the weight of at least 300 feet of water. The hot, leathery skin of the pillow stretched as the molten lava filled it, and the pillow detached to roll downslope and adapt its still flexible shape to the space where it came to rest among earlier pillows. Radial columnar joints may develop inside the pillow as it cools, crystallizes and shrinks.

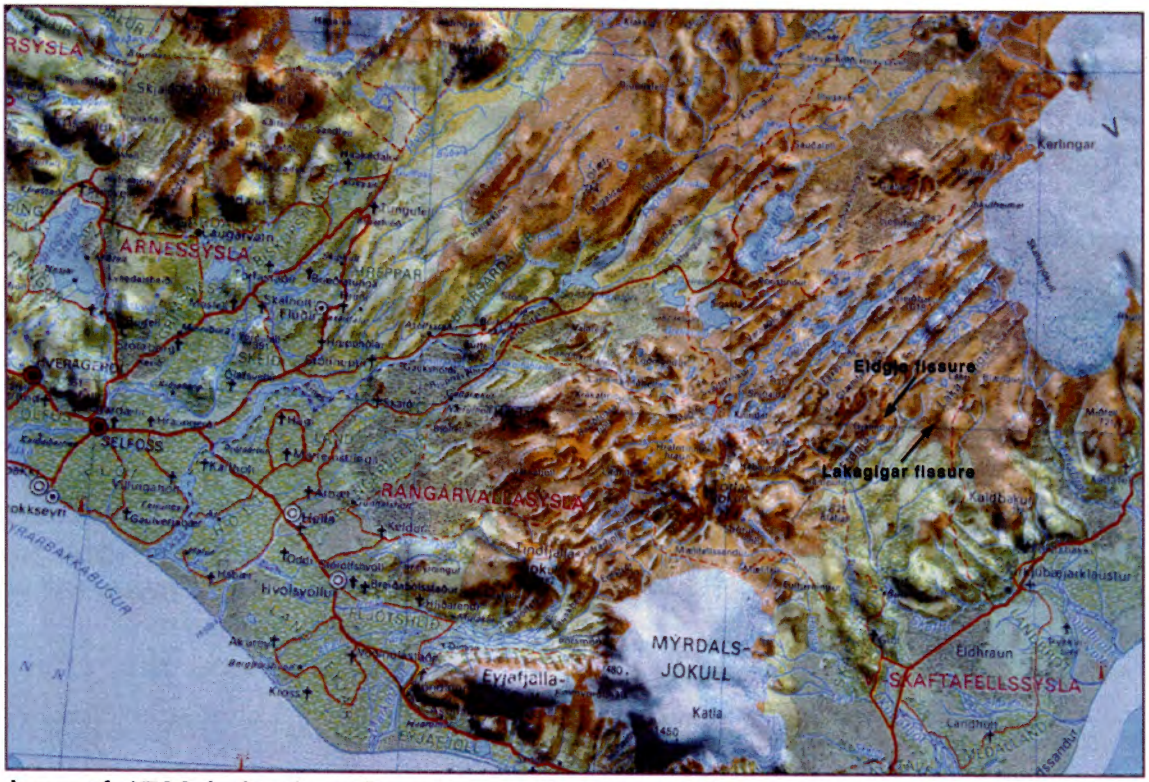
When the water pressure above the subglacial volcano became less than the equivalent of 300 feet of water, the basalt exploded, shattering magma and pillows to form the hyaloclastites that onlap pillows in this picture.

Rhyolite lava erupted from a fissure under the ice sheet to produce this ridge of rhyolitic hyaloclastite volcanoes in south-central Iceland.



Large somewhat ball-shaped masses of rhyolite that appear to be made of obsidian pillows are scattered through the rhyolitic hyaloclastite of subglacial fissure eruptions at Laumannalaugar in south-central Iceland. Jim Eagan stands next to one that shows the curved surfaces of the presumed pillows. Might the balls be bombs from the basal parts of the volcanoes blown out with the hyaloclastite?

The obsidian flow originated in 1480 along the southern end of a fissure where a bit of white steam can be seen rising at the base of the pinkish rhyolitic subglacial volcano. Successively to the north the same fissure erupted dacite lava, andesite lava, and basalt lava at about the same time.



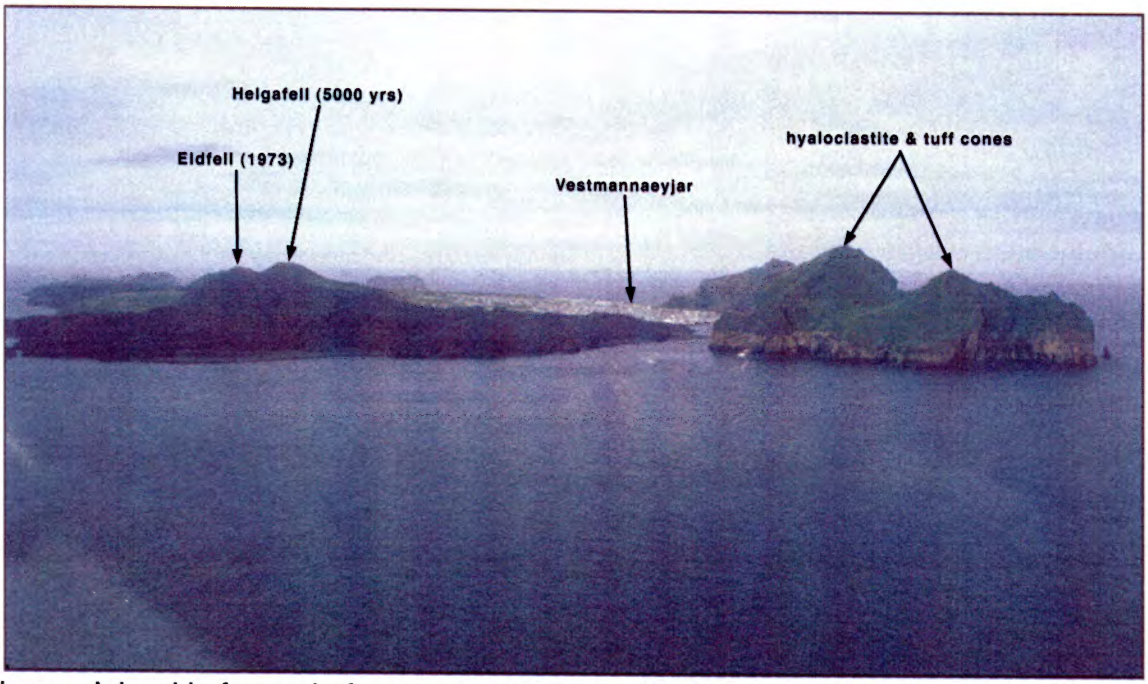
In June of 1783 Lakagigar fissure, supplied from Grimsvotn's magma reservoir under Vatnajokull to the northeast, erupted along a 25 km length to eject 0.3 cubic km of tephra and 12.3 cubic km of basalt from huge fire fountains. Enormous emissions of sulfur dioxide stunted crops and caused a famine. Eldgja fissure supplied from Katla under Myrdalsjokull had expolded in 930 to bury the countryside in ash and partly fill Skafta Canyon with basalt from 1000 meter high fire fountains.

You are looking southwestward along one of the en echelon segments of the Lakagigar fissure. The eruption began on June 8, 1783 after swarms of powerful earthquakes announced the migration of the magma southwestward from Grimsvotn along the fissure. Powerful steam blasts at the beginning of the eruption along each segment of the fissure produced tephra cones that were enlarged by spatter from the 1000-meter-high fire fountains that followed. The highly fluid magma from the fire fountains buried the countryside in 12.3 cubic km of lava over a period of 50 days. Huge amounts of sulfur dioxide blanketed the country in a bluish haze that stunted plant growth and produced a famine that killed large numbers of livestock and people.

You are looking along Lakagigar fissure where it cuts through hyaloclastite at the top of Laki Mountain, a subglacial volcano. Fire fountains blew out on either side of the mountain at lower elevations where access to the surface was easier. Steam blasts probably produced the pits shown along this high-elevation segment of the fissure.

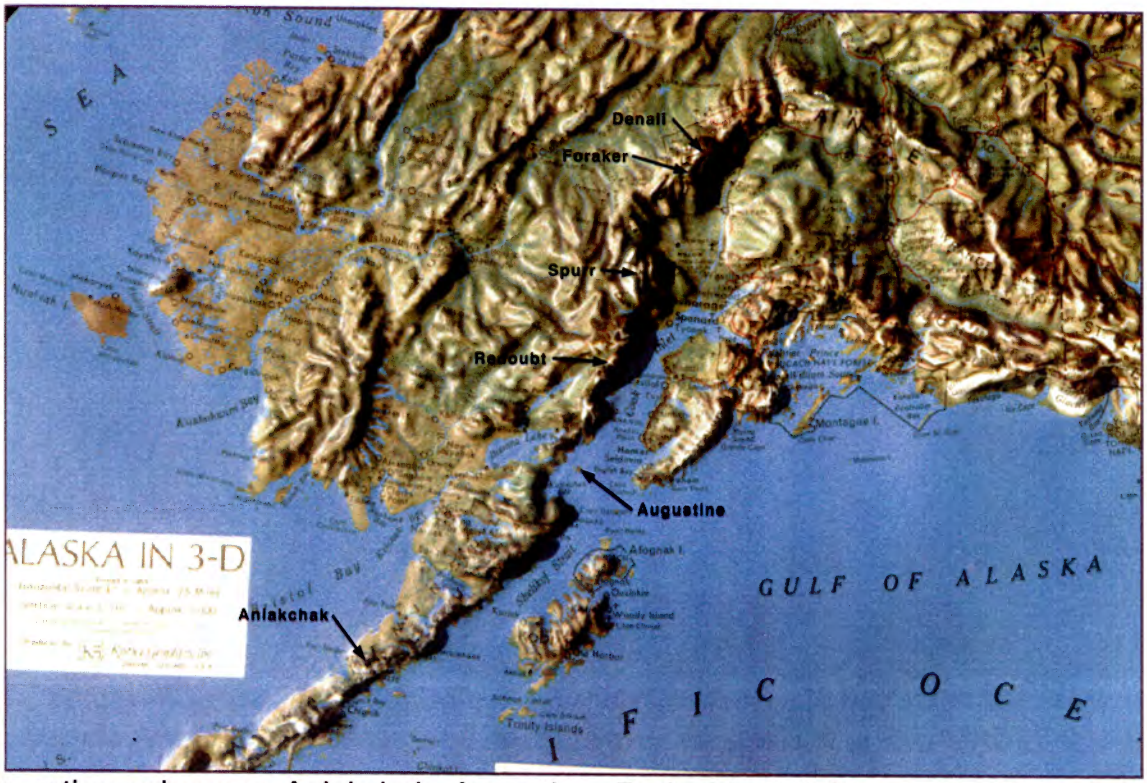
The cones scattered over this lava flow are rootless cones (pseudocones) of tephra and spatter blown out by steam explosions as the flow covered marshes and ponds.

The Pjorsa River eroded deeply into a 7800-year-old lava flow to expose the columnar-jointed root of a pseudocone. Perhaps the molten lava squeezed into the cavity left by steam explosions to cool quietly and slowly as it crystallized and contracted to form the columnar joints perpendicular to the cooling surfaces.

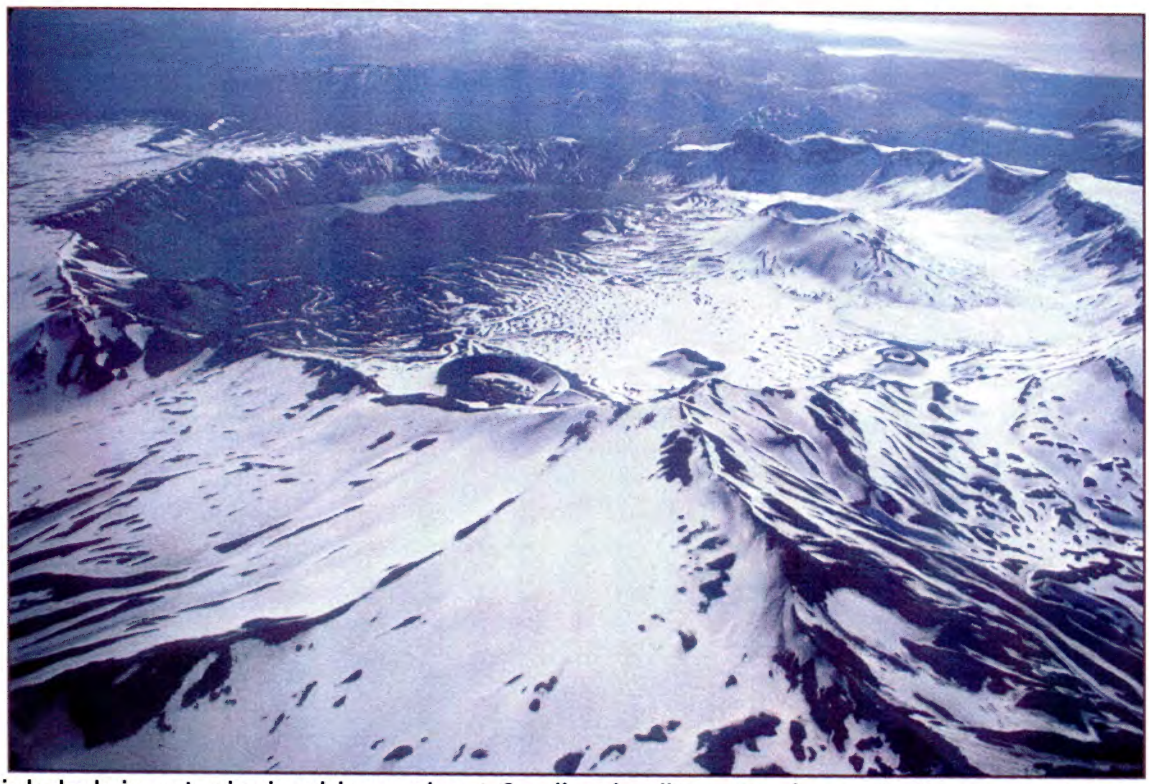


Heimaey Island is formed of several overlapping hyaloclastic and tuff cones united 5000 years ago by the building of Helgafell shield topped by a scoria cone. Eldfell started growing on the outskirts of the town of Vestmannaeyjar on January 23, 1973. It covered the town deeply with ash, and crushed some of the houses with lava during its 155 day eruption. Only heroic efforts to pump seawater on the advancing flow prevented the closing the harbor and destruction of even more houses.

