# A STEREO PICTURE GUIDE TO ANDESITE AND RHYOLITE VOLCANICS

**By**

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**1998**

You are looking southward at Redoubt Volcano rising 10,197 feet above Cook Inlet in Alaska's Chigmit Mountains. The volcano erupted from December 1989 through the spring of 1990. Ash from the eruptions covers the glaciers on its flanks. Recent snows blanket the ash on the upper slopes. A mass of brecciated lava too thick to flow is forming a tholoid in the vent. Steam escapes around it. Picture taken June 28, 1990

# Viewing Stereo Images

The two small pictures at the top of each page are a stereo pair. To see the image in three dimensions, you need to look at the right image with the right eye and the left image with the left eye. To do this, pick out some prominent feature in the pictures and stare beyond the pictures. The two prominent features, one from each picture, should float together in the center. This center image will be in three dimensions. At first it may not be in focus. You are accustomed to associate convergence of your eyes with focus. If you continue to stare at the center image, your mind will ultimately relent and focus on the center image while your gaze remains parallel, each eye looking at its respective image.

A simple exercise may help prepare you for this unaccustomed way of viewing. With your hands at arm's length in front of your eyes, touch your two index fingers together as you look beyond them. You should see a sausage image between your two index fingers. Your eyes are parallel, the right one looking at the right finger, the left one at the left finger. The two images have floated apart, the right one to the left and the left one to the right to form the sausage. The feeling in your eyes is the one you should try to imitate when looking at the stereo images. Some will master the technique instantly. It will take longer for others. If you don't succeed at first, keep trying at odd times. Try sometime when you are really tired and tend to see double images anyway when you stare at objects. If I could learn to do it, anyone with two good eyes can. I worked at it off and on for over two years before I suddenly learned the knack.

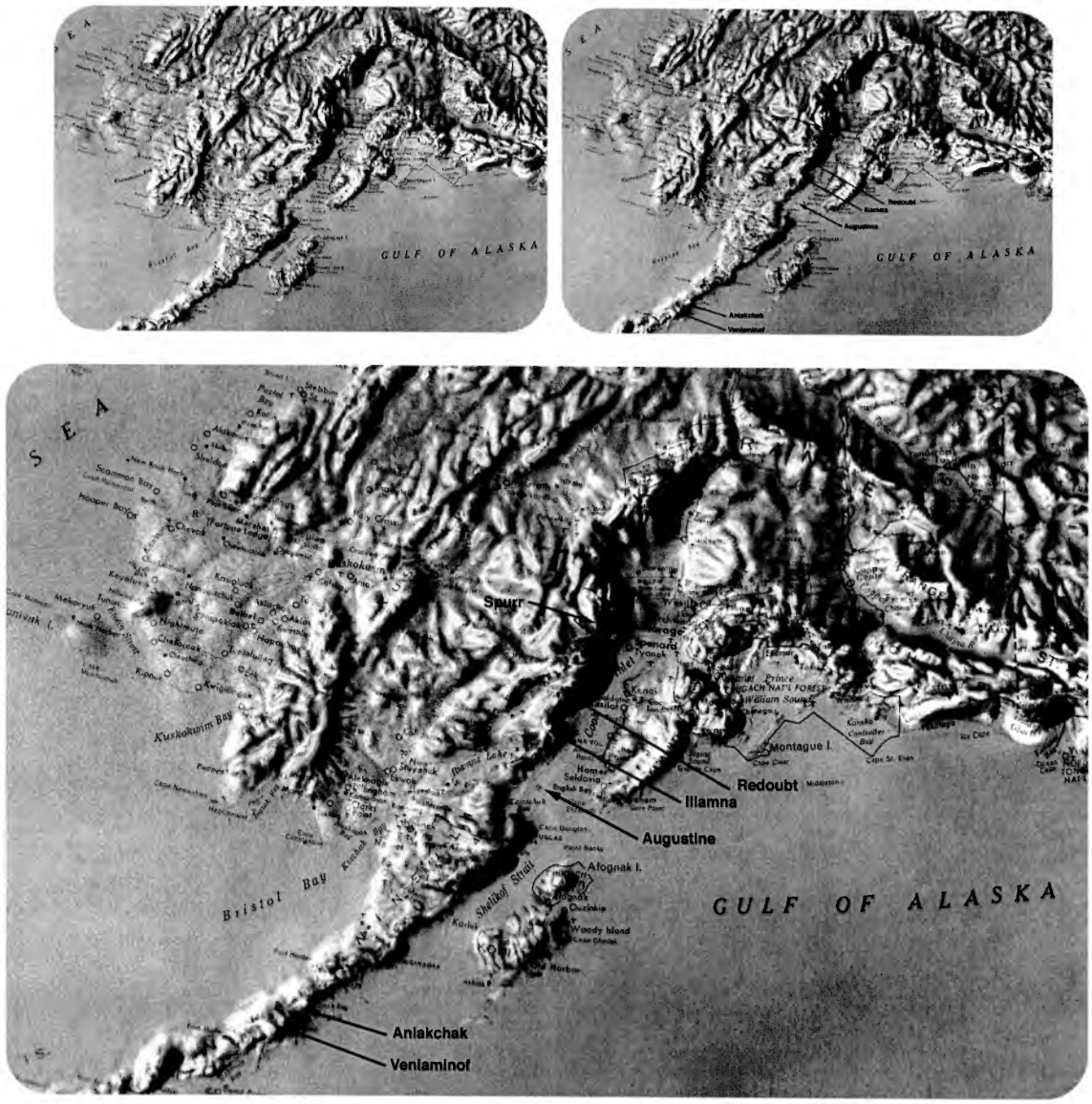
Your eyes are just a few inches apart. With that small separation, you can see in three dimensions for about 1100 feet. Most of these images were taken from a small airplane flying at a velocity of about 100 mph. The interval between the two images varied from one second to several seconds, giving an effective eye base of between 100 and several hundred feet. With this eyebase, you can see in three dimensions for miles. These pictures produce spectacular three dimensional views not easily obtainable in any other way.

# Andesite and Rhyolite Volcanics

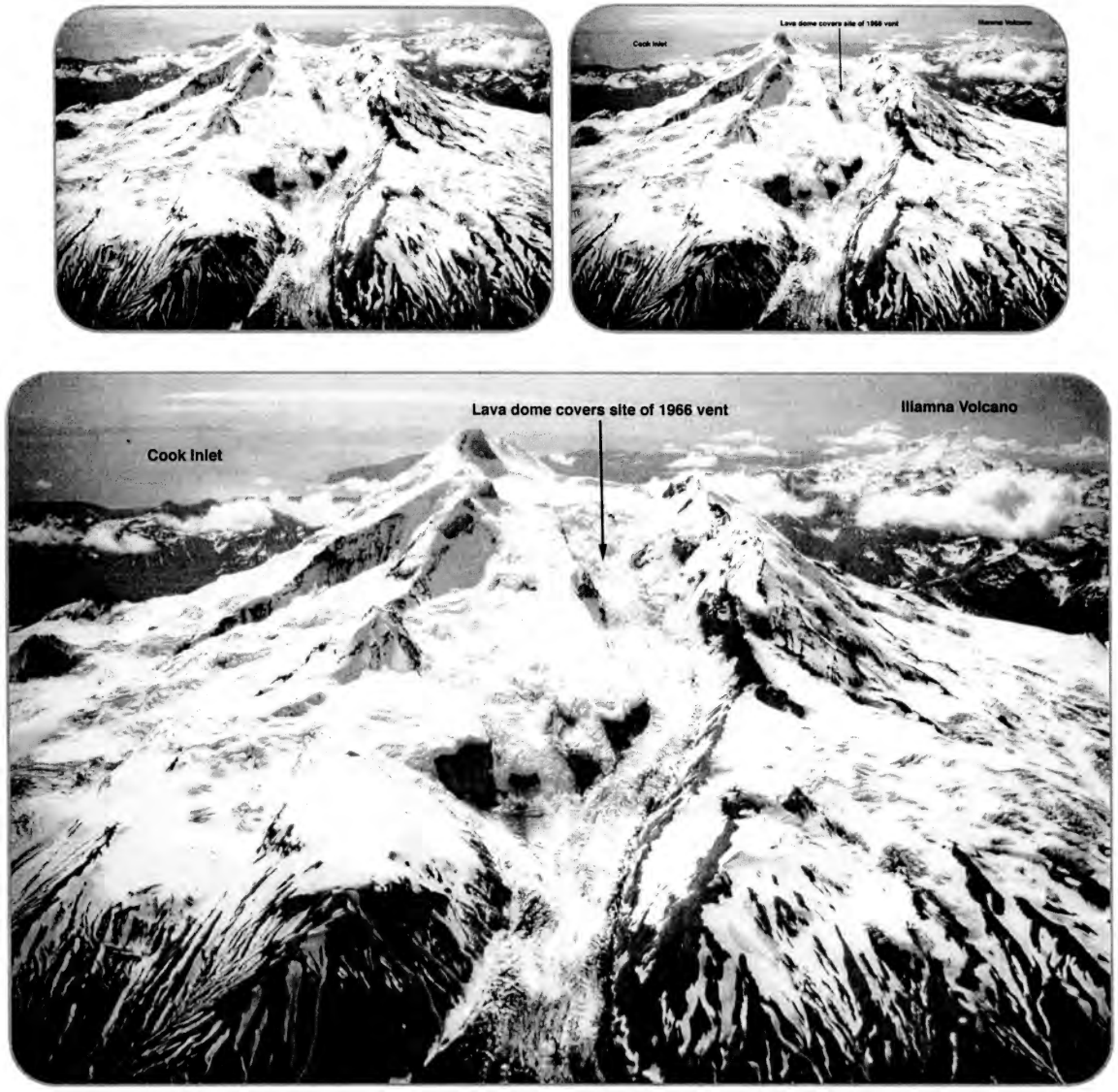
Rhyolite magmas contain the greatest percentage of silica, are the thickest, most viscous, and can be the most explosive of the rock melts. Andesites are intermediate in character between rhyolites and basalts, which are the hottest and most fluid of the magmas.

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 tend to 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.



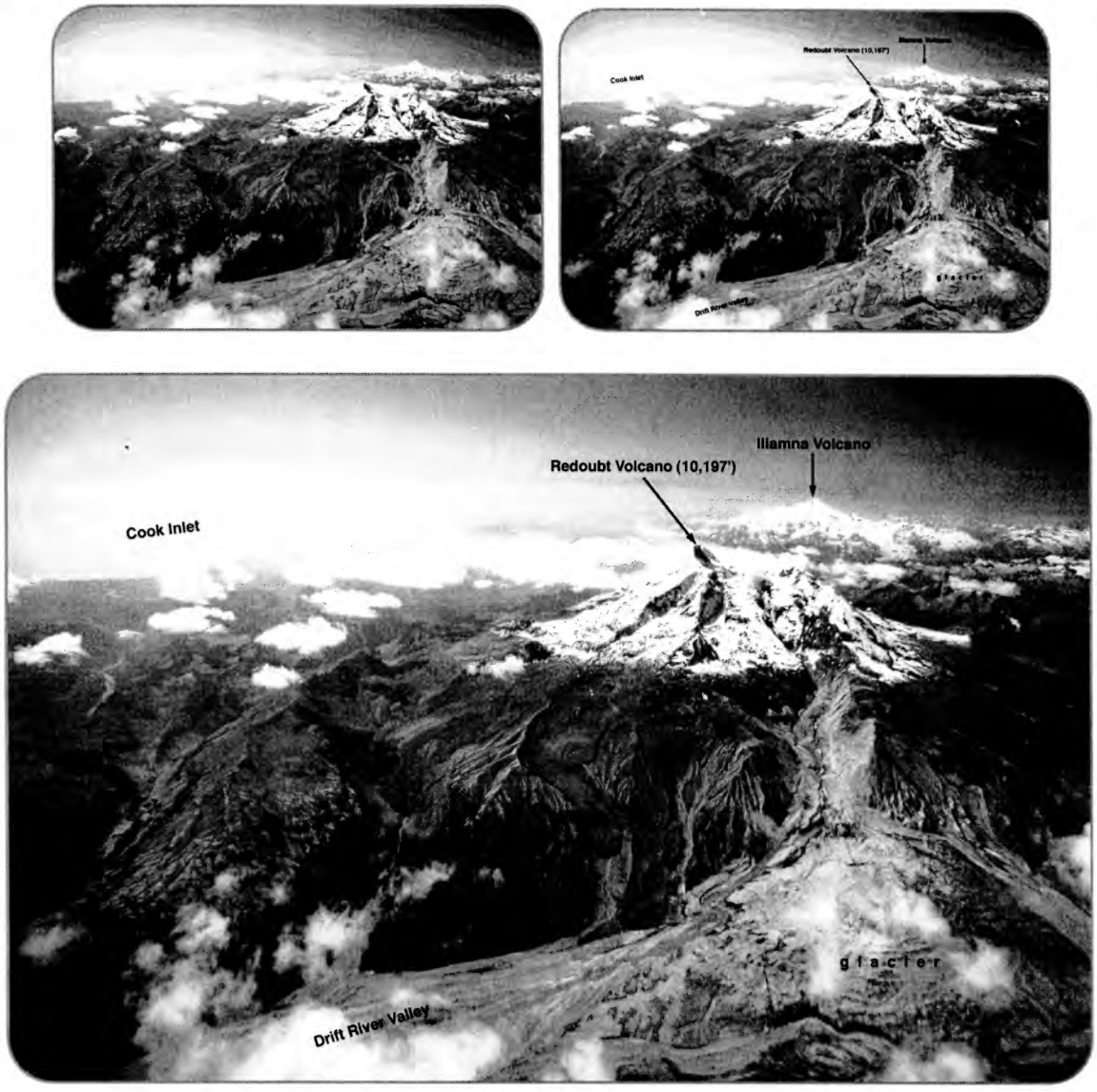

Relief map of Alaska shows the locations of the volcanoes shown on succeeding pages.



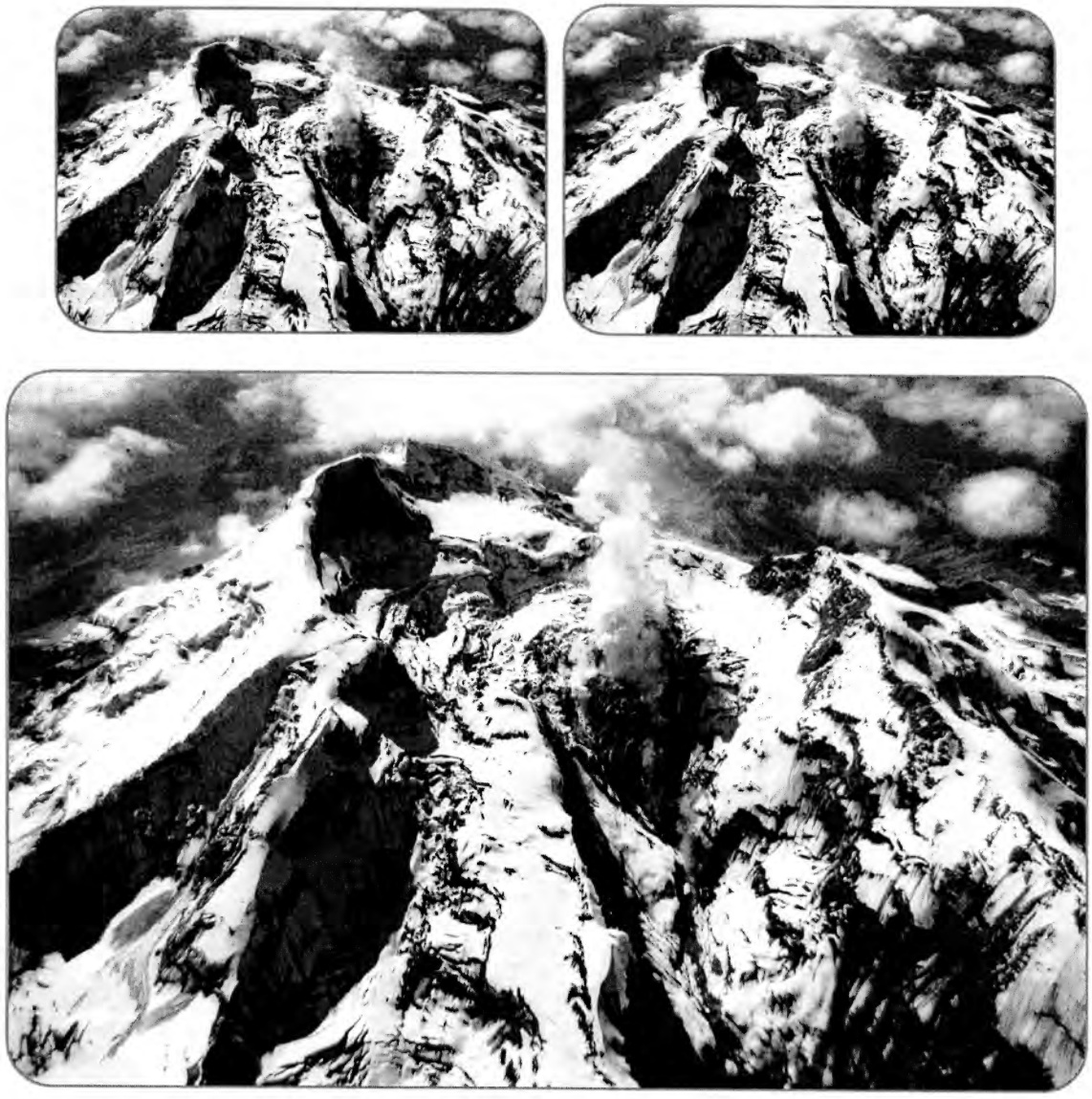

You are looking southward on July 19, 1983 at Redoubt Volcano in the Chigmit Mountains at the northern end of the Alaska Peninsula. It rises 10,197 feet above Cook Inlet and last erupted in 1968, covering its glacier with ash and pyroclastic flows. Thirty layers of ash in the northern Cook River Inlet area have been attributed to eruptions of Redoubt Volcano in the last 10,000 years. Its earliest eruptions, about 900,000 years ago, were thin basaltic and basaltic andesite flows. The magma then presumably absorbed more crustal rocks and became highly explosive, dacitic in composition. In its later stages it has become less explosive and andesitic in composition. Its upper cone consists of 30 to 60 meter thick andesite flows on top of an apron of pyroclastic flows and debris flows.*

Brantley, S.R. et al, 1990, "The eruption of Redoubt Volcano, Alaska, December 14, 1989-Ausust 31, 1990, USGS Circular 1061.

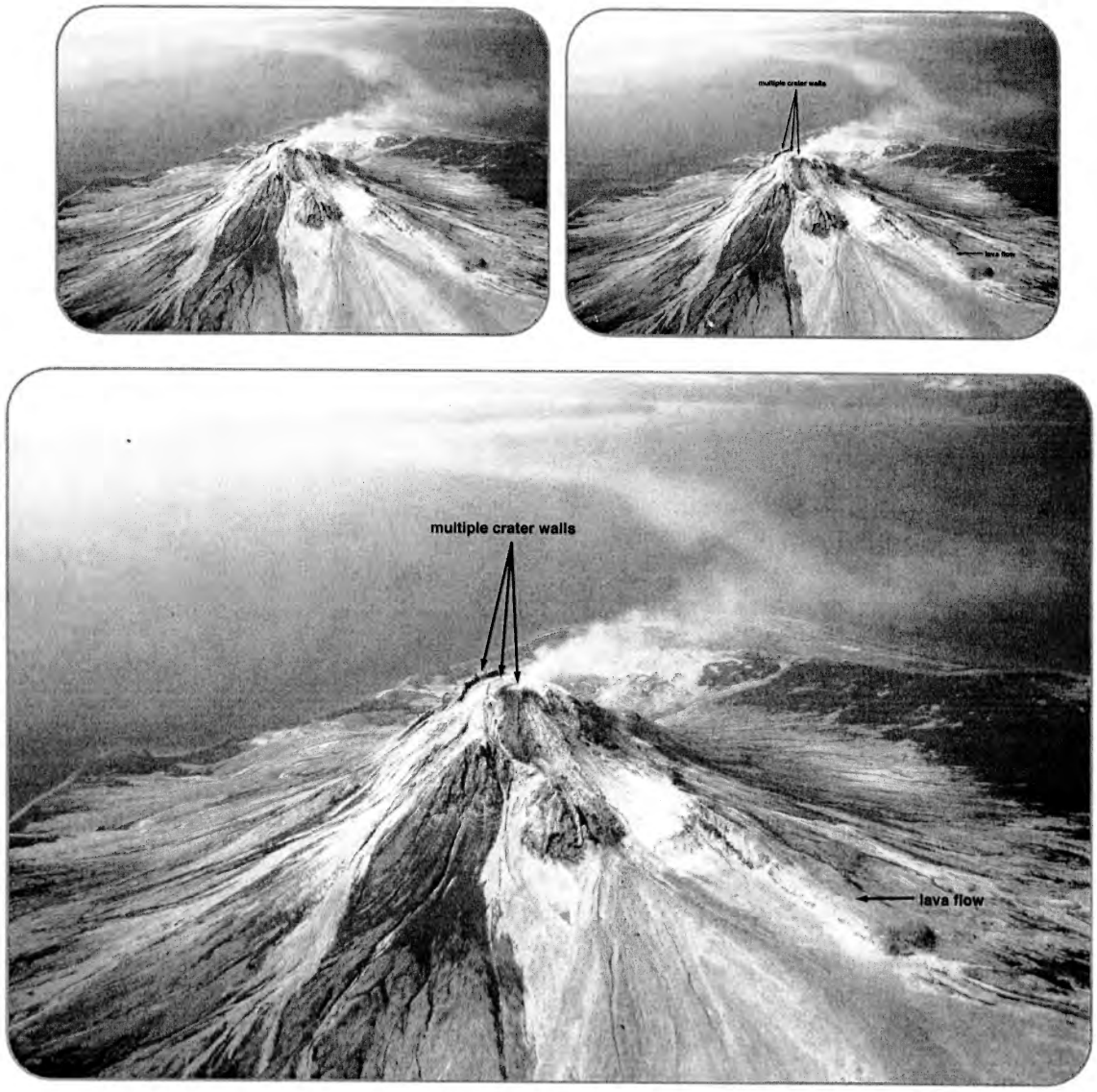
You are looking toward the southwest on June 28, 1990 at Redoubt Volcano in the Chigmit Mountains north of the beginning of the Alaska Peninsula. Blockade Glacier and the small cirque glaciers of the Neacola Mountains in the foreground are covered with ash from the explosions of Redoubt that started in December of 1989 and extended through the spring of 1990.



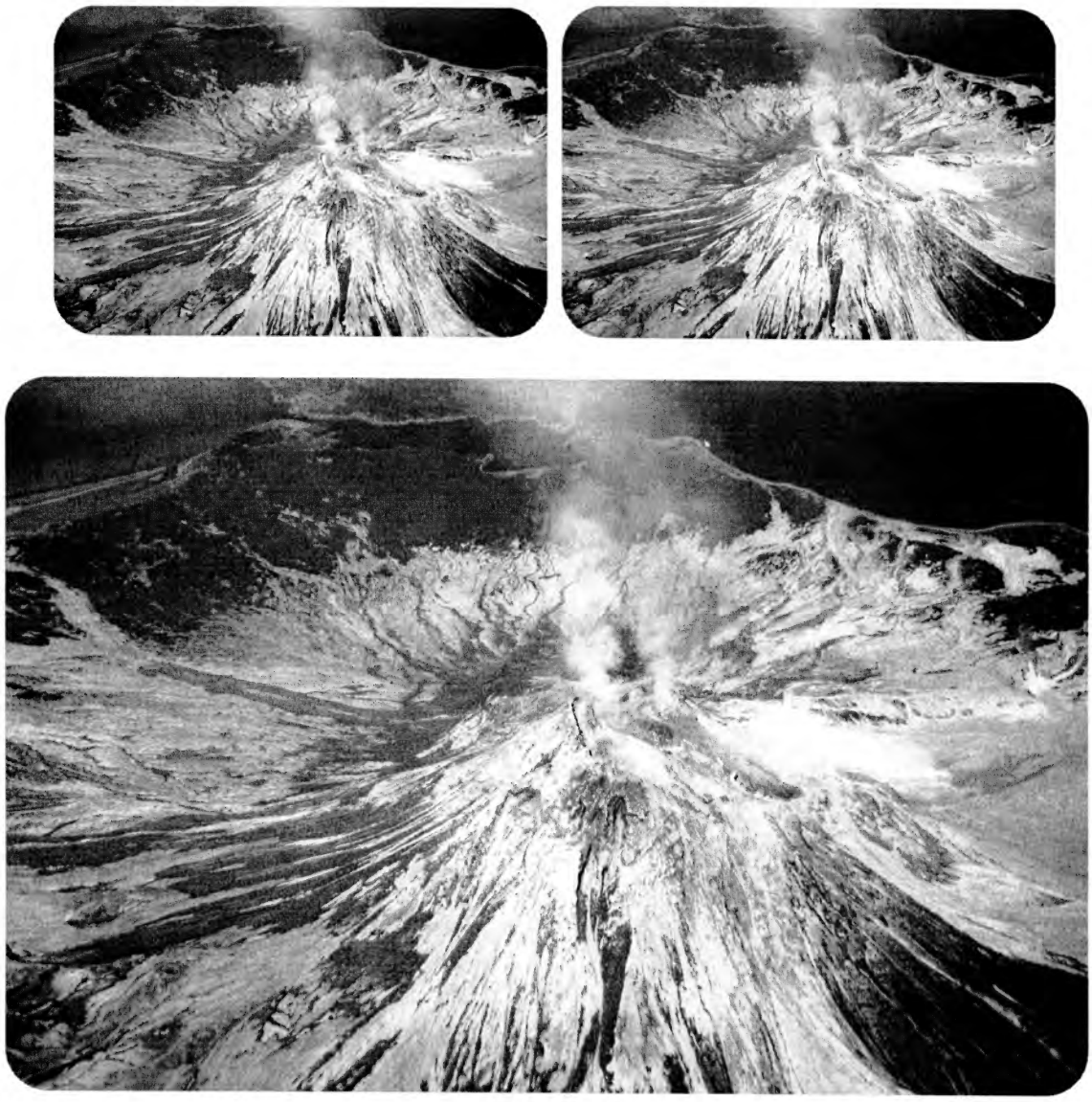

You are looking southward on June 28,1990 at Redoubt Volcano in the Chigmit Mountains of the Alaska Range. It began violent eruptions in December, 1989 and continued intermittent explosions through the spring of 1990. Its glacier, covered with ash and mudflows, extends almost across the Drift River Valley. It was feared that Redoubt's mudflows might overwhelm Union Oil's oil tank farm at the mouth of the Drift River Valley, or that its glacier could surge across the valley to form a temporary dam that could give way in a huge outburst flood to wipe out the tank farm. The dikes around the oil tanks were increased in height, and they withstood the floods and mudflows. The glacier did not surge to block the valley.



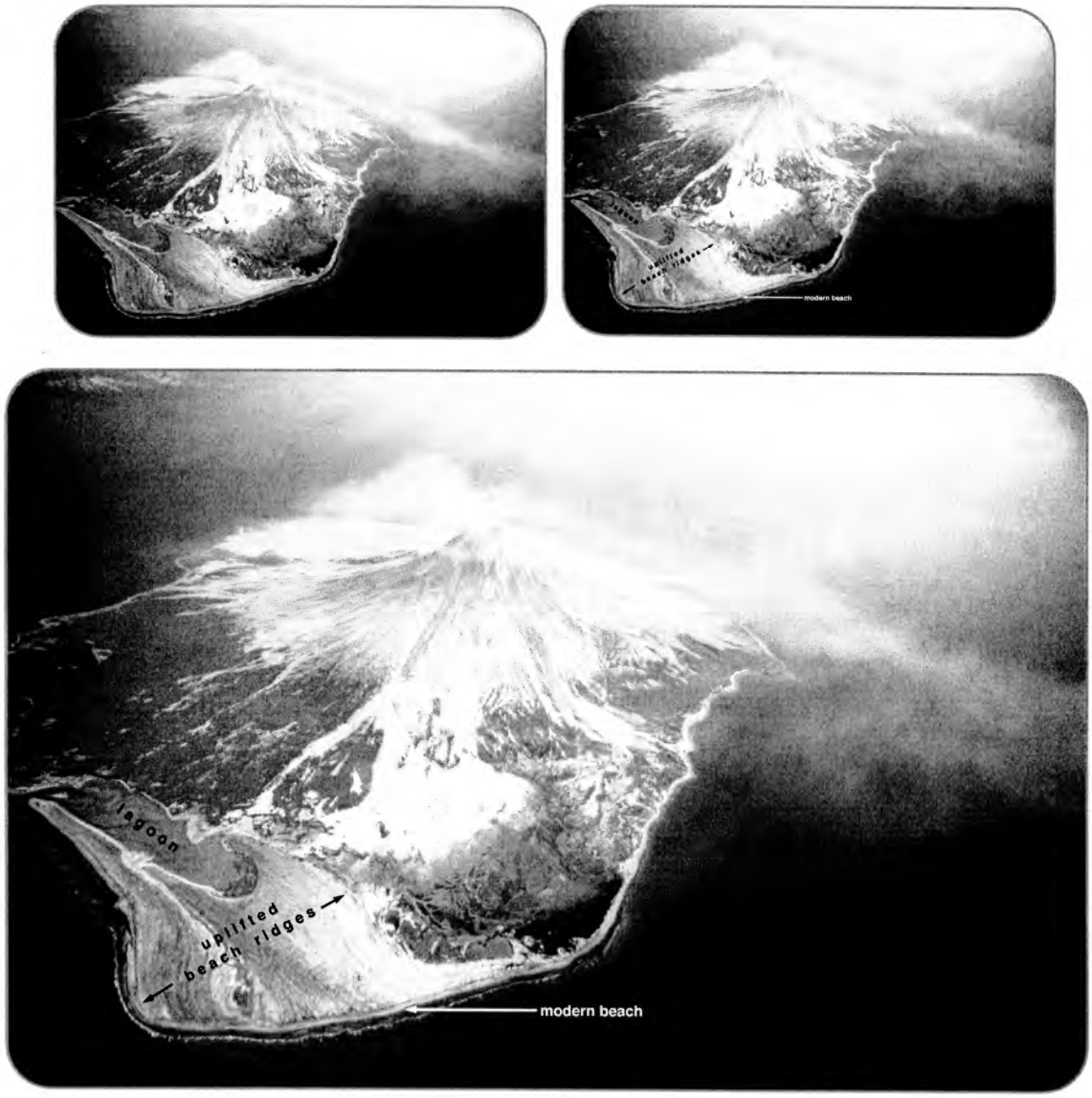
You are looking southward on June 28,1990 at Redoubt Volcano in the Chigmit Mountains of the Alaska Range. Steam rises from a tholoid, which is a hot plug of viscous, brecciated lava that breaks up as it rises in the vent.



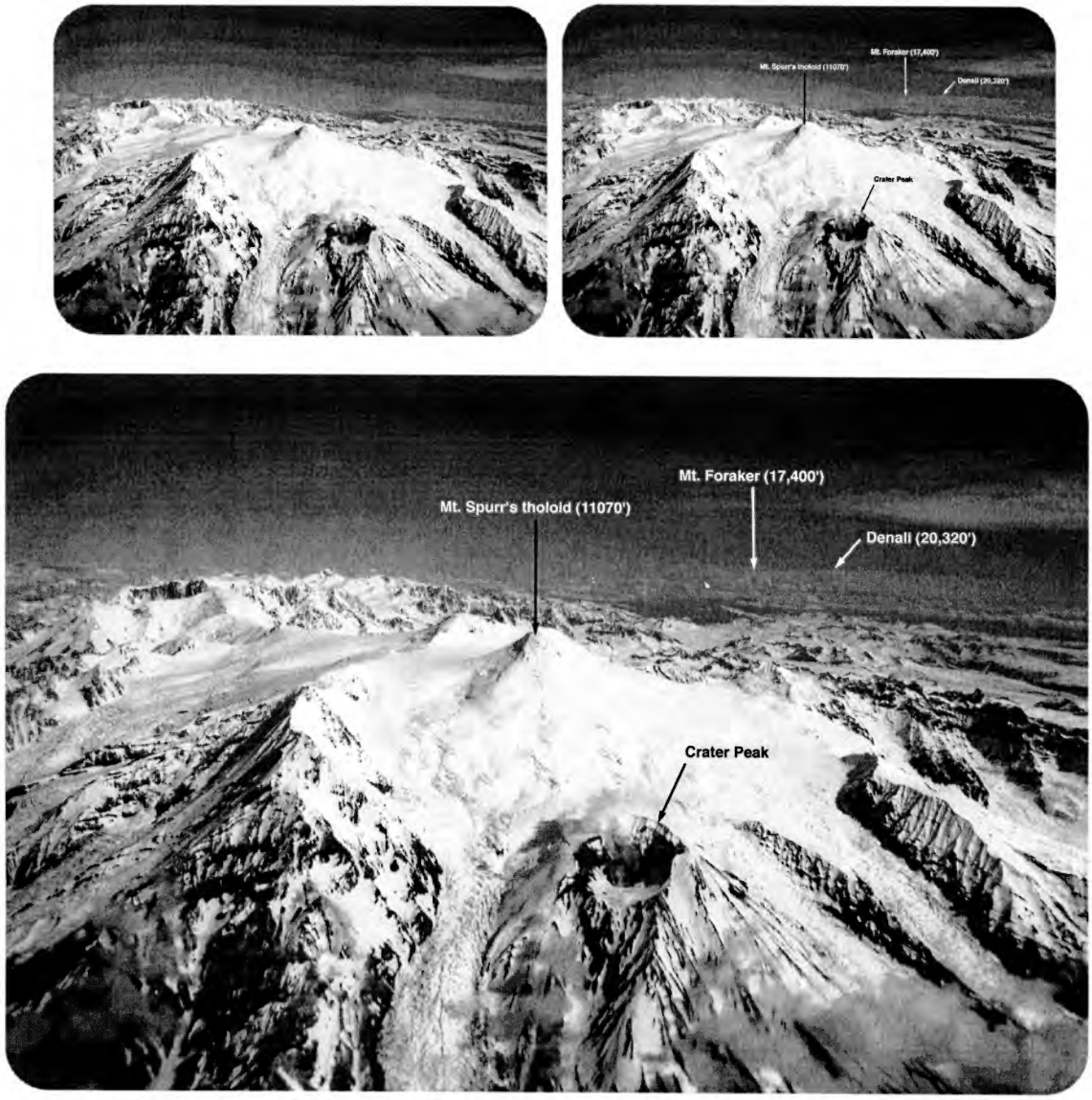

You are looking toward the southwest, on June 16, 1986, at Augustine Volcano in Kamishak Bay at the northern end of the Alaska Peninsula. The volcano rises about 4,500 feet above the bay. Mildly explosive eruptions, repeated about every four to five years in recent times, have migrated northward, leaving behind a succession of partial crater walls flanking the southern side of the vent. A steep-sided, viscous lava flow is visible on the volcano's northern flank.



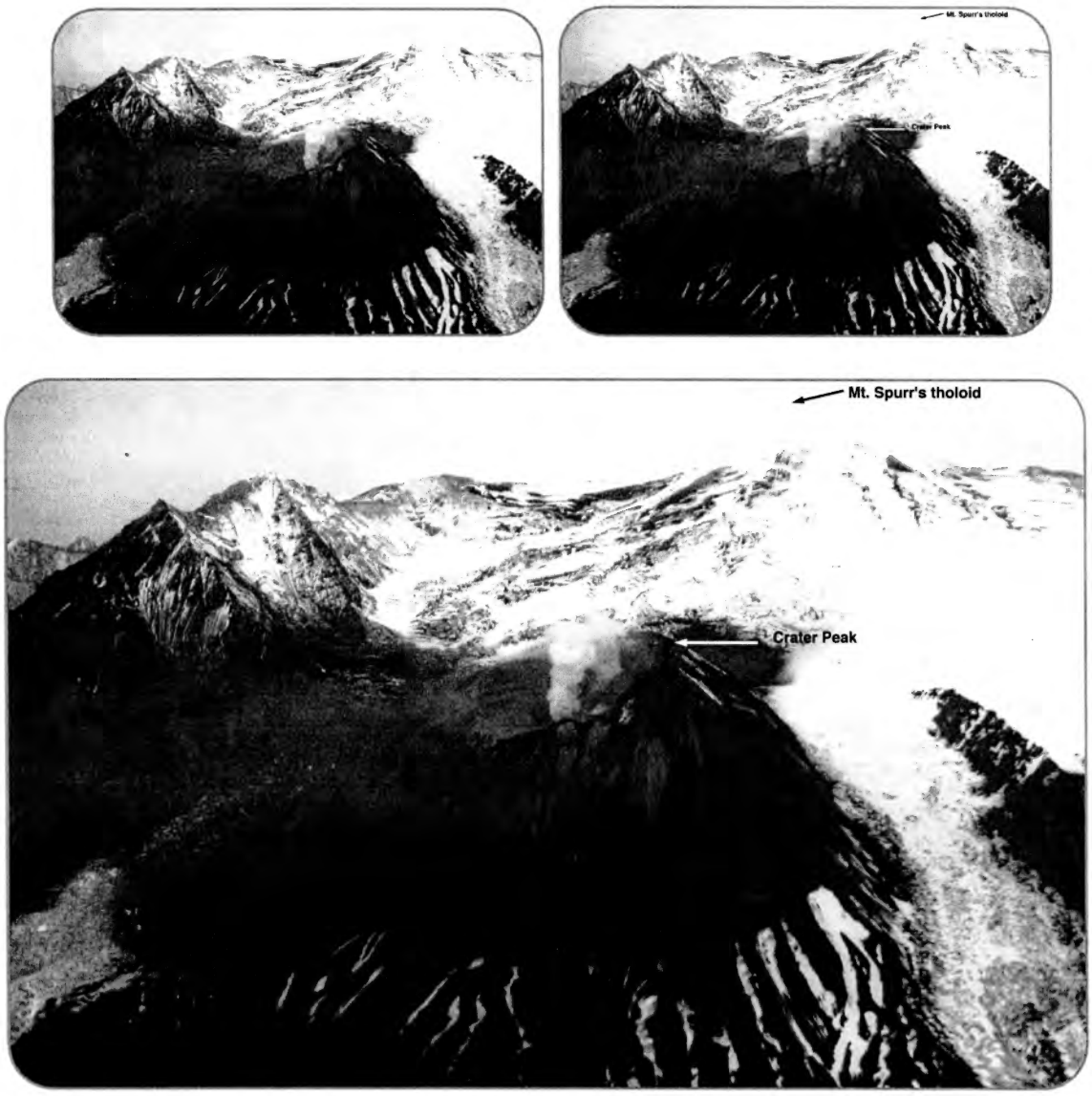
You are looking toward the west. Steam rises along several of the nested crater walls at the summit of Augustine Volcano in Kamishak Bay, Alaska, June 16, 1986.




