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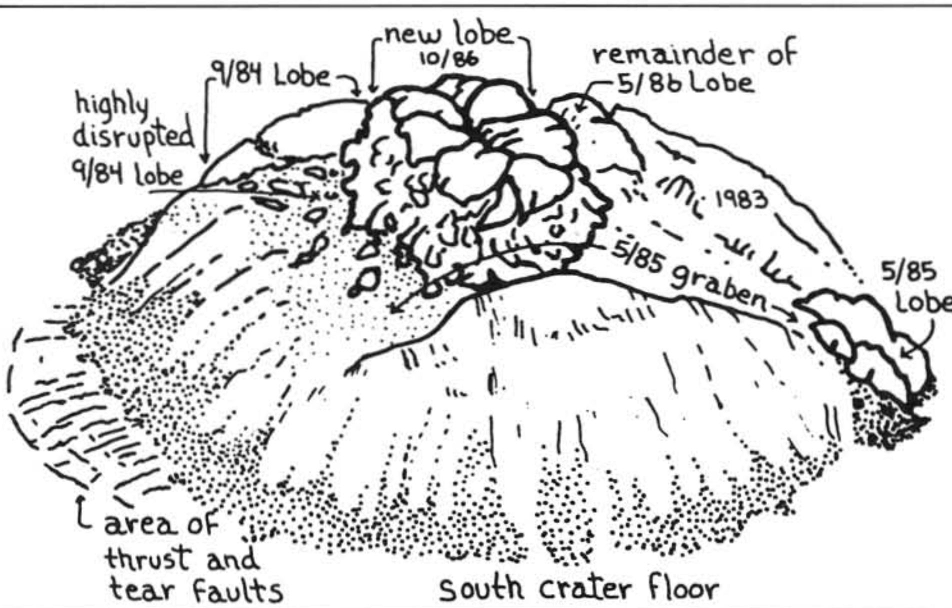

THIS MONTH:

Geologic guide: Monitor Ridge climbing route at Mount St. Helens

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The style to be followed is generally that of U.S. Geological Survey publications (see the USGS manual *Suggestions to Authors,* 6th ed., 1978). The bibliography should be limited to "References Cited." Authors are responsible for the accuracy of the bibligraphic references. Names of reviewers should be included in the "Acknowledgments."

Authors will receive 20 complimentary copies of the issue containing their contribution. Manuscripts, news, notices, and meeting announcements should be sent to Beverly F. Vogt, Publications Manager, at the Portland office of DOGAMI.

COVER ILLUSTRATION

Photo shows view north from south crater rim of Mount St. Helens toward lava dome. Spirit Lake and area devastated by the lateral blast of May 18, 1980, lie north of dome. Mount Rainier is in background. Sketch of lava dome is from photos taken October 28, 1986, showing dome details in roughly the same view as photo (sketch by Bobbie Meyers, USGS, David A. Johnston Cascades Volcano Observatory). Article on climbing Mount St. Helens begins on next page.

OIL AND GAS NEWS

ARCO releases results of 1987 Mist drilling program

ARCO Oil and Gas Company drilled eight exploratory wells and one redrill at Mist Gas Field during 1987. Of these, seven were completed as gas wells, with one plugged and abandoned and one abandoned redrill. This is the greatest number of successful gas completions in a single year since the field was discovered in 1979. Combined flow rates for the seven new gas wells is 10-12 million cubic feet (MMcf) of gas per day, with combined proven reserves of 11-14 billion cubic feet (Bcf) of gas, which will extend the life of the field for many years. Production at Mist should increase from the current 10 MMcf to about 15 MMcf of gas per day once these wells are all connected to gas pipelines.

During 1987, ARCO's rental and royalty payments plus taxes added up to over $1 million in direct payments to Columbia County. The total economic impact, statewide and primarily in Columbia County, of ARCO's involvement in the Mist Gas Field in 1987 was over $6 million.

Permit for Columbia Basin wildcat issued

ARCO has been issued an oil and gas drilling permit for a significant wildcat well in eastern Oregon's Columbia Basin. The Hanna No. 1, located about 6 mi northeast of Heppner in sec. 23, T. 2 S., R. 27 E., Morrow County, has a proposed total depth of 9,000 ft. This well will penetrate the surface volcanic rocks that dominate the area to test the underlying strata containing a sedimentary section that is interpreted to have favorable conditions for hydrocarbon generation and entrapment.

Recent permits

Permit no.	Operator, Well API number	Location	Status, proposed total depth (ft)
397	ARCO Hanna -1 36-049-00002	NE ¼ sec. 23 T. 2 S., R. 27 E. Morrow County	Location; 9,000.
398	ARCO CFI 34-1-55 36-009-00232	SE ¼ sec. 1 T. 5. N., R. 5. W. Columbia County	Application; 1,625.
399	ARCO Johnston 44-19-65 36-009-00233	SE ¼ sec. 19 T. 6. N., R. 5. W. Columbia County	Application; 3,125.
400	ARCO Col. Co. 12-19-65 36-009-00234	NW , sec. 19 T. 6. N., R. 5. W. Columbia County	Application; 3,300.

□

SW Oregon miners, BLM form committee

Representatives from the U.S. Bureau of Land Management's (BLM) Medford district Glendale and Grants Pass resource areas and from the miners in the Grave and Galice Creek areas of southwestern Oregon have organized to provide a forum for issues, opportunities, and new mining-industry information. The committee consists of nine mining representatives and three BLM staff members.

Recently, BLM committee members, accompanied by miners, toured two placer operations and a patented lode claim during their meeting. Mining operations and activities incidental to mining were discussed at each location.