Many houses were completely crushed as they were overridden by the lava flow from Eldfell. This one, along the edge of the lava flow, was only partly crushed.



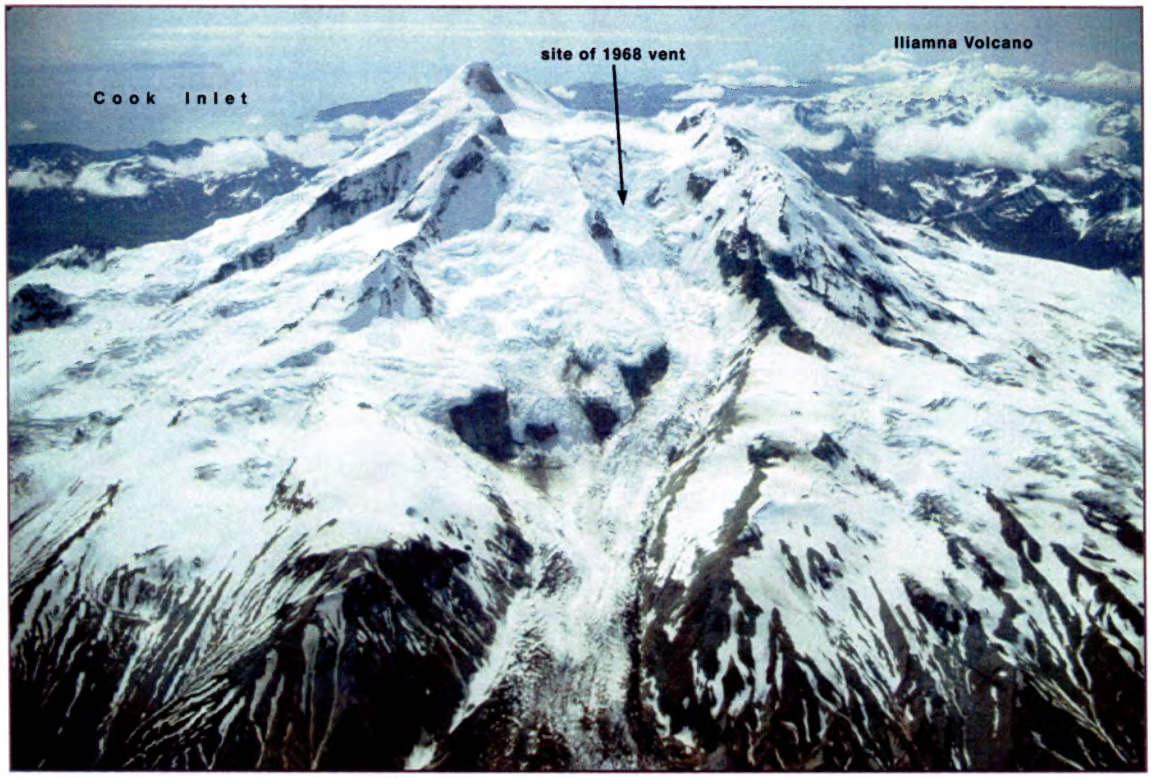
The active volcanoes Aniakchak, Augustine, Redoubt, and Spurr are a few of those developed along the subduction zone where the Pacific Ocean plate dives under Alaska's continental crust. Melting of some of the continental crust by basaltic magma increases the silica content to form the andesitic magmas of these large volcanoes.



Aniakchak is a typical caldera, about 6 miles in diameter, formed after explosive eruptions emptied the underlying magma chamber, and the top of the volcano collapsed into it. Subsequent volcanism has partly filled the caldera with cinder cones and lava flows. Picture taken by Doug Dresser 6/15/1984.

Augustine volcano rises about 4500 feet above Kamishak Bay. Mildly explosive eruptions, repeated about every 4 or 5 years in recent times, have migrated northward, leaving a succession of partial crater walls flanking the vent on its southern side. A steep-sided, viscous lava flow descended and stopped on the volcano's northern flank.

Uplifted beach ridges on the southwestern end of Augustine Island indicate that the island is tilting, perhaps because the bulk of the volcano is on the northeastern end, or perhaps because magma is shifting below the island. The modern beach truncates the uplifted beach ridges while longshore currents transport the sand to the west to deposit it as a barrier in front of the lagoon. Both pictures taken 6/16/1986.

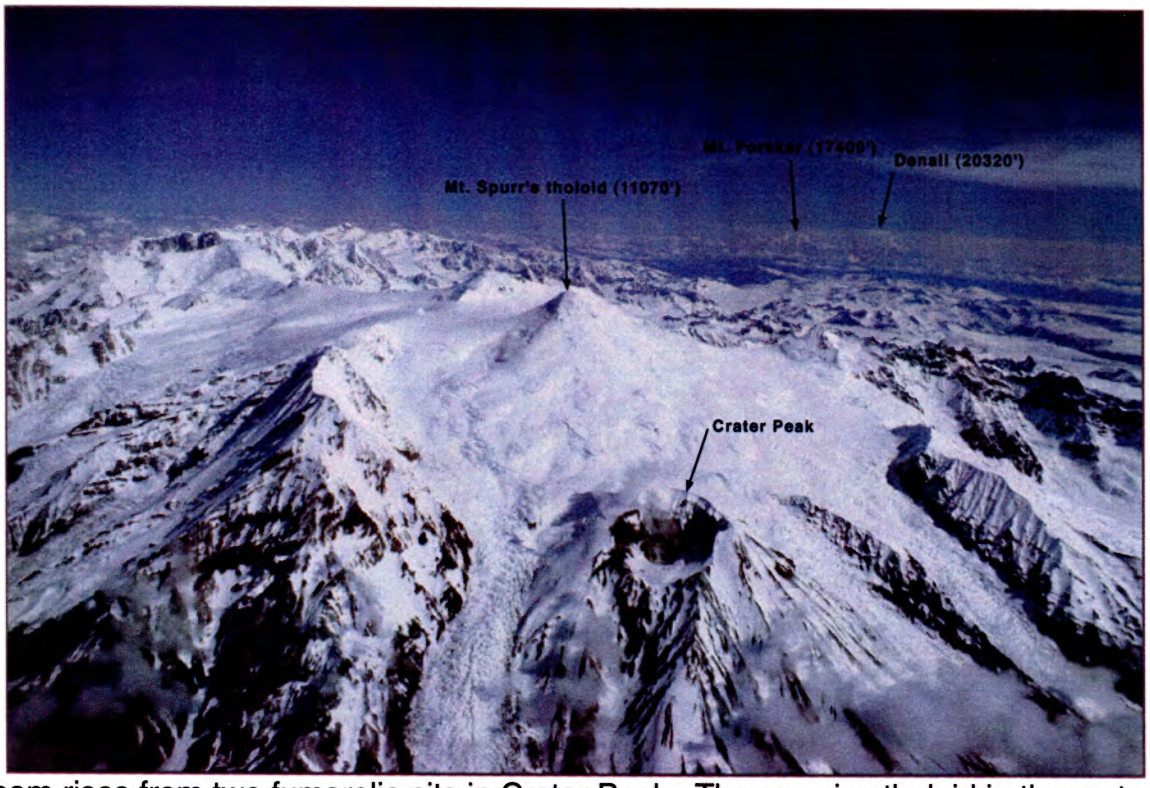


Redoubt Volcano rises 10,197 feet above Cook Inlet and owes the features on its northern flank in this July 19th,1983 picture to its last eruption in 1968, when it covered its glaciers with ash and pyroclastic flows. Its upper cone consists of 30 to 60 meter-thick andesite flows on top of an apron of pyroclastic flows and debris flows.

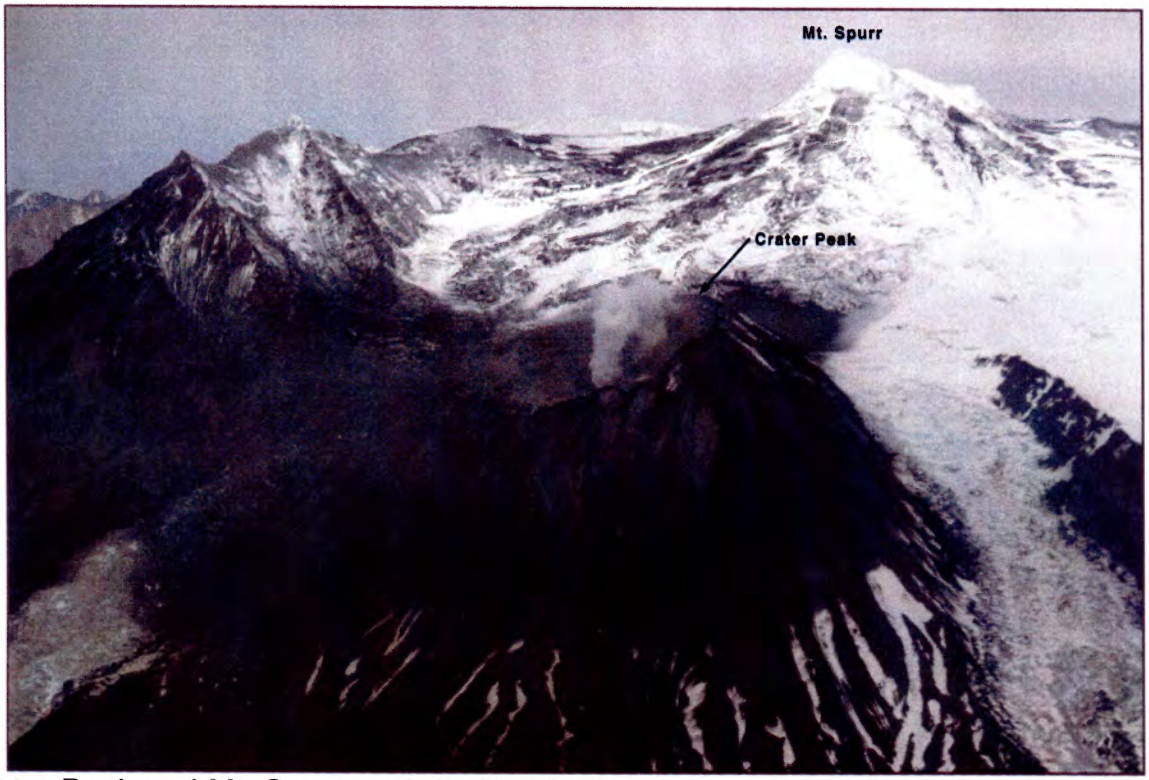
Blockade Glacier and the Chigmit Mountains are covered with ash from the explosive eruptions of Redoubt Volcano that began in December of 1989 and continued through the spring of 1990. Some of the ash at higher elevations is covered by recent snow. Picture taken June 28th, 1990.

Steam rises from the tholoid that plugs the vent for Redoubt's recent eruptions. Ash and debris flows cover the glacier at its foot. Redoubt expolded repeatedly from December 1989 through the spring of 1990. Picture taken 6/28/1990.

Close view of the tholoid that plugs Redoubt's vent. The tholoid is a plug of hot, viscous lava that breaks up and crumbles as it rises in the vent like a giant bottle stopper. Steam rises through it. Picture taken 6/28/1990.

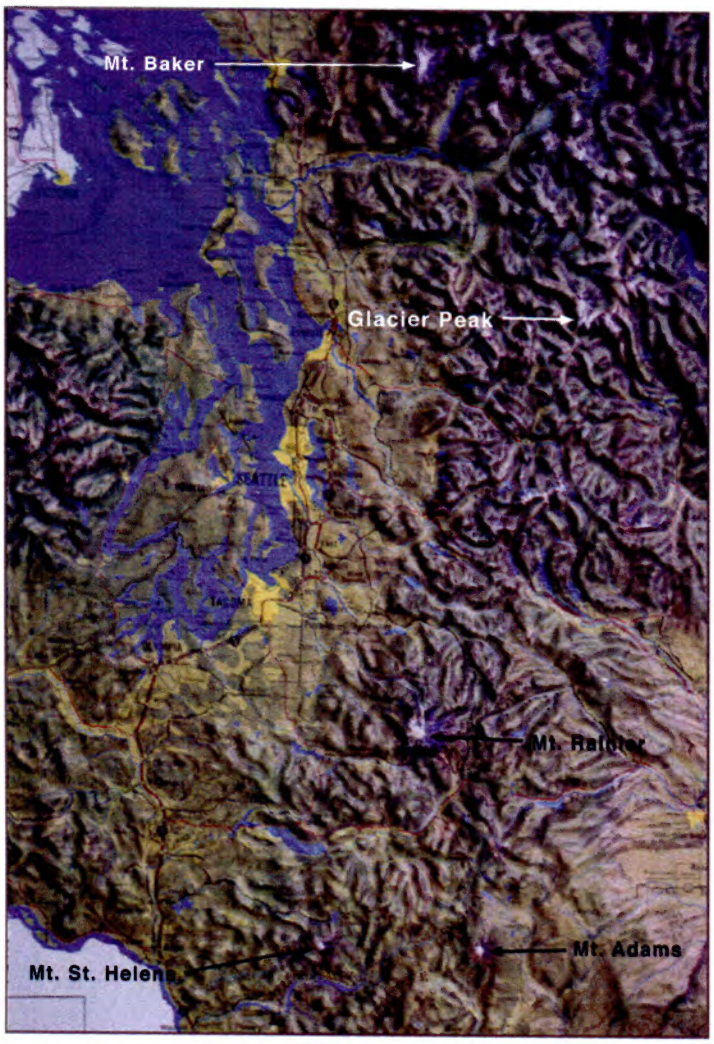


Steam rises from two fumarolic pits in Crater Peak. The massive tholoid in the crater at the top of Mt. Spurr forms such a good plug that a parasitic vent, Crater Peak, becomes the relief valve for the volcano. Foraker and Denali, about 100 miles distant, rise high enough to generate their own cloud cover. Picture taken 6/21/1985.