You are looking toward the northeast at uplifted beaches on the southwestern corner of Augustine Volcano. The modern beach is eroding the old, uplifted beach ridges on the southwestern side of the island. Longshore currents transport the sand around the corner to deposit it on the western side as a barrier in front of the lagoon. The uplifted beach ridges, developed only on this corner of the island, indicate that the island is being tilted by the migration of the magma under it. Picture taken on June 16, 1986.



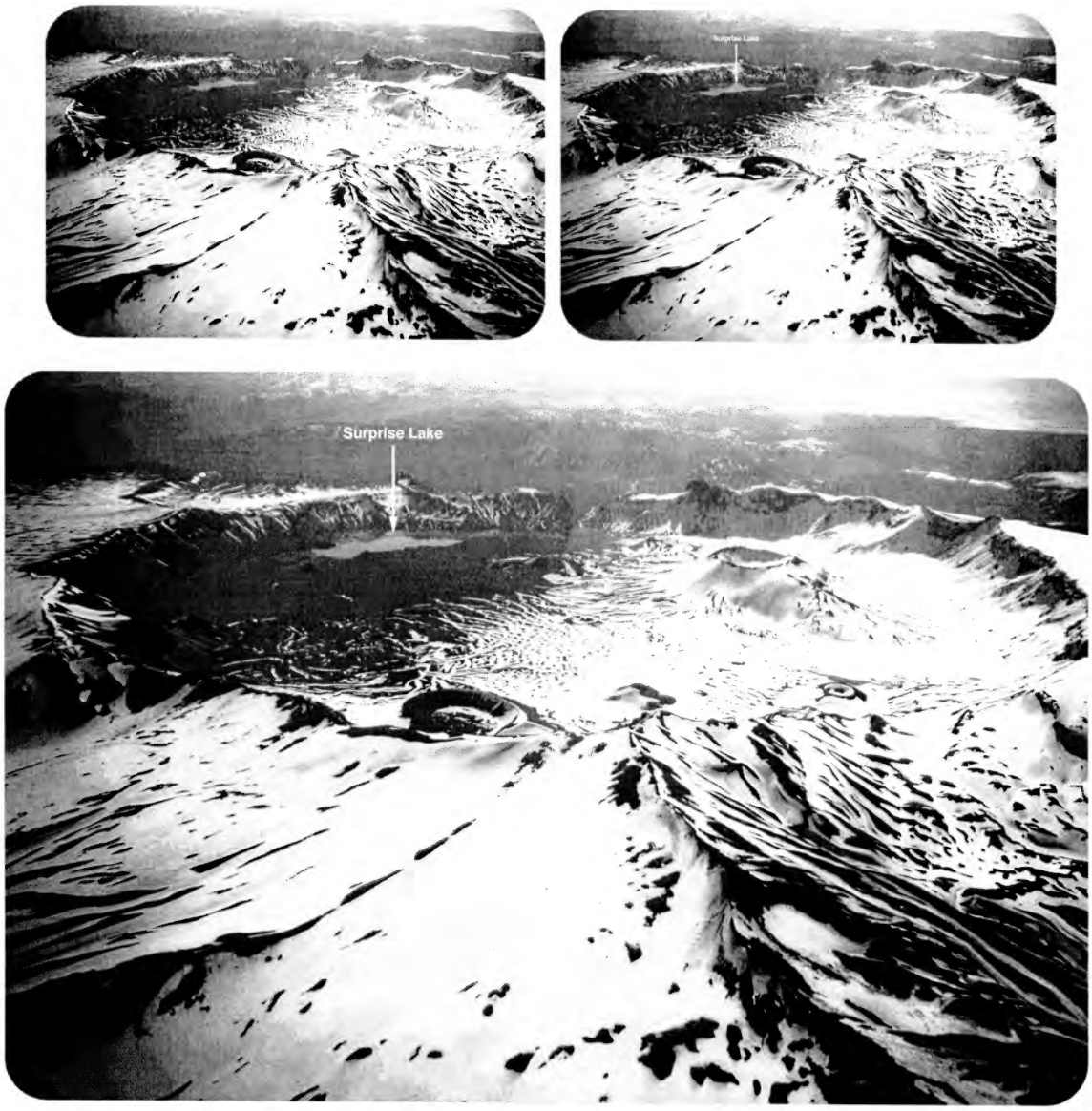

You are looking northward across Mount Spurr, the northernmost volcano of the Aleutian-Alaska Range chain. Steam rises from two fumarolic pits in Crater Peak because a massive volcanic dome, a tholoid, forms such a good plug in the caldera at the top of Mount Spurr. Mounts Foraker and Denali, about 100 miles distant, rise high enough to generate their own cloud cover. Picture taken June 21, 1985.




You are looking northward at Crater Peak on the southern flank of Mt. Spurr in the Tordrillo Mountains of Alaska. The picture was taken on June 28, 1992, one day after ash exploded out of Crater Peak.

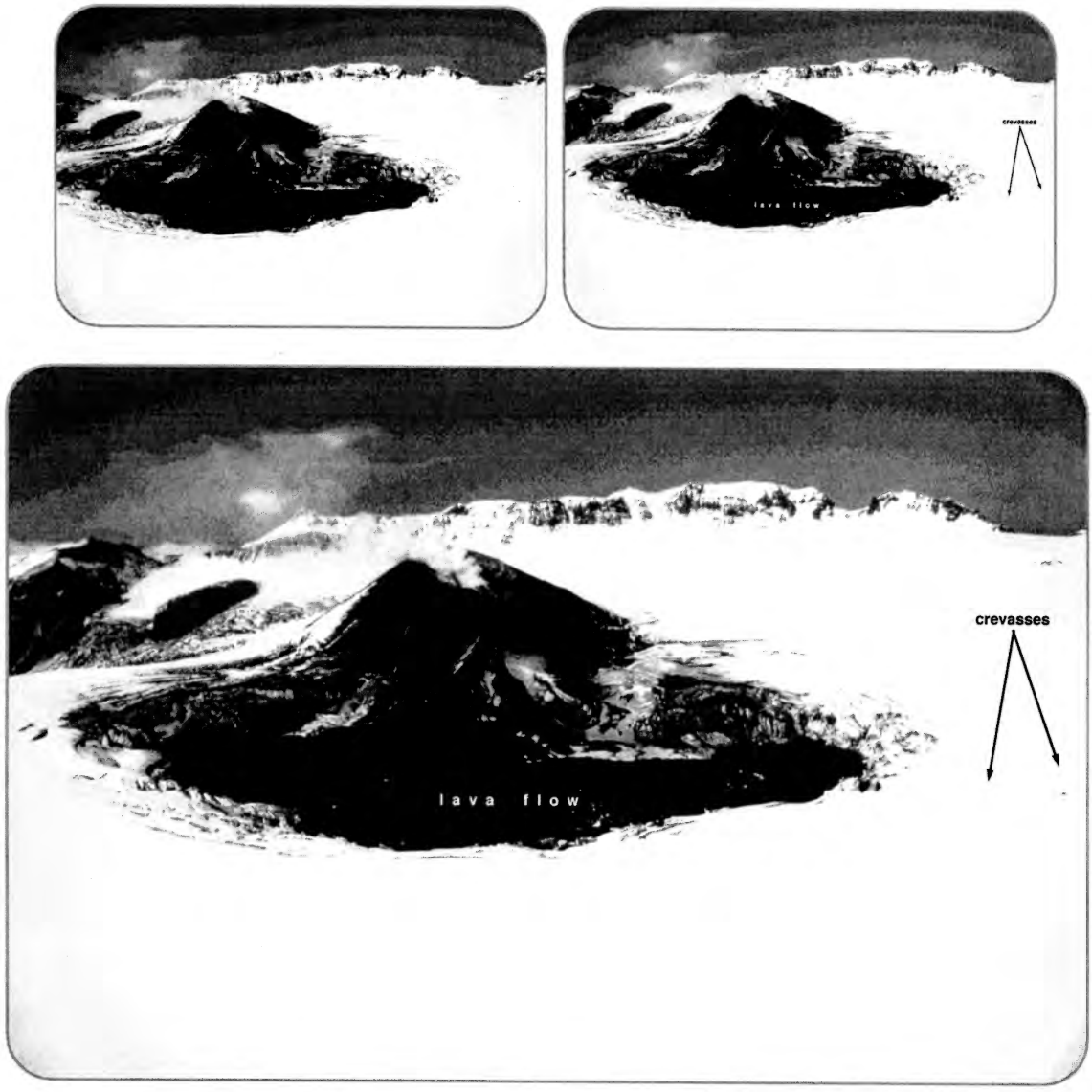
You are looking toward the northwest at Mt. Foraker, about 100 miles north of Mt. Spurr and its parasitic cone, Crater Peak. A blanket of ash from the eruption of Crater Peak on June 27, 1992 covers the glaciers on Mt. Foraker. This picture was taken on July 1, 1992

You are looking toward the west at ash from Mount Spurr's June 27, 1992 eruption. It covers mountains and tributary glaciers on either side of Yentna Glacier in the Alaska Range north of Mount Spurr. Little ash appears to have fallen on Yentna Glacier, but it covers the glaciers that feed the Yentna. The ash must have plastered the landscape as it swept past in a tabular cloud whose base sloped gently downward just above and almost parallel to the surface of the Yentna Glacier.

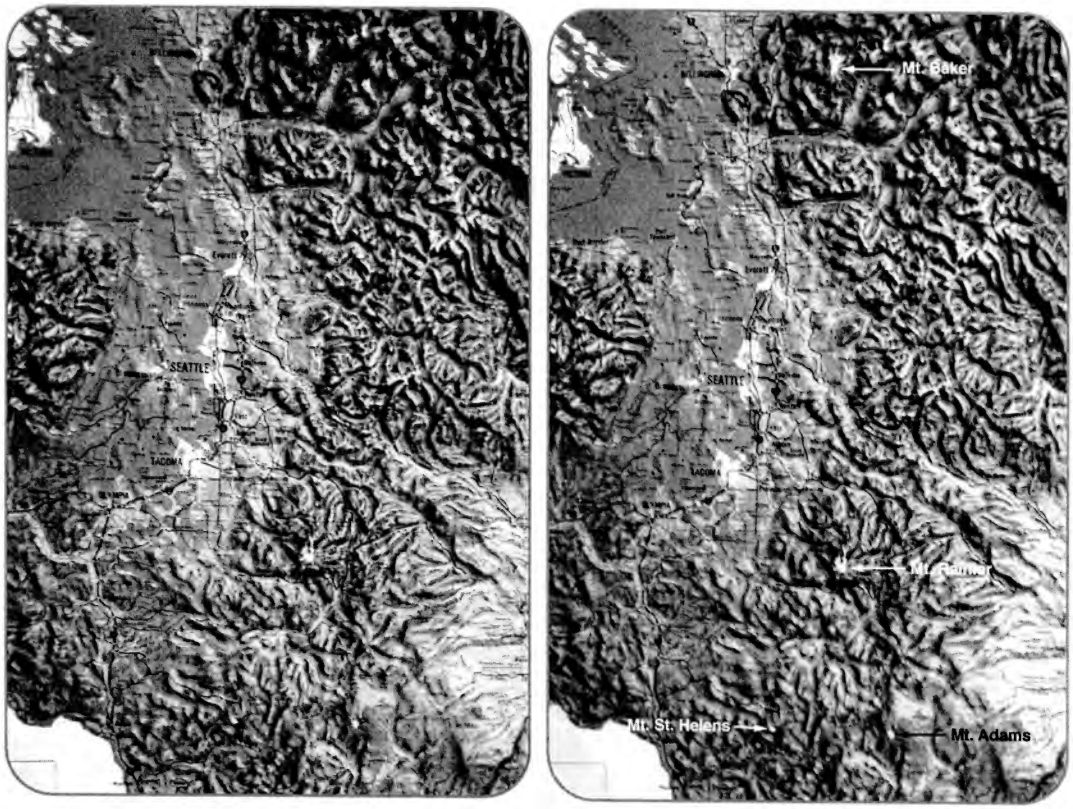


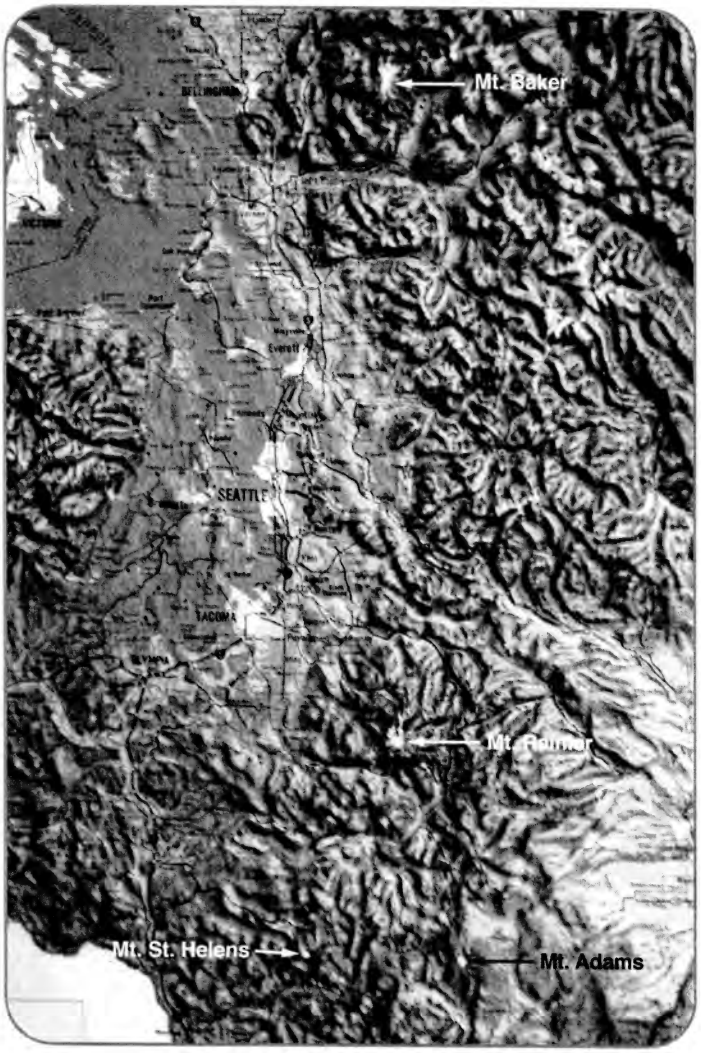

Cinder cones and lava flows partly fill Aniakchak's caldera on the Alaska Peninsula. The caldera is about six miles in diameter. Picture taken by Doug Dresser looking east on June 15, 1984.

You are looking toward the east at a cinder cone protruding through the ice field that fills the caldera at the top of Veniaminof Volcano on the Alaska Peninsula. Picture taken by Doug Dresser, June, 1984.



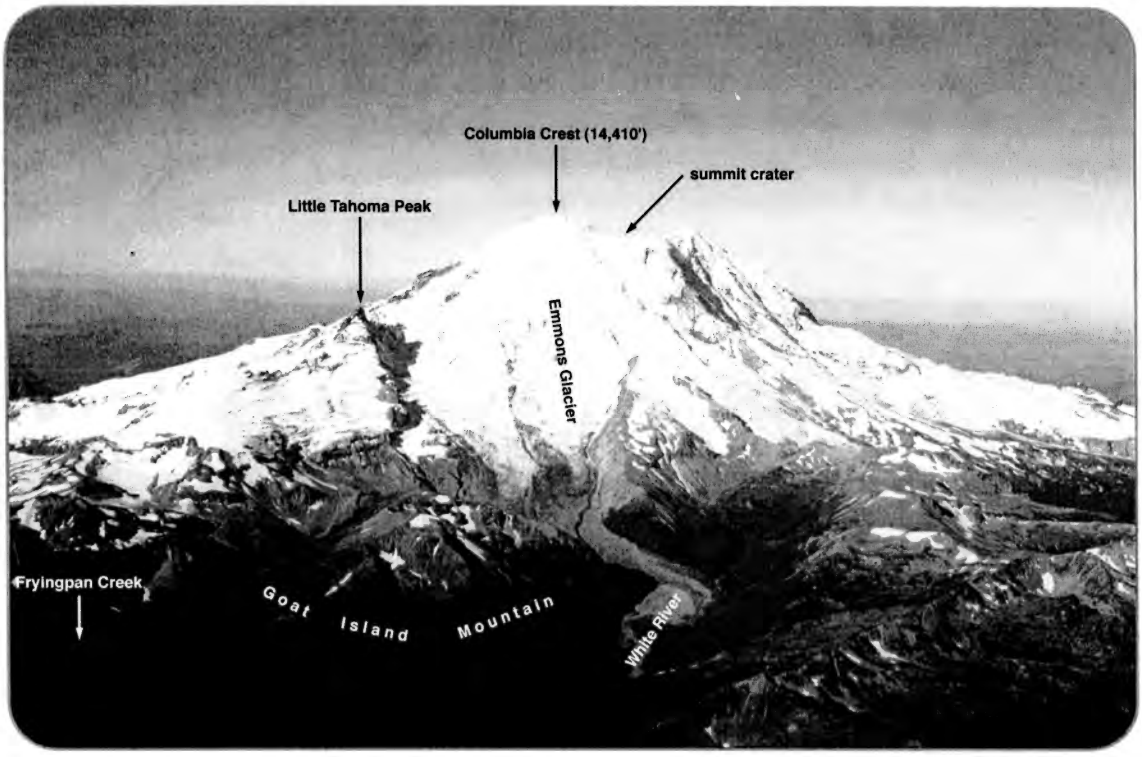

You are looking northward at the cinder cone in Veniaminof Caldera on the Alaska Peninsula. A lava flow from the base of the cinder cone has melted a hole in the ice field. Crevasses surround the hole. Picture taken by Doug Dresser, June, 1984.




A stereo relief map shows the locations of the Washington volcanoes pictured and described on succeeding pages.

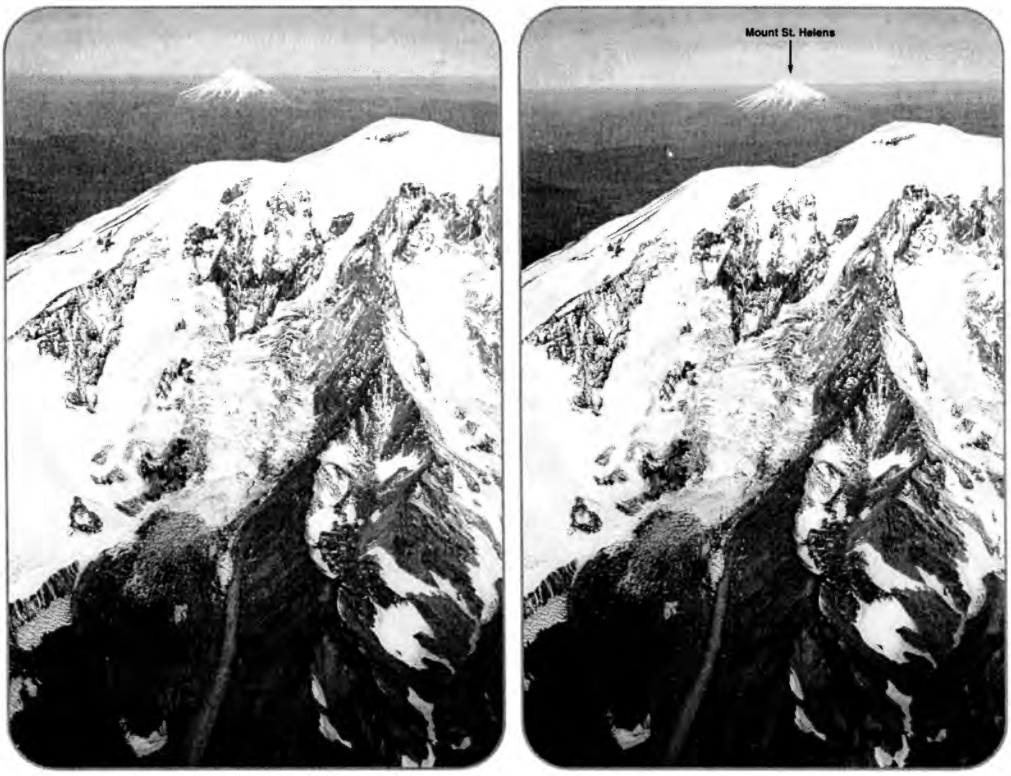
You are looking westward at Mount Baker, a volcano in theCascade Mountains of northern Washington. It began steaming in 1975 in what could have been a precursor to an eruption. However, the mountain did not swell and the steaming subsided without an eruption. An eruption will produce gigantic mudflows from the melting of the glaciers that mantle its slopes. This picture was taken on September 5, 1975.

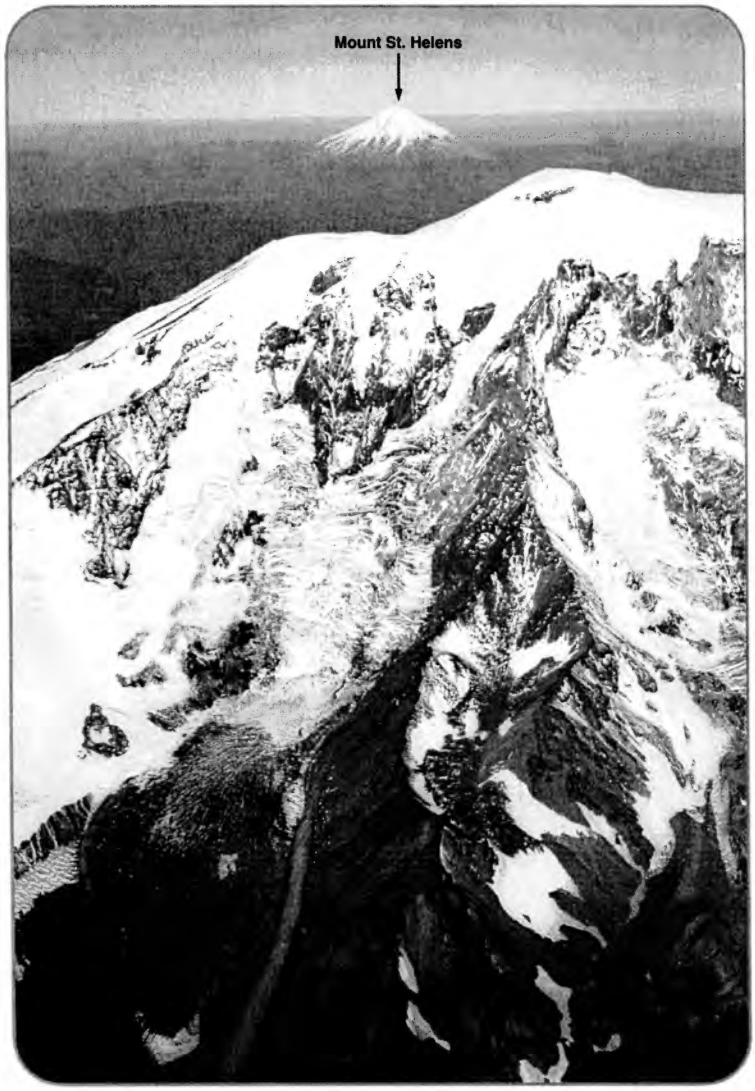



You are looking southwestward at Mount Rainier in the Cascade Mountains of west-central Washington. Little Tahoma Peak is a remnant of the flank of a larger and somewhat taller Rainier, probably rising to an elevation of about 15,000 feet.* Columbia Crest is a Holocene cone built on the edge of the summit crater. The last major eruption of Rainier took place between 550 and 600 years ago. More than 55 mudflows have flowed off Mount Rainier in the last 10,000 years; most have not been coincident with eruptions. Because Rainier contains much structurally weak, locally altered rock capped by ice, any slight warming, swelling, or earthquake activity may trigger mudflows. A major eruption will release catastrophic mudflows that will overwhelm villages all the way to Puget Sound. Five hundred years ago the Electron Mudflow deposited about 16 feet of debris a little over half way to Puget Sound near the present site of Orting. The mudflows are fast-flowing rivers of slurry jammed with debris and floating huge boulders. This picture was taken on September 5, 1975.

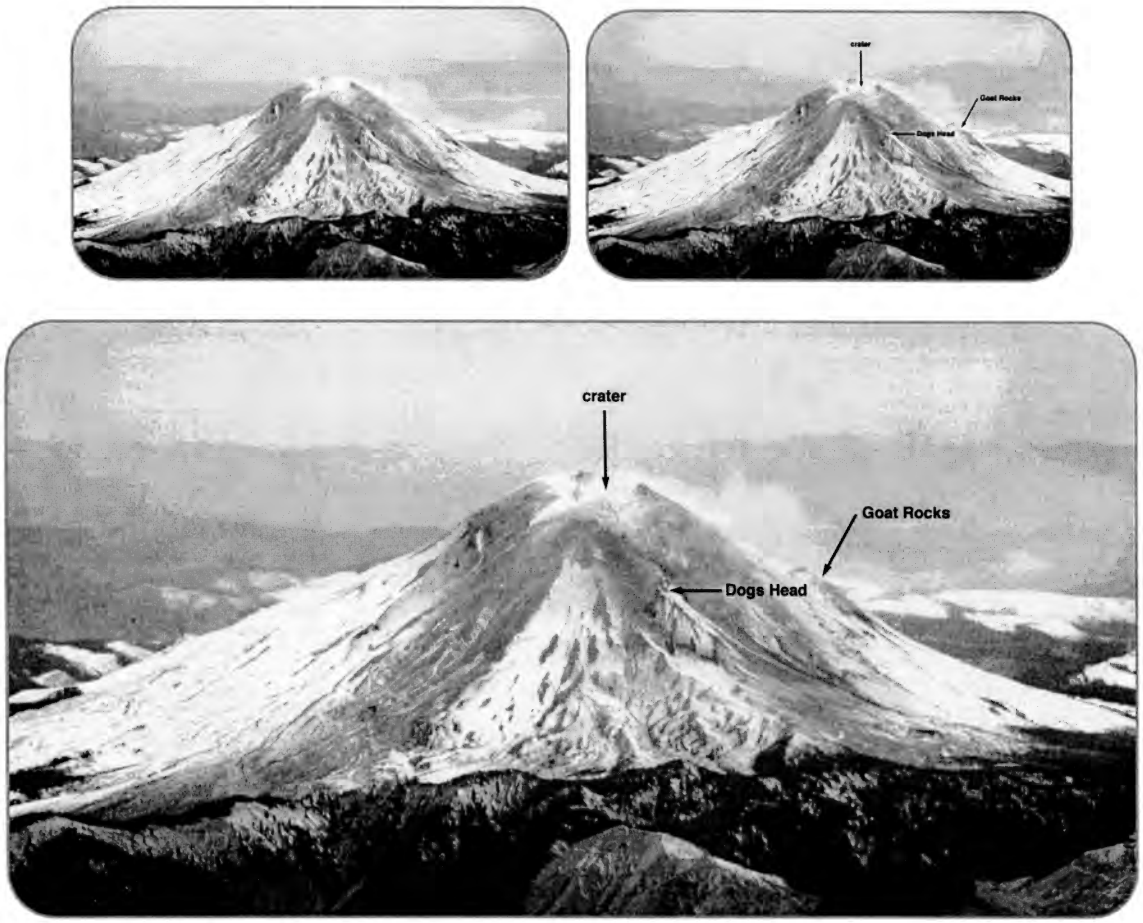
*Fiske, R.S, Hopson, C.A, and Waters A.C. 1963, "Geology of Mount Rainier National Park, Washington" USGS Professional Paper 444.

You are looking northward at Mount Rainier in Washington. Little Tahoma Peak is a remnant of the eastern flank of an earlier and larger Mount Ranier. Columbia Crest is a Holocene volcanic cone built on the eastern rim of the summit crater. The mountains in the foreground are covered with ash from the eruptions of Mount St. Helens. This picture was taken on July 21, 1980, the day before Mt. St Helen's fourth eruption of 1980.



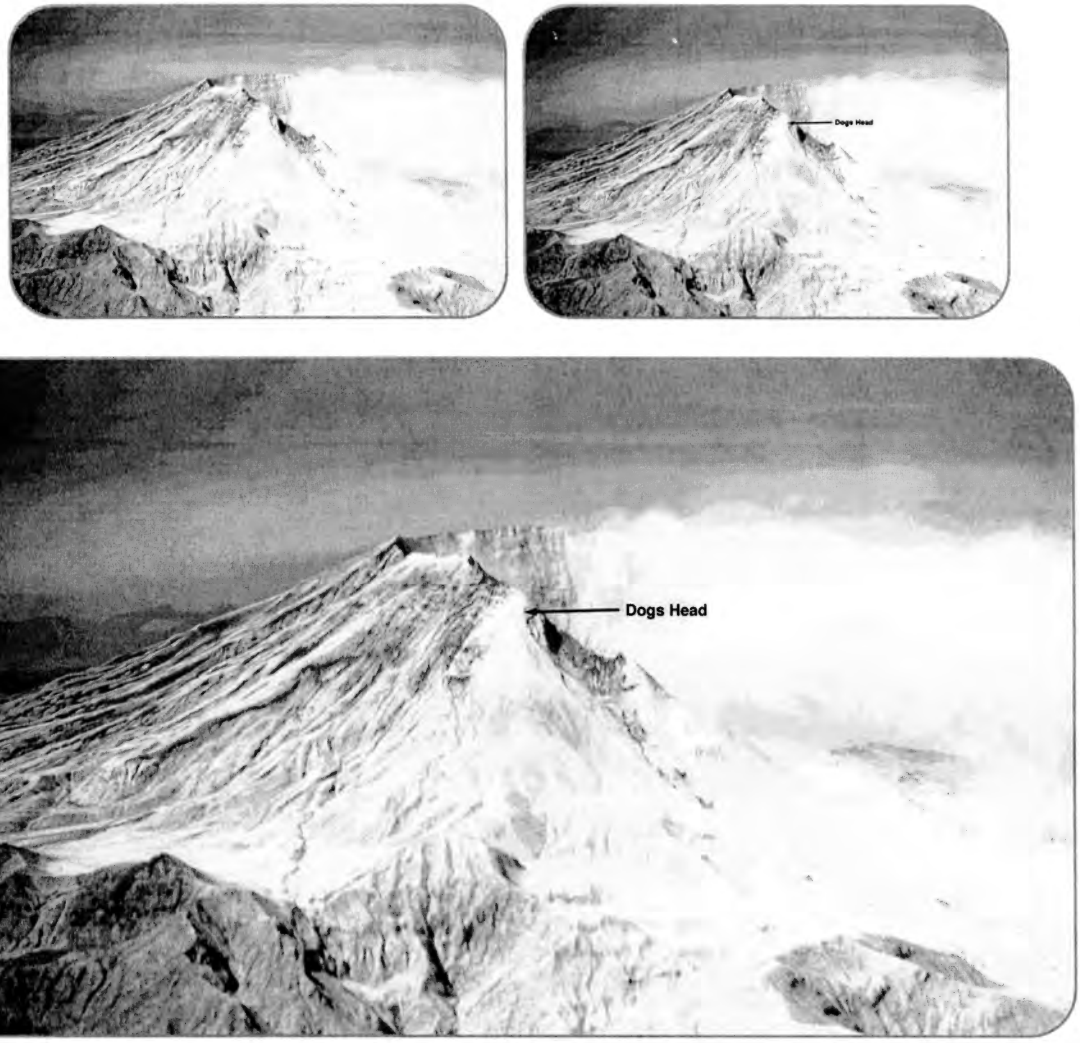




You are looking westward across the glaciers and moraines on Mount Adams in the foreground at Mount St. Helens in the distance. Both are large andesitic volcanoes. This picture was taken on September 5, 1975 before the eruptions began on Mount St. Helens in the spring of 1980.




You are looking westward at Mount St. Helens on April 12, 1980. The mountain owes most of its size and shape 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 to 15,000 years. The Dogs Head dacite dome formed a bit more than 1,900 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 the explosive expulsion of dacitic magma. Goat Rocks is a dacite dome sealing the vent of the last volcanic blasts in 1857. The crater at the top of the mountain is steaming as rising magma superheats the ground water to the point where it explodes, shattering the rock and spraying rock debris over the snow. Such explosions first formed a small crater on March 27, 1980. Subsequent explosions formed an adjacent larger 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 debris avalanche, 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.

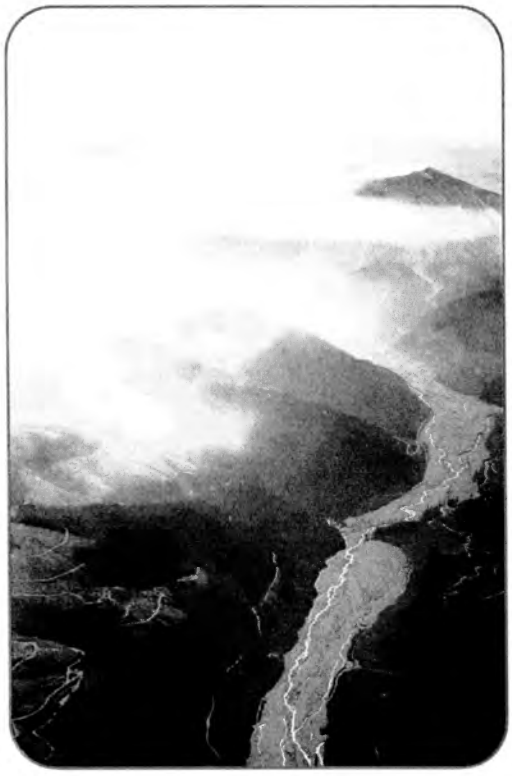


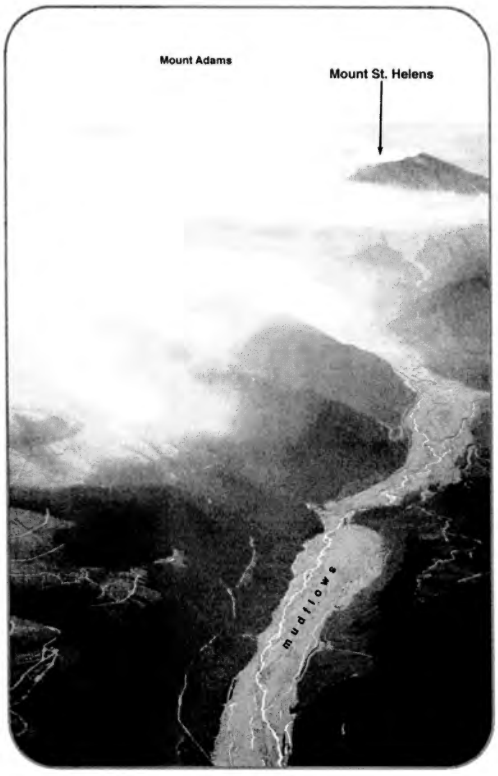

You are looking toward the southwest at Mount St. Helens on July 21, 1980 after the eruptions on May 18, May 25, and June 12. The primary eruption on May 18 reduced the elevation of the mountain from 9,677 feet to 8,365 feet. If you compare this picture to the one on the previous page, you will see that Dogs Head dacitic dome is now much closer to the summit. The large amount of steam issuing from the volcanic dome presaged an imminent eruption. The next day, on July 22, this eruption blasted a crater in the volcanic dome that had been built over the vent after the June 12 eruption.

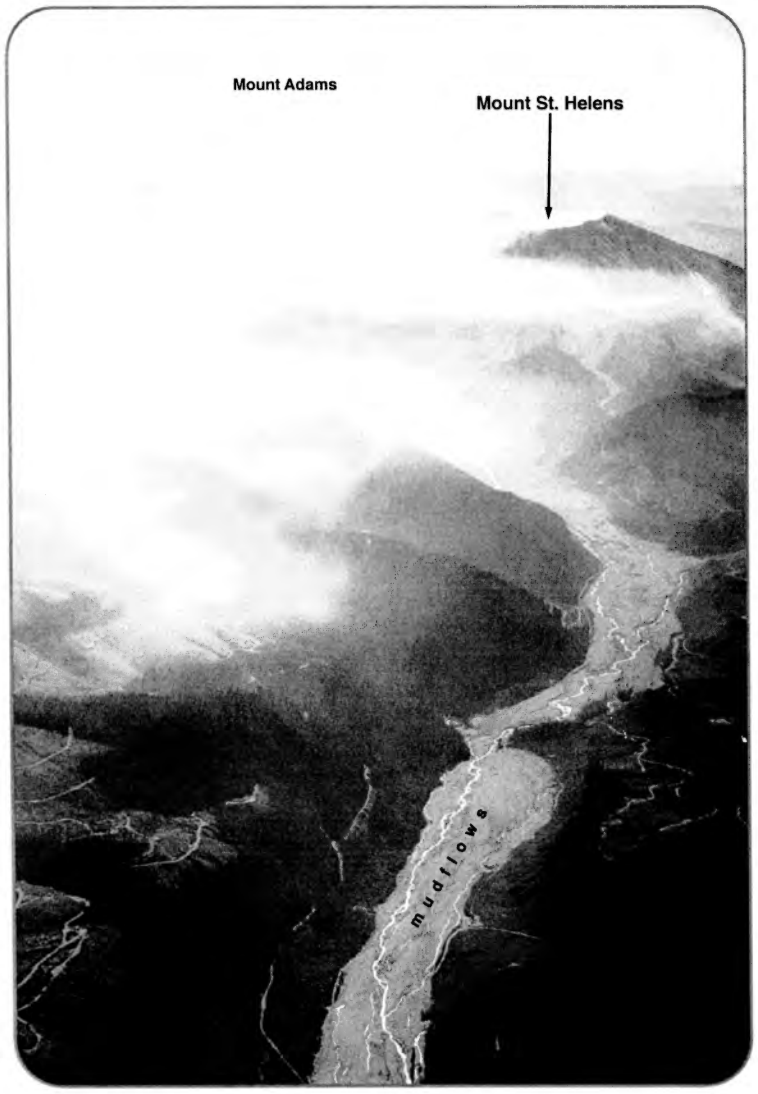
data taken from: Lipman, P.W. and Mullineaux, D.R., 1981, "The 1980 Eruptions of Mount St. Helens, Washington" USGS Professional Paper 1250.

You are looking toward the northeast across the blasted-off dacite dome that had formed the summit of Mount St. Helens before the May 18th eruption. The andesite flow dates from the Kalama eruptive period about 400 to 500 years ago. Hot debris avalanches emitted from the dacite dome above the andesite flow partially filled the area between the flow's natural levees. The mudflows on the flank of the volcano formed from the melting of debris-laden glaciers and were triggered by the heat of pyroclastic flows and ash falls on May 18. This picture was taken on July 21, 1980, the day before Mount St. Helen's fourth eruption.

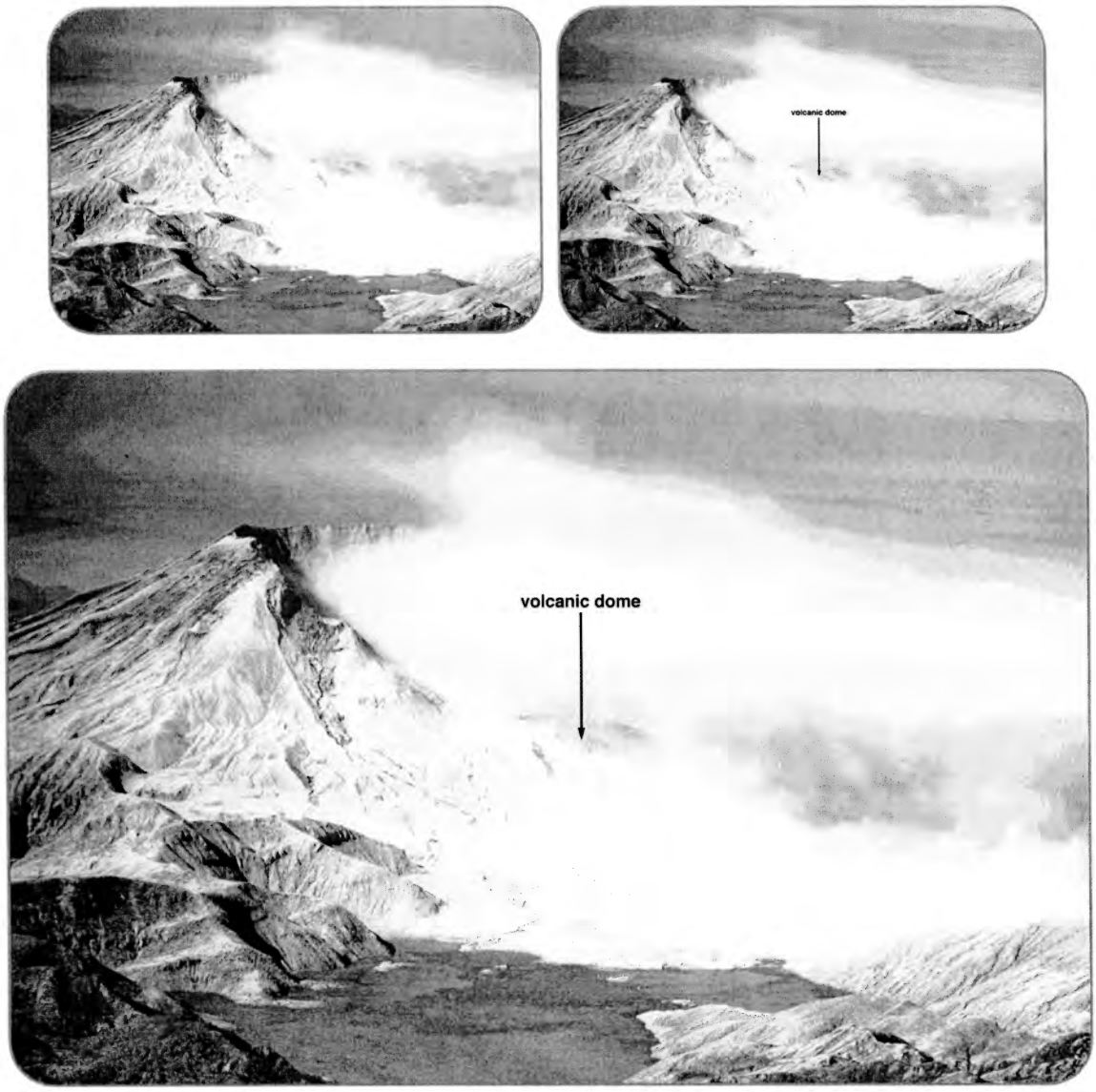
data taken from: Lipman, P.W. and Mullineaux, D.R., 1981, "The 1980 Eruptions of Mount St. Helens, Washington" USGS Professional Paper 1250.





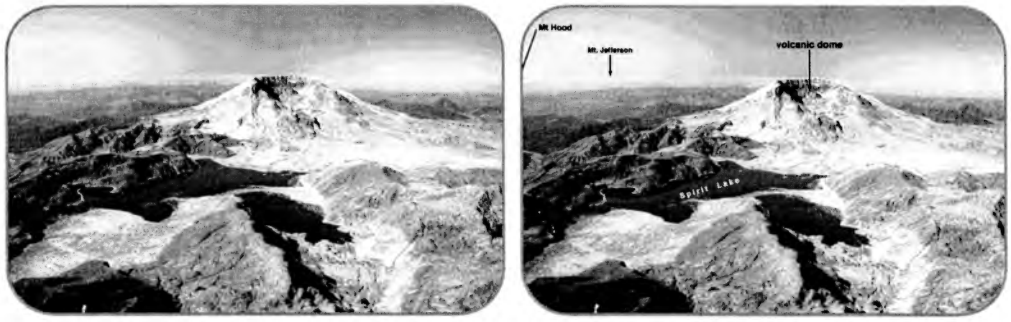



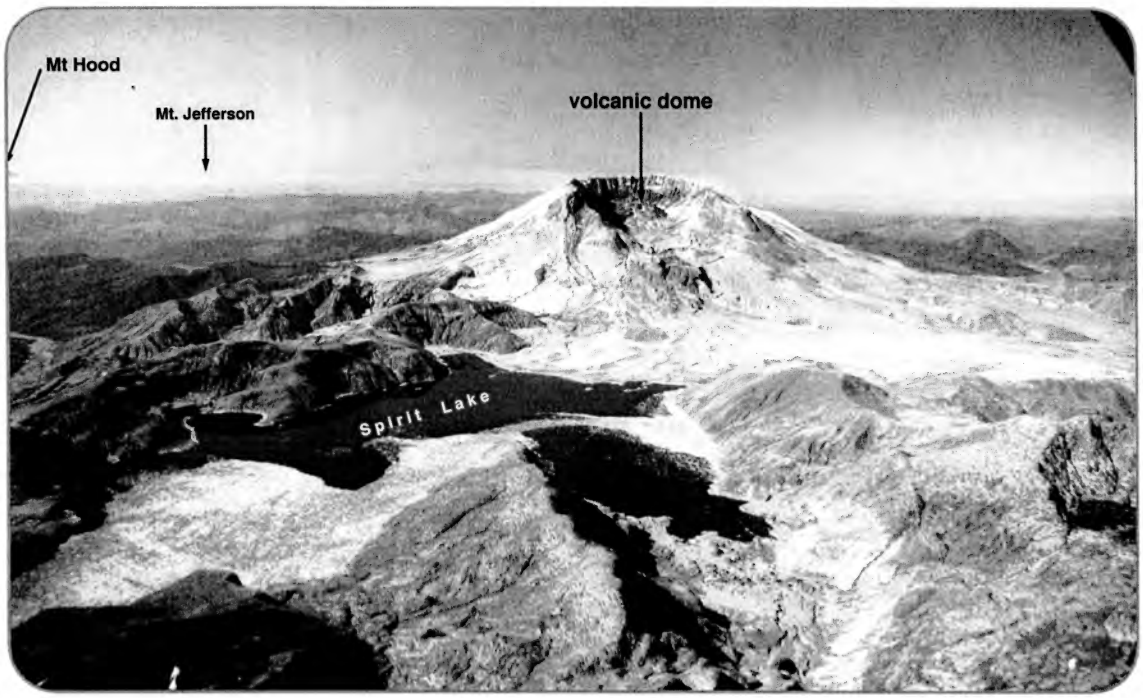

You are looking eastward at the mudflows that filled the valley of the South Fork of the Toutle River when Mt. St. Helens erupted on May 18, 1980. Much steam from Mt. St. Helens presages an eruption the next day, July 22, 1980.




You are looking southward at Mount St. Helens on July 21, 1980, the day before its fourth eruption. The volcanic dome in the crater was built after the June 12 eruption to a diameter of 365 meters. The July 22 eruptions produced ash columns to heights of between 14 and 18 kilometers and blasted a new crater, about 300 meters in diameter, through the center of the hot June lava dome. No new lava dome was built until after the next eruption on August 7. Between August 8 and August 10 a dome rose to fill the crater to just below its rim.

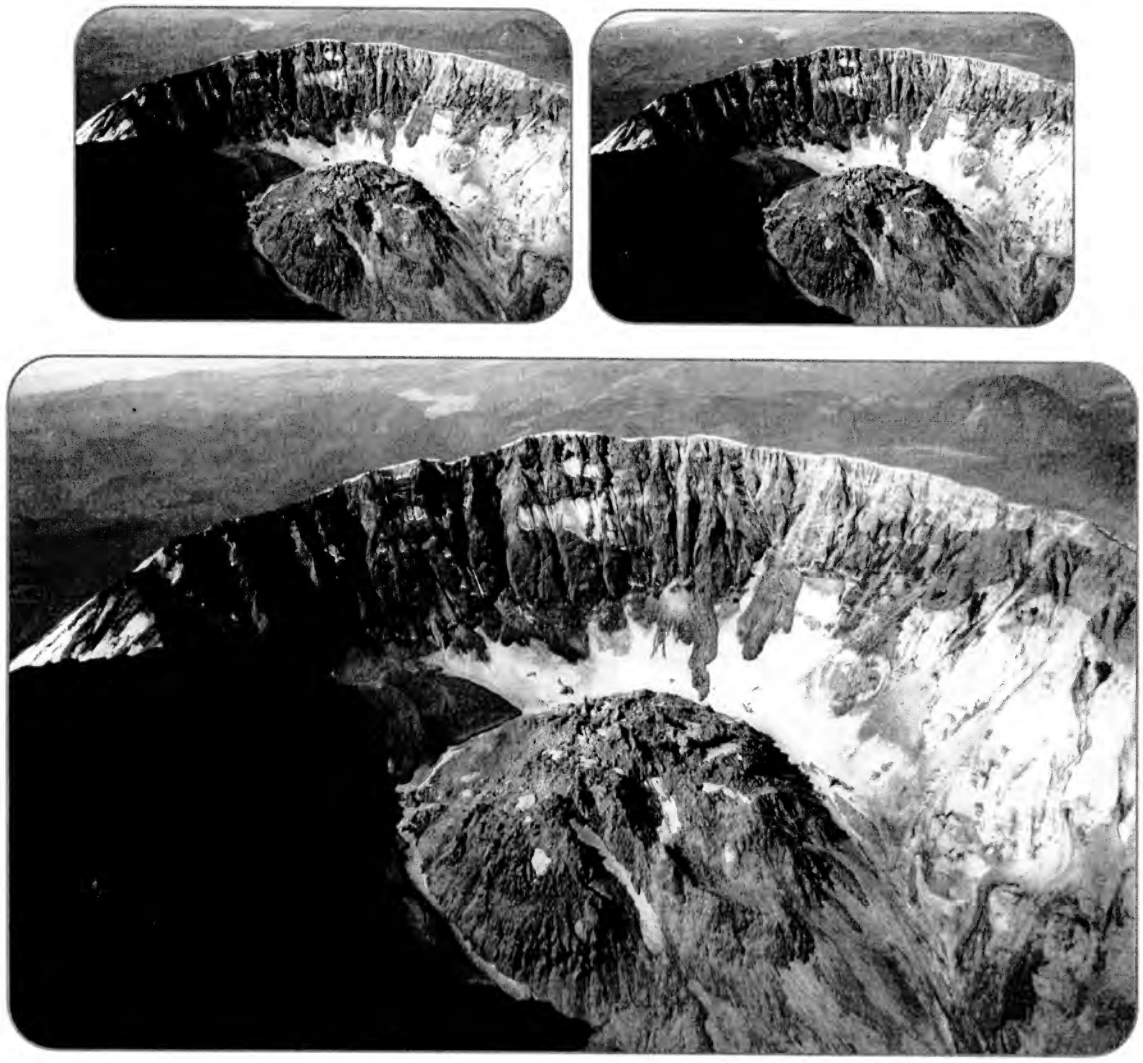
data taken from: Lipman, P.W. and Mullineaux, D.R., 1981, "The 1980 Eruptions of Mount St. Helens, Washington" USGS Professional Paper 1250.



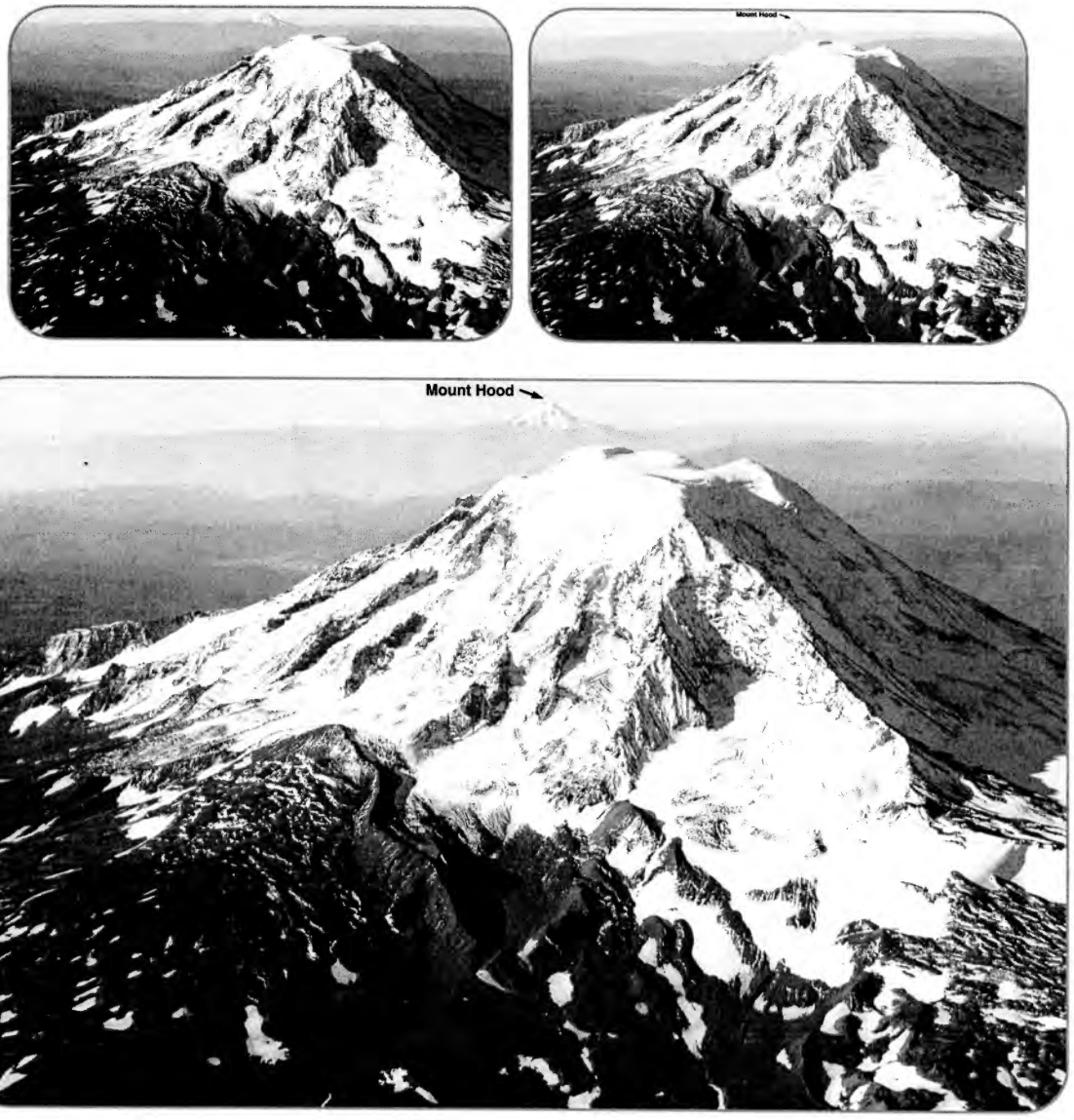



You are looking southward at Mt. St. Helens on August 1, 1993. Most of the volcanic dome grew over the vent in one day to a diameter of 200 meters and a height of 40 meters after the October 18 eruption of pyroclastic flows. Part of this dome was blown away by explosions on December 13, and a new dome rose and expanded adjacent to the old dome through the end of 1980.

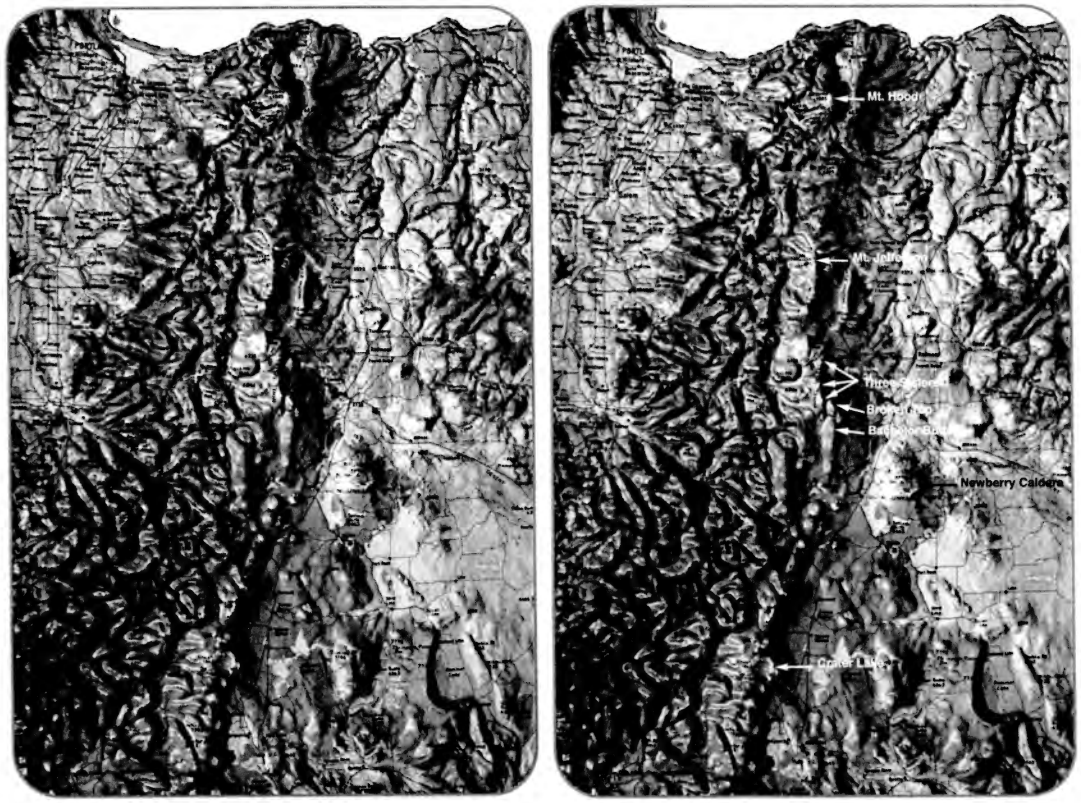
data taken from: Lipman, P.W. and Mullineaux, D.R., 1981, "The 1980 Eruptions of Mount St. Helens, Washington" USGS Professional Paper 1250.

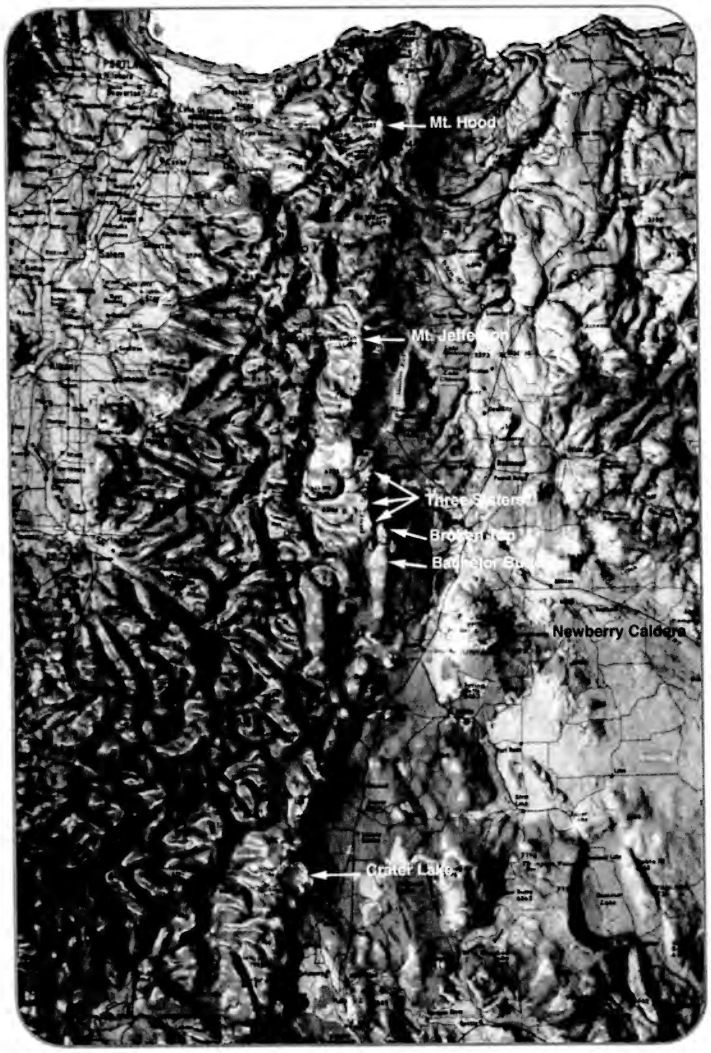


You are looking southward at the jagged volcanic dome plugging the vent of Mt. St. Helens. The dome grows from gas-depleted lava that congeals over the vent because it is too thick to flow. Viscous lava forced up through cracks in the dome may congeal as jagged ridges.

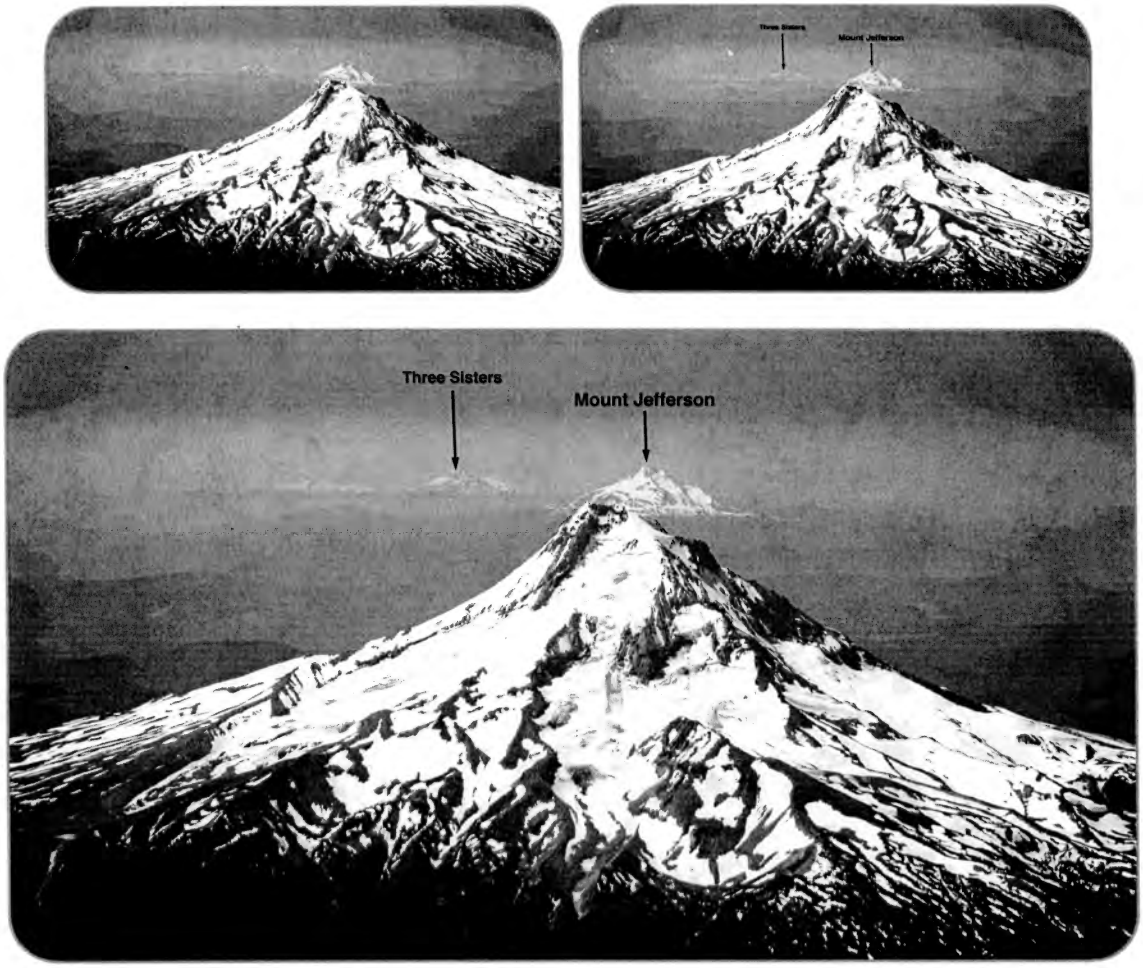



You are looking southward across the top of Mount Adams along the crest of the Cascade Mountains at Mount Hood. Both are currently dormant andesitic volcanoes that could become explosively active.

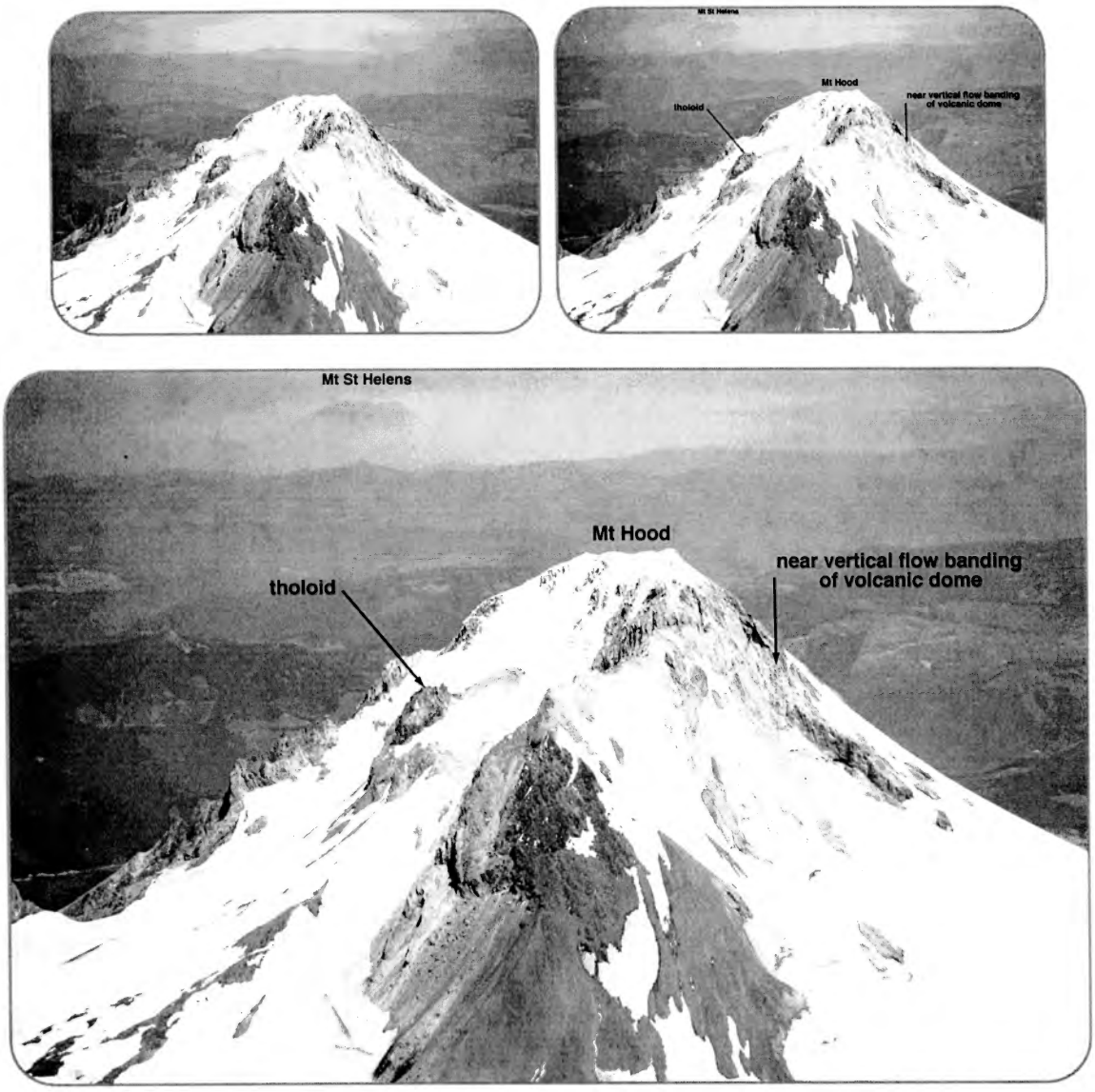


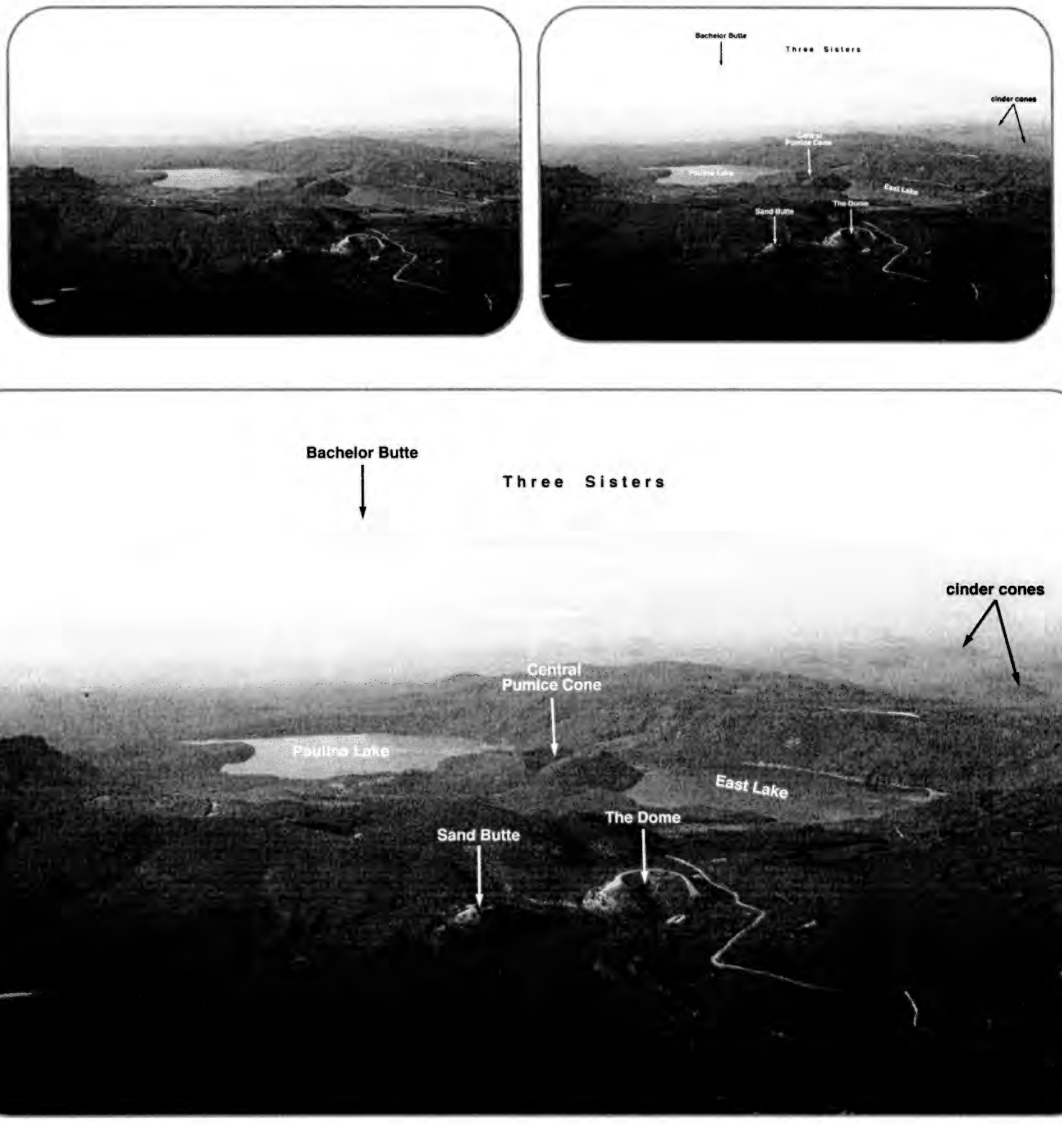

A stereo relief map shows the locations of the Oregon volcanoes pictured and described on the next eight pages.




You are looking southward past Mount Hood in the foreground at Mount Jefferson and the Three Sisters in Oregon. All are large dominantly andesitic stratovolcanoes. This picture was taken on July 21, 1980.