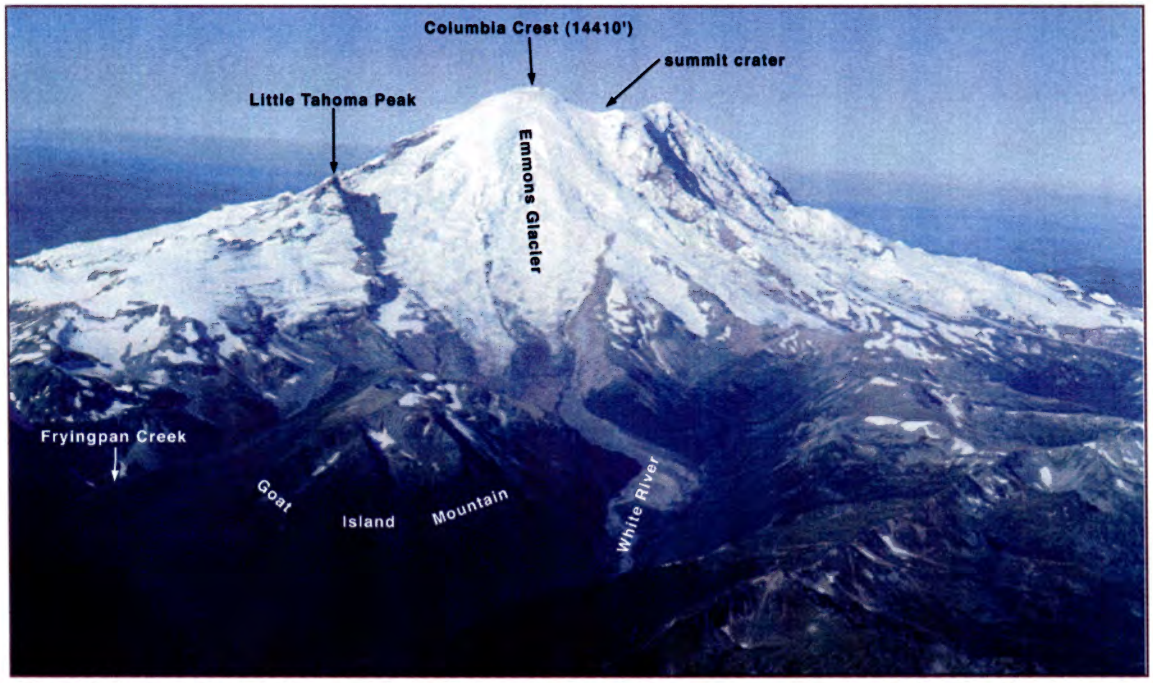


Crater Peak and Mt. Spurr on June 28, 1992, one day after Crater Peak exploded into thick cloud cover to send ash northward on a southerly wind.

Ash from June 27, 1992 explosions at Crater Peak on the southern flank of Mt. Spurr coat part of Kahiltna Glacier and Mt. Foraker about 100 miles north of Crater Peak. Picture taken July 1, 1992.



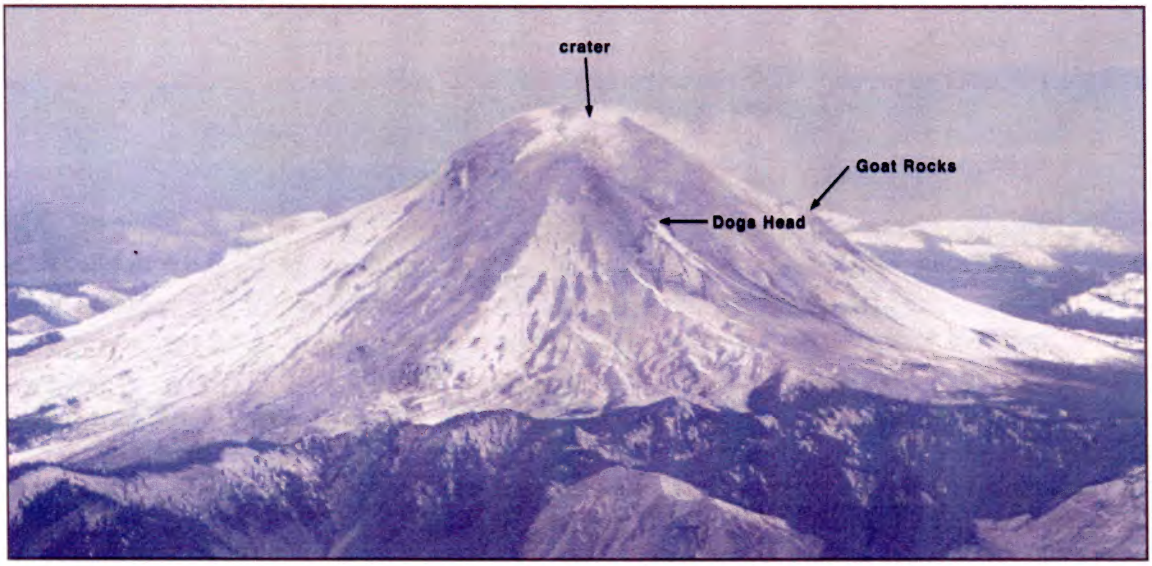
Index map shows the locations of major Cascade volcanoes in the state of Washington. Views of Rainier, Adams, and St. Helens are shown on subsequent pages.



Looking SW. at Mt. Rainier. Little Tahoma Peak is a remnant of the flank of a larger and taller Rainier, perhaps at 15000'. Columbia Crest is a holocene cone built on the edge of the summit caldera. The last major eruption was between 550 and 600 years ago. More than 55 mudflows, most not coincident with eruptions, have flowed off Rainier in the last 10,000 years. Because Rainier contains much structurally weak, altered rock capped by ice, any slight warming, swelling or earthquake may trigger mudflows. A major eruption will release catastrophic mudflows all the way to Puget Sound.

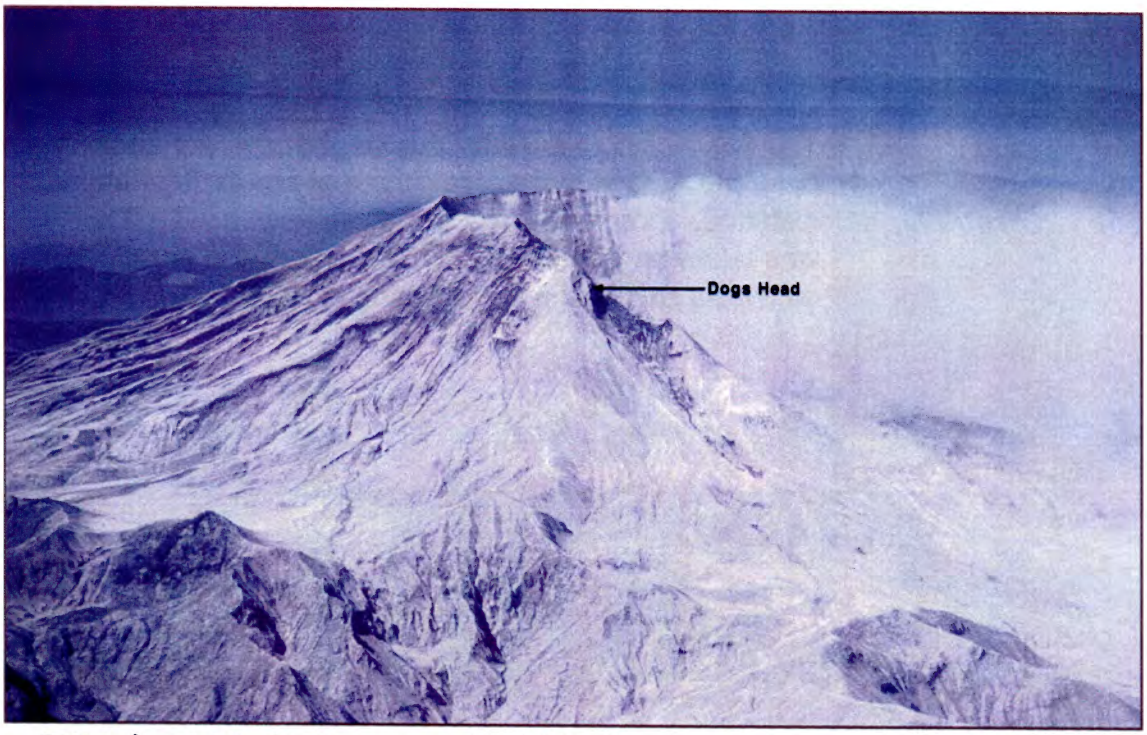
Looking N. at Rainier. Rainier appears to have migrated westward as it has been rebuilt in the collapsed edifices of perhaps several larger ancestral Rainiers that may have risen to 15,000 feet or higher in elevation. Ash from eruptions of Mt. St. Helens blankets the ridges in the foreground. Upper picture taken 9/1975. Lower one taken July 21st just the day before St. Helen's 4th eruption in 1980.

You are looking westward across the glaciers and moraines of Mount Adams in the foreground at Mount St. Helens in the distance. Both are large andesitic volcanoes. This picture was taken on September 5, 1975 before the eruptions began on Mount St. Helens in the spring of 1980

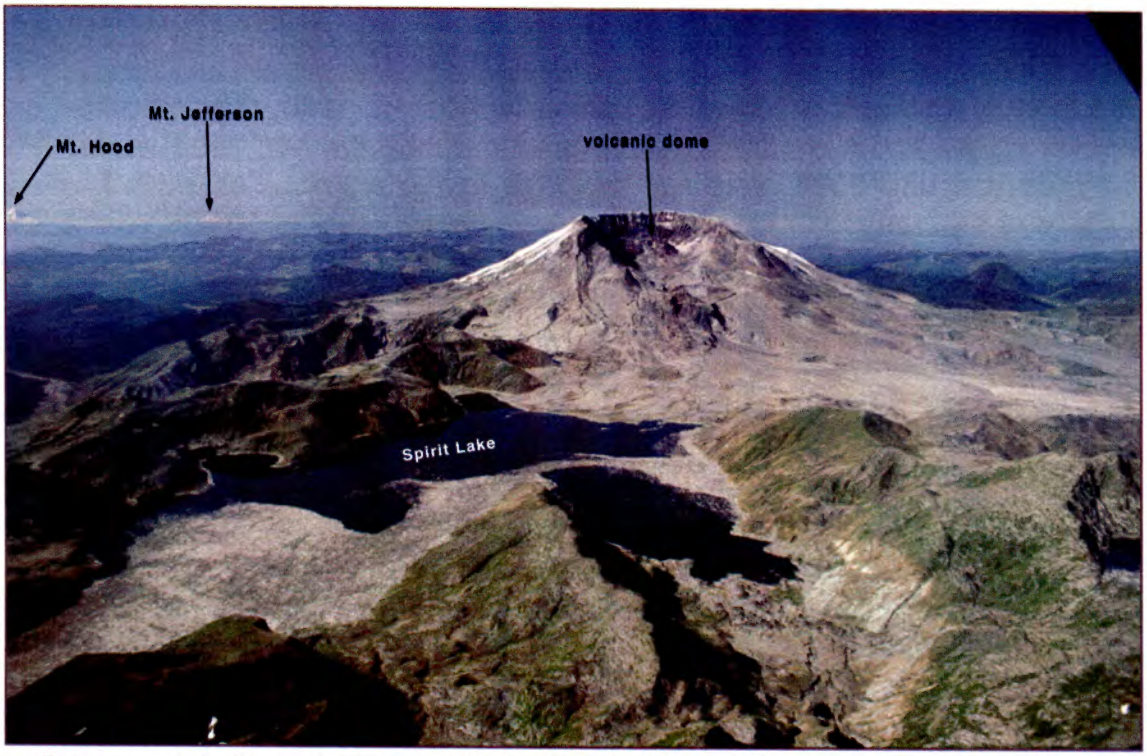


You are looking westward at Mount St. Helens on April 12, 1980. The mountain owes most of its shape and size to volcanic eruptions during the last 2500 years. From 40,000 years ago until 2500 years ago explosive dacitic eruptions alternated with dormant intervals that ranged in length from a few hundred years to 15,000 years. Dogs Head dacite dome formed a bit more than 1900 years ago near the beginning of the modern cycle of more frequent eruptions that built the cone you see here. These eruptions included andesitic and basaltic pyroclastics and flows as well as explosive expulsion of dacitic magma. Goat Rocks is a dacite dome that seals the vent of the last volcanic blasts in 1857. The crater at the top of the mountain is steaming as rising magma superheats the groundwater to the point where it explodes, shattering the rock and spraying rock debris over the snow. Such phreatic explosions first formed a small crater on March 27, 1980. Subsequent explosions formed an adjacent crater by March 29, and it merged with the first crater by April 7. The whole northern flank of the volcano, including Goat Rocks, swelled, cracked, and steepened as magma continued to rise. By May 12, Goat Rocks, near the base of the bulge, had migrated northward 106 meters at a rate of up to two meters per day. On May 18 a magnitude 5 earthquake shook loose the oversteepened rock on the north flank in a gigantic landslide that allowed the gas-charged magma to blow out both vertically and horizontally. The total volume of this pyroclastic flow, the combined landslide and magma blast, was about 2.6 cubic kilometers.

data taken from: Lipman, P.W. and Mullineaux, D.R., 1981, "The 1980 Eruptions of Mount St. Helens, Washington" USGS Professional Paper 1250.



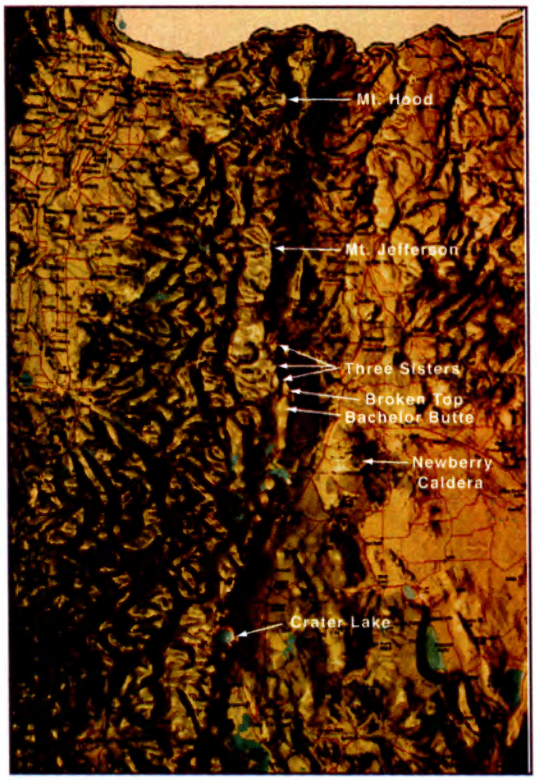
View SW toward Mt. St. Helens on 7/21/80 after the eruptions of May 18, May25, and June 12. The primary eruption on May 18 reduced the elevation of the mountain from 9677 feet to 8365 feet. Dogs Head is now closer to the summit. The large amount of steam issuing from the volcanic dome presaged the eruption of 7/22/80. It blasted a crater in the volcanic dome that had been built over the vfent after the June 12 eruption.



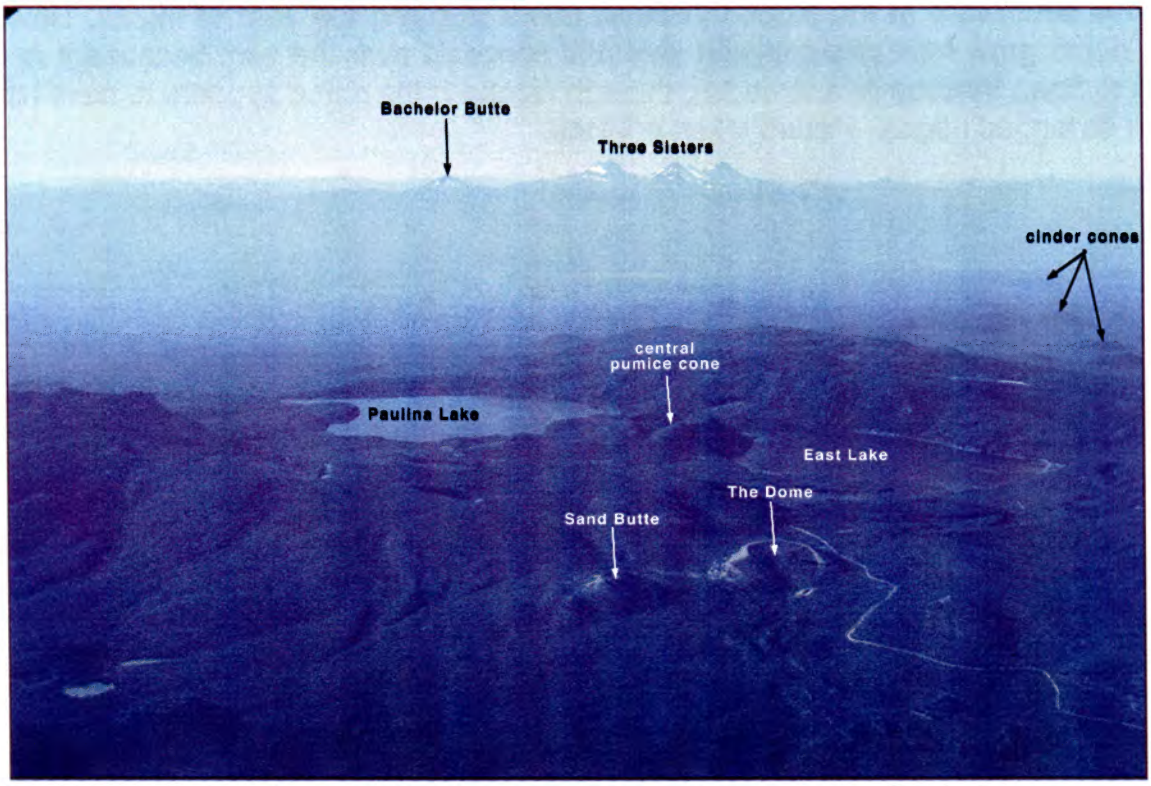
View S toward Mt. St. Helens on 8/1/93. Most of the volcanic dome grew over the vent in one day to a diameter of 200 meters and a height of 40 meters after the October 18 eruption of pyroclastic flows. Part of this dome was blown away by explosions on December 13, and a new dome rose and expanded adjacent to the old dome through the end of 1980.

View is southward at the jagged volcanic dome plugging the vent of Mt. St. Helens. The dome grew from gas-depleted lava that congeals over the vent because it is too thick to flow. Viscous lava forced up through cracks in the dome appears to have hardened as jagged ridges. Picture taken 8/1/1993.

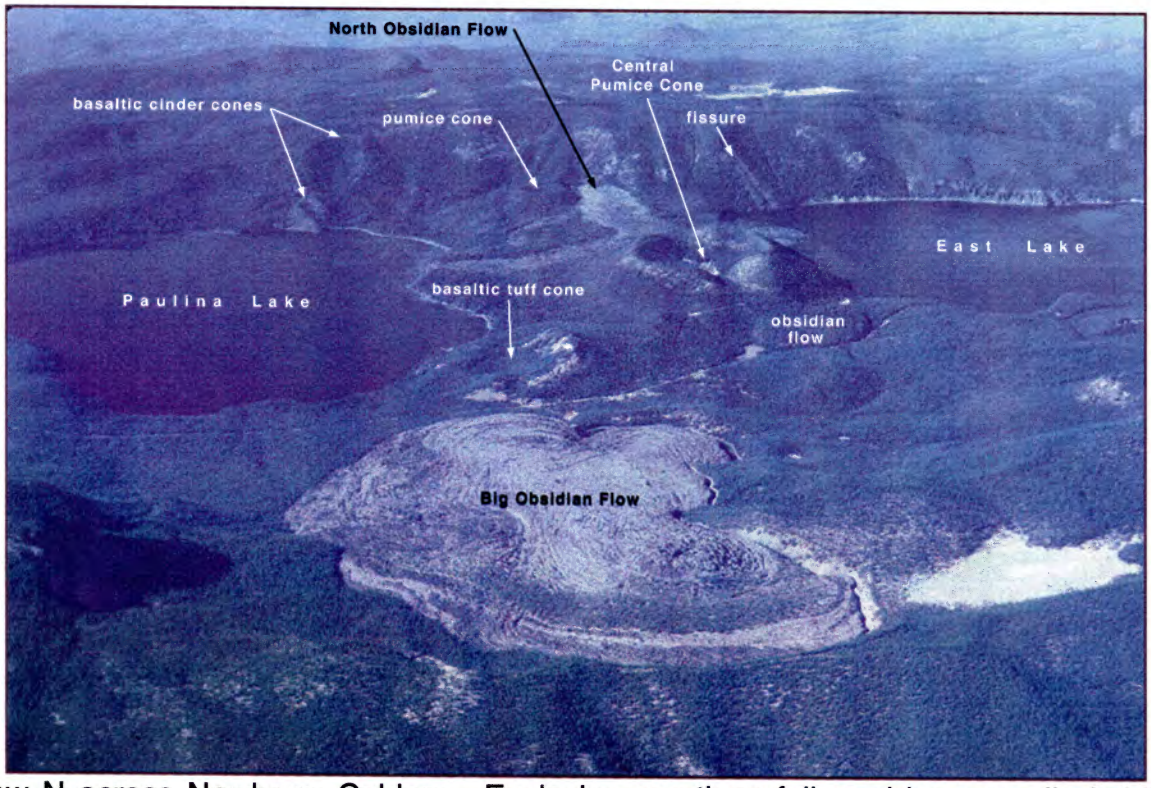
View southward over Mt. Adams of Mts. Hood and Jefferson along the crest of the Cascade Mountains. All are currently dormant dominantly andesitic volcanoes that could become explosively active. Glacial erosion gnaws into the edifices to weaken them in anticipation of further eruptions. Picture taken 9/5/1975.



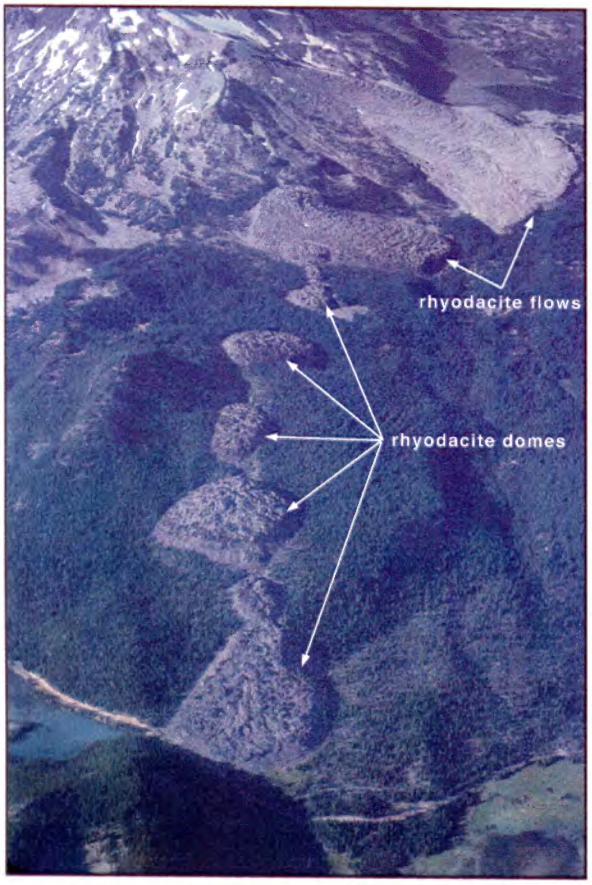
Index map of the Oregon Cascades showing some of the major volcanoes. Pictures of Newberry Caldera and rhyolites at the base of South Sister follow.



View NW across Newberry Caldera containing East Lake and Paulina Lake separated by Central Pumice Cone, which grew to its 700 foot height inside the caldera about 1700 years ago. The caldera measures 5 x 4 miles, and it formed when the summit of a large shield volcano collapsed as the magma withdrew to pour out lower on the flanks and supply the more than 150 cinder cones around it. Sand Butte, The Dome, and three other cinder cones are pointed out in the picture. The edifice of Newberry volcano is built largely of basalt and rhyolite of alternate and sometimes simultaneous eruptions. The Three Sisters and Bachelor Butte, in contrast, are dominantly andesitic volcanoes along the spine of the Cascade Mountains.



View N across Newberry Caldera. Explosive eruptions followed by a small obsidian flow that breached the cone wall formed Central Pumice Cone about 1700 years ago. North Obsidian Flow split into two branches as it diverted around the small pumice cone and Central Pumice Cone. The final volcanic eruptions in the caldera were either the oozing out of Big Obsidian Flow or the explosive expulsion of mixed rhyolite and basalt from the fissure. Picture taken 9/4/1975.*



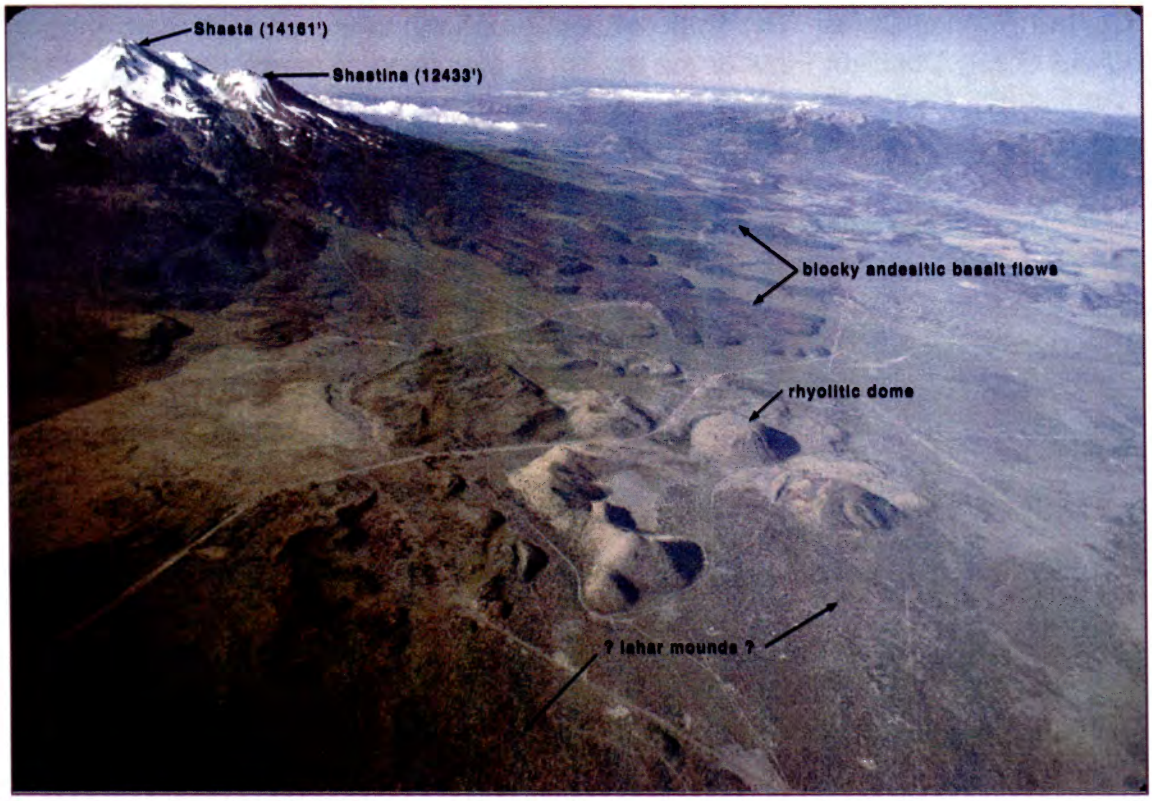
*Information from: Williams, H., 1935, "Newberry Volcano of Central Oregon", Bull. GSA, vol 46, p253-304, and Higgins, M.W., 1969, "Airfall Ash and Pumice Lapilli Deposits from Central Pumice Cone, Newberry Caldera, Oregon", USGS Prof. Paper 650D, pD26-D32.