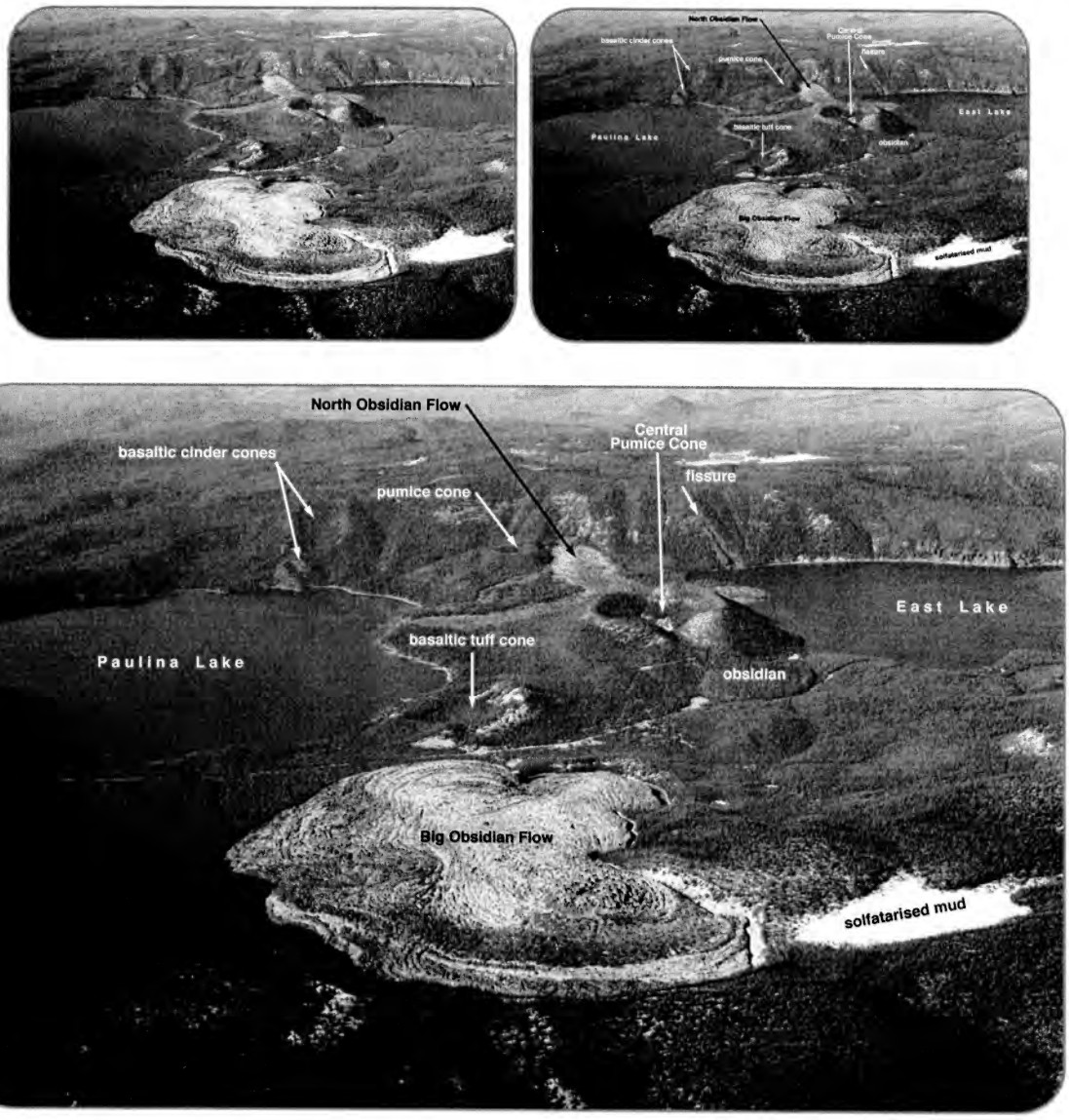



View northwest of Mount Hood in Oregon. Mt. St. Helens, emitting much steam, is dimly visible in the background on July 21, 1980, the day before its 4th eruption in 1980.



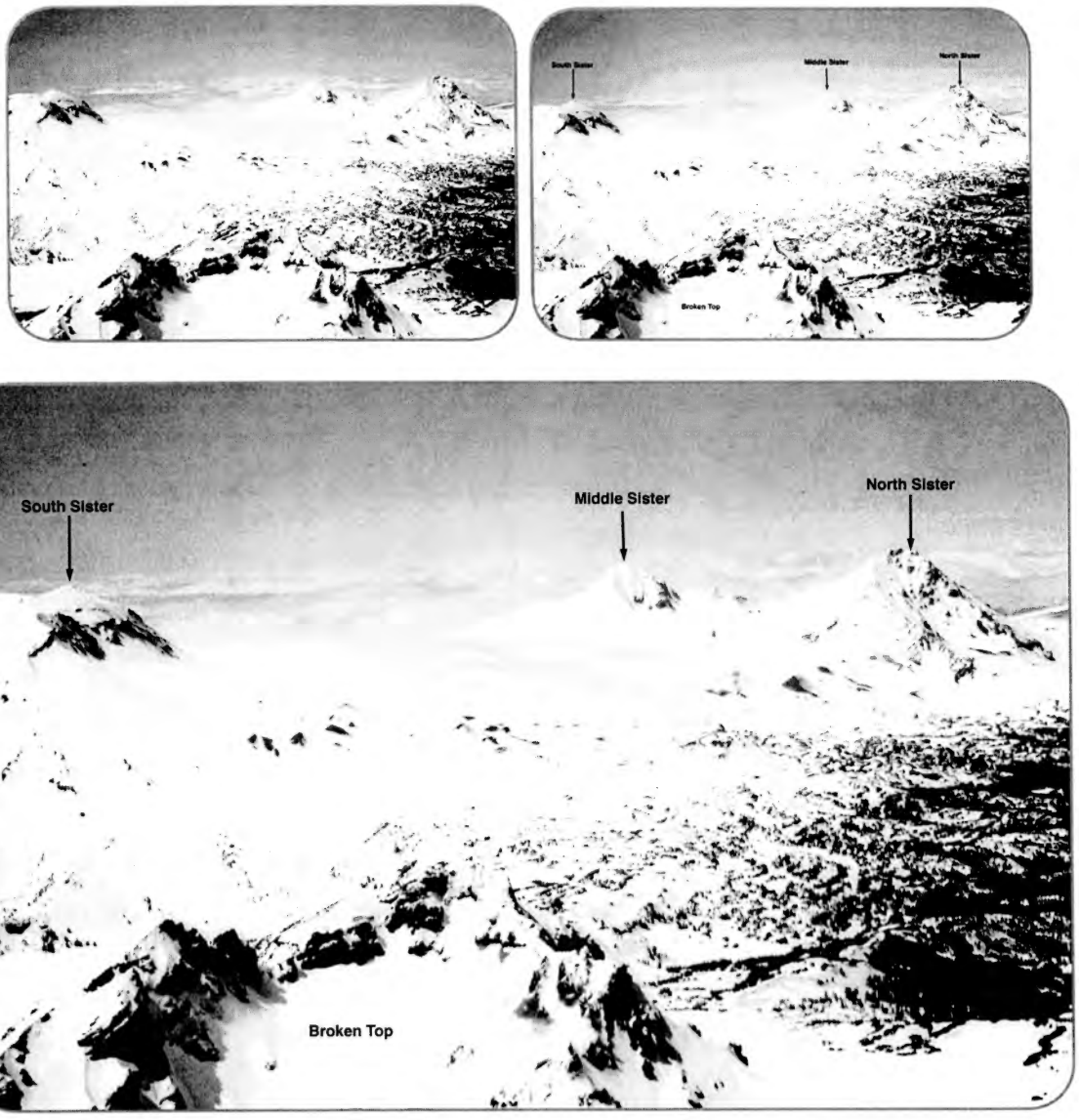

You are looking toward the northwest. Newberry Caldera contains East Lake and Paulina Lake separated by Central Pumice Cone, which grew to its 700 foot height inside the caldera about 1700 years ago.** The caldera measures five miles long by four miles wide. It formed when the the summit of a large shield volcano collapsed as the magma withdrew to pour out lower on the flanks and perhaps to supply the more than 150 basaltic cinder cones on its flanks. Sand Butte, The Dome and two other cinder cones are pointed out in the picture. The edifice of the Newberry shield is built largely of basalt and rhyolite of alternate and sometimes simultaneous eruptions. Little andesite was erupted.* The Three Sisters and Bachelor Butte, in contrast, are dominantly andesitic volcanoes along the spine of the Cascade Mountains. This picture was taken September 4, 1975.

*information taken 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 Professional Paper 650D, pD26-D32.

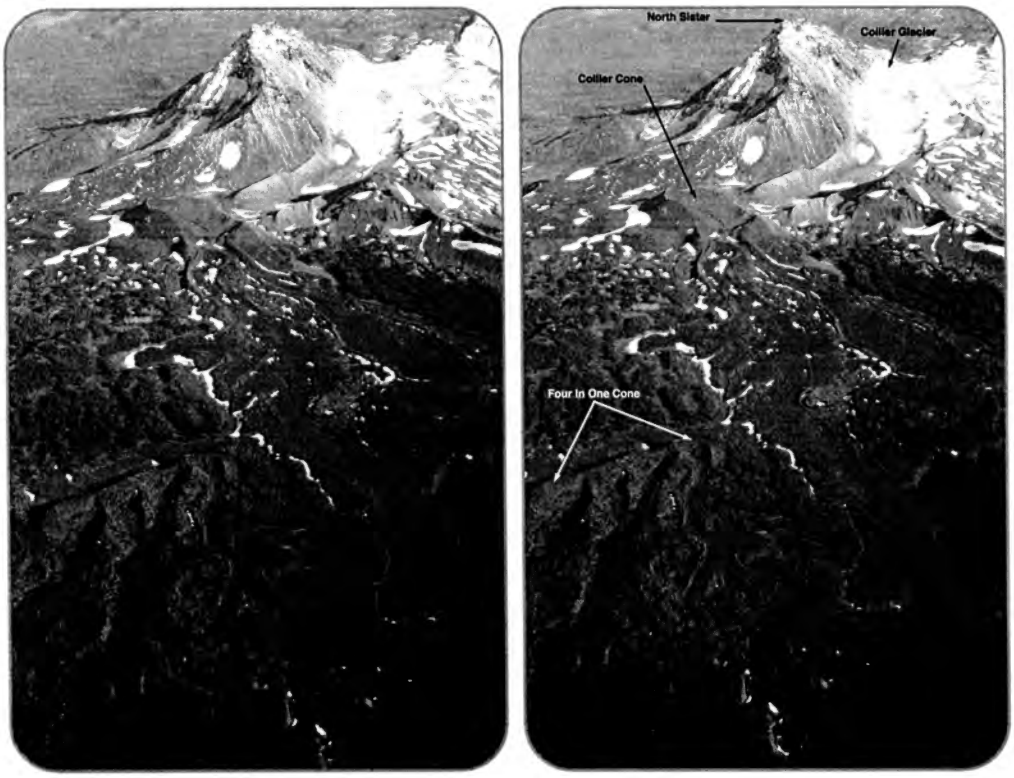



You are looking northward across Newberry Caldera. Viscous, gas-deficient rhyolitic magma oozed from vents along the caldera walls to form the thick obsidian flows. North Obsidian Flow oozed out of its vent after Central Pumice Cone formed about 1700 years ago** and split into two branches as it deflected around both pumice cones. Big Obsidian Flow may mark the latest volcanic activity in the caldera, or nearly simultaneous explosions of rhyolite and basalt along the fissure may be the last event.* This picture was taken September 4, 1975.

*information taken 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 Professional Paper 650D, pD26-D32.

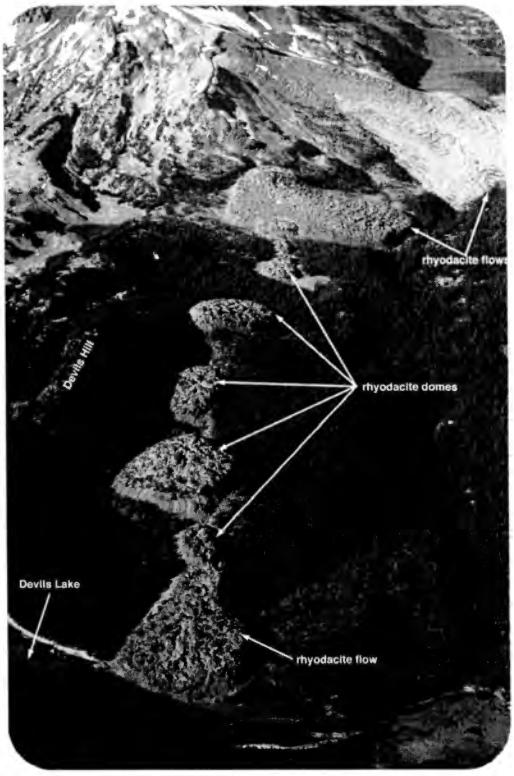


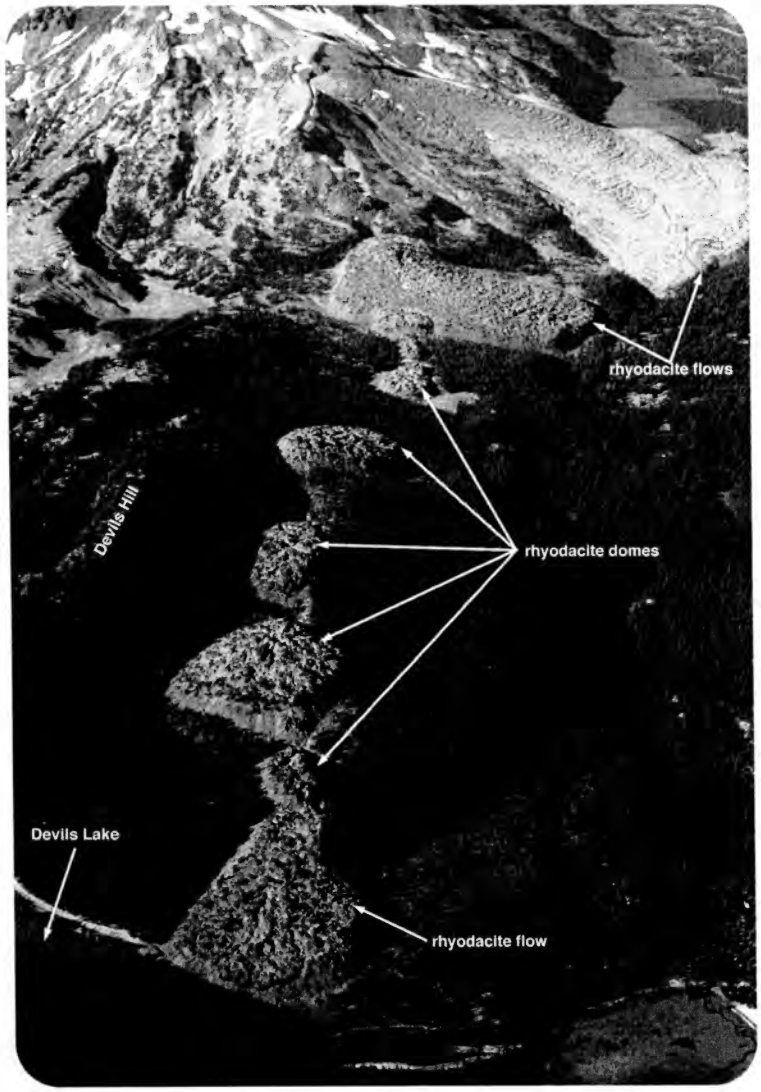

You are looking toward the northwest across Broken Top at the Three Sisters volcanoes along the crest of the cloud-covered Cascade Mountains in Oregon. This picture was taken May 7, 1975.



You are looking toward the southeast at Collier Cone at the base of the North Sister. The basaltic andesite flows from Collier Cone are younger than the 2600 year old andesite flows from Four In One Cone.* This picture was taken September 4, 1975.

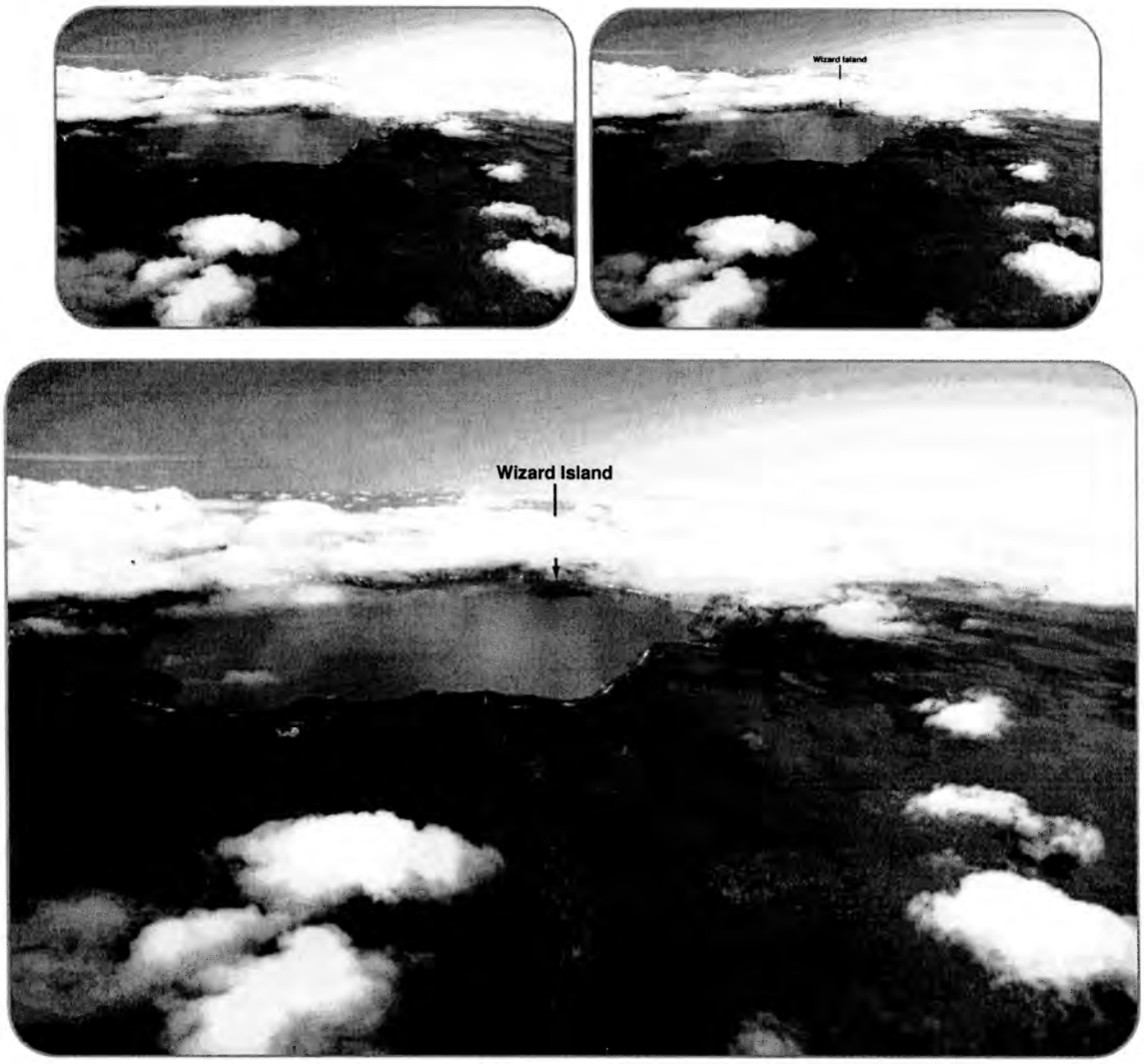
Taylor, E. M., MacLeod, N.S., Sherrod, D.R., and Walker, G.W., 1987, "Geology of the Three Sisters Wilderness, Deschutes, Lane, and Linn Counties, Oregon" USGS MF Map 1952.



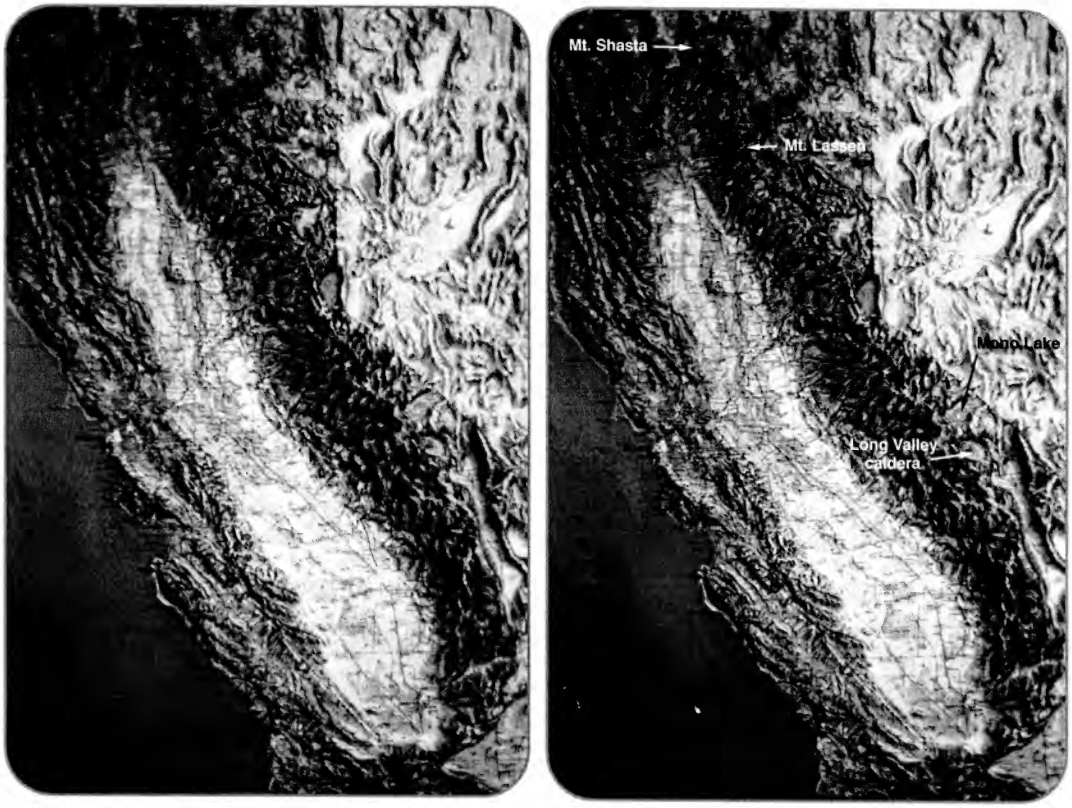

You are looking northward toward the base of the South Sister Volcano. Viscous flows and domes of rhyodacite oozed from a rift between 2000 and 2900 years ago.*

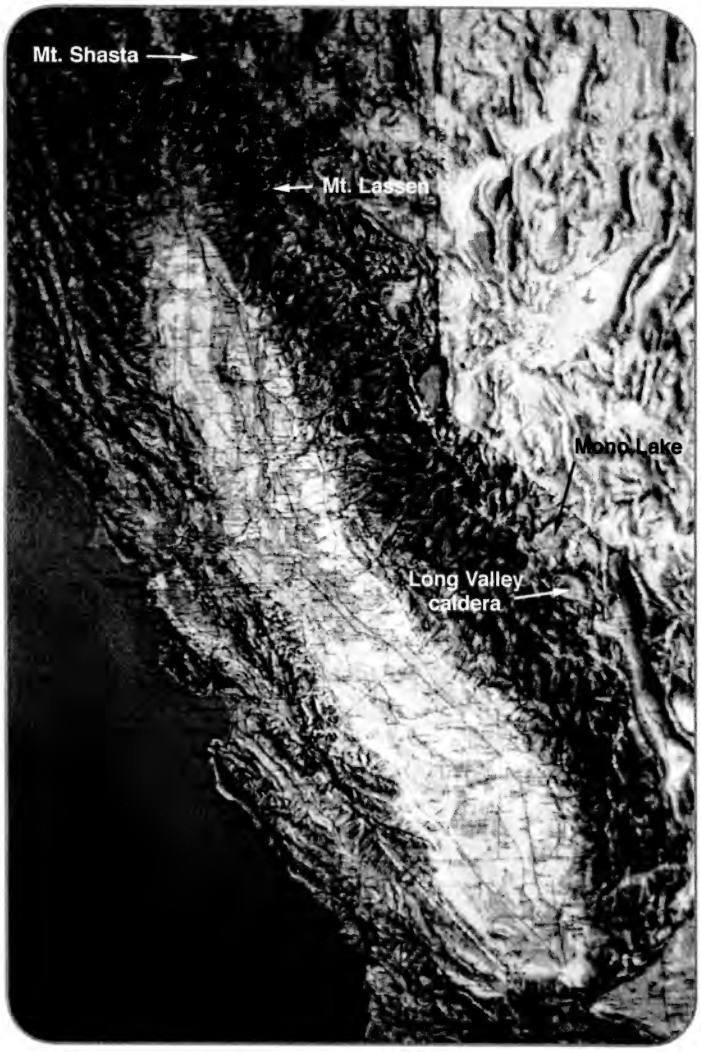
*Taylor, E. M., MacLeod, N.S., Sherrod, D.R., and Walker, G.W., 1987, "Geology of the Three Sisters Wilderness, Deschutes, Lane, and Linn Counties, Oregon" USGS MF Map 1952.



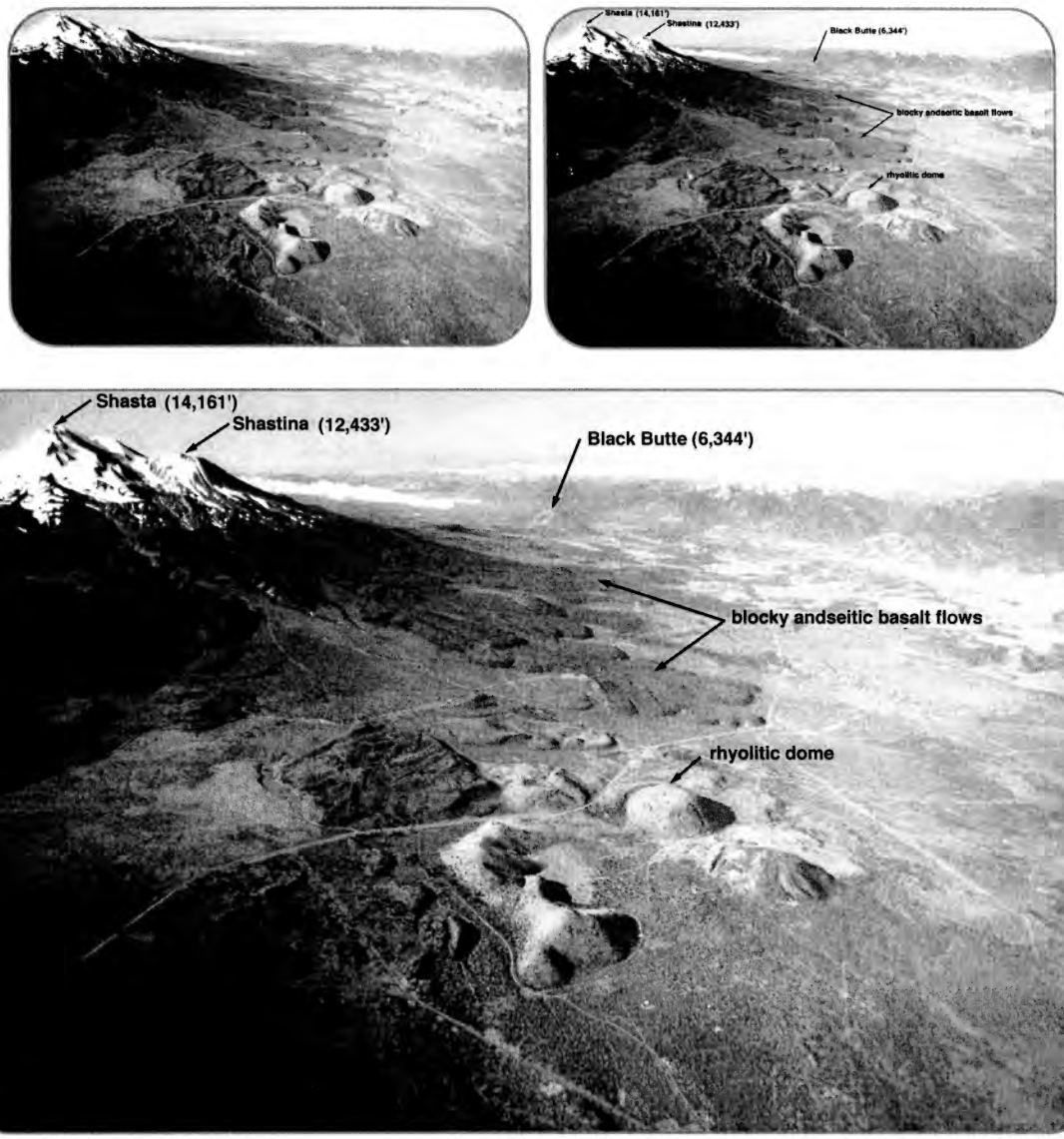

You are looking toward the southwest at Crater Lake in Oregon. Crater Lake fills a caldera, five to six miles in diameter, that is the stump of Mount Mazama, once perhaps between 12,000 and 15,000 feet in elevation. It was high enough to support glaciers that carved valleys on its flanks below the present level of the rim. A large part of the summit collapsed into the magma chamber emptied by powerful eruptions about 6,000 years ago. The volume of the missing summit is estimated to be about 17 cubic miles. The eruptions deposited about six cubic miles of ash and debris. Thus, an additional 11 cubic miles of magma must have withdrawn from the magma chamber to account for the volume of the missing summit. Wizard Island is a cinder cone built in the caldera somewhat more than 800 years ago, as indicated by tree ring counts.* Picture taken August 14, 1982.

*data taken from: Shelton, John S. 1966, "Geology Illustrated", W. H. Freeman & Co. p314-317.



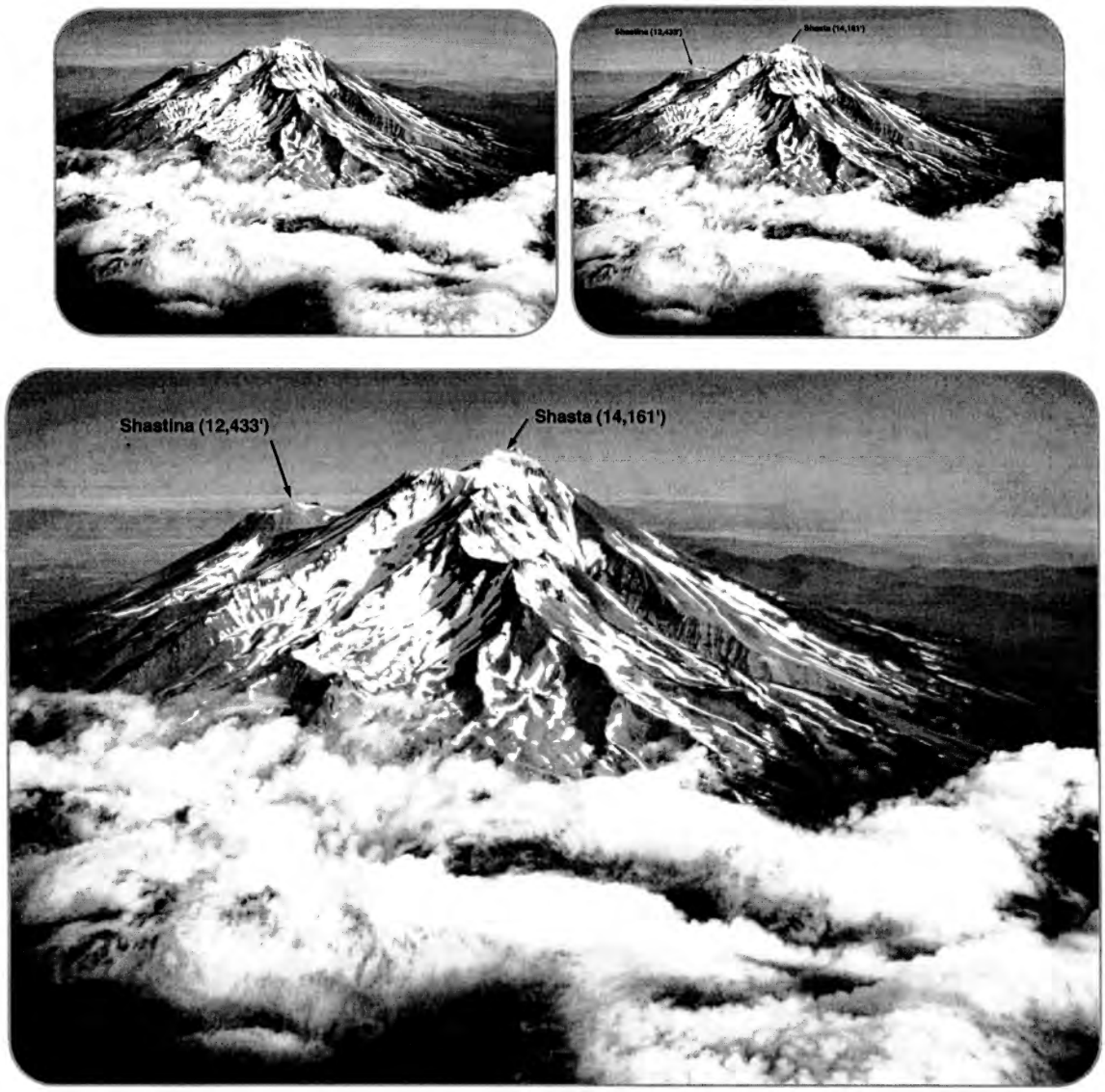




A stereo relief map shows the locations of the California volcanoes pictured and described on succeeding pages. The Inyo and Mono Craters volcanic chains extend from Long Valley Caldera to Mono Lake.




You are looking toward the southwest at Mount Shasta in northern California. 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 hunderd 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 the magma to migrate laterally along the fissure to the site of Shastina. A plug also seals the vent of Shastina, and the rise of that plug may have triggered ash flows down Diller Canyon on its southwestern side. Andesitic basalt flows then sprang from fissures on Shastina's side, pouring out steep-sided, blocky flows around the northwestern base of the volcano. Black Butte grew near the end of this activity as an explosion crater about a mile wide that then filled with a nearly vertical-sided plug that rose above the crater and shed immense volumes of volcanic scree over the slopes below.* Picture taken August 14, 1982.

*data from: Williams, Howel, 1932, "Mount Shasta, A Cascade Volcano", Jour. of Geology, vol. 40, p417-429.

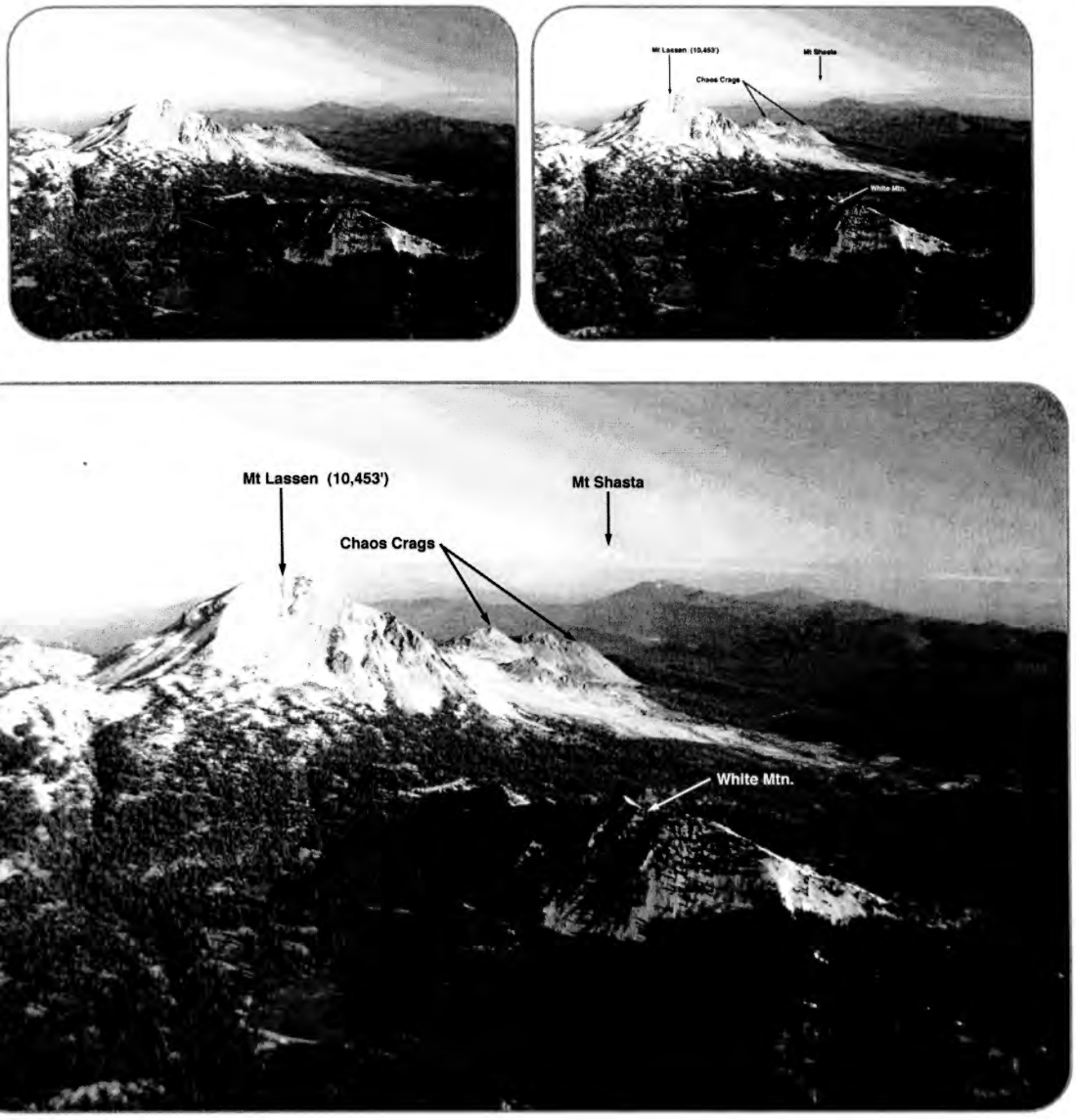



You are looking toward the northwest at the eighty cubic mile edifice of Mounts Shasta and Shastina in northern California. A plug of hornblende andesite fills the half-mile diameter crater in Shastina. All valleys that drain glaciers on Shasta have had repeated debris flows during the last 500 years. Of the debris flows, about four per century have been large magnitude.*

*Osterkamp, W.R., Hupp, C.R., and Blodgett, J.C., 1986, Magnitude and Frequency of Debris Flows and areas of Hazard on Mount Shasta, Northern California", USGS Professional Paper 1396C.

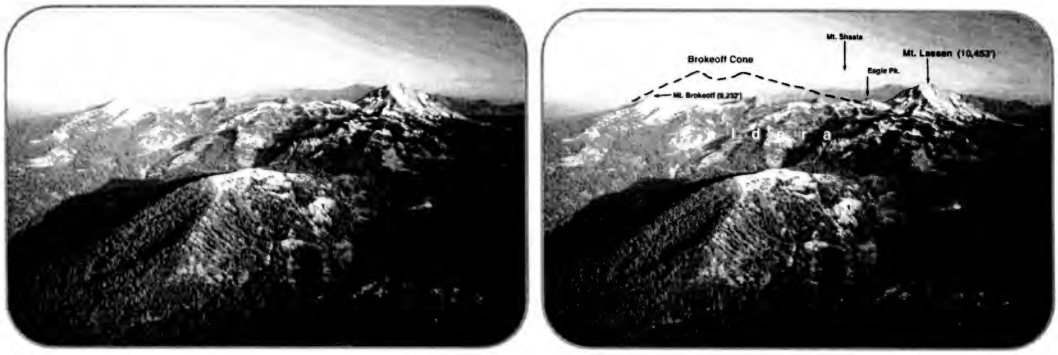
You are looking toward the southwest at Black Butte, a plug dome near the western base of Mount Shasta in northern California. A glowing plug of hornblende andesite with nearly vertical sides rose repeatedly above the rim of the crater. As it rose, it shed large amounts of scree onto the slopes below, covering much of the original cone and building a conical mountain 2500 feet above the valley bottom. Picture taken August 14, 1982.*

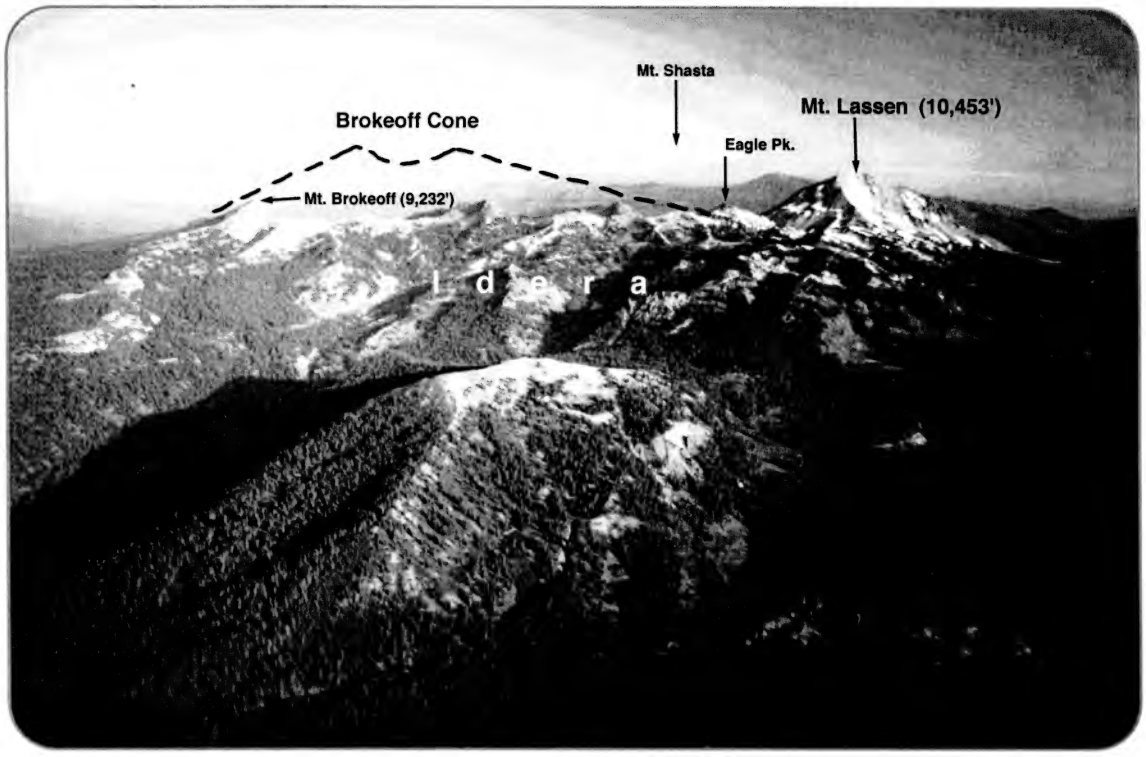
*data from: Williams, Howel, 1932, "Mount Shasta, A Cascade Volcano", Jour. of Geology, vol. 40, p428.




You are looking toward the northwest at Mount Lassen, Chaos Crags, and Mount Shasta. Mount Lassen is a plug dome of dacite that last erupted from May of 1914 into the summer of 1917. Explosions at irregular intervals during the first year were followed by lava spilling out of the summit crater in May, 1915 to melt the snows and cause extensive mudflows. A horizontal blast blew out of the northeast side of the crater on May 22. Activity then declined and the volcano became dormant in the summer of 1917.* Picture taken August 14, 1982.

*data taken from: Williams, Howel, (1932), "Geology of the Lassen Volcanic National Park, California", Calif. University Geological Sciences vol. 21, p195-385.

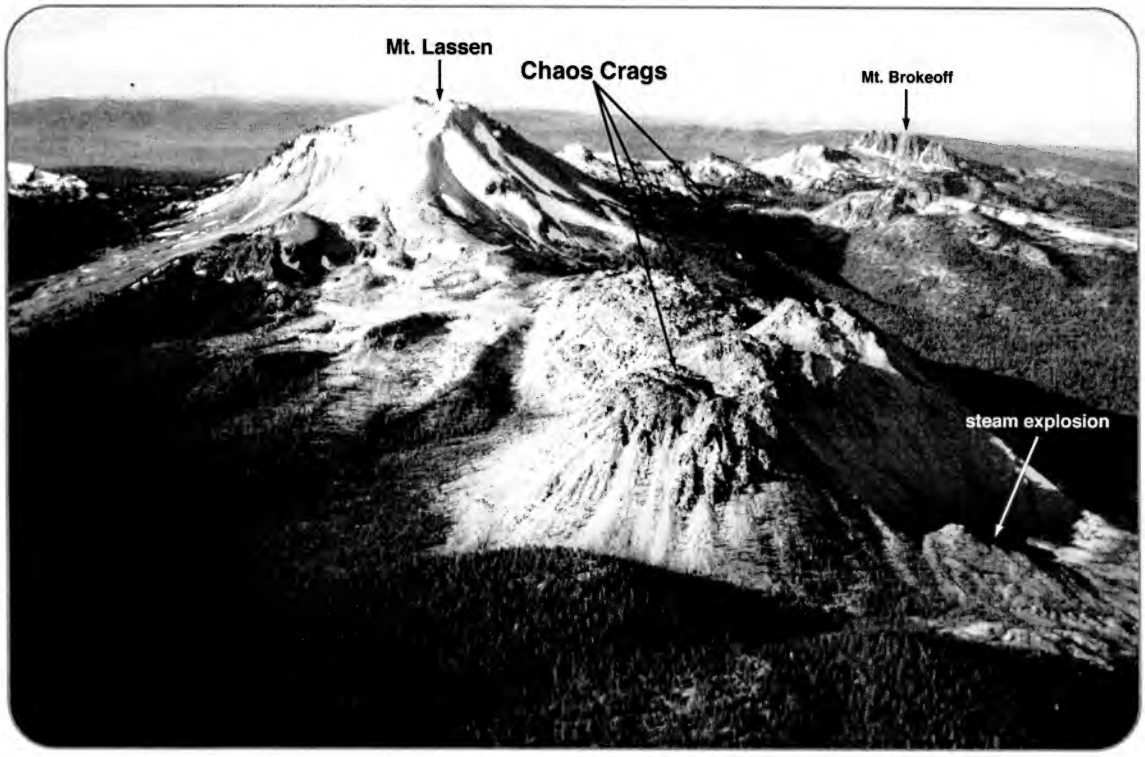





You are looking toward the northwest at the caldera formed by the collapse of Brokeoff Cone. Mount Lassen is a plug dome of dacite that grew on the eastern flank of the caldera after its collapse. Brokeoff Cone consisted of andesite flows interbedded with tuff and breccia. Eagle peak is a dacite dome that punched through pre-Lassen columnar dacite flows. Picture taken August 14, 1982.

*data taken from: Williams, Howel, (1932), "Geology of the Lassen Volcanic National Park, California", Calif. University Geological Sciences vol. 21, p195-385.

You are looking eastward at steam rising from hot springs in the Brokeoff Caldera.. The light-colored rocks are solfatarised volcanics. Picture taken August 14, 1982.

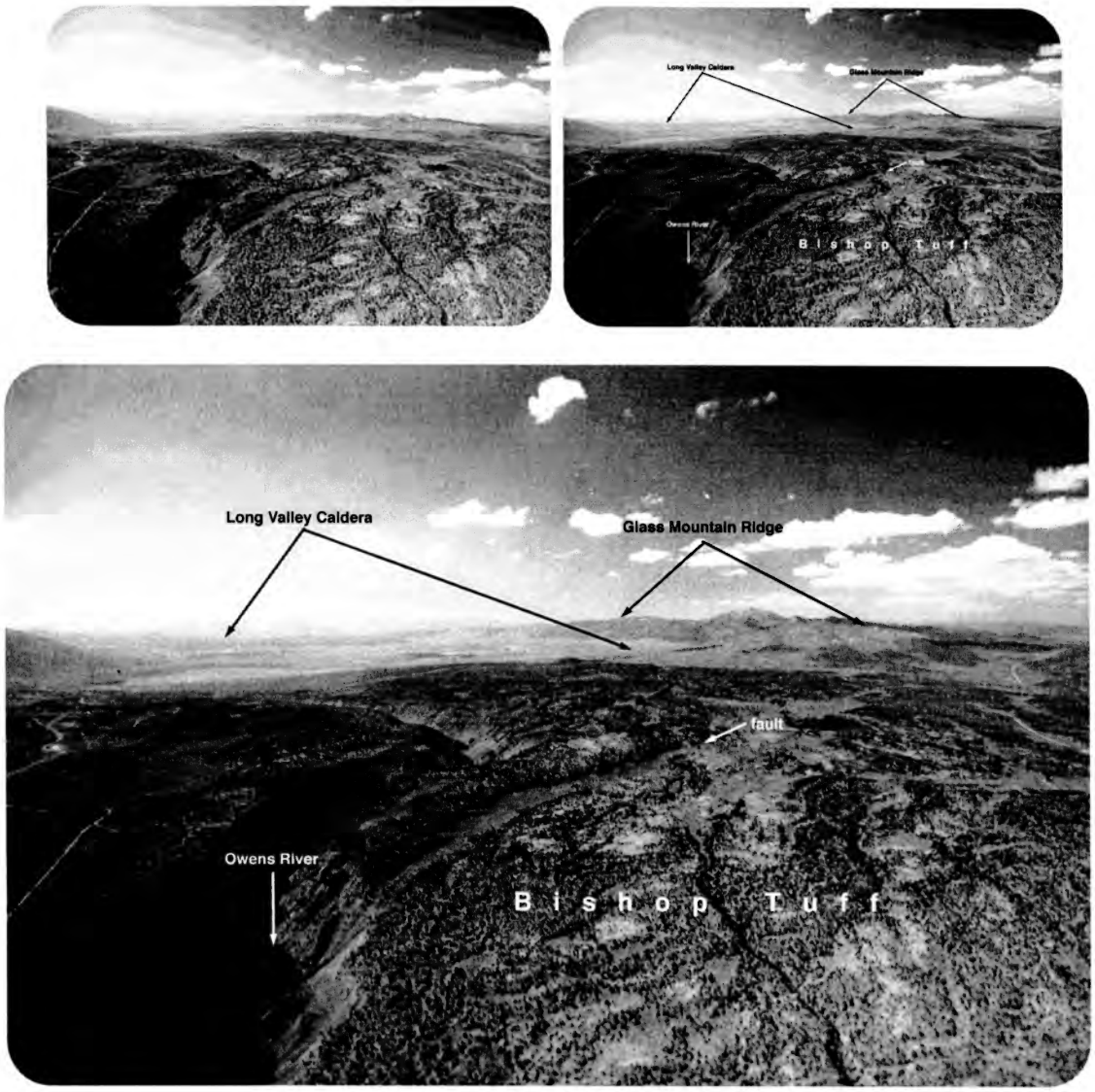



You are looking southward at the dacite domes of Chaos Crags north of Mount Lassen. About 200 years ago a steam explosion at the base of the north dome set loose an avalanche of dacite rubble that slid at high speed for over two miles down the mountain out of the lower right corner of the picture. The avalanche of rubble, the Chaos Jumble, crossed a valley and rose 400 feet up the side of Table Mountain on the other side.* Picture taken August 14, 1982.

*data taken from: Williams, Howel, (1932), "Geology of the Lassen Volcanic National Park, California", Calif. University Geological Sciences vol. 21, p195-385.

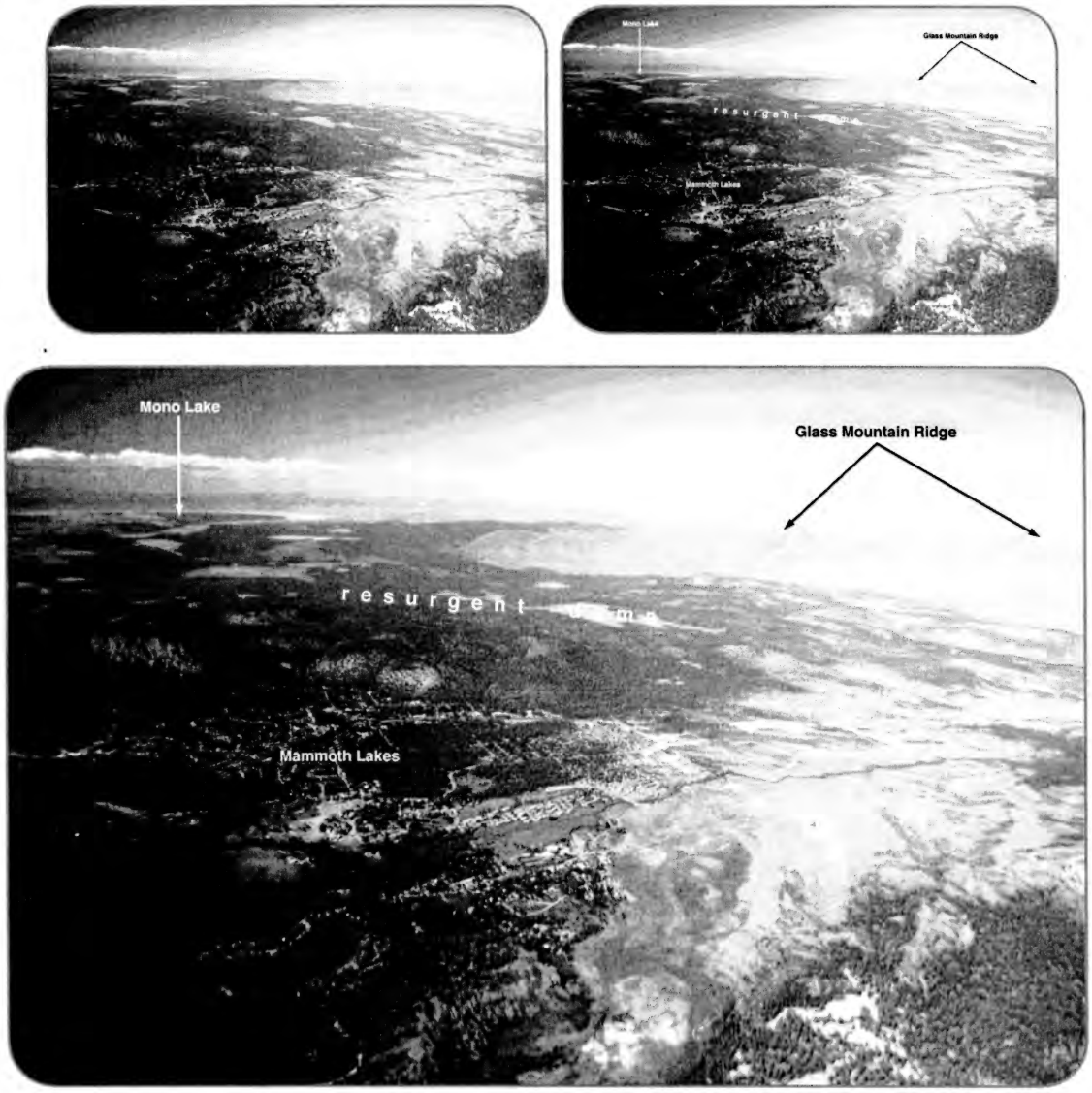
You are looking northward at nested cinder cones east of Mount Lassen. A smaller cone has been built inside the crater of the larger cone by eruptions of diminished intensity. Basalt lavas containing phenocrysts of quartz flowed from the base of the cinder cone. The last one, in 1851, flowed into the north end of Butte Lake.* Picture taken August 14, 1982.

*data taken from: Williams, Howel, (1932), "Geology of the Lassen Volcanic National Park, California", Calif. University Geological Sciences vol. 21, p195-385.



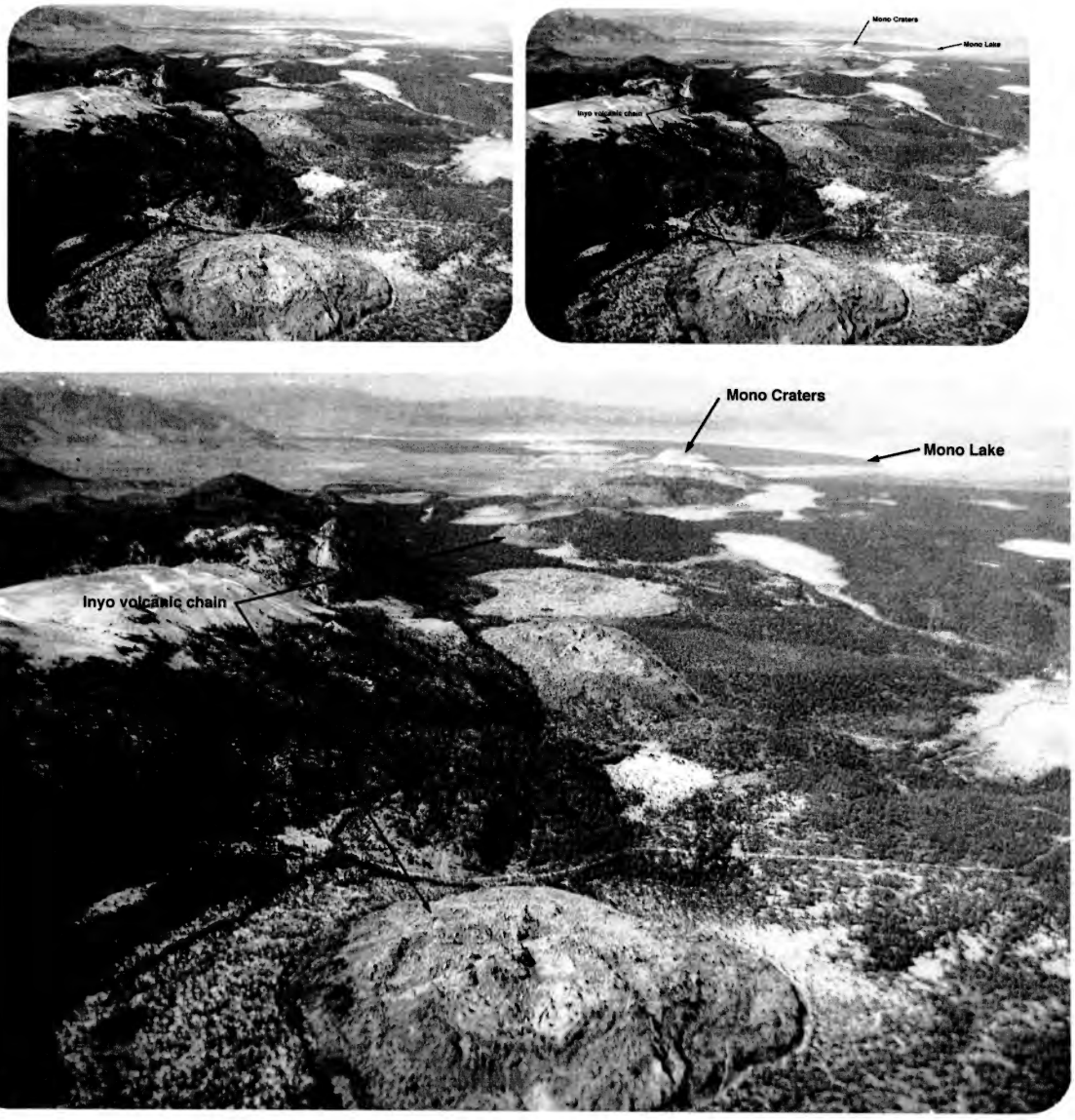

You are looking toward the northwest. The Owens River is cut into the Bishop Tuff erupted from the 10 x 20 mile Long Valley Caldera 730,000 years ago. That eruption expelled about 140 cubic miles (600 cubic km) of magma as plinian ash falls and incandescent ash flows. The volcanism at Long Valley Caldera actually began about 3,200,000 years ago with the eruption of trachybasaltic and trachyandesitic flows. From 3,000,000 to 2,600,000 years ago quartz latite domes and flows erupted from the north and northwest rims of the present caldera. The rhyolite domes, flows, and tuffs of Glass Mountain Ridge formed between 2,100,00 and 800,000 years ago as a silicic magma chamber arched up the area now occupied by the caldera. The roof of this magma chamber collapsed during the eruption of Bishop Tuff, and as much as 4500 feet of Bishop Tuff magma ponded in the caldera. Volcanism continued on this new caldera floor with explosions of tephra and extrusion of thin, hot, fluid obsidian flows. These were arched into a resurgent dome in the western part of the caldera between 730,000 and 650,000 years ago.* Picture taken August 13, 1982.

*Bailey, Roy A., 1987, "Long Valley caldera, eastern California", GSA Centennial Field Guide-Cordilleran Section.




You are looking toward the northeast across the western end of Long Valley Caldera. After the initial rise of the resurgent dome ended about 650,000 years ago, crystal-rich rhyolite began erupting in the moat, first in the northern part and proceeding clockwise around the moat. The eruptions were spaced at about 200,000 year intervals at 500,000, 300,000 and 100,000 years ago. A 30 mile long fissure grew northward from the western moat to Mono Lake. First, from 300,000 to 200,000 years ago, trachybasalt and trachyandesite poured out of the southern end of the fissure around the western end of the dome. Then from 150,000 to 50,000 years ago quartz latite domes and flows built Mammoth Mountain volcano where the fissure intersected the southwestern caldera wall. The fissure spread northward and rhyolite domes and flows welled up along it between 40,000 to 600 years ago. Between May of 1980 and January of 1983 rising magma pushed the resurgent dome up 20 inches accompanied by swarms of earthquakes. * Picture taken August 13, 1982.

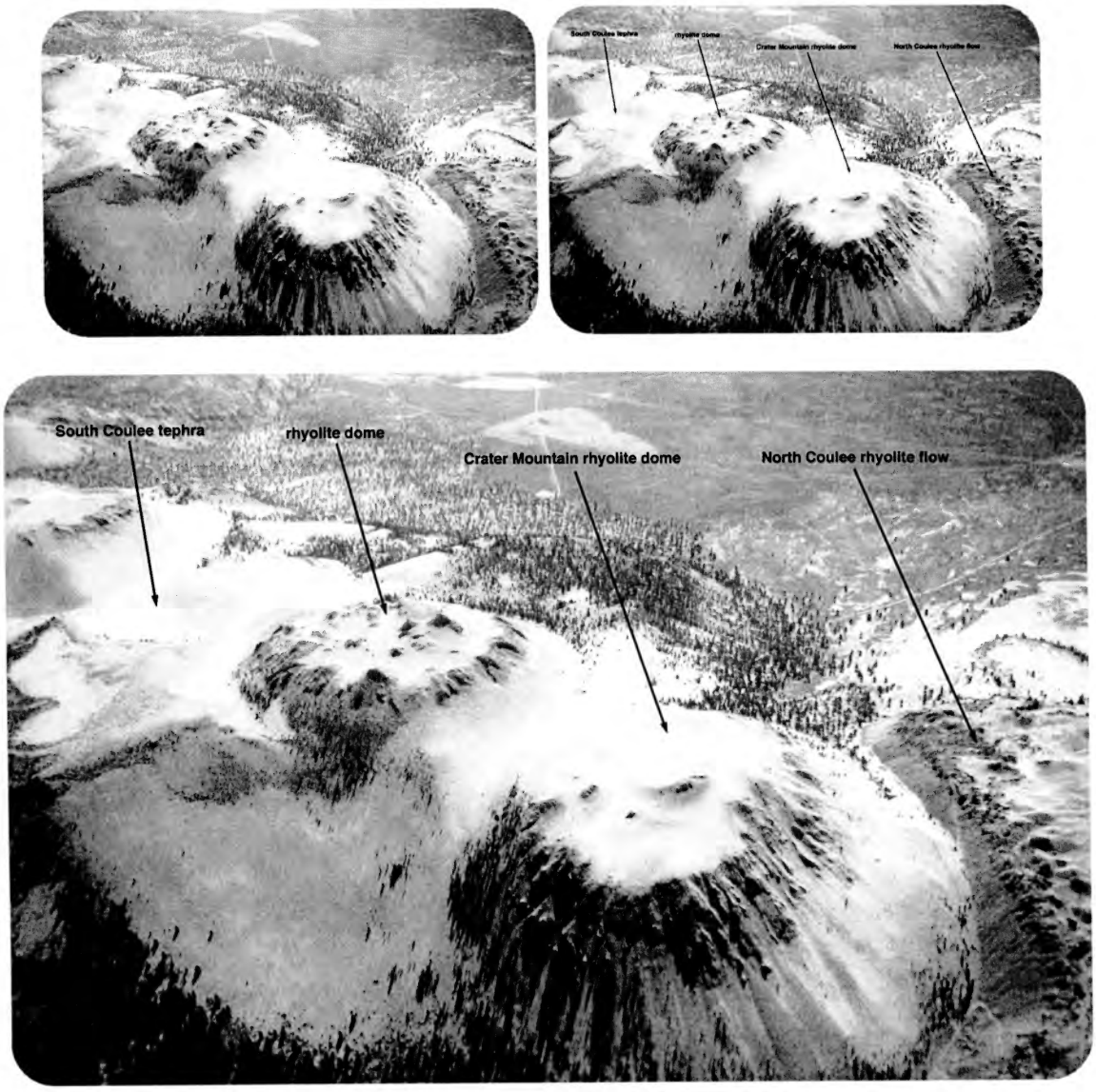
*Bailey, Roy A., 1987, "Long Valley caldera, eastern California", GSA Centennial Field Guide-Cordilleran Section.



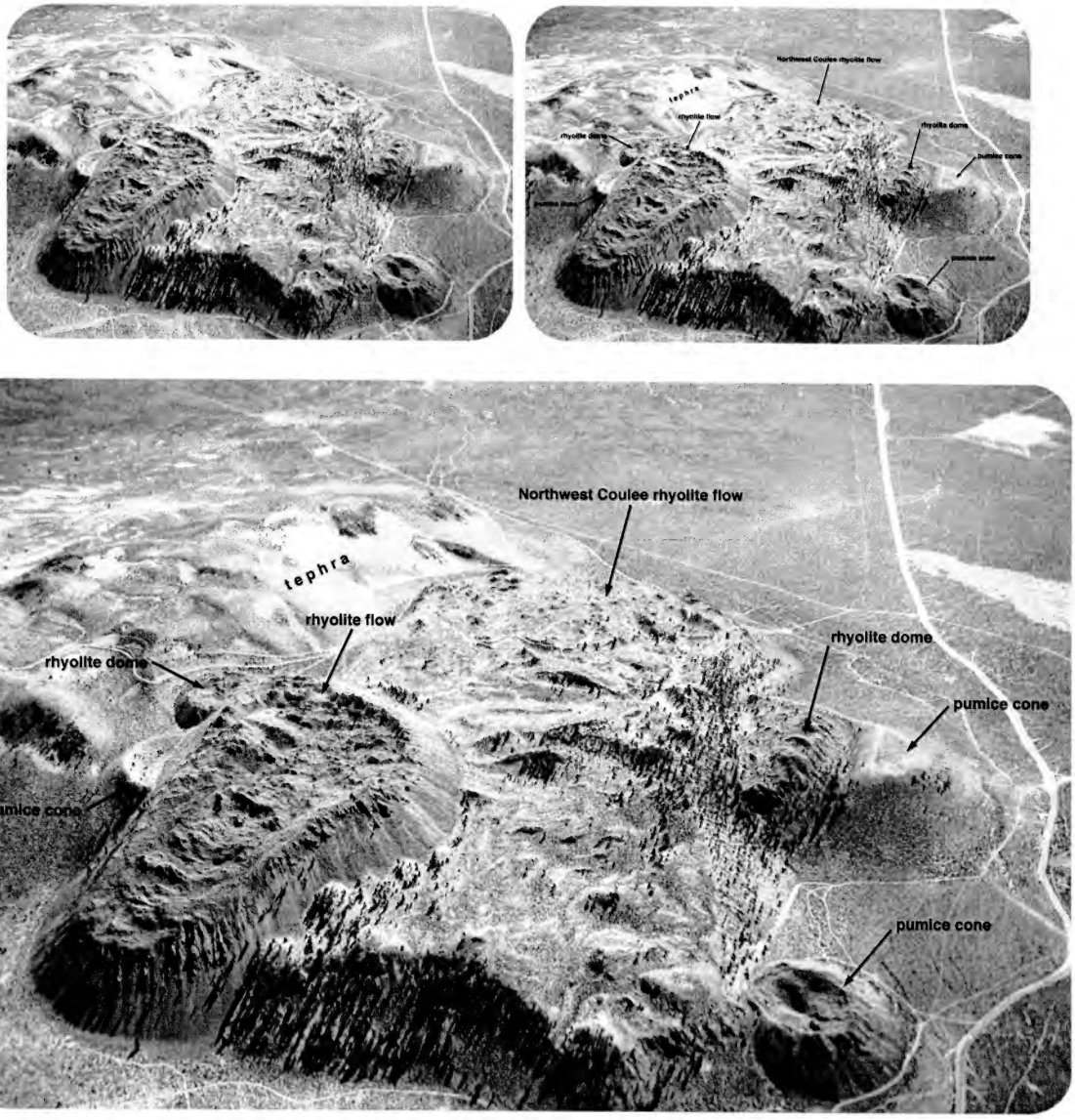

You are looking northward along the Inyo volcanic chain - Mono Craters rift at rhyolite domes and flows emplaced during the last few thousand years. Picture taken August 13, 1982.

You are looking toward the northwest at rhyolite domes, tephra, and flows along the Mono Craters rift at the eastern foot of the Sierra Nevada Mountains in California. Eruptions have taken place along the chain at 500 year intervals for the last 3000 years. The last eruptions occurred about 600 years ago.* Picture taken August 13, 1982.

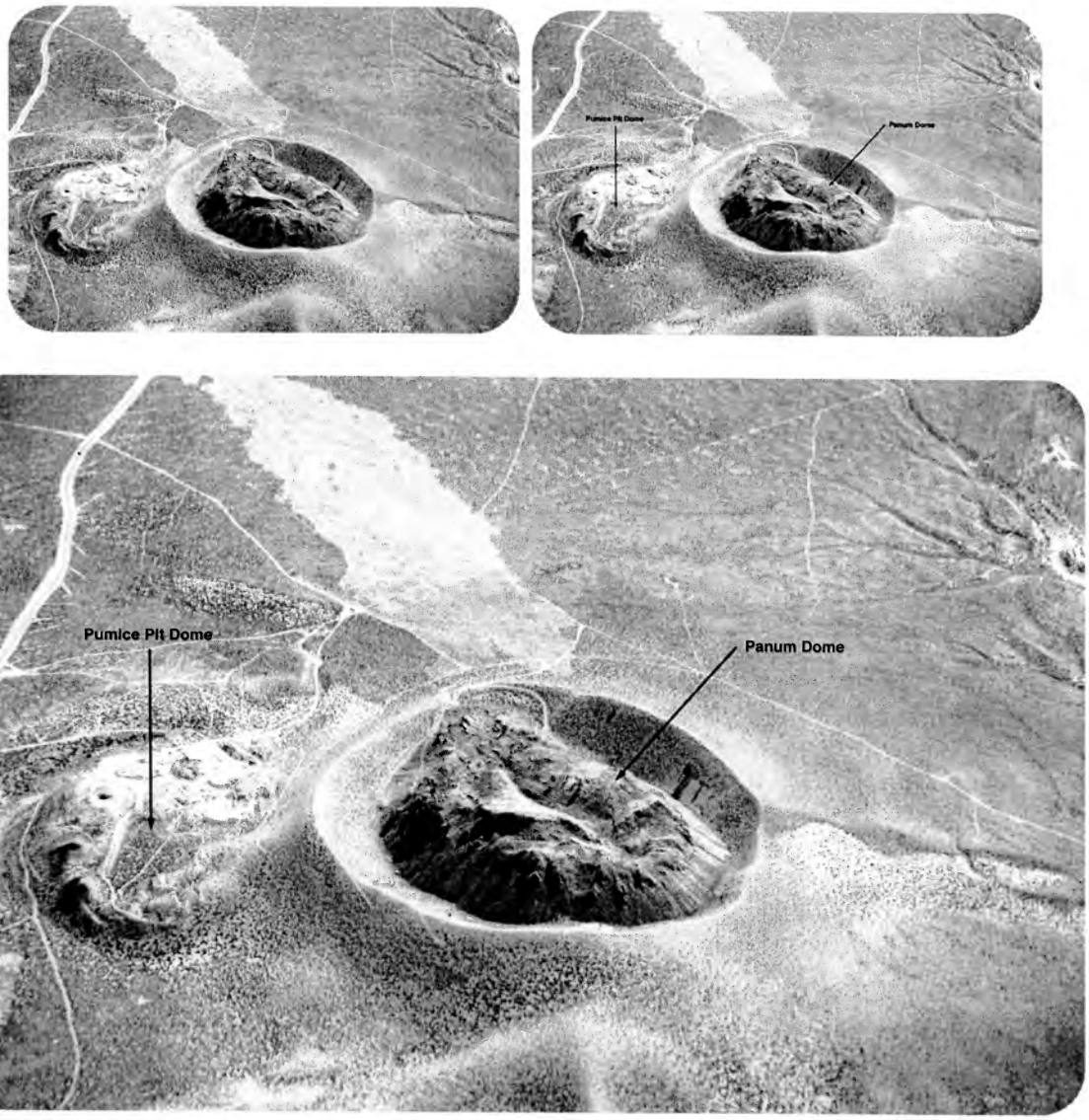
*Bailey, Roy A., 1987, "Long Valley caldera, eastern California", GSA Centennial Field Guide-Cordilleran Section.



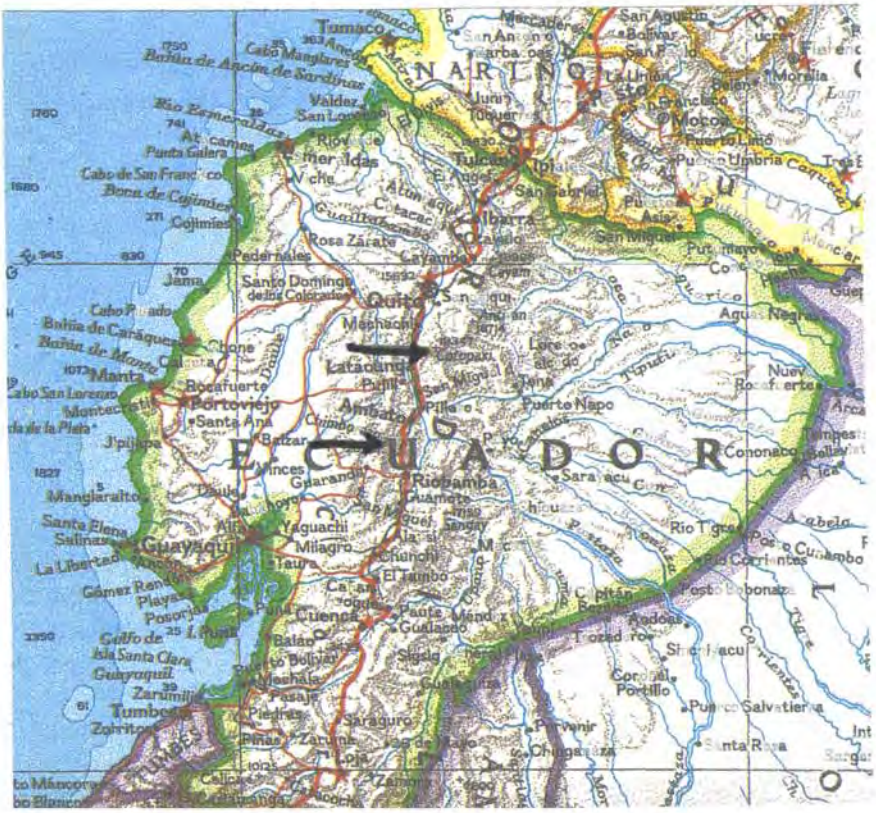

You are looking toward the southwest at 600 year old tephra partially blanketing the rhyolite domes and flows of the Mono Craters volcanic chain. Picture taken August 13, 1982.