View is northward toward the base of South Sister Volcano. Viscous flows and domes of rhyodacite oozed from a rift between 2000 and 2900 years ago.**

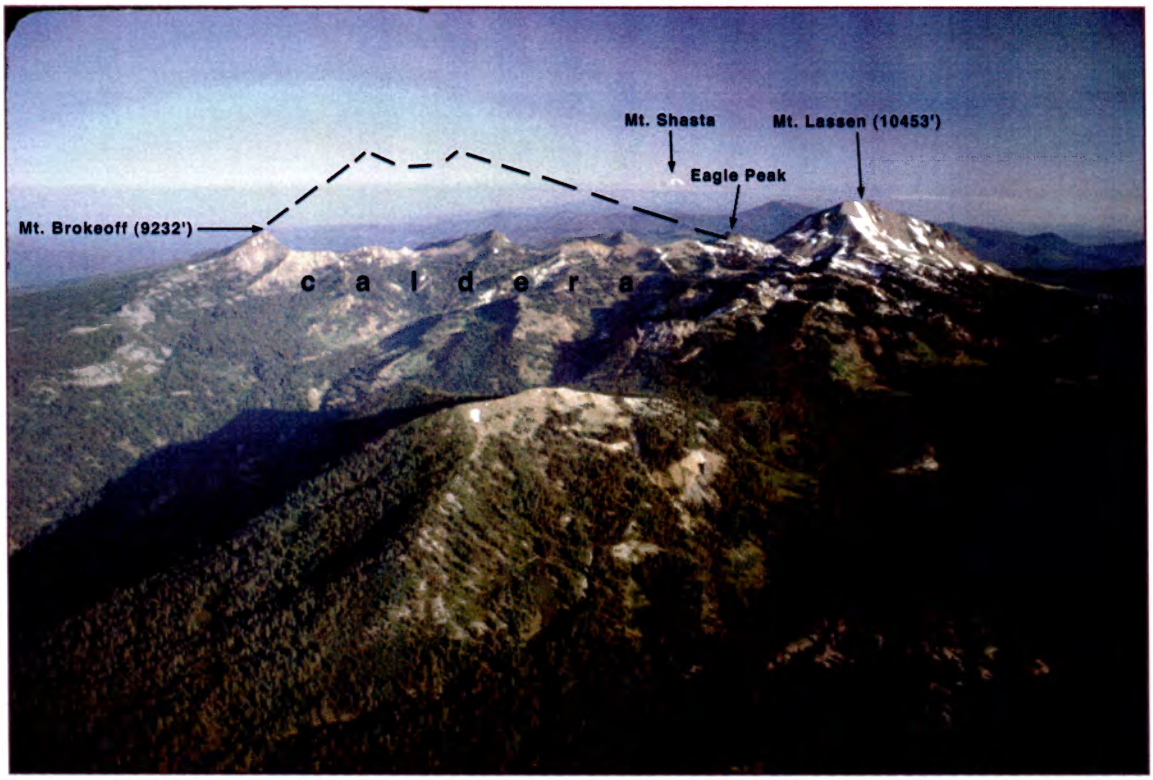
**Taylor, E.M., Macleod, N.S., Sherrod, D.R., and Walker, G.W., 1987, "Geology of the Three Sisters Wilderness, Deschutes, Lane, and Linn Counties, Oregon" USGS MF Map 1952.

California index map shows volcanic features to follow.

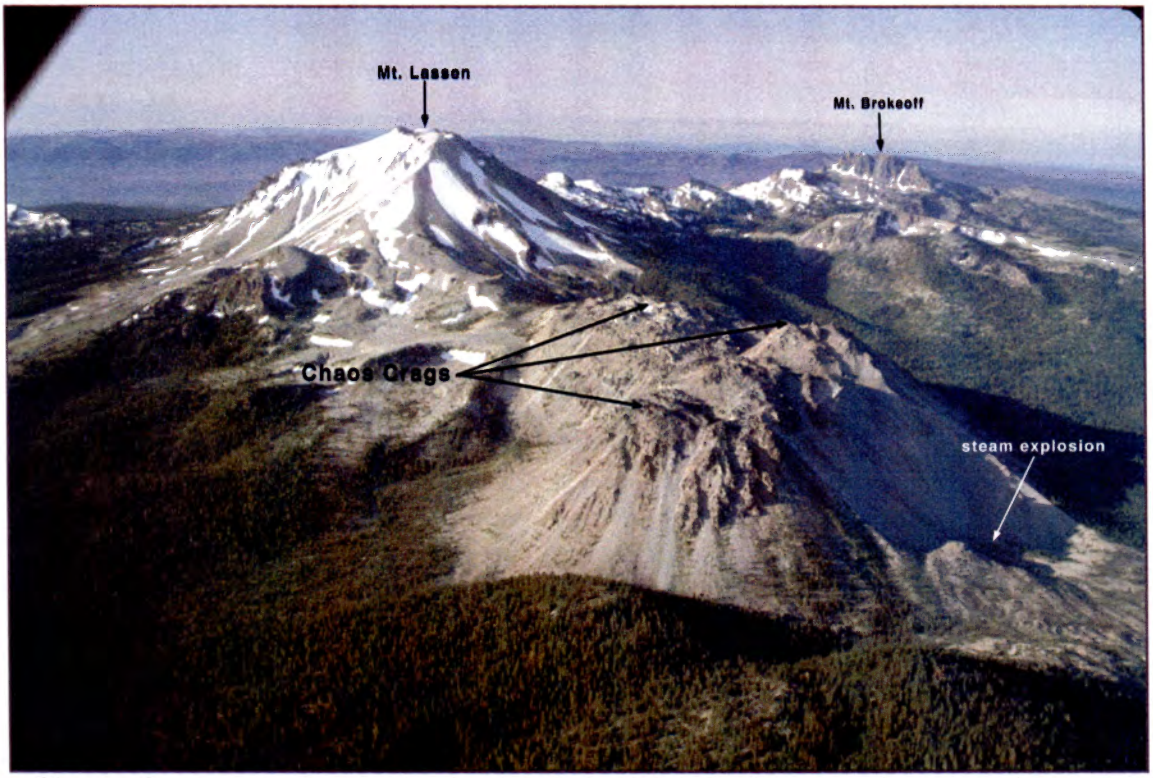
data from: Williams, Howell, 1932, "Mount Shasta, A Cascade Volcano", Jour of Geology, vol. 40, p.417-429.



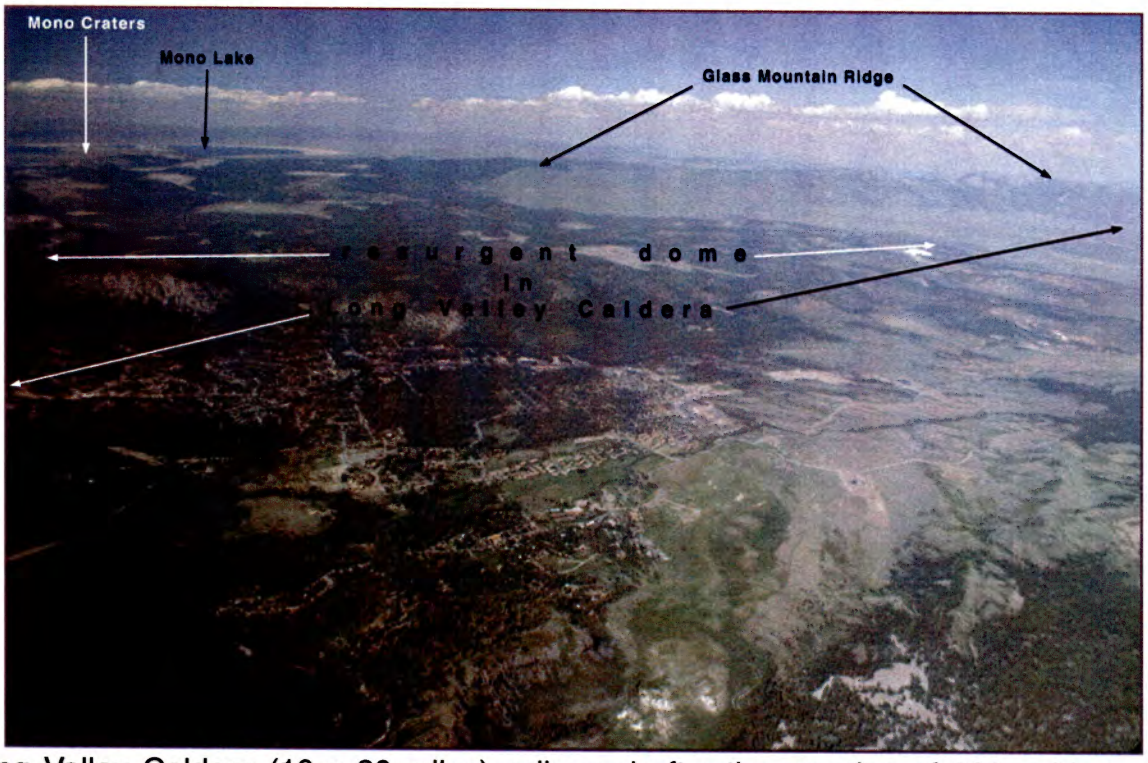
Mt Shasta is constructed largely of andesite flows that are replaced at the summit by short, viscous flows of dacite. Final explosions from Shasta's vent a few hundred years ago produced a mantle of pumice. Shastina grew in post-glacial times as an andesitic cone along an east-west fissure on the flank of Shasta. The solid plug in Shasta's vent presumably forced magma to migrate along the fissure to the site of Shastina. A plug also seals Shhastina's vent, and caused andesitic basalt flows to spring from fissures on Shastina's northwestern side.



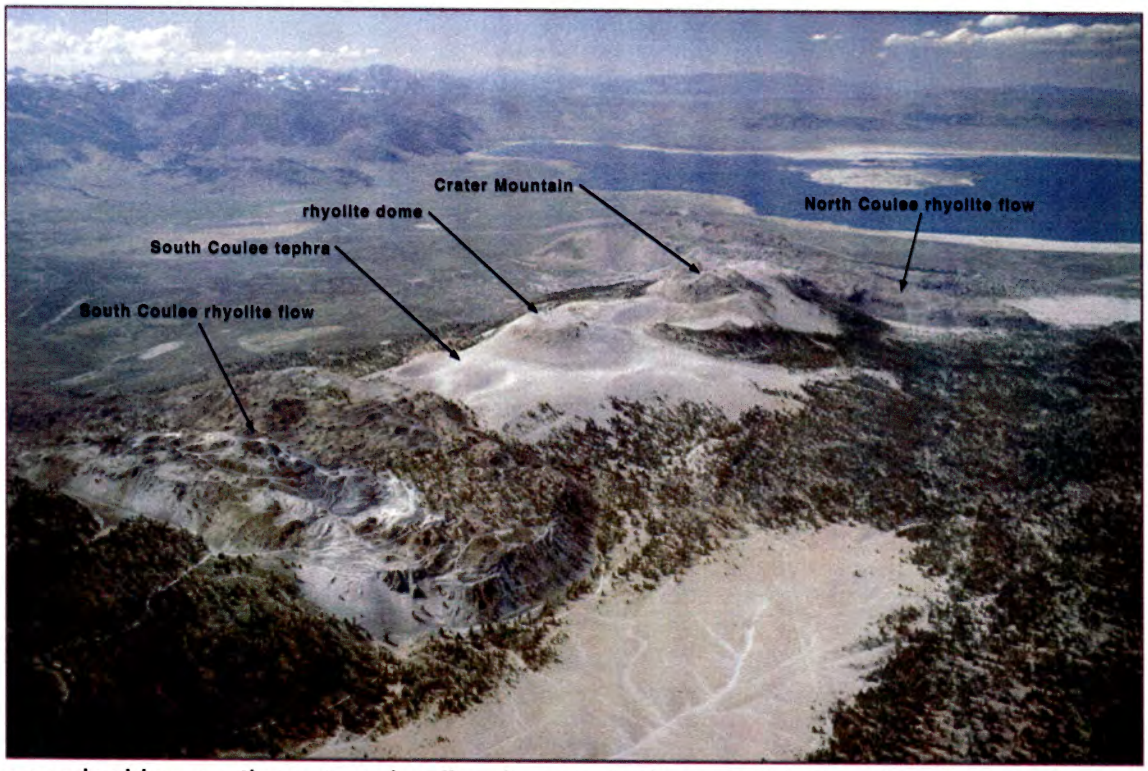
Mt Lassen is a dacite plug dome that grew on the eastern flank of the caldera resulting from the collapse of Brokeoff Cone. Brokeoff Cone consisted of andesite flows interbedded with tuff and breccia. Eagle Peak is a dacite dome that punched through pre-Lassen columnar dacite flows. Lassen last erupted from mid 1914 thru mid 1917.



The Chaos Crags are dacite domes. About 200 years ago a steam explosion at the base of the north dome set loose an avalanche of dacite rubble, the Chaos Jumble, that slid at high speed two miles down the mountain, across a valley, and 400 feet up the other side. Both pictures taken 8/14/1982.