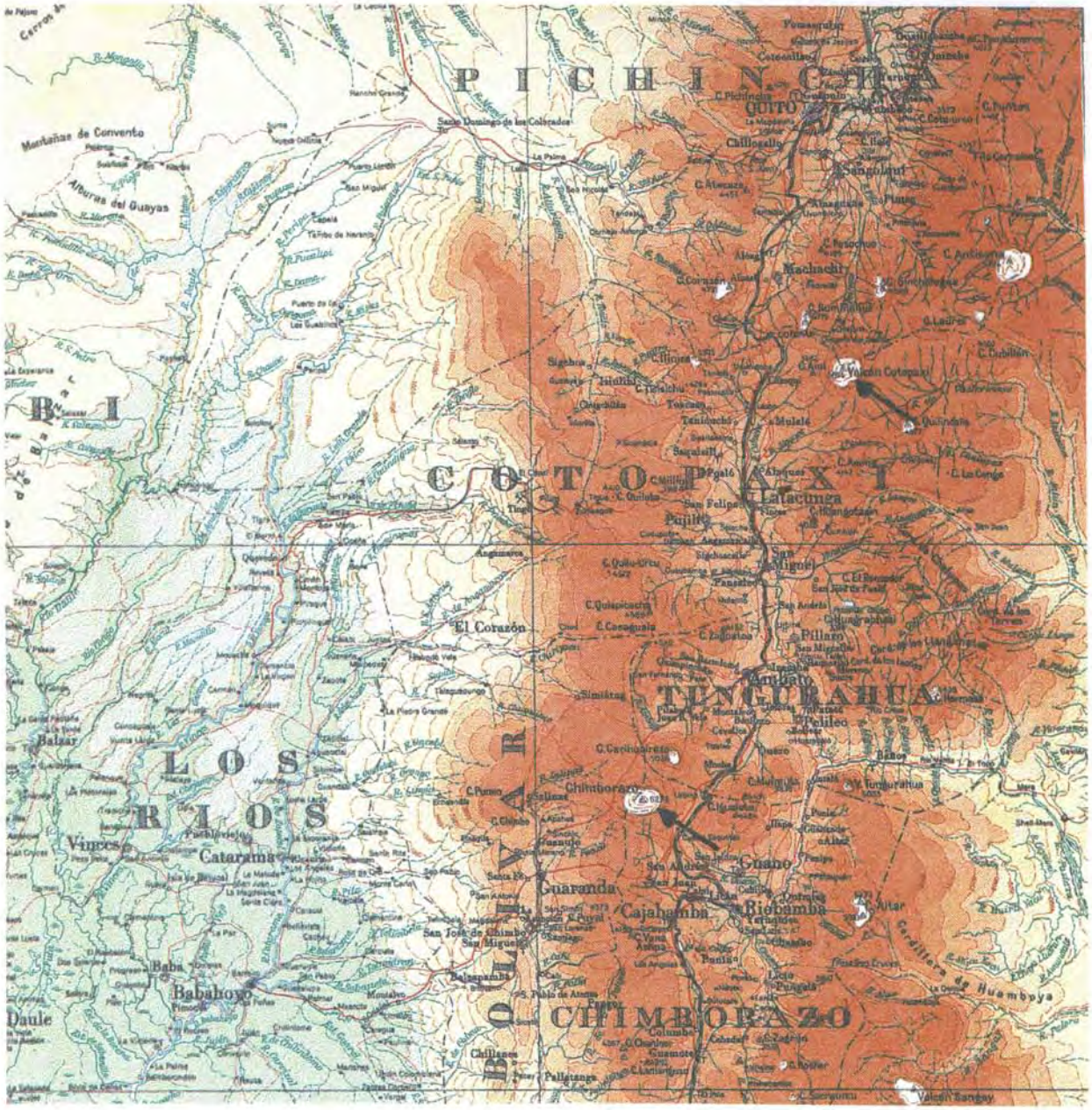

You are looking toward the southwest at rhyolite domes, flows, and pumice cones near the northern end of the Mono Craters chain. Because the magma was thick and viscous, the flows and domes have steep sides. Picture taken August 13, 1982.



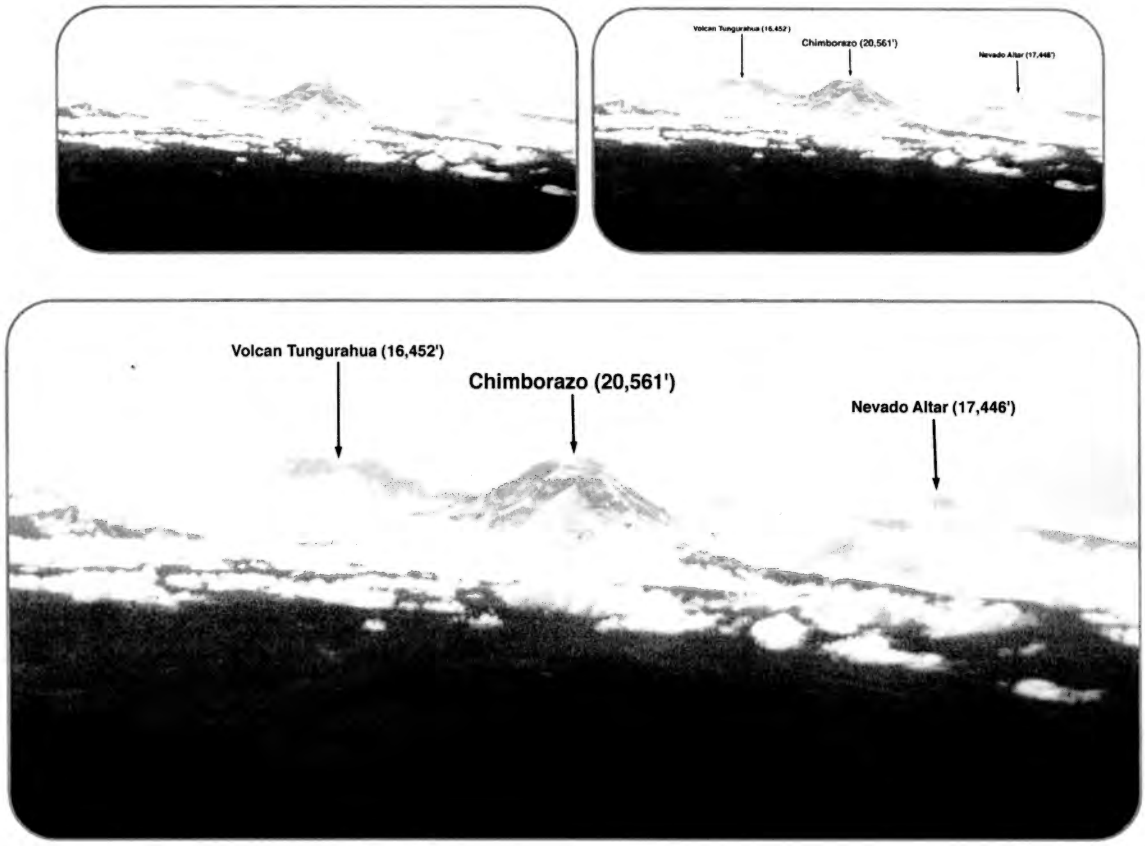

You are looking toward the southwest at Panum Dome, a rhyolite dome built inside a pumice cone about 600 years ago at the northern end of the Mono Craters chain. The initial explosive eruption built the pumice cone. Most of the gas-rich magma that had risen to the top of the magma chamber had been blown out when the remaining gas-depleted, viscous magma froze over the vent to produce the dome. Picture taken August 13, 1982.



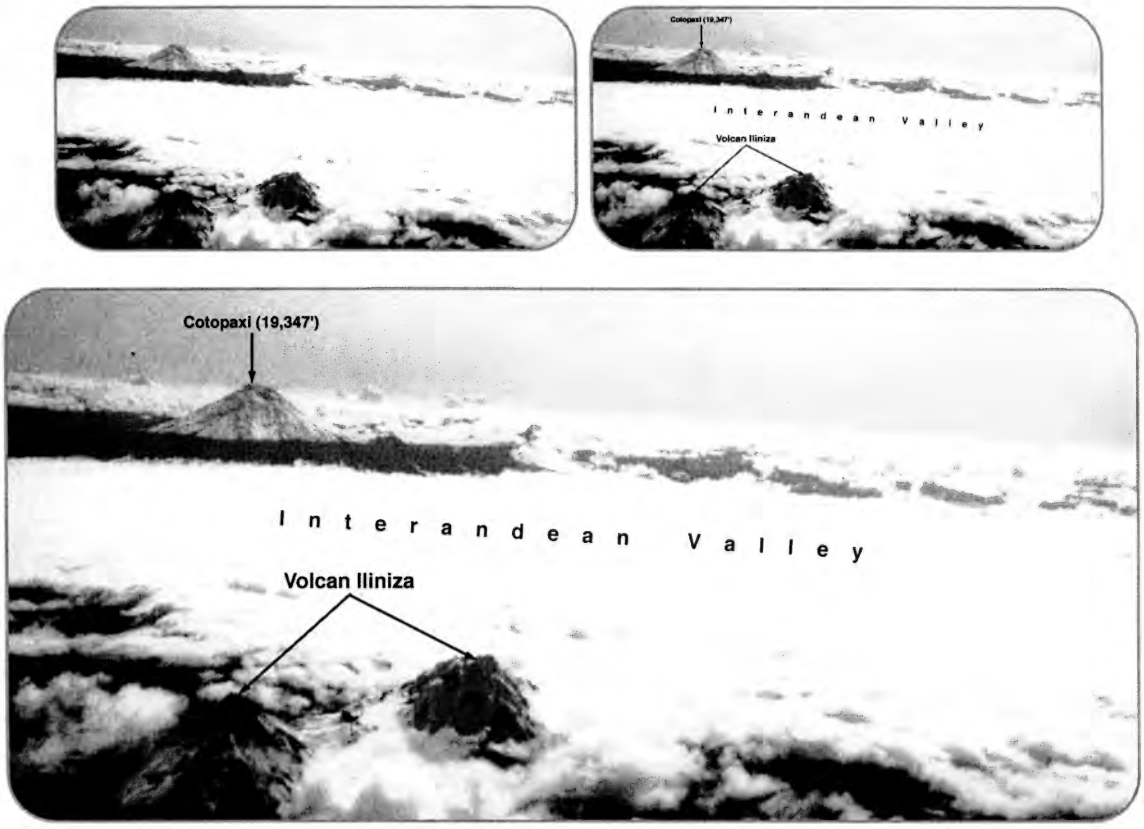

The upper arrow points to Cotopaxi, at 19,347' the highest active volcano in South America. The lower arrow points to Chimborazo, at 20,561' the highest peak in Ecuador.




The arrows point to Cotopaxi on the eastern side of the interandean valley and Chimborazo on the western side. Because the tops of both are covered by glaciers, eruptions produce gigantic mudflows. Map compiled and drawn by American Geographical Society of New York.



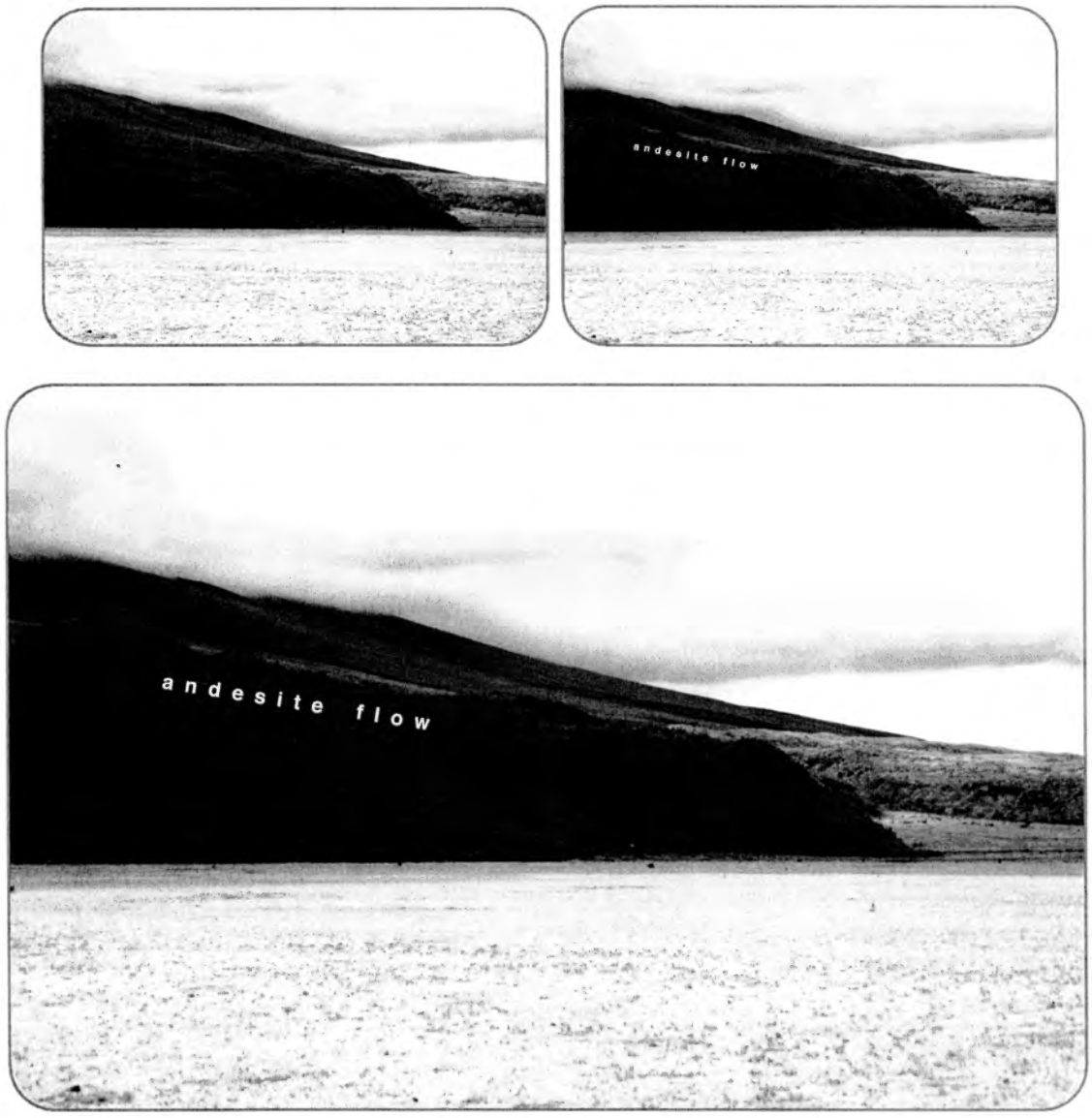

You are looking southeastward at andesitic volcanoes along the Interandean Valley, a graben that follows the crest of the Andes through Ecuador. Chimborazo is along its western edge. Tungurahua and Altar flank its eastern side. Picture taken December 23, 1982




You are looking eastward across the Interandean Valley at Cotopaxi, South America's highest active volcano. On June 25, 1877, Cotopaxi, accompanied by much rumbling, blew a huge column of ash straight above the crater high into the atmosphere. At ten o'clock the next morning frothy molten lava poured through gaps and notches in the crater rim. The mountain was immediately covered with steam as the lava exploded the snow and ice. A mudflow of ice, mud, and rock poured down the mountain at speeds up to 50 miles per hour. It streamed northward down the Interandean Valley for 150 miles at an average velocity of 17 miles per hour.* Picture taken December 23, 1982.

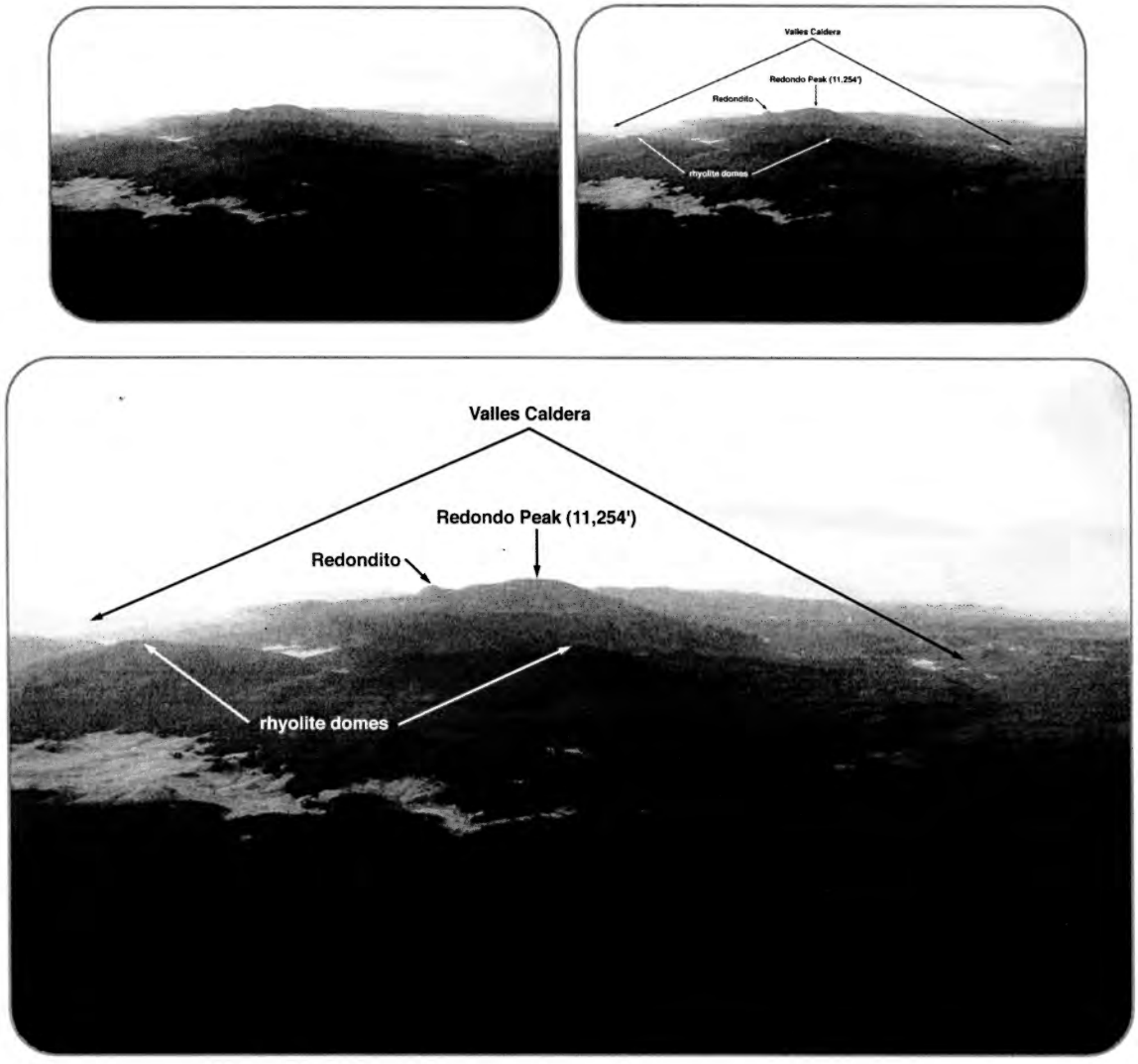
Bonney, T.G., 1899, "Volcanoes, Their Structure and Significance" G.P. Putnam's Sons, p.39-43.

The clouds have parted for a rare view of the rim on the western side of Cotopaxi's summit crater. The crater, about one half mile in diameter, steams fitfully. Picture taken December 29, 1982.



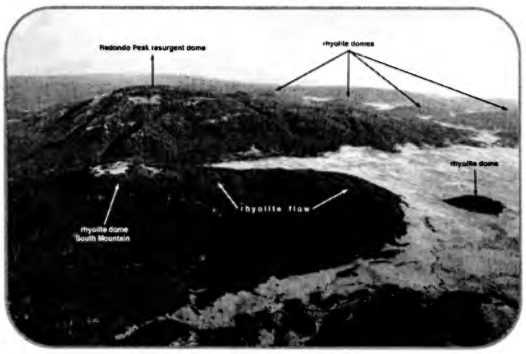

The steep front of this 1903 andesite flow breccia stopped on an old lake bed at the 14,000 foot level on the northern flank of Cotopaxi, Ecuador. Picture taken December 29, 1982.

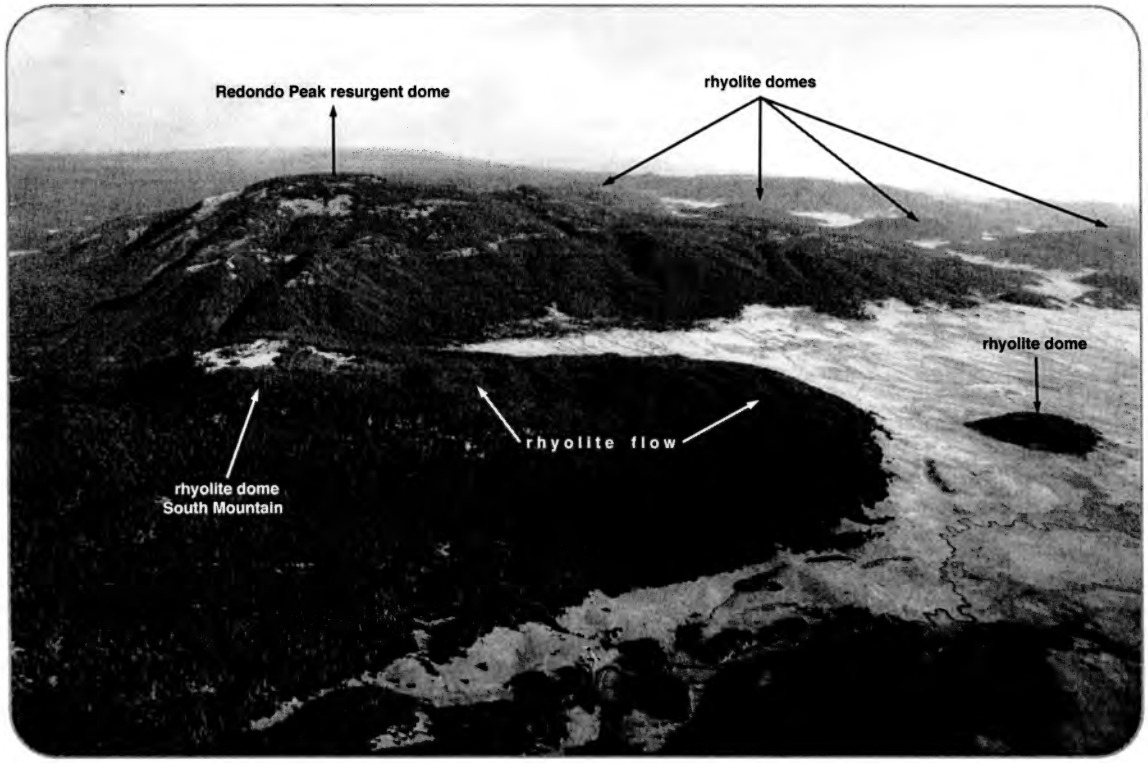
An arrow points to the Valles Caldera at the top of the Jemez Mountains, an ignimbrite shield volcano, in northern New Mexico.



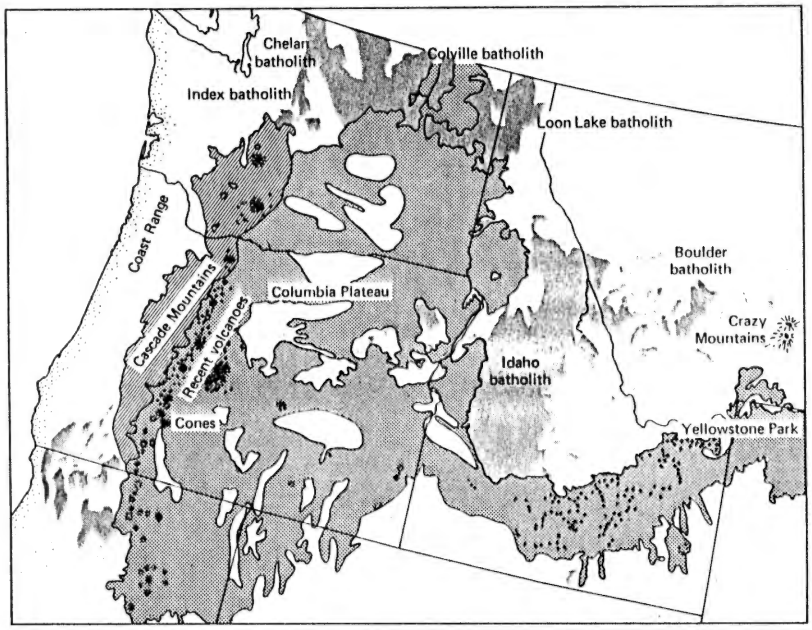

You are looking eastward at the Jemez Mountains in northern New Mexico. Redondo Peak is part of the resurgent dome arching up the central part of the Valles Caldera at the top of the Jemez Mountains. Rhyolite domes intrude along the ring fracture around the moat of the caldera. Picture taken June 12, 1996.

You are looking southward down the flank of the Jemez Mountains in northern New Mexico. The Jemez River has carved Canyon de San Diego through the Bandalier Tuffs that were erupted as ash flows from the Valles Caldera during two episodes, 1.5 million and then one million years ago. Some of the ash flows were hot enough and retained enough heat to weld their glass shards together, forming layers of welded tuff, such as those that underlie these sloping surfaces. Some were cooler and thinner and remained unwelded. Air-fall pumice preceeded each of the episodes of ash flow eruption. Picture taken June 12, 1996.



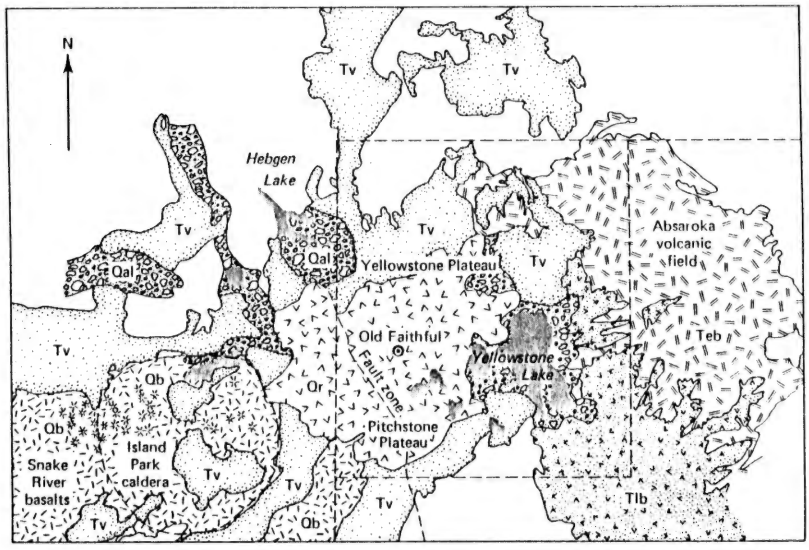




You are looking toward the northwest across the moat around the resurgent dome in the Valles Caldera at the top of the Jemez Mountains in northern New Mexico. After the collapse of the ignimbrite shield, rising magma arched up the ash flow tuffs to form the resurgent dome near the center of the caldera. Rhyolite domes and flows squirted up through fractures in the moat. Picture taken June 12, 1996.



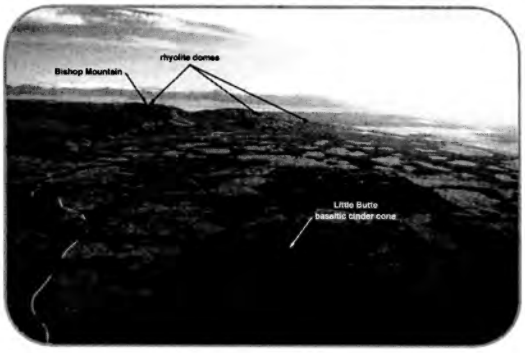

Distribution of volcanic and igneous intrusions in the northwestern United States.
(after the Tectonic Map of the United States, American Association of Petroleum Geologists)

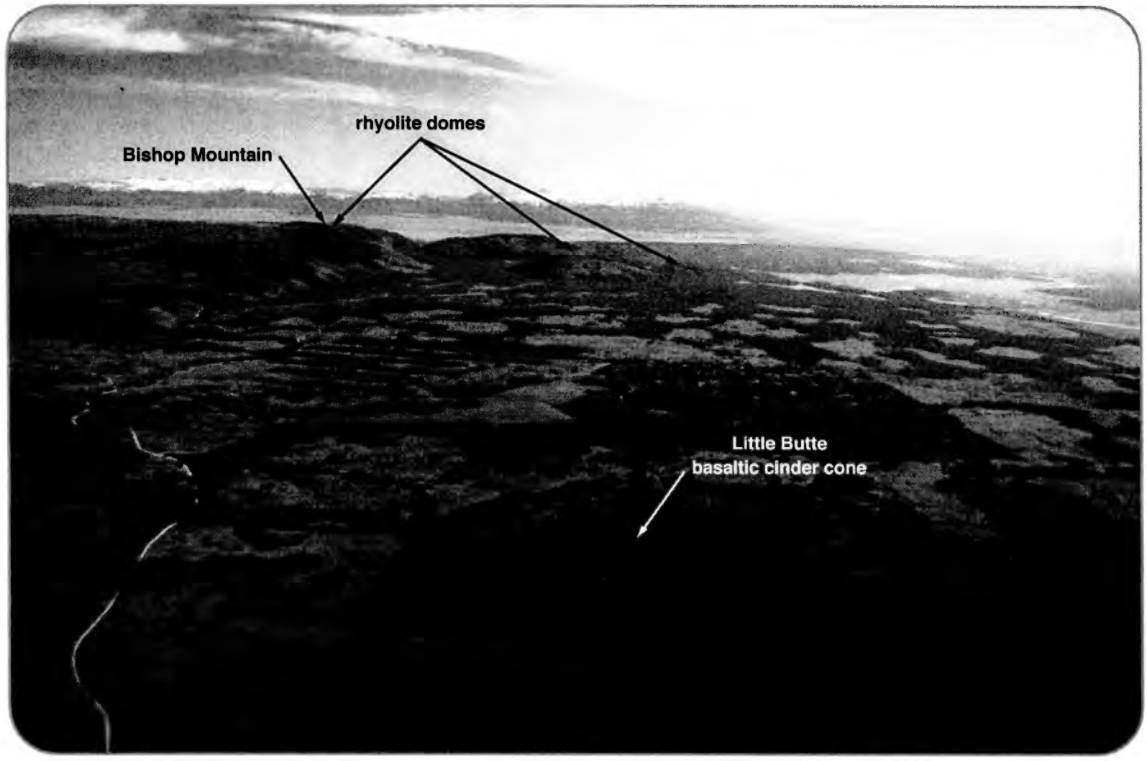
Sketch map of the Yellowstone Park region. The areas undesigned are mainly outcrop areas of rock that predate the volcanic activity. The youngest lavas are designated Qb (Quaternary basalt) and Qr (rhyolite). Slightly older volcanics are indicated by Tv (Tertiary volcanics); Teb (Tertiary early basic lavas and breccias); and Tlb (Tertiary late basic breccias). The stars mark craters in the Snake River basalt lavas.
(after maps of Montana and Wyoming in Hamilton, 1960)



You are looking southward at the western part of the Island Park Caldera. Two million years ago 1200 cubic kilometers of ash flow tuffs poured out of the ignimbrite shield volcano over the Island Park area. The ash flows came in such rapid succession that the retained heat welded their glass shards together to form the Huckleberry Ridge welded tuff. Because these violent eruptions emptied much of the magma chamber, the unsupported ignimbrite shield collapsed. Rhyolite ash flows erupted across the caldera floor and rhyolite domes and flows squirted out of the concentric faults around the rim. Then, basalt flows alternated with rhyolite ash flows within the caldera. Finally, basalt flows largely covered the caldera floor.* Picture taken June 23, 1983

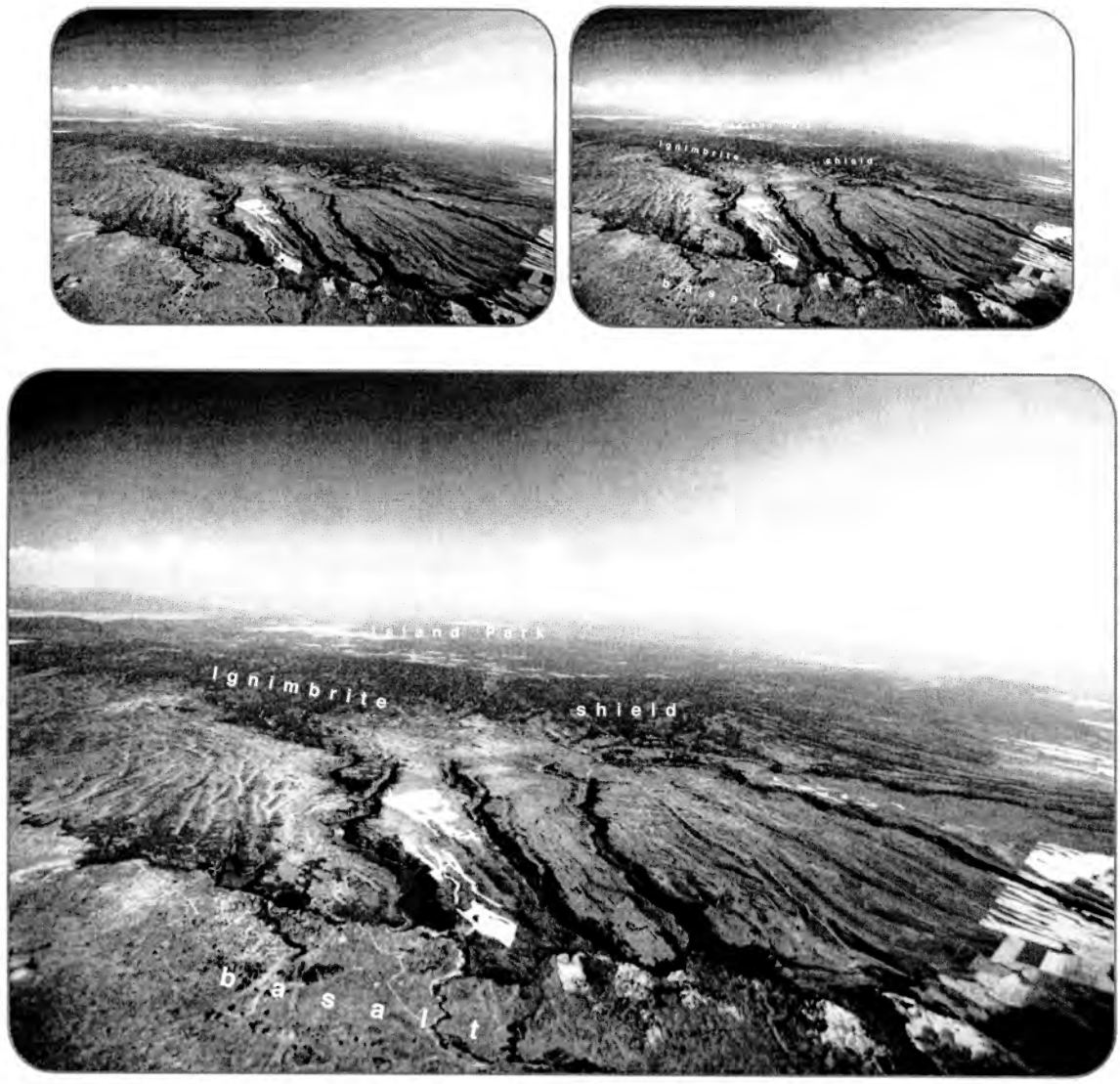
*data from: Hamilton, Warren, 1965, Geology and Petrogenesis of the Island Park Caldera of Rhyolite and Basalt, Eastern Idaho", USGS Professional Paper 504-C.



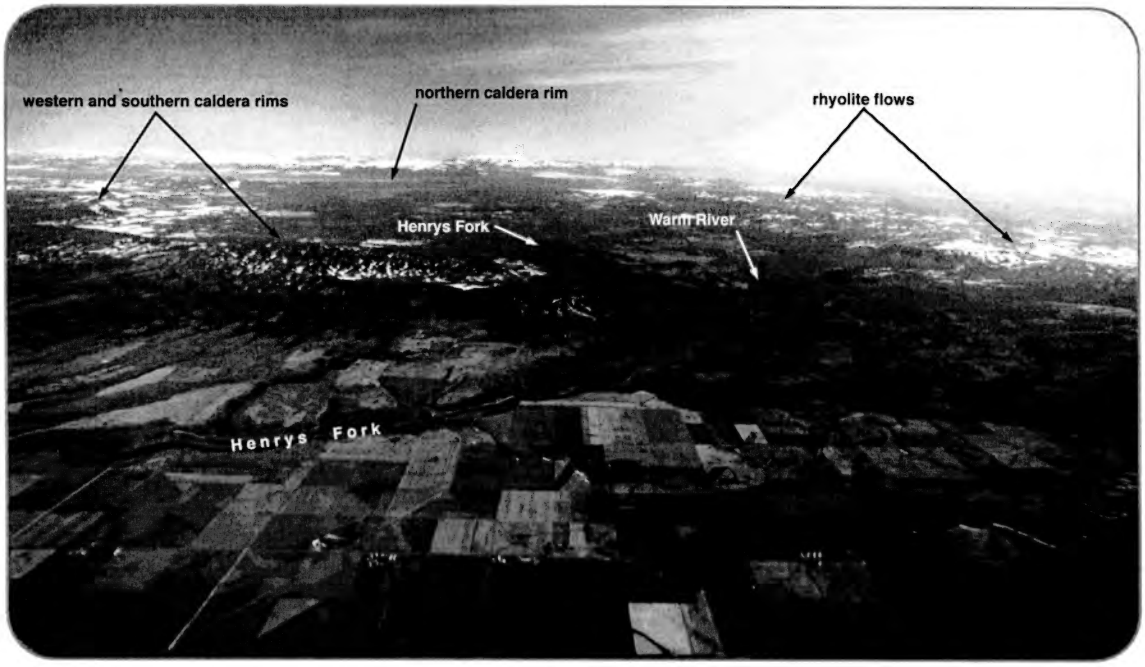




You are looking northward across the floor of the western end of the Island Park Caldera. The rhyolite domes grew during and immediately after the caldera's subsidence. The largest one forms Bishop Mountain on the rim of the caldera and is cut by the faults that ring the caldera. Olivine basalt flows partially bury the rhyolite domes and cover most of the surface of the caldera floor. Little Butte is an eroded basaltic cinder cone.* Picture taken June 23, 1983.

*data from: Hamilton, Warren, 1965, Geology and Petrogenesis of the Island Park Caldera of Rhyolite and Basalt, Eastern Idaho", USGS Professional Paper 504-C

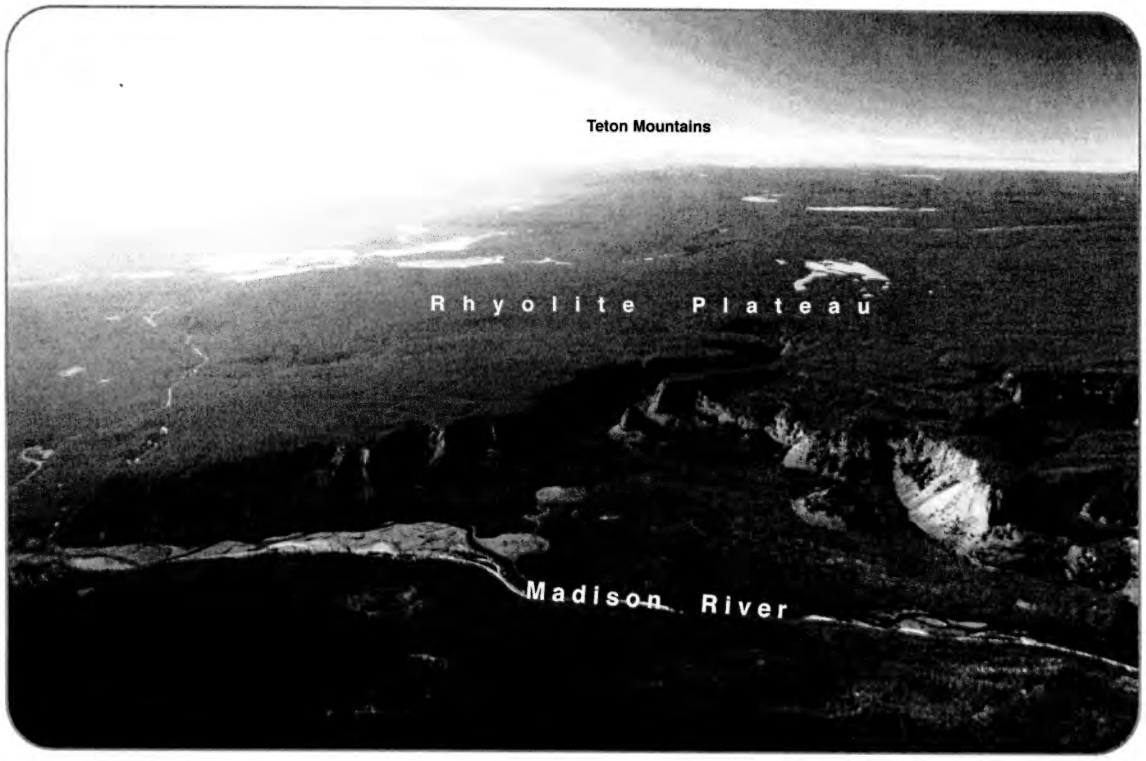



You are looking toward the northeast across the southwestern edge of the Island Park Caldera. The upper part of the ignimbrite shield collapsed into the partially emptied magma chamber. The remaining lower part was eroded by streams before basalt flows on the northeastern Snake River Plain partially buried it, temporarily blocking the gorges to form lakes that overflowed to cut narrow canyons in the basalt. A number of the streams have been dammed at the overflow sites to form reservoirs. Picture taken August 17, 1981.



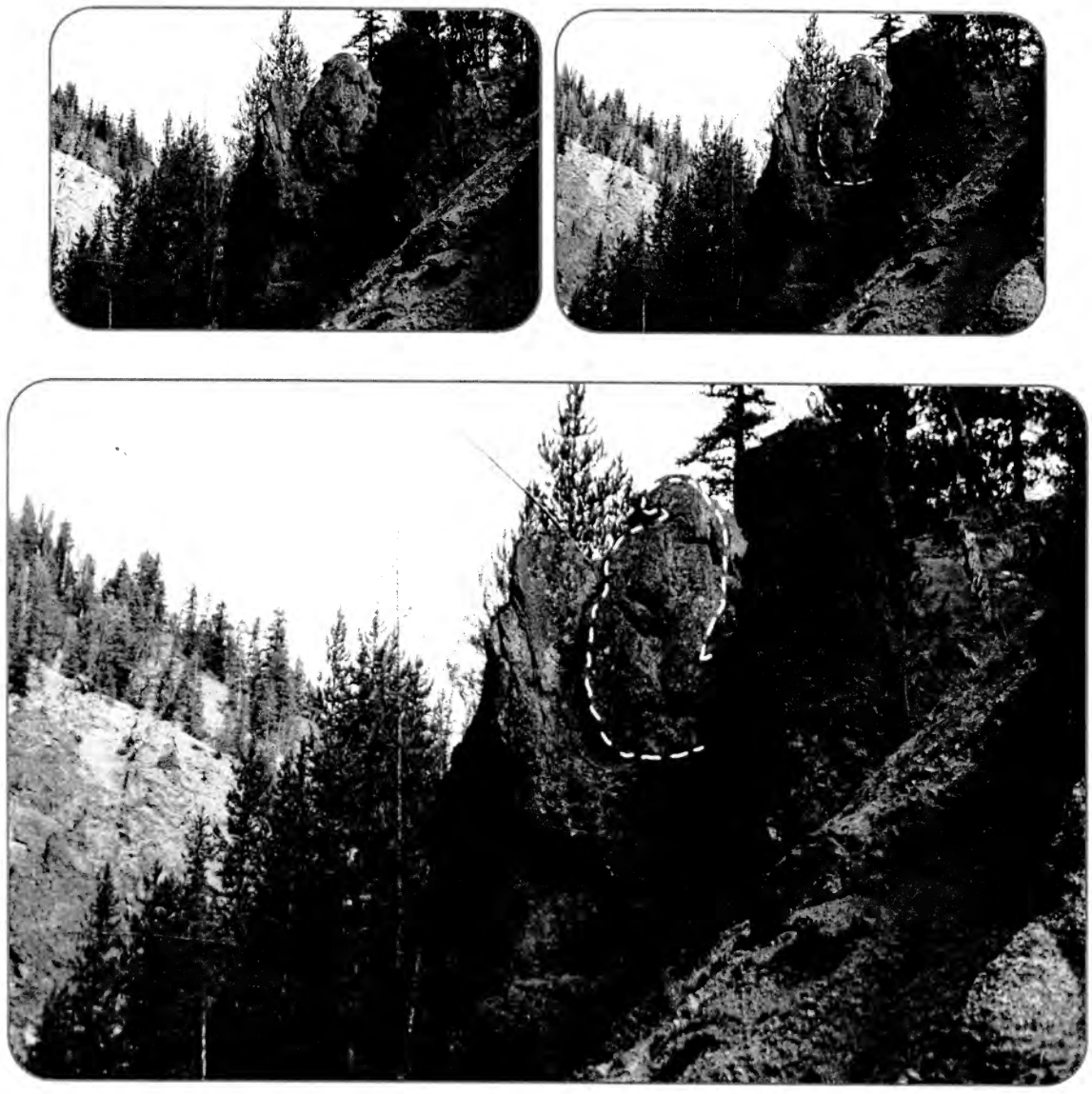

You are looking northward at Island Park Caldera. The eastern margin of the caldera is buried by rhyolite flows, most of which poured out of the Yellowstone Caldera to the east. Picture taken June 23, 1983.

Locations of the volcanic features shown in Yellowstone Park are indicated on this relief map.

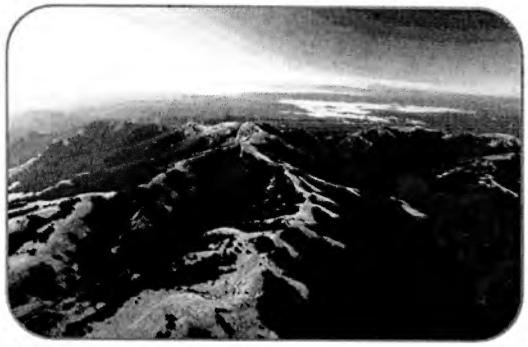


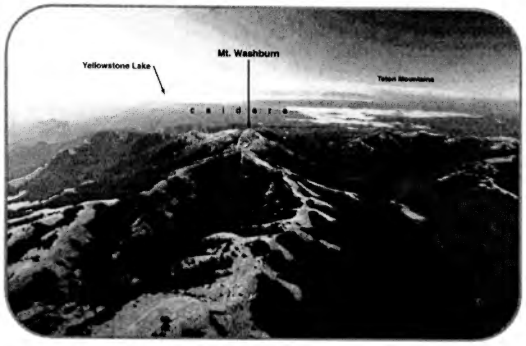

You are looking southward at a thick rhyolite flow exposed in cliffs across the Madison River in the western part of Yellowstone Park. The rhyolite flowed across this area to form the Rhyolite Plateau during the interval between the Bull Lake and Pinedale glaciations, about 117,000 years ago. Picture taken August 11, 1981.

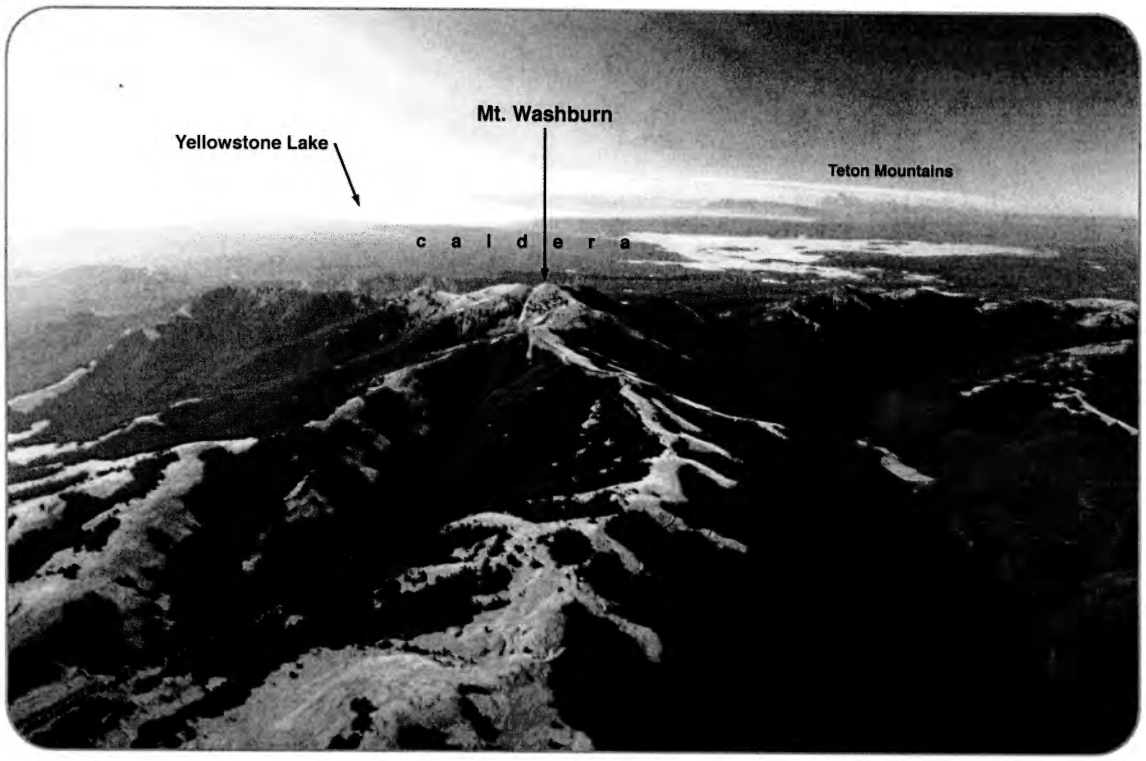
Fragments of spherulitic obsidian are aligned along nearly vertical flow bands in this breccia within the 117,000 year-old rhyolite flow exposed along the Firehole River in the western part of Yellowstone Park.



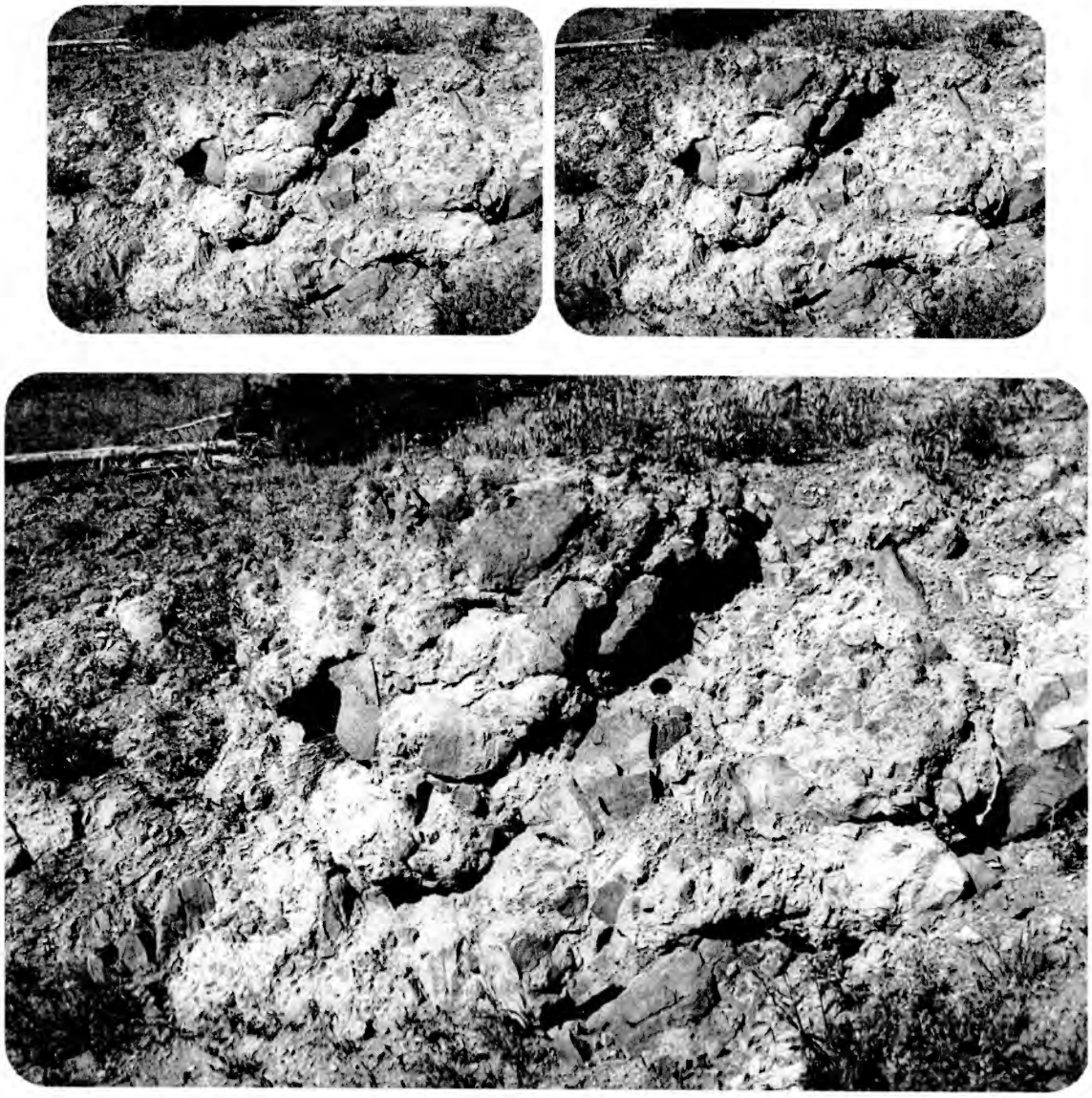
The white dashed line follows flow bands contorted into a refolded fold within the 117,000 year-old rhyolite flow in western Yellowstone Park. This outcrop is along the Firehole River.






You are looking southward over Mount Washburn on the northern rim of the Yellowstone Caldera. Mount Washburn is the northern half of an Eocene-age andesite volcano. Its southern half collapsed into the caldera after eruptions of ignimbrites in the Pleistocene. Since then, much of the caldera floor has been covered by rhyolite flows. Picture taken August 11, 1981.

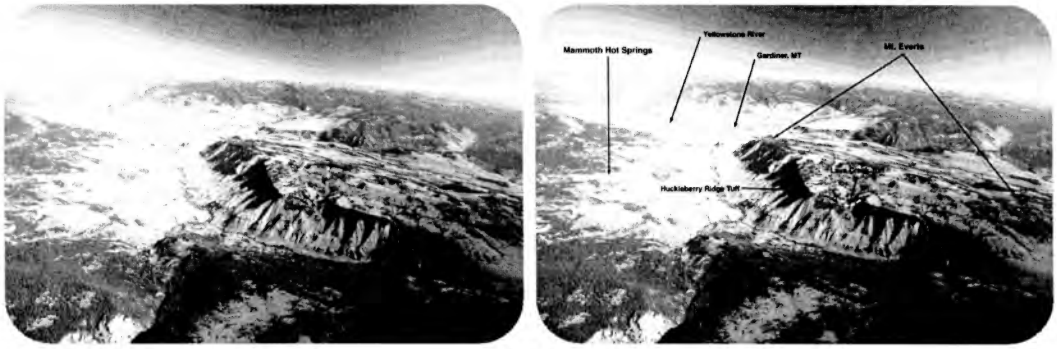


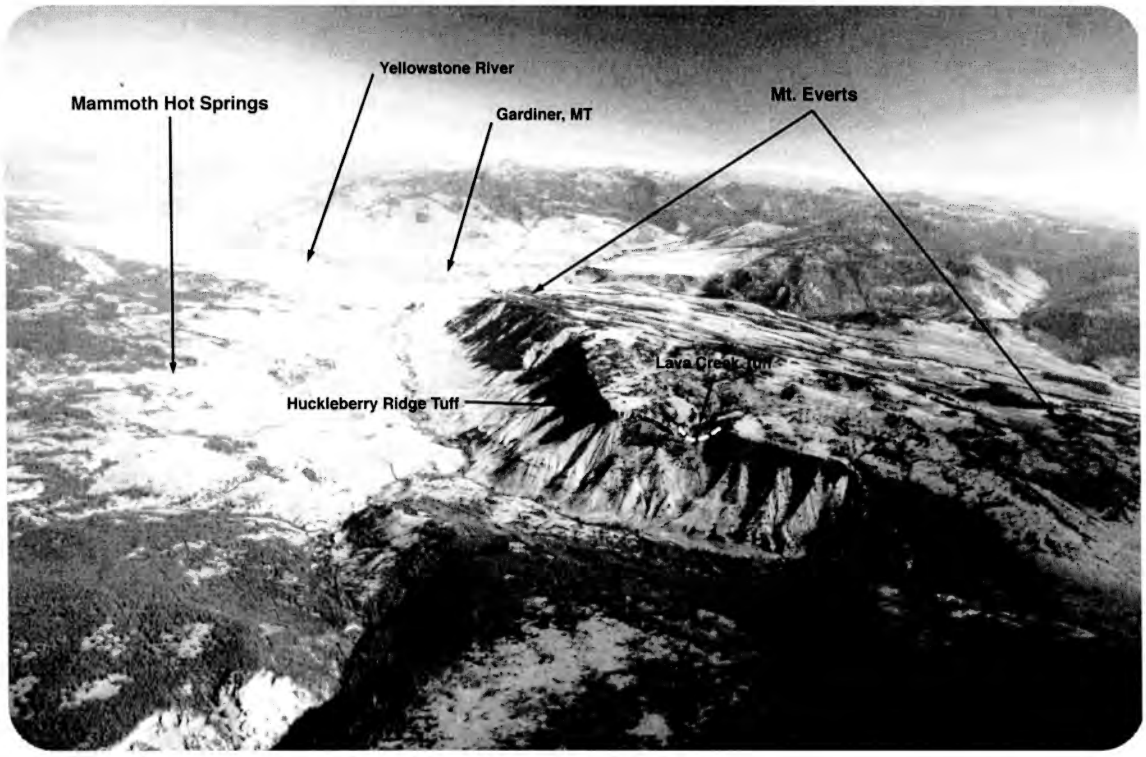
Mudflow breccia

Torrential rains accompanied explosive eruptions of Mount Washburn about 50,000,000 years ago. They mobilized the ash into mudflows that picked up a variety of sizes and types of volcanics as they flowed down the slopes to come to rest near the base of the volcano as deposits of mudflow breccia.

Autobreccia

The fragments in this breccia are all of similar size, and all consist of andseite, the same andesite that makes up the shattered matrix between the fragments. This breccia may form as a gas-rich andesite lava stops flowing, crystallizes, shrinks, and develops a system of cracks. The lava adjacent to the cracks explodes into the cracks, shattering itself and leaving solid chunks of similar size more or less centered between the cracks. These autobreccias occur in many of the andesite flows that added to the bulk of Mount Washburn as they flowed down its flanks about 50,000,000 years ago.

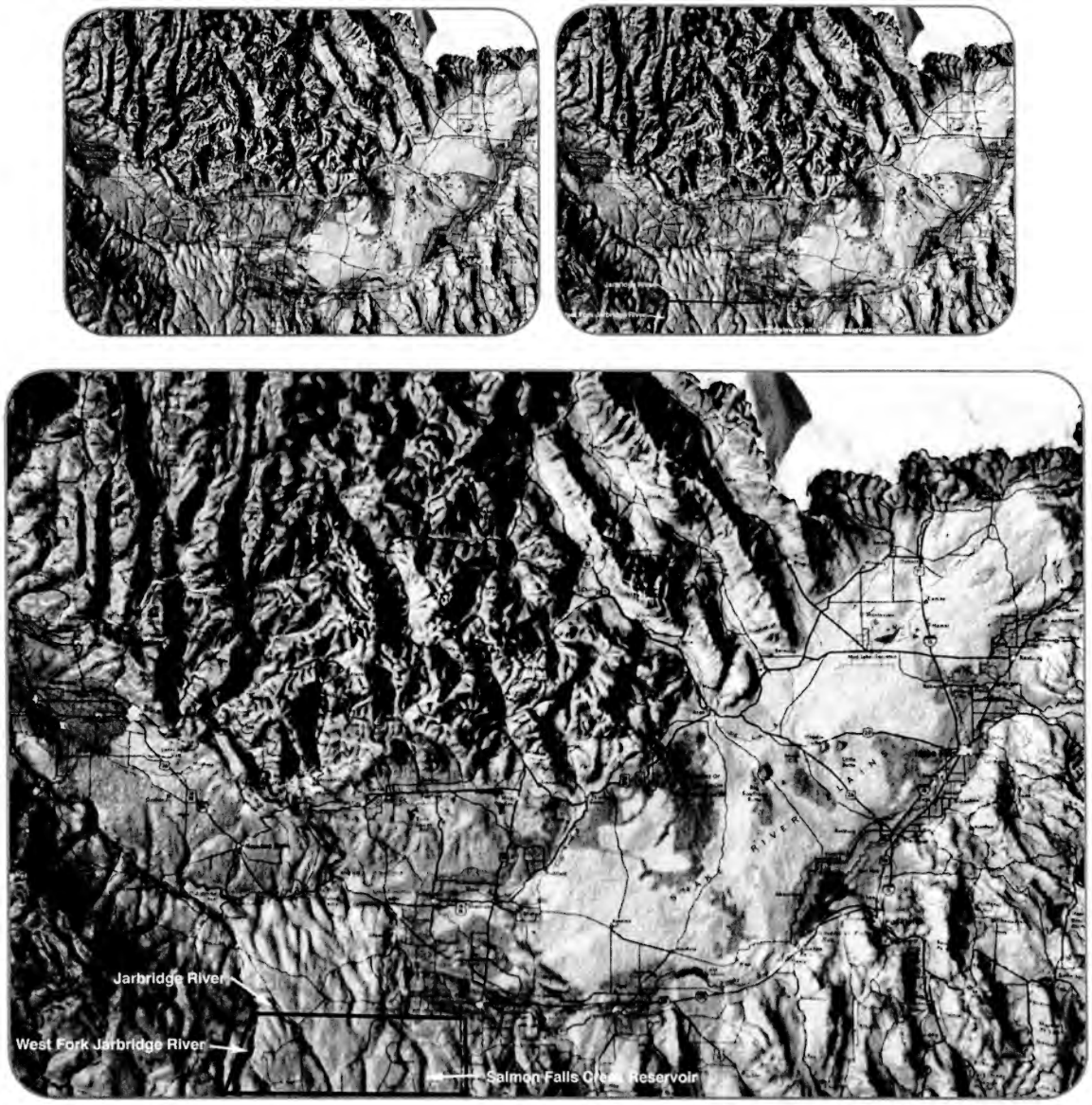





You are looking toward the northwest in northern Yellowstone Park. Mount Everts is capped by the 2,000,000 year-old Huckleberry Ridge Tuff. A valley carved into it contains the 600,000 year-old Lava Creek Tuff. Both tuffs filled the present topography at the time of eruption. They compacted the most where they were thickest, over the valleys, creating sags in their surfaces that channeled the streams to re-excavate the buried valleys. The Yellowstone ice-cap of Pinedale age drained down the Yellowstone River, sculpting the top of Mount Everts into a fluted topography.

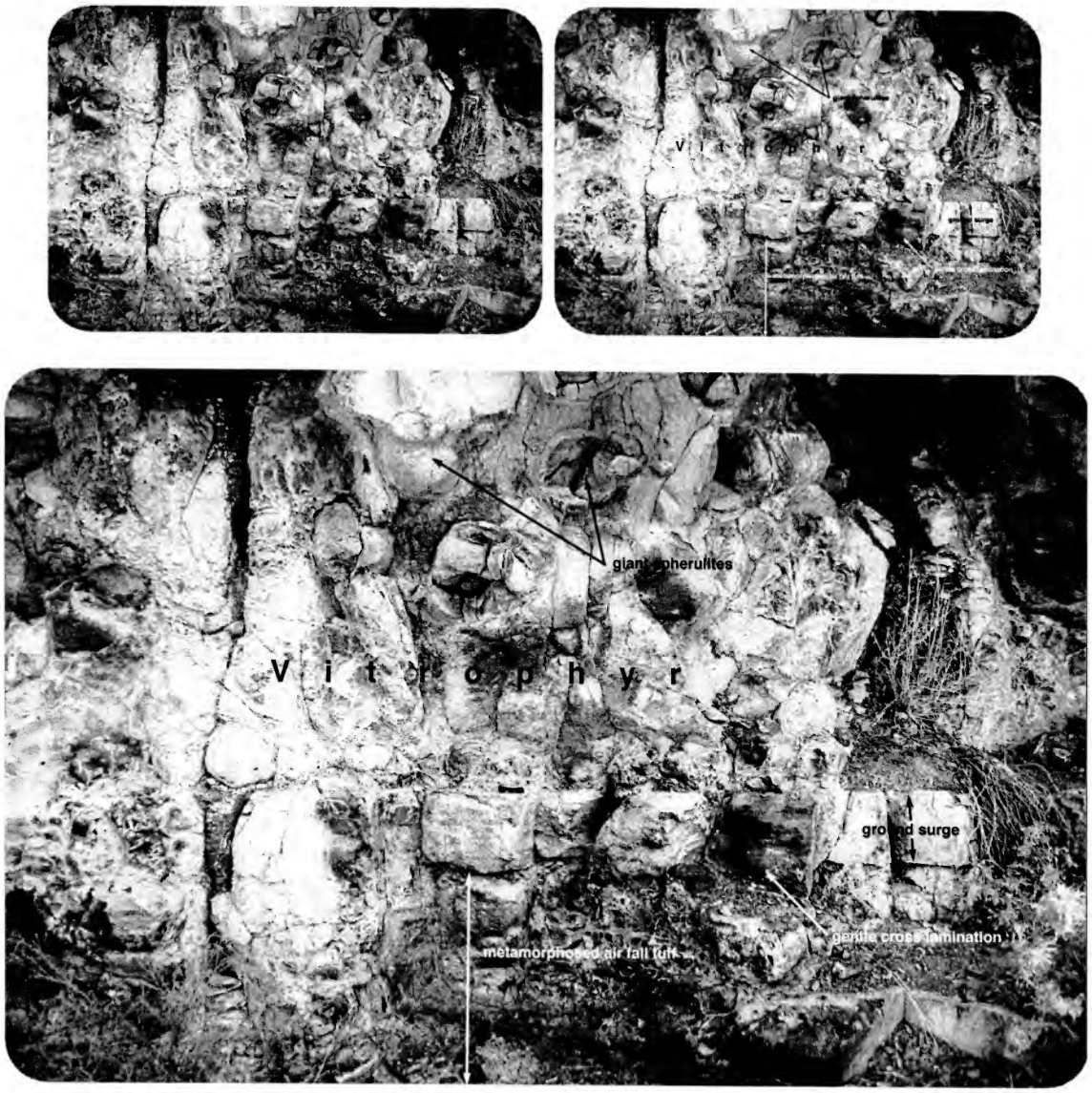
You are looking east southeast along the northern shore of Yellowstone Lake. Mary Bay and Squaw Lake are maars, which are craters or pits produced by steam explosions. These explosions occurred between 3500 and 10,750 years ago, probably just after the melting of the Yellowstone ice cap removed the confining weight of the ice from above them. Picture taken October 6, 1986.

You are looking toward the southeast along the western shore of the West Thumb of Yellowstone Lake. West Thumb is a caldera that collapsed after the eruption of voluminous rhyolite flows about 155,000 years ago. Duck Lake is a maar, a steam explosion pit surrounded by a rampart of fragments blown out about 2,500 years ago. Picture taken October 6, 1986.



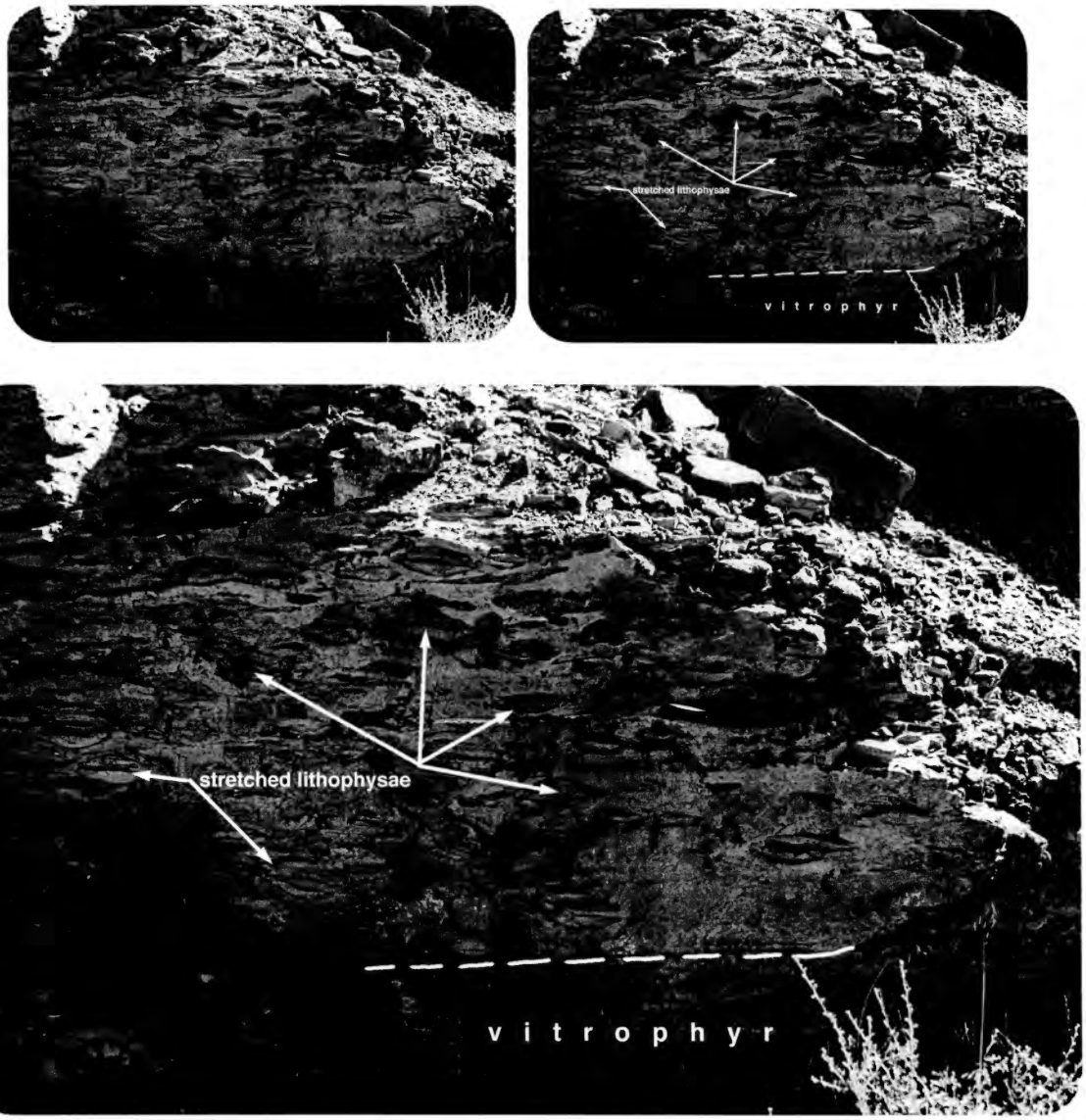

Like a fiery torch, the Yellowstone hot spot burned its track across Idaho as North America drifted over a plume of magma rising from the earth's mantle. It melted silicic crustal rocks that erupted as huge rhyolitic ash flows that spread over southwestern Idaho. The black box outlines the area where the pictures of the welded tuffs on the succeeding pages were taken.

You are looking at an exposure of Cougar Point Tuff XI along the west fork of the Jarbridge River in southwestern Idaho. The glass shards in the tuff are welded together from the heat of a series of ash flows erupted in rapid succession to form a single cooling unit. The basal ledge shows crude columnar joints. The Cougar Point Tuff contains 14 or more welded ash flow cooling units erupted about 11 million years ago. This unit, number XI, is about 300 feet thick and is the most widespread of the Cougar Point Tuffs. Its eruption temperature has been estimated at 850 to 900 degrees centigrade.



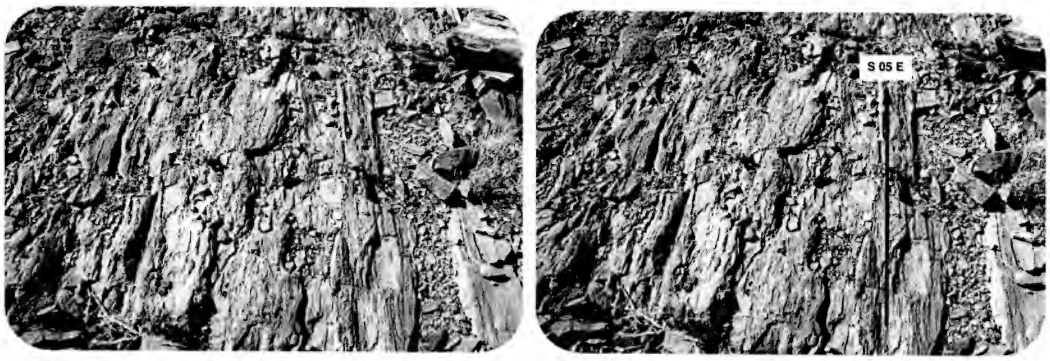

You are looking at an exposure of the base of Cougar Point Tuff XIII on the eastern rim of Jarbridge Canyon in southwestern Idaho. The air-fall tuff visible below the base of the ignimbrite has been vitrified by the heat from the welded tuff. Gentle cross lamination is just visible in the ground surge deposit that formed as sheets of superheated air blasted out at high velocity from the base of the ash flow. The estimated speed of the ash flow is about 170 miles per hour. The ground surge may have been twice that velocity. 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. Giant spherulites started to crystallize in it.*

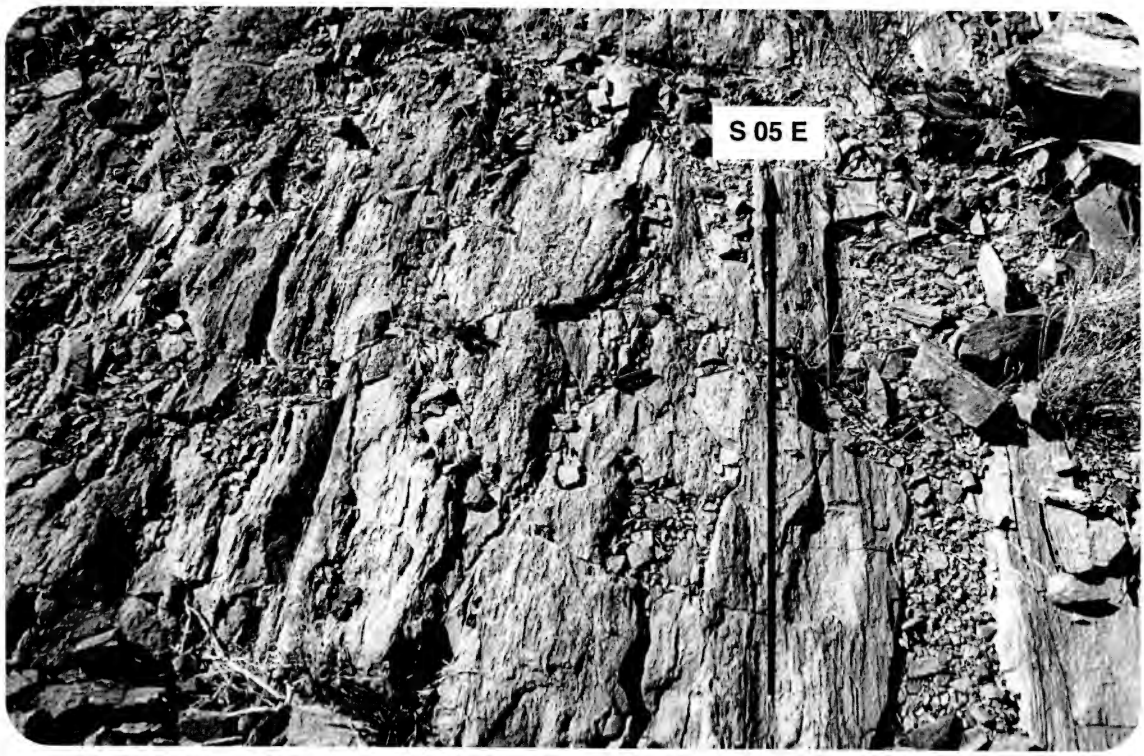
Information from personal communication: Martha M. Godchaux and Bill Bonnichsen during the 1996 Tobacco Root Geological Society Field trip.