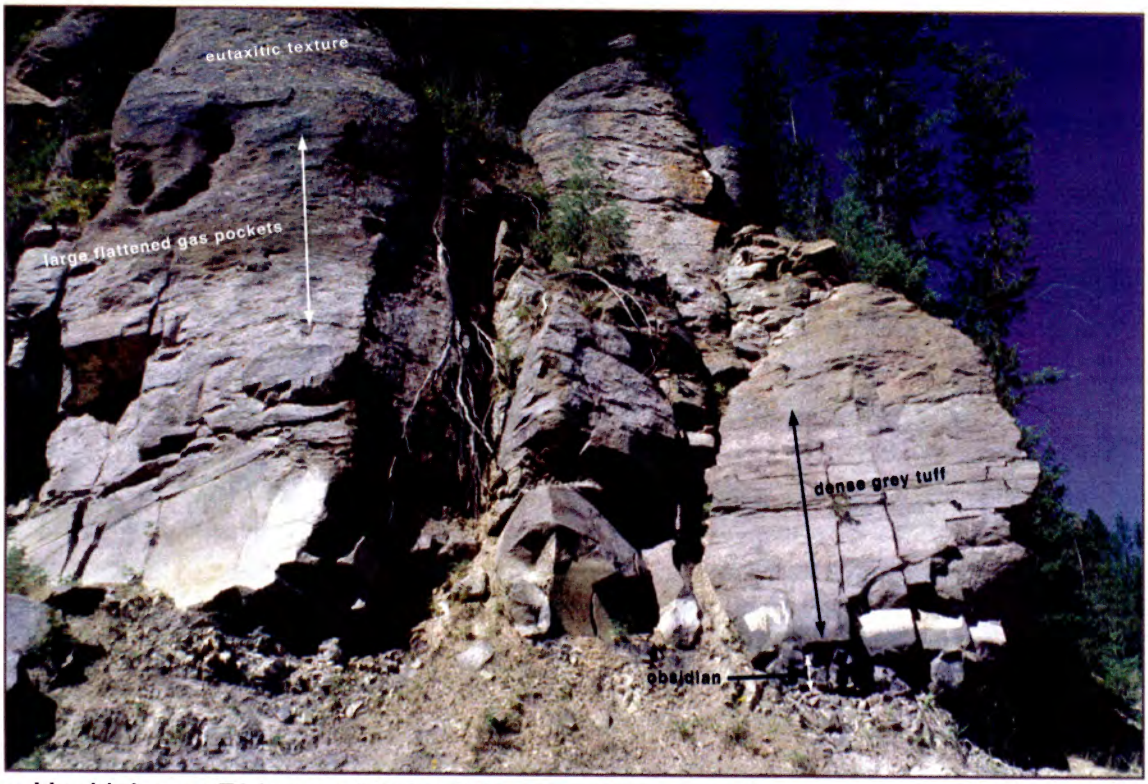


Long Valley Caldera (10 x 20 miles) collapsed after the eruption of 600 cubic km of Bishop Tuff about 730,000 years ago. The remaining lava ponded in the caldera and was arched into a resurgent dome between 730,000 and 650,000 years ago. Magma rising under the dome arched the dome upward 20 inches between May 1980 and January 1983.



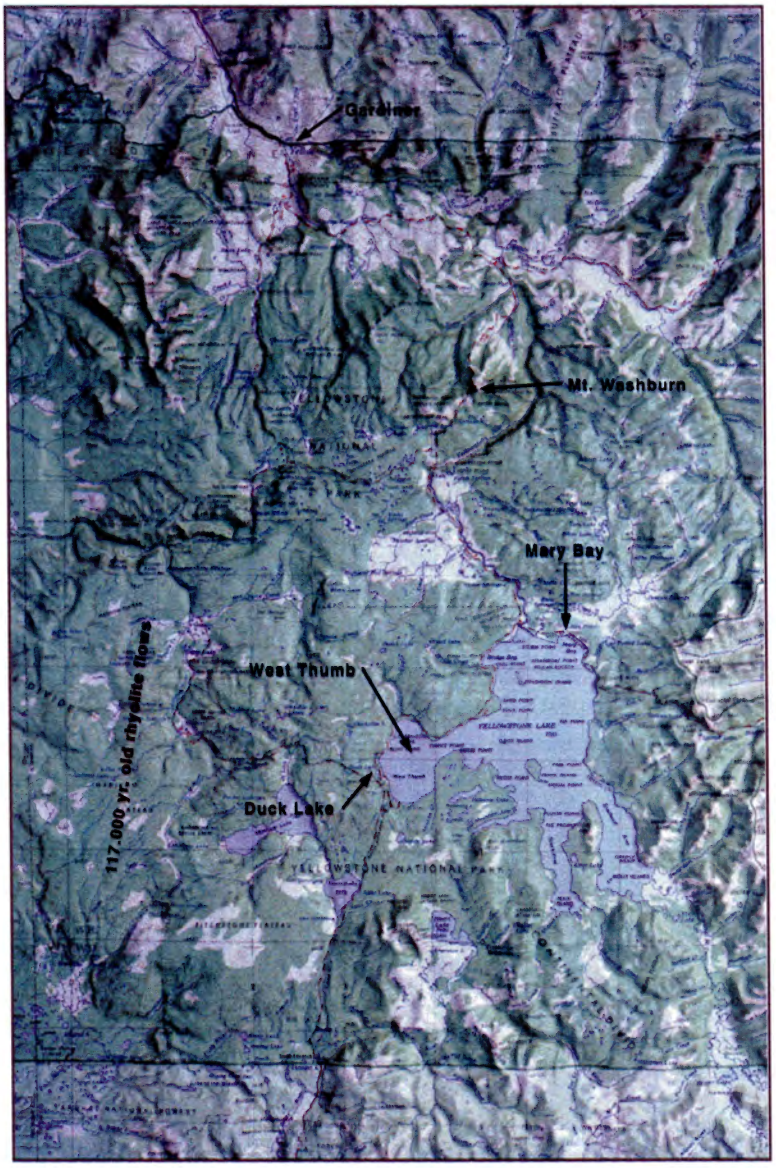
You are looking northwest at rhyolite domes, tephra, and flows along Mono Craters rift Eruptions have taken place along the chain at about 500 year intervals for the last 3000 years. The last eruptions occurred about 600 years ago. Both pictures taken 8/13/1982.

Island Park Caldera collapsed after 1,200 cubic kilometers of rhyolitic lava blew out as incandescent ash flows 2 million years ago to accumulate as the Huckleberry Ridge Welded Tuff. Since then the floor of the caldera has been smoothed by flows of basalt. This view shows just the western part of the caldera. The eastern part is covered by the plateau rhyolite flows of Yellowstone Park.

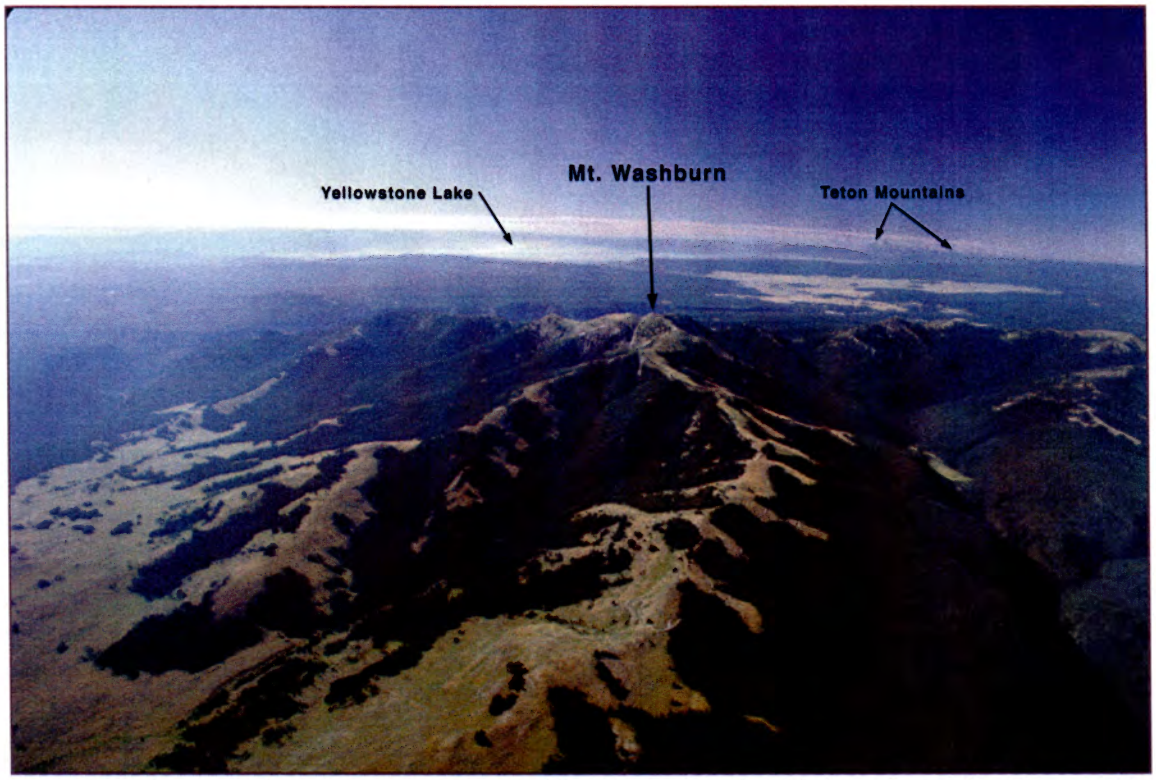


The Huckleberry Ridge welded tuff is a cooling unit of a series of ash flows. At the chilled base of the tuff the weight of the overlying tuff compressed and welded the glass shards together to form obsidian. The obsidian grades upward into dense grey welded tuff. Its gases presumably rose and formed large flattened gas pockets in the overlying tuff that, in turn, grades upward into hundreds of feet of eutaxitic textured welded tuff. This outcrop occurs north of Island Park in Montana's Gravelly Mountains.

Yellowstone Caldera

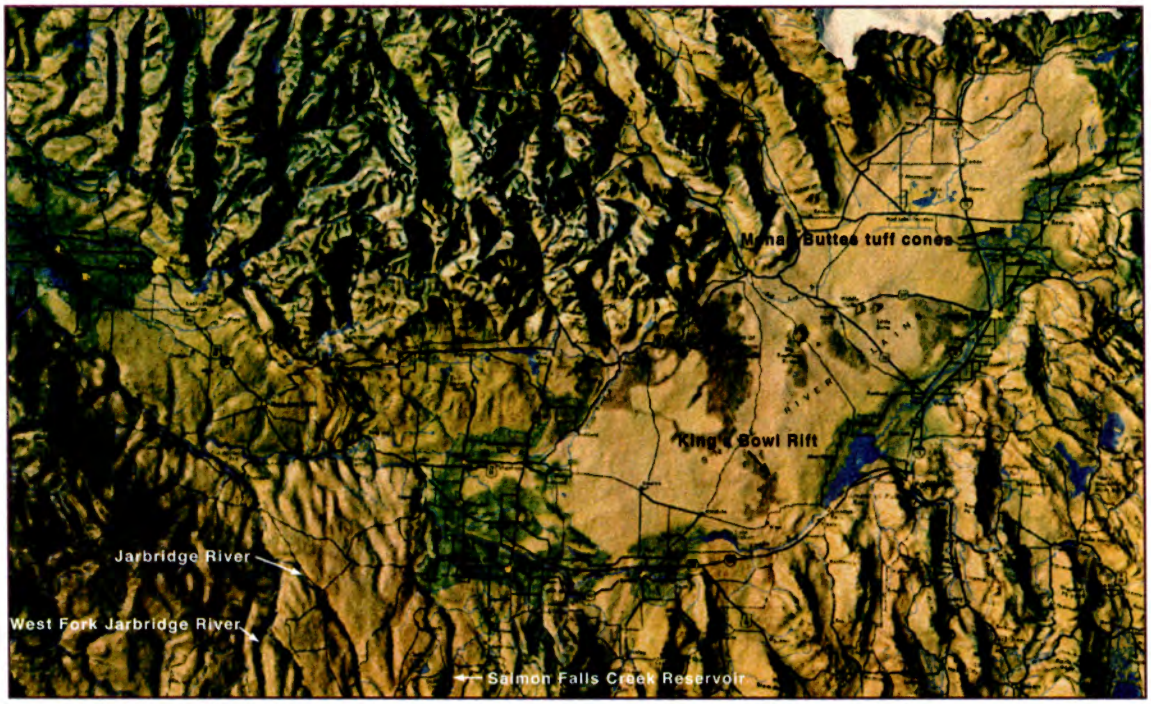


The Yellowstone Caldera is the combined caldera for the Mesa Falls Tuff (about 1,200,000 years old) and the Lava Creek Tuff (about 600,000 years old). Mt. Washburn is the north half of an Eocene andesite volcano. The south half collapsed into the caldera. Yellowstone Lake is a caldera lake. West Thumb is a smaller caldera that collapsed after extruding voluminous rhyolite flows 155,000 years ago. Mary Bay and Duck Lake are post-glacial steam explosion pits or maars. Interglacial rhyolite flows (about 117,000 years old) cover the western part of the caldera which probably merges into the Island Park Caldera (Huckleberry Ridge Tuff - about 2,000,000 years old).



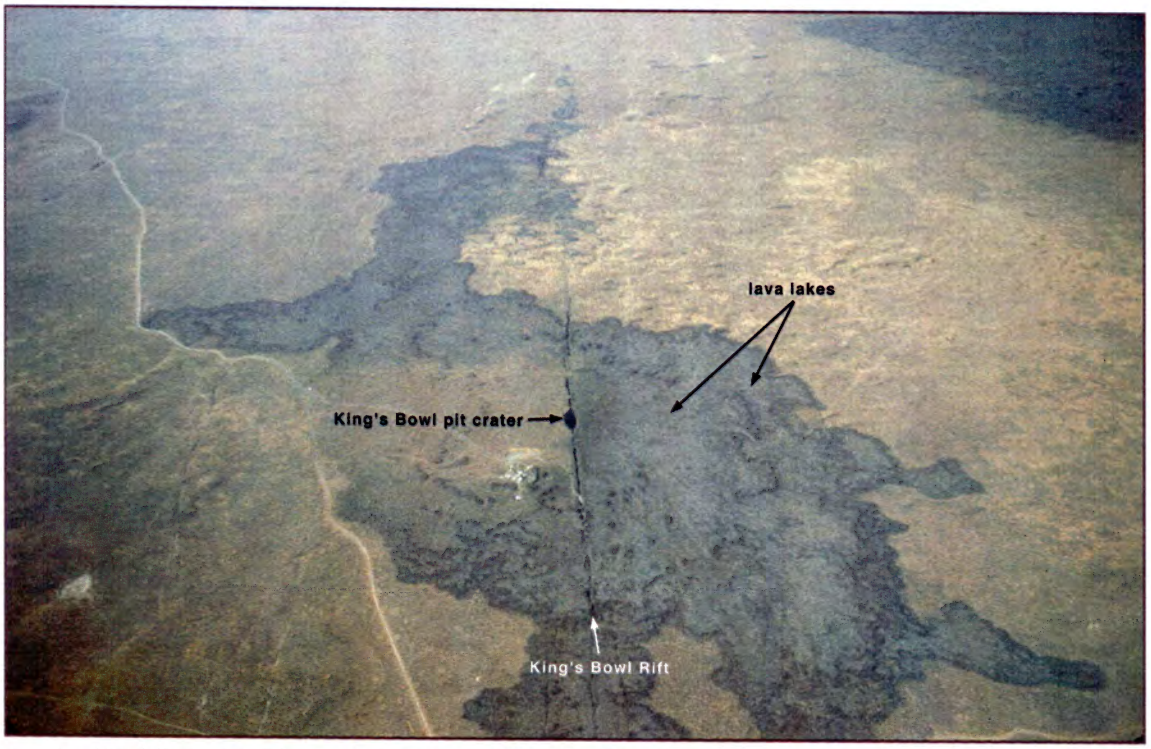
You are looking southward over Mount Washburn at the Yellowstone Caldera. Mount Washburn is the north half of an Eocene andesite volcano. The south half lies buried under rhyolite flows that covered the collapsed jumble. Could some of the rhyolite flows be lava that ponded in the caldera after its collapse?