You are looking at the lower half of an unnamed welded tuff that is only anout 10 feet thick. It lies above Cougar Point Tuff XIII east of Jarbridge Canyon in southwestern Idaho. Flow of this thin, hot, lava-like ignimbrite stretched the lithophysae (gas cavities). Flow velocity may have been in the range of 60 to 110 miles per hour. The flow agglutinated, degassed, and devitrified while it was being deposited. Flow indicators are all aligned, indicating a source N 05 W of this locality.*

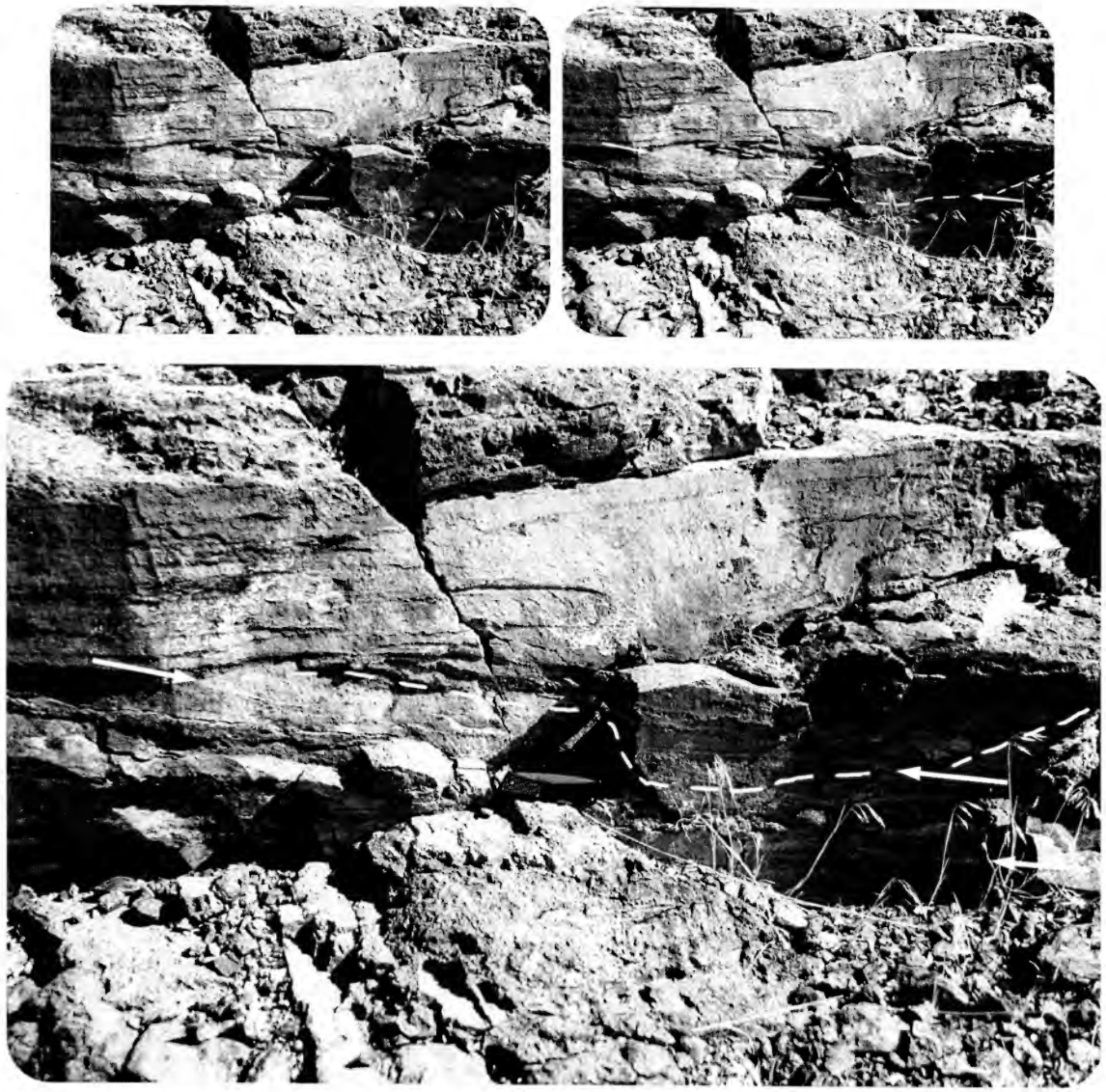
*Information from personal communication: Martha M. Godchaux and Bill Bonnichsen during the 1996 Tobacco Root Geological Society Field trip.



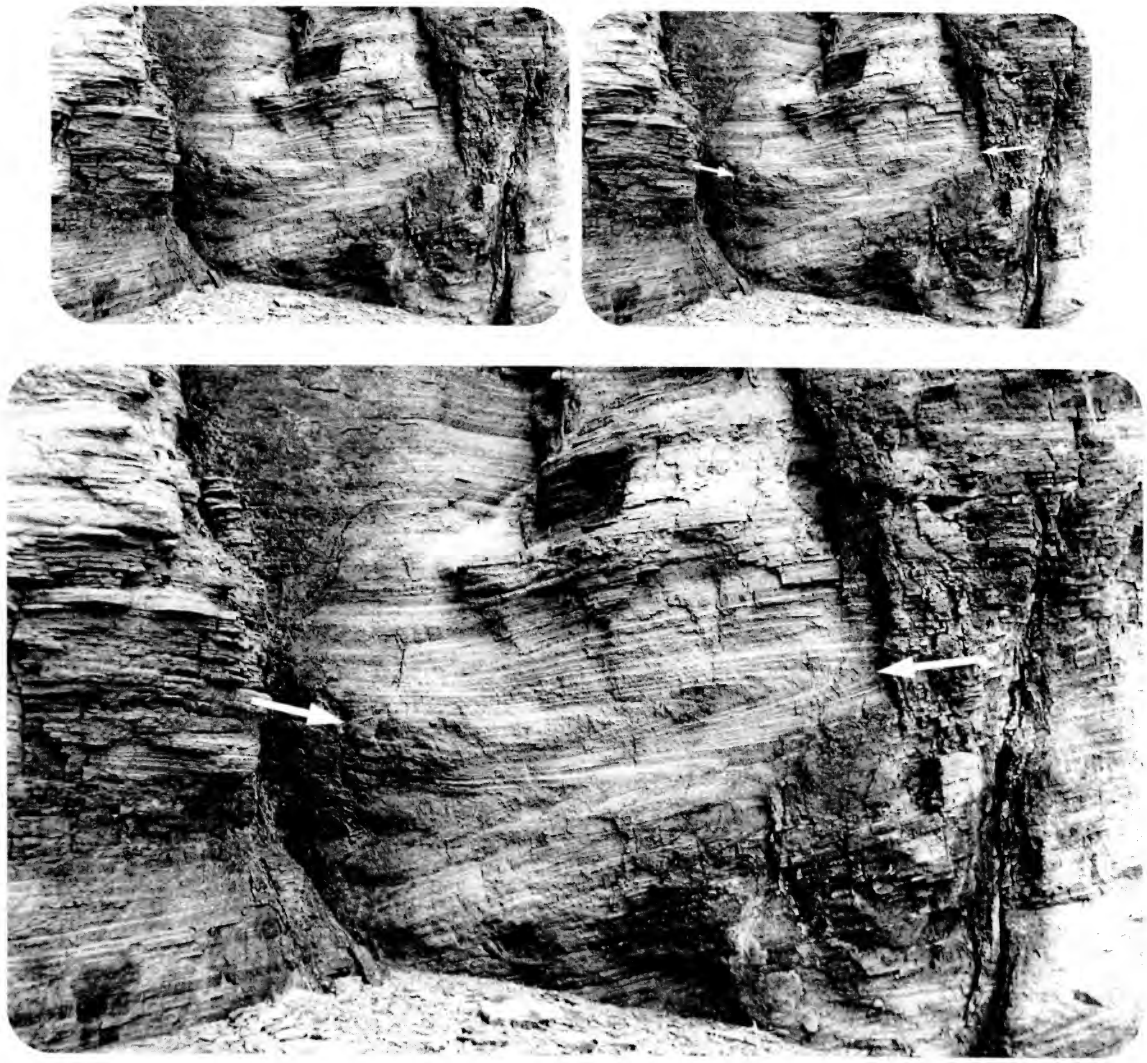

You are looking at striations in the middle part of the thin welded tuff above Cougar Point Tuff XIII east of Jarbridge Canyon in southwestern Idaho. The striations were etched into the tuff by its flow as it agglutinated and welded to form a hot, pasty, lava-like ignimbrite sheet.*

*Information from personal communication: Martha M. Godchaux and Bill Bonnichsen during the 1996 Tobacco Root Geological Society Field trip.

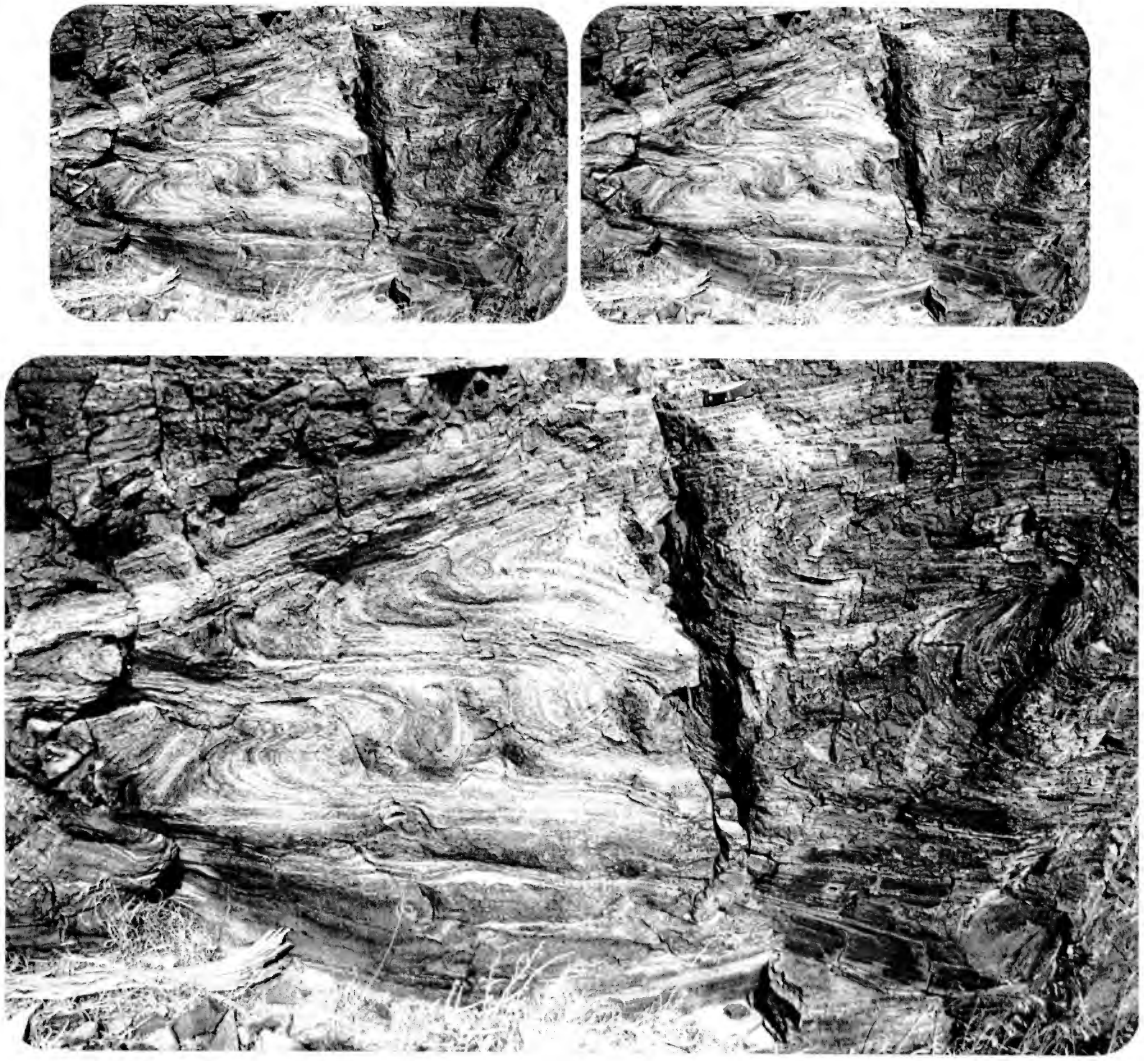


You are looking at the upper part of the thin tuff above Cougar Point Tuff X111 east of Jarbridge Canyon in southwestern Idaho. The arrows point to the edges of tongue-like isoclinal, recumbent folds in the tuff. The dashed line attempts to follow the trace of the somewhat bent axial plane of one fold. The face of the outcrop is nearly perpendicular to the long axis of the tongue, as shown by the closed ellipse outcrop pattern. Because it seems unlikely that a welded tuff only 10 feet thick could be fluidized after deposition by the latent heat of crystallization, these folds were most likely produced as primary features during emplacement of the hot lava-like ignimbrite.

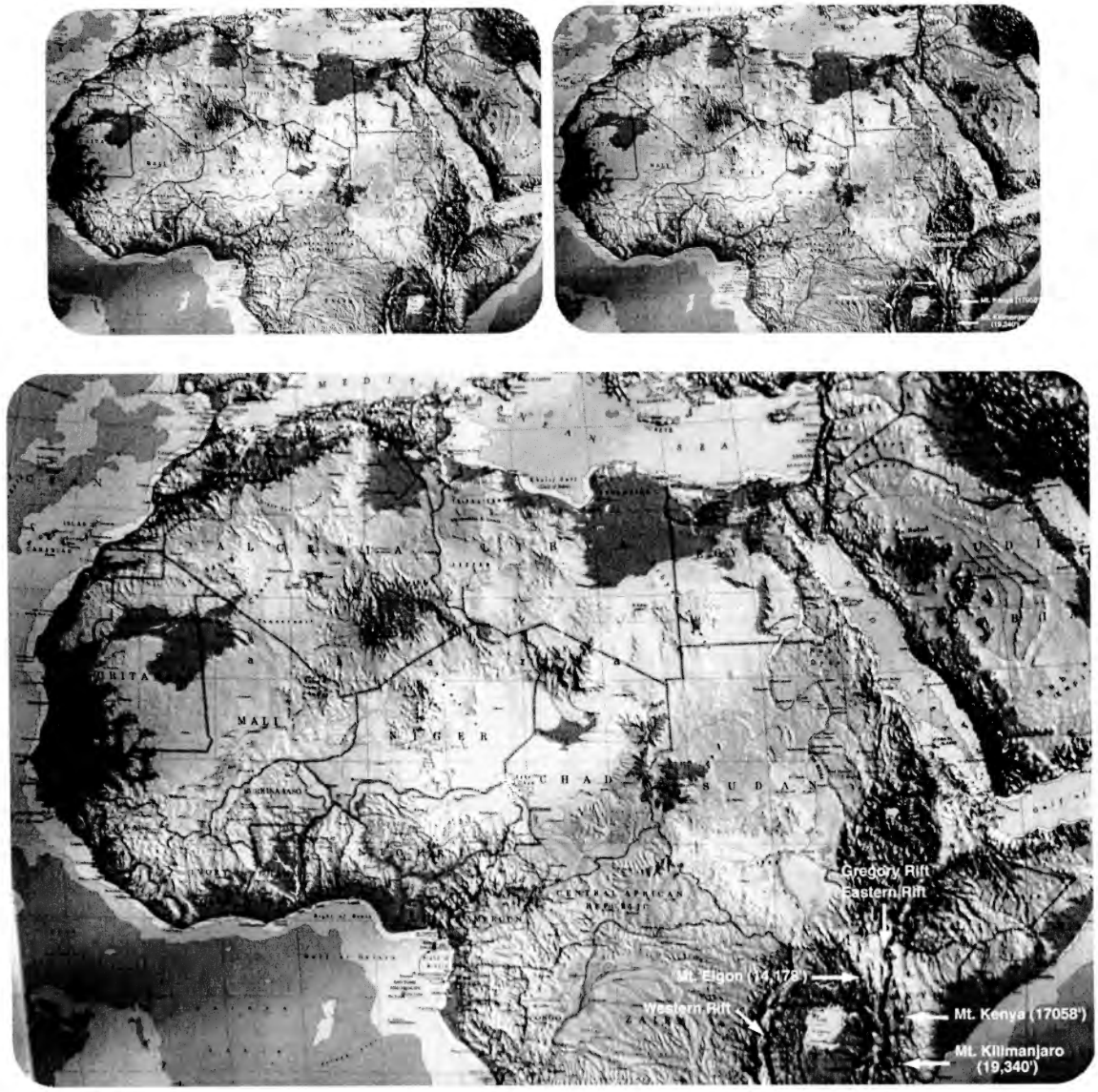
*Information from personal communication: Martha M. Godchaux and Bill Bonnichsen during the 1996 Tobacco Root Geological Society Field trip.



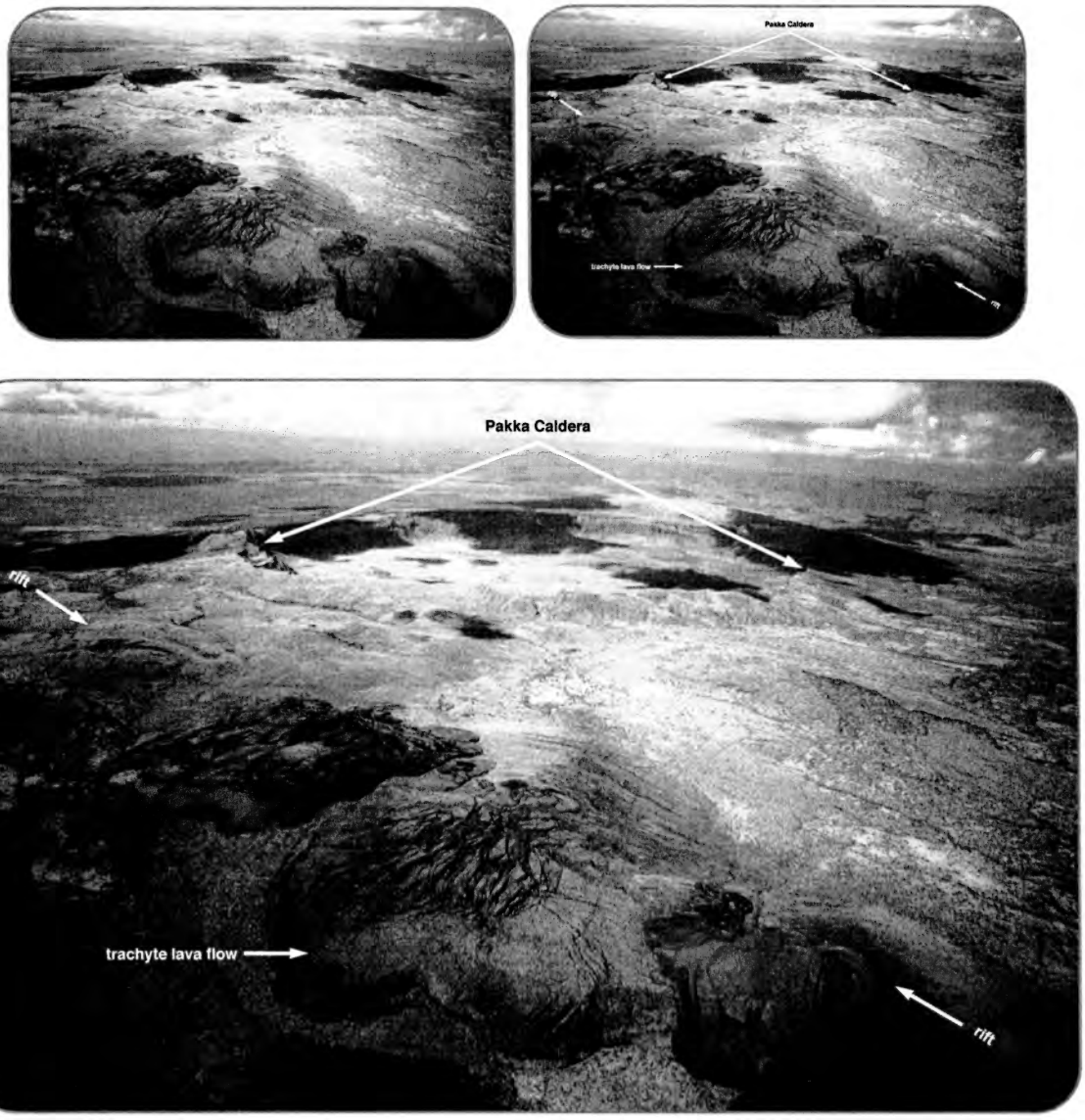
You are looking at cross sections of tongue-like,nearly isoclinal and recumbent folds in the Tuff of McMullan Creek at Grey's Boat Landing on Salmon Falls Creek Reservoir in southwestern Idaho. The arrows point to the closed ellipse cross section along the edges of the tongue-like fold. These folds presumably formed as the hot ash flows agglutinated into lava-like flows while they were being emplaced. On the next page the folds are shown on an exposure that is nearly perpendicular to this one.



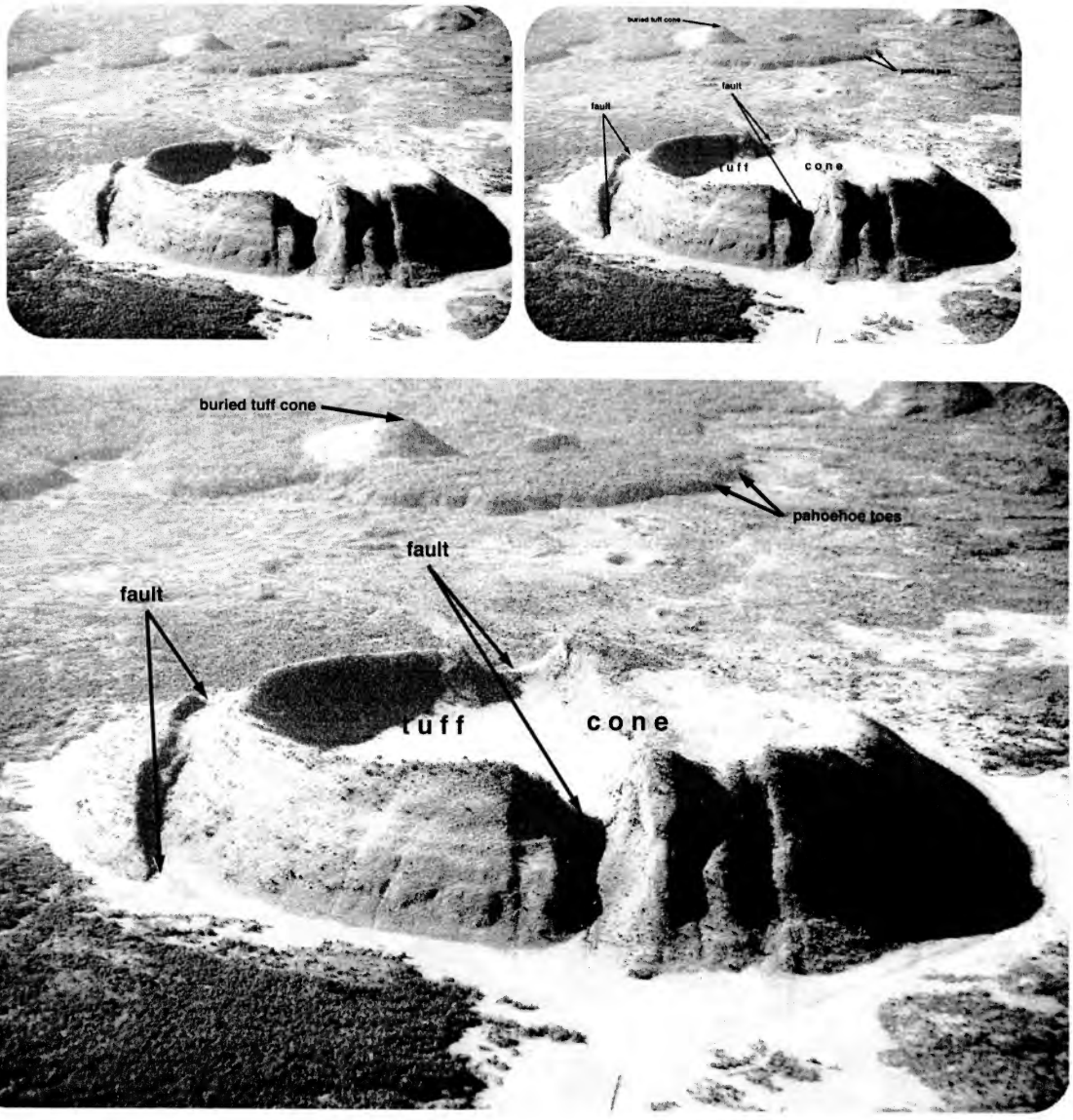
You are looking toward the northwest at an exposure nearly parallel to the long axes of tongue-like, isoclinal, recumbent folds in the Tuff of McMullan Creek at Grey's Boat Landing on Salmon Falls Creek Reservoir in southwestern Idaho. The folds cascaded over one another in response to flow directed toward the southwest, presumably as the hot ash flow agglutinated to form a lava-like flow.



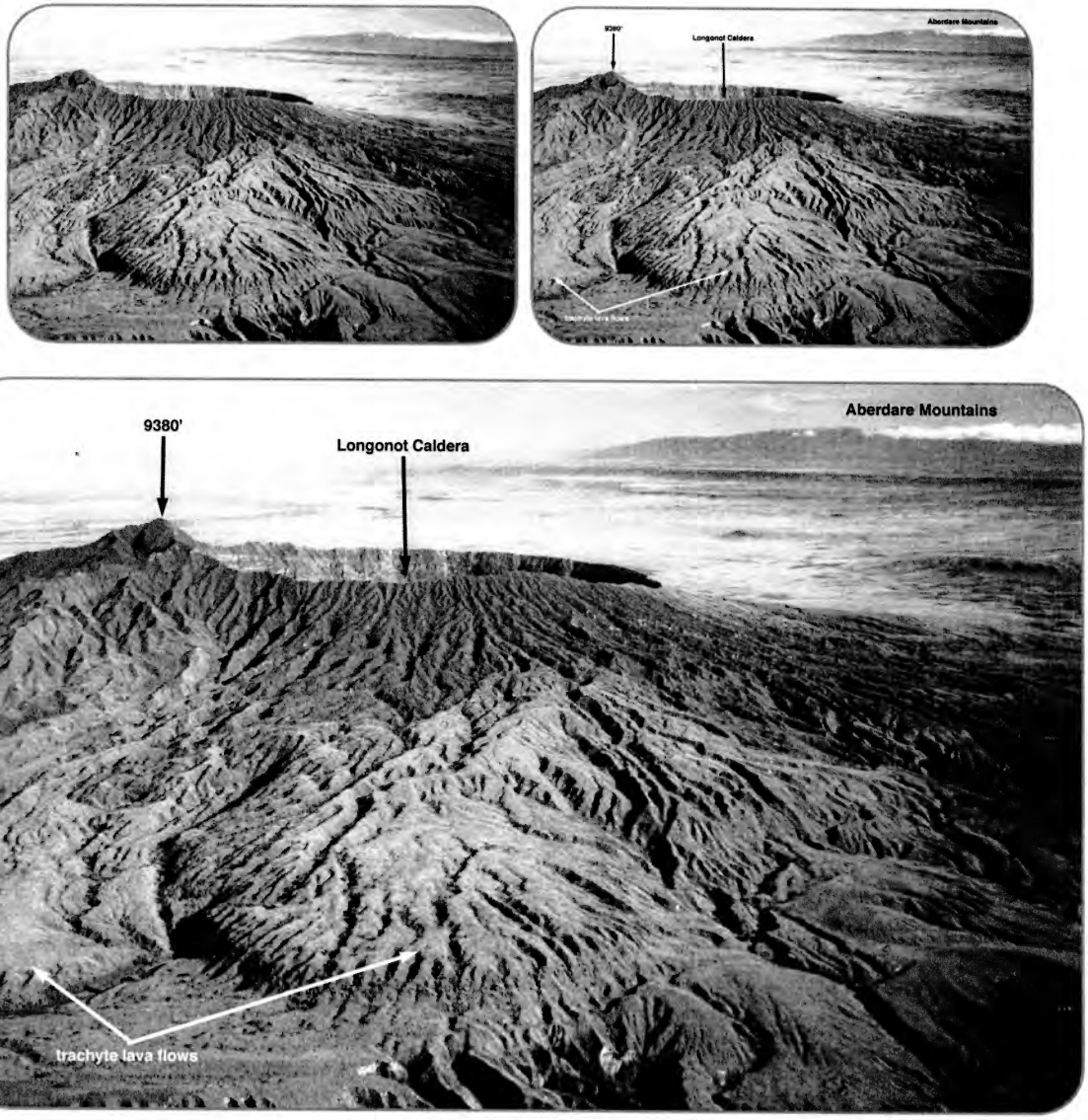

This relief index map shows the eastern rift valley, the Gregory Rift, in Kenya and the large volcanoes (Mts. Elgon, Kenya, and Kilimanjaro) that flank the rift. The rift started forming about 20,000,000 years ago, but it filled with volcanics about as fast as it sank. Its present form as a valley bordered by steep scarps dates from the last 2,000,000 years. Many fault scarps crease its floor, providing conduits for volcanoes that have developed, in general, successively toward the south as the rift extended southward. Active volcanoes within the rift are confined to Tanzania near the southern end of the Eastern Rift. The volcanoes in Kenya are dormant. The next five pictures show some of the basaltic and trachytic volcanics within the rift, beginning near its mid point in Kenya and progressing southward.



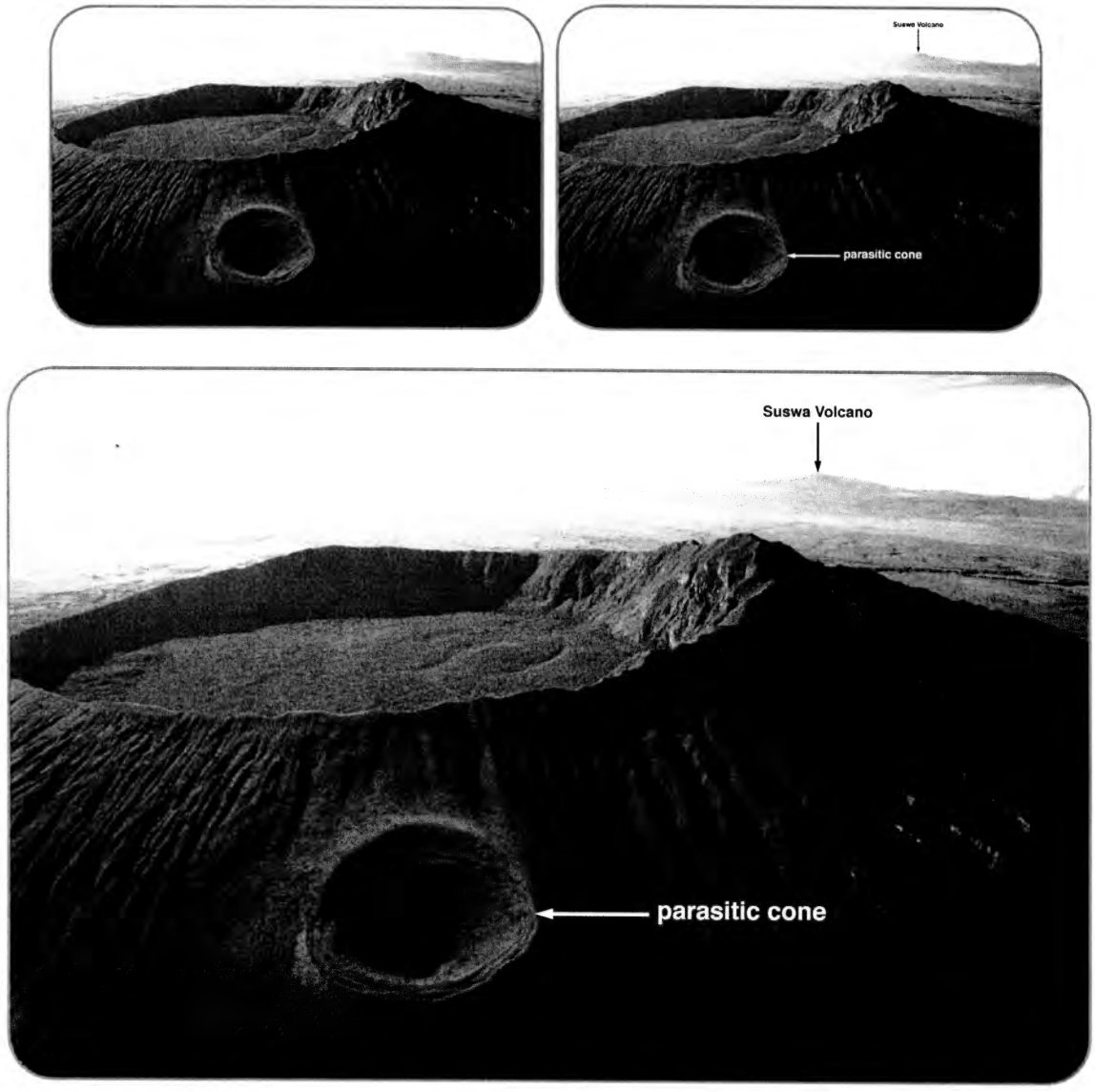

You are looking toward the southwest at Pakka Caldera in the north-central part of the Gregory Rift Valley in Kenya. Pakka is a trachytic volcano whose top collapsed into the partially emptied magma chamber after explosive eruptions. In the foreground viscous trachytes formed flows with steep sides while more fluid basalts produced flatter flows where they oozed out along a rift. Picture taken January 2, 1988.




You are looking southward at a tuff cone cut by normal faults in the Gregory Rift Valley north of Lake Naivasha. In the background basalt flows have partially buried a tuff cone. Picture taken January 2, 1988.




You are looking toward the northeast at Longonot Volcano in the Gregory Rift of Kenya. The Aberdare Mountains border the eastern side of the rift. Picture taken January 2, 1988.




You are looking southward across the top of Longonot Volcano in the Gregory Rift of Kenya. Because the lava flows that fill the caldera and form its flat floor made an impenetrable plug, the last eruption, about 500 years ago, burst out the side of the volcano to form the parasitic cone. Picture taken January 2, 1988.

You are looking westward at Suswa Volcano in the Gregory Rift of Kenya. Suswa has a younger, inner caldera within a larger outer caldera. A ring graben separates the elevated floor of the inner caldera from the outer caldera. It is possible that a ring dike of magma withdrew to cause the collapse that formed the ring graben. It also seems possible that the "Lost Land" could be the floor of the inner caldera pushed up by resurgent magma. Arching of the caldera floor sufficient to produce enough tension to form the ring graben should also produce radial faults, but none are visible. Phonolite, the extrusive equivalent of nepheline syenite, forms much of Suswa. Included among the lava flows are sheets of welded tuff, from 10 inches to eight feet in thickness, that contain unusual glassy globules. The globules are banded like the glassy matrix of the welded tuff and must be fragments of it. How they formed is unknown. The welded tuff was a hot one, the composition of ilmenite-magnetite pairs giving an eruptive temperature of between 1030 and 1048 degrees centigrade.* Picture taken January 2, 1988.

*Hay, R.L., Hildreth, W., and Lamb, R.N., 1979, "Globule Ignimbrite of Mount Suswa, Kenya", GSA Special Paper 180, p167-175.

Augustine Volcano in Kamishak Bay, Alaska
June 16, 1986