You are looking southward at a thick rhyolite flow exposed in the cliffs across the Madison River in the western part of Yellowstone Park. The rhyolite flowed across this area to form the Rhyolite Plateau during the interval between the Bull Lake and Pinedale glaciations, about 117,000 years ago.

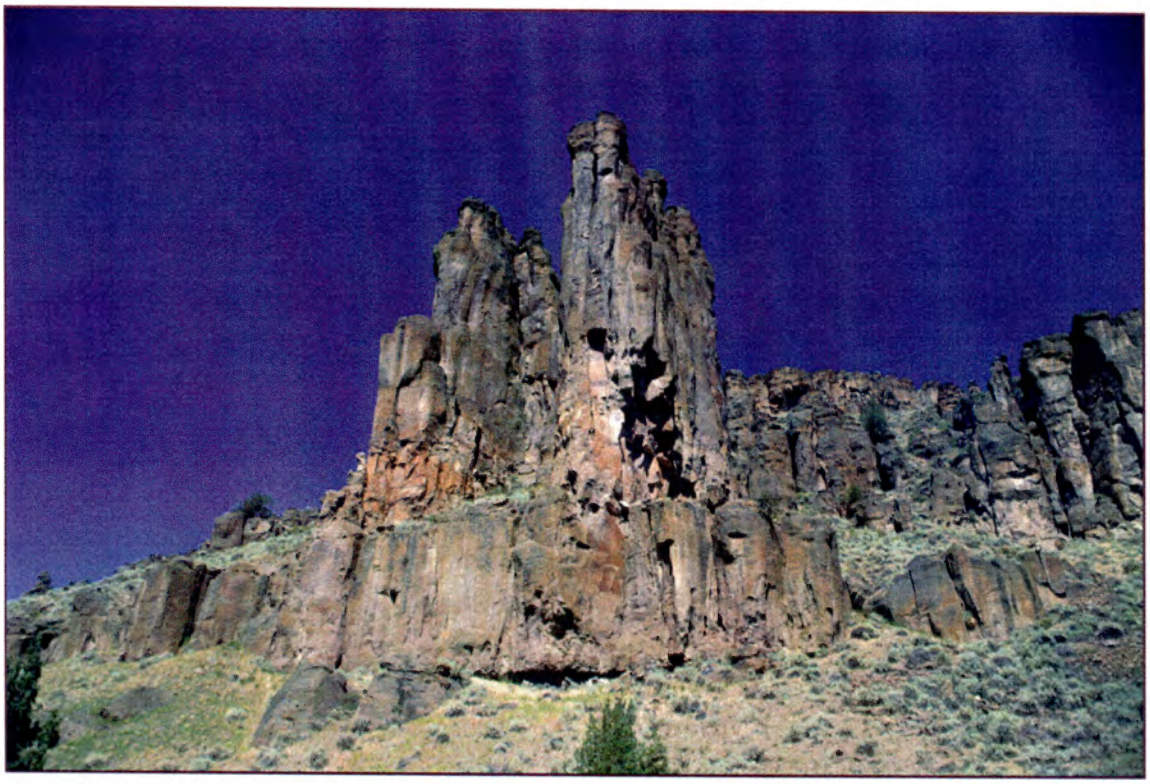


Like a fiery torch, the Yellowstone hotspot burned its track through the crust as it melted silicious rocks that then erupted as huge rhyolitic ash flows followed by outpourings of basalt. Menan Buttes and King's Bowl rift are sites of recent basaltic eruptions; Jarbridge River, its West Fork, and Salmon Falls Creek Reservoir are sites of rhyolitic ash flows erupted in rapid succession to form cooling units of welded tuff about 11 million years ago.

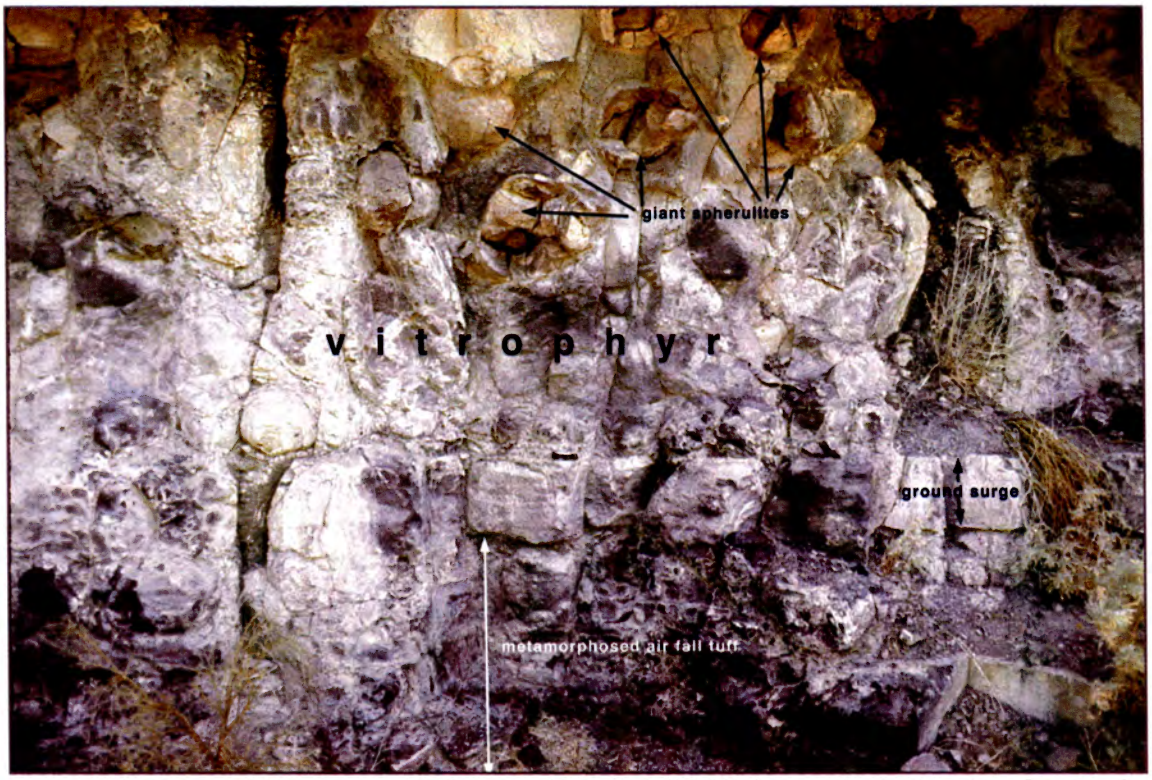
Water from Snake River floodplain gravels, heated by gas-charged basaltic lava, flashed to steam to produce powerfully explosive eruptions that blew out the extra large craters. The steam that permeated the ash dissolved some of the glass fragments to become saturated with silica that then precipitated between the volcanic fragments to form the soft volcanic rock called tuff. Menan Buttes are typical tuff cones showing many gullies incised on their flanks into of the soft impermeable tuff.



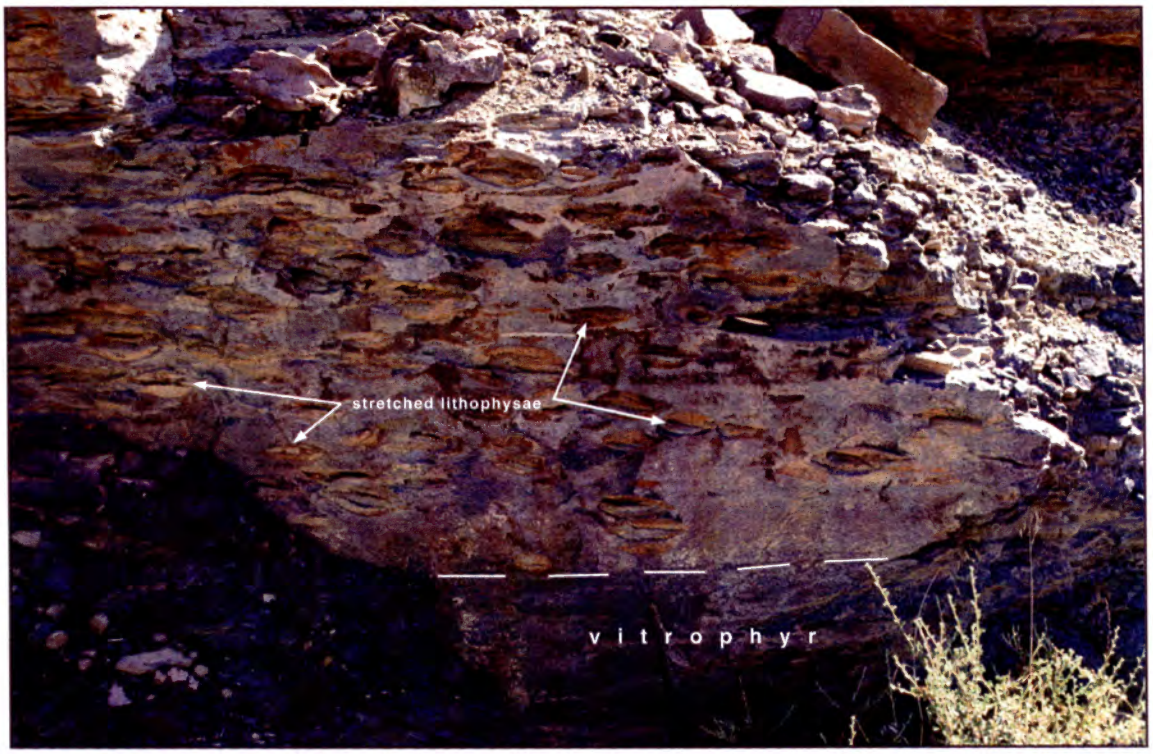
You are looking southeastward at King's Bowl, a pit crater, along the rift. Lava squeezed out from the rift to form lava lakes dammed by a natural levees of congealed lava along their edges. The pit crater formed as steam blew out under a sealed portion of the rift. Wind blew ash from that blowout to cover part of the lava lake east of the rift.



Cougar Point Tuff XI is one of fourteen Cougar Point tuffs, each one erupted about 11 million years ago as a series of ash flows poured out in rapid succession to form a cooling unit of welded tuff. This one is 300 feet thick and is the most widespread of the Cougar Point Tuffs. Its basal ledge shows crude columnar joints, and its eruption temperature has been estimated at 850 to 900 degrees centigrade. West Fork Jarbridge River.



The ground surge at the base of Cougar Point Tuff XIII formed as sheets of superheated air blasted out from the base of the ash flow at perhaps 340 mph, about twice the estimated velocity of the ash flow itself. Glass shards welded together to form the vitrophyr above the ground surge as it cooled rapidly from its eruptive temperature of about 800 degrees centigrade. Spherulites formed as the glass attempted to crystallize.



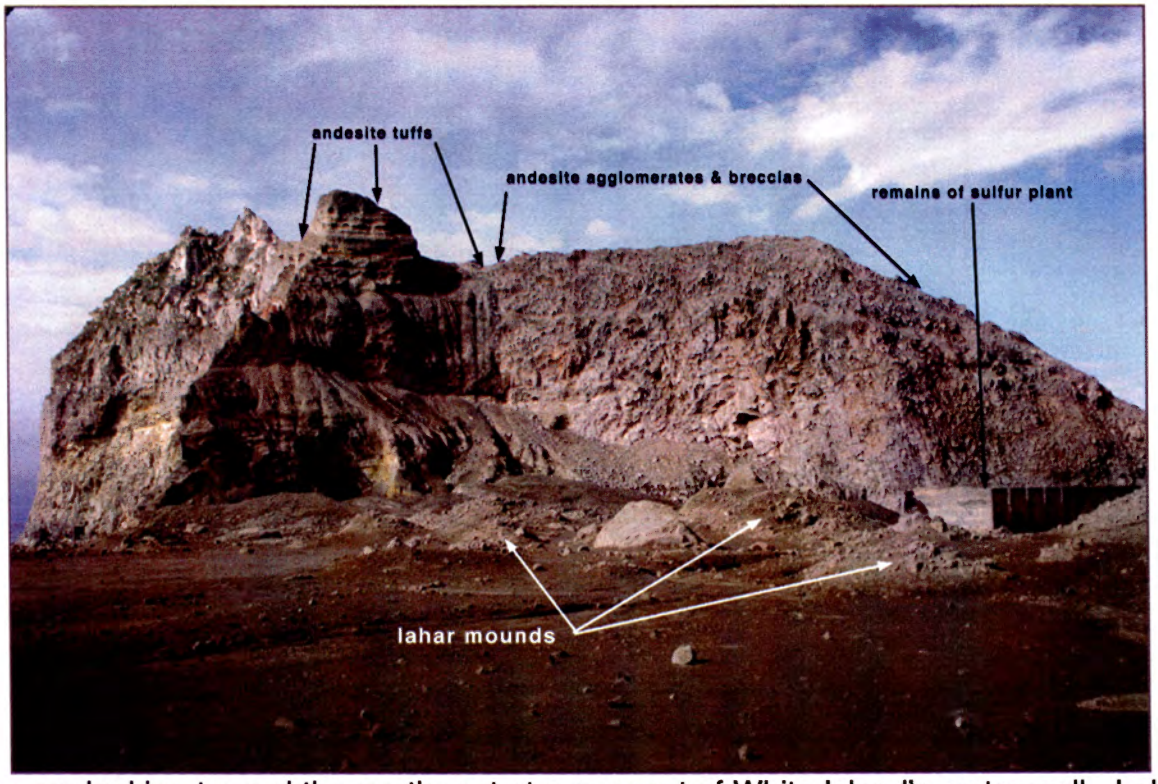
Sixty to 110 mph flow of thin, hot, lava-like ignimbrite stretched the gas chambers (lithophysae) that formed above the vitrophyr in this unnamed welded tuff above Cougar Point Tuff XIII. This tuff, only 10 feet thick, agglutinated, degassed, and devitrified while it was being deposited. Flow indicators are all aligned, indicating a source to the north of this locality east of Jarbridge Canyon.

Arrows point to the closed ellipse cross section across a tongue-like fold in Tuff of McMullan Creek at Salmon Falls Creek Reservoir, SW Idaho. The tongue extends toward you and is part of a cascade of folds, as shown below, formed as the hot ash agglutinated into lava-like flows while they were emplaced.

You are looking toward the northwest at an outcrop that is perpendicular to the outcrop shown in the picture above. The folds cascaded over one another in response to south-westward flow of the ash flow as the hot ash flow agglutinated to form a lava-like flow.

Auckland, New Zealand's largest city, is built around 48 basaltic volcanoes, a few of which are visible here. Their eruptions span the period from 60,000 years ago to the last few hundred years. Each volcanic eruption built a volcanic cone that then plugged that spot so well that subsequent eruptions emerged elsewhere.

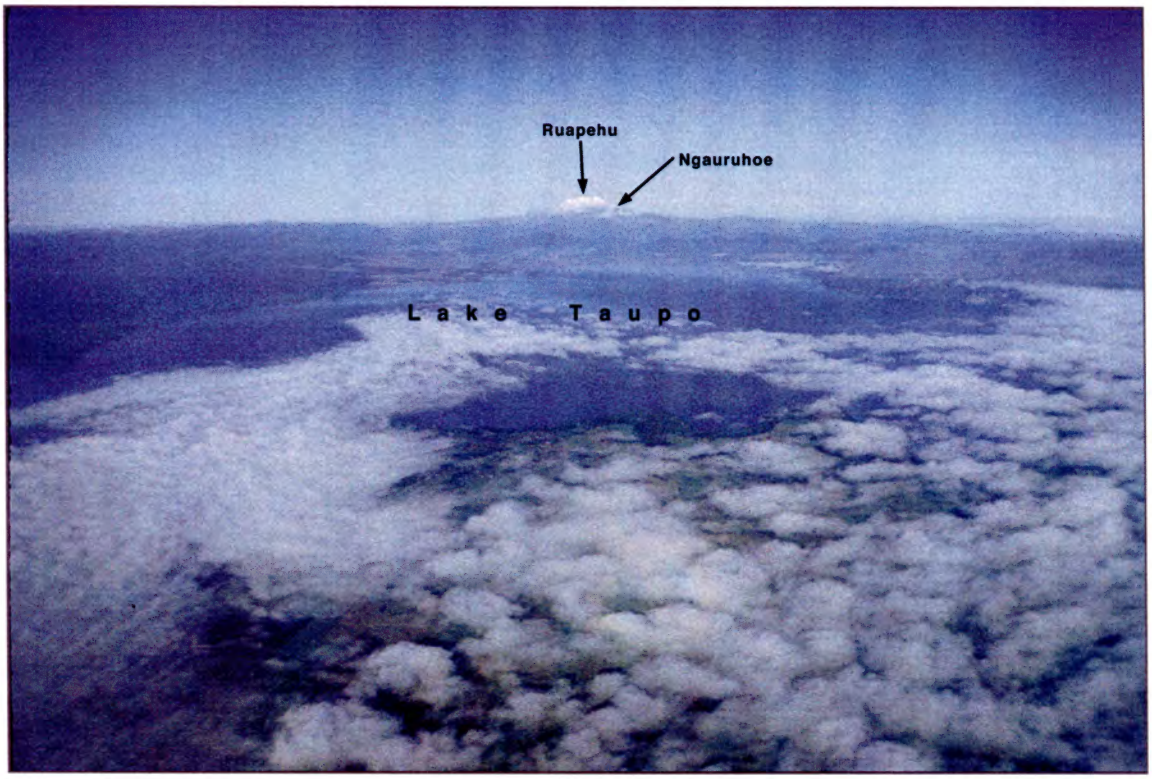
White Island is an active andesitic volcano in New Zealand's Bay of Plenty, about 32 miles east of the North Island. It is the northernmost volcano of a series of volcanoes occupying a rift valley that extends northeastward across the central part of North Island.



You are looking toward the southwest at a remnant of White Island's crater wall. Lahar mounds are viscous knots of debris in a volcanic mudflow; the more fluid parts of the mudflow drained away around them. The mudflow came from the inside northwest wall of the volcano and overwhelmed the sulfur plant, killing 11 workmen in 1914.

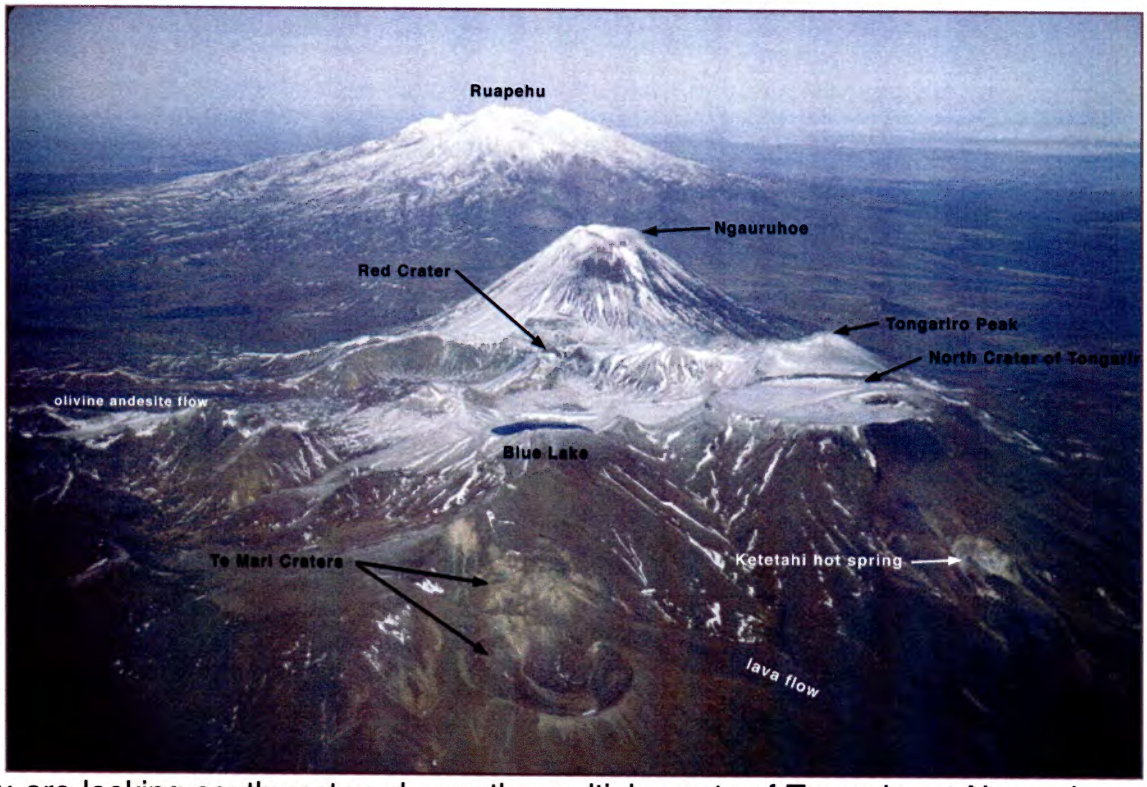
Bright yellow sulfur-rich water occupies White Island's crater lake. The 1914 mudflow originated from collapse of the hydrothermally weakened rock on the inside of the crater wall on the opposite side of this crater lake.

You are looking toward the southwest along Tarawera Rift near Rotorua on New Zealand's North Island. The flash intrusion of a basalt dike accompanied by earthquakes began shortly after midnight on June 10, 1886. By 2:10 a.m. the dike had cracked open part of the 10-mile-long rift across 800-year-old rhyolite domes (Wahanga, Ruawahia, and Tarawera) and the older Plateau Dome. A mushroom-shaped cloud of basaltic ash pierced by fire balls and lightning flashes rose with a roar 30,000 feet into the air. The rift extended southwestward under Lake Rotomahana, which blew out at 3:20 a.m., destroying the famous pink and white terraces and blasting a column of ash and mud up over seven miles into the night sky. While mud and ash rained down from this explosion, hot pyroclastic surges of mud and ash swept across hills up to 1100 feet above the lake. Ash and mud continued to explode along the entire 10-mile length of the rift until 6:00 a.m. when the eruption ceased. Three villages near the mountain were obliterated, and 150 people died. Visible in the rift where it crosses Ruawahia Dome are the light-colored rocks of the rhyolite overlain by a mantle of darker basaltic ash from the rift eruption.

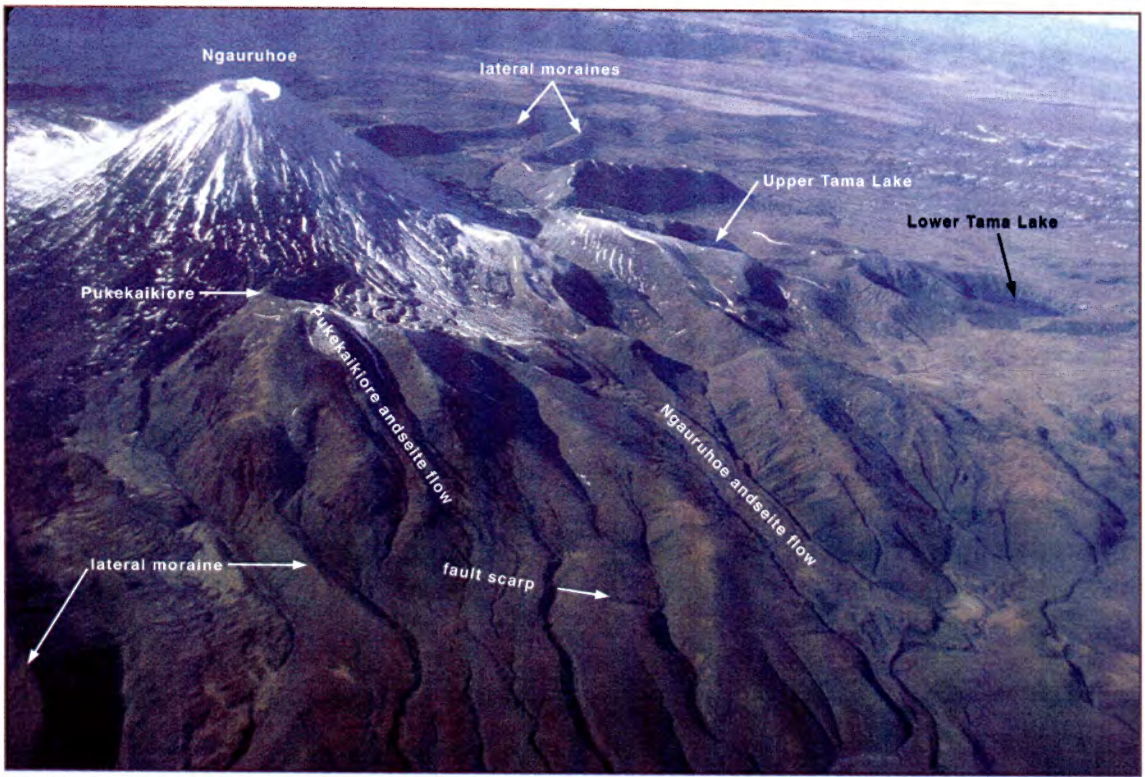


You are looking toward the southwest across Lake Taupo at Ngauruhoe and the massive volcano Ruapehu on New Zealand's North Island. Lake Taupo has been the site of volcanic eruptions for the last 300,000 years. The last two, 26,500 and 1800 years ago, were colossal eruptions that produced and modified the caldera occupied by Lake Taupo. The eruption 1800 years ago occurred in seven stages*. Stage 1: Minor explosions below ancestral Lake Taupo deposited a small ash fall deposit close to the lake. Stage 2: Magma pressure raised the vent above the lake, and a high eruption cloud rained pumice over a large area downwind (east) of Taupo. Stage 3: Lake water mixed with a gas-charged foam of magma to deposit a thin, white, ash-rich pumice. Stage 4: Gas-depleted magma mixed with lake water to form a high, water-rich eruption plume that deposited mud and ash. Stage 5: The vent area cleared of water and a 50km-high eruption plume rained pumice over a large area as parts of the eruption cloud collapsed to produce small pyroclastic flows. Stage 6: A fountaining eruption plume produced huge pyroclastic flows, the Taupo Ignimbrite, that covered much of the central part of North Island and sped at velocities estimated at 350 to 550 miles per hour, topping Ngauruhoe as it sped around Ruapehu. Stage 7: After perhaps 25 to 30 years, volcanic domes formed under the lake, producing huge rafts of pumice that were deposited on a beach about 15 feet above present lake level.

*"The Taupo Eruption", Institute of Geological & Nuclear Sciences Information Series #12.



You are looking southwestward over the multiple vents of Tongariro at Ngauruhoe and Ruapehu. Ruapehu last erupted explosively from 9/95 into 7/96. Ngauruhoe's last eruption of ash and pyroclastic flows was in 1975. The olivine andesite flow came from Red Crater and flowed down a glaciated valley.



Ngauruhoe is a postglacial volcano that has grown in the last 2500 years. Its andesite lavas partially fill the crater of Pukekaikiore and spill down the valley to cover the fault scarp that cuts diagonally across the lower slopes of Pukekaikiore. At least 60 eruptions have been recorded from Ngauruhoe since 1839. Picture taken June 23, 1997.