—Matt Craddock, BLM News

Geologic guide to the Monitor Ridge climbing route, Mount St. Helens, Washington*

by William M. Phillips, Washington Division of Geology and Earth Resources, Olympia, Washington 98504

INTRODUCTION

For nearly seven years following the cataclysmic eruption of May 18, 1980, the summit of Mount St. Helens lay in the forbidden "red zone," with access prohibited to all but a handful of scientific researchers. Mountain climbers could only look wistfully at the volcano, once among the most popular ascents in the Pacific Northwest.

Now, due to waning eruptive activity and improved eruption prediction by scientists—as well as active lobbying by various mountaineering groups—Mount St. Helens is once again open to climbers. Beginning May 15, 1987, the U.S. Forest Service (USFS), which is responsible for the Mount St. Helens National Volcanic Monument, instituted a climbing permit system.

Making the trudge to the top has proved spectacularly popular. According to Forest Service estimates, as many as 12,000 people may have reached the 8,363-ft summit by Labor Day, 1987. In good weather, climbers crowd the mountaintop, eating lunch and exchanging "where were you when the mountain blew" stories.

Before 1980, when the mountain boasted a 9,677-ft summit, Mount St. Helens was recognized as an excellent climb for the novice mountaineer. Lacking truly steep slopes and offering splendid scenery, "America's Fujiyama" was ascended by thousands. Today, climbing Mount St. Helens offers unparalleled opportunities for close views of some of the most spectacular volcanic terrain in North America. Remarkable panoramas of crater walls, the lava dome, and Spirit Lake reward the climber at the summit. And while dangers do exist (outlined in "Climbing hazards" below), the ascent is, weather permitting, well within the abilities of most physically fit people. The trip to the top and back takes most people six or seven hours.

This article presents a guide to geologic features along the popular Monitor Ridge climbing route (Figures 1, 2, and 3). On Monitor Ridge are a number of well-displayed volcanic landforms, including lava levees and pressure ridges. Descriptions of points of geologic interest visible from the summit are also presented.

MAKING THE CLIMB

Climbing permits

Climbing permits are required for all travel above 4,800 ft (about timberline) on the mountain. The permits are valid for 36 hours: from noon of the day prior to the date of the permit to midnight on the day of the permit.

From November 1 to May 15, climbers simply register before and after climbing at Yale Park, located 2 mi west of Cougar, on Washington State Route 503 (Figure 1). No other written permit is required.

From May 16 to October 31, a quota system is in effect, limiting permits to 100 per day. Advance reservations for 70 permits per day are available by mail or in person at Monument headquarters at Amboy. "Day of the climb" reservations for 30 permits are available on a first-come, first-served basis at Jack's Restaurant and Store, located on Highway 503, 23 mi east of Woodland, Wash., and 3.5 mi west of Yale Park, open daily from 5:00 a.m. to 9:00 p.m. These permits may be obtained the afternoon before or the morning of the day of the climb. Climbers must still sign in and out at the Yale Park register regardless of the type of permit.

Climbing Mount St. Helens is extremely popular. During the summer of 1987, advance permits for weekend climbs were booked up by early June. The Forest Service reported processing up to 600 calls per day concerning mountain climbing. Day-of-climb permits often required waiting in line all night at Yale Park (where camping is not permitted). To avoid disappointment, plan ahead and get your permit early!

A party size of 12 is the maximum per climbing permit. However, smaller groups are recommended in order to minimize damage to biological or geological features of the Monument and to preserve the backcountry spirit of the mountain.

Hikers interested in exploring the crater must sign in and out at the Yale Park register but do not otherwise need a written permit. The crater is open to hikers only when the crater floor is snow-covered. Camping is not permitted in the crater. The Spirit Lake basin, north of Mount St. Helens and below 4,800 ft, is closed to public access.

The Mount St. Helens National Volcanic Monument can be contacted at **Mount St. Helens National Volcanic Monument, Route 1, Box 369, Amboy, WA 98601.** The special telephone number for information on all climbing concerns, such as permit availability, mountain conditions, or gear requirements, is (206) 247-5800.

Climbing access

Climbing routes within the Mount St. Helens National Volcanic Monument are reached from the south side of the volcano, near Cougar, Washington (Figure 1). Access roads are plowed during winter to the junction of Roads 83 and 830, and to the junction of Roads 83 and 8312. Plowing of roads and parking areas is conducted by the Washington State Snow Park program. All parked vehicles must display a valid "Snow Park" emblem, which costs $10 and is available from some stores in the Monument area but not in the Monument.

Climbing hazards

While Mount St. Helens is not considered a difficult mountain, scaling it exposes climbers to some hazardous conditions. Chief among these are rapidly changing weather conditions. The wise climber should prepare for travel on slick, steep, snow- or ice-covered slopes in fog, heavy rain, or snow. Take a compass, the U.S. Geological Survey 1:24,000-scale topographic map of Mount St. Helens, and an ice axe. Crampons are a good idea for early-season climbs when the route will be snow covered. Beware of hypothermia, and take plenty of extra warm clothes.

Water is scarce and of uncertain quality on the climbing routes. Particularly during the summer, climbers should prepare for the desert (sunglasses, sunblock lotion, hats) and bring extra fluids.

The south slopes of Mount St. Helens lack distinctive landmarks. Climbers hurrying down from the summit may follow ravines or lava levees that end considerable distances from trailheads. Plan the descent of the mountain carefully, preferably following the same route as on the way up.

NOAA weather radios are an excellent and inexpensive investment for all mountaineers; continuous 24-hour broadcasts from stations in Olympia and Portland can be received at Mount St. Helens. In case of volcanic emergency, projected ash trajectories will be broadcast.

**Because we know that it will be of interest to our readers, this article was reprinted from* Washington Geologic Newsletter, *v. 15, no. 4 (October 1987), p. 3-13, with kind permission of the Washington Division of Geology and Earth Resources.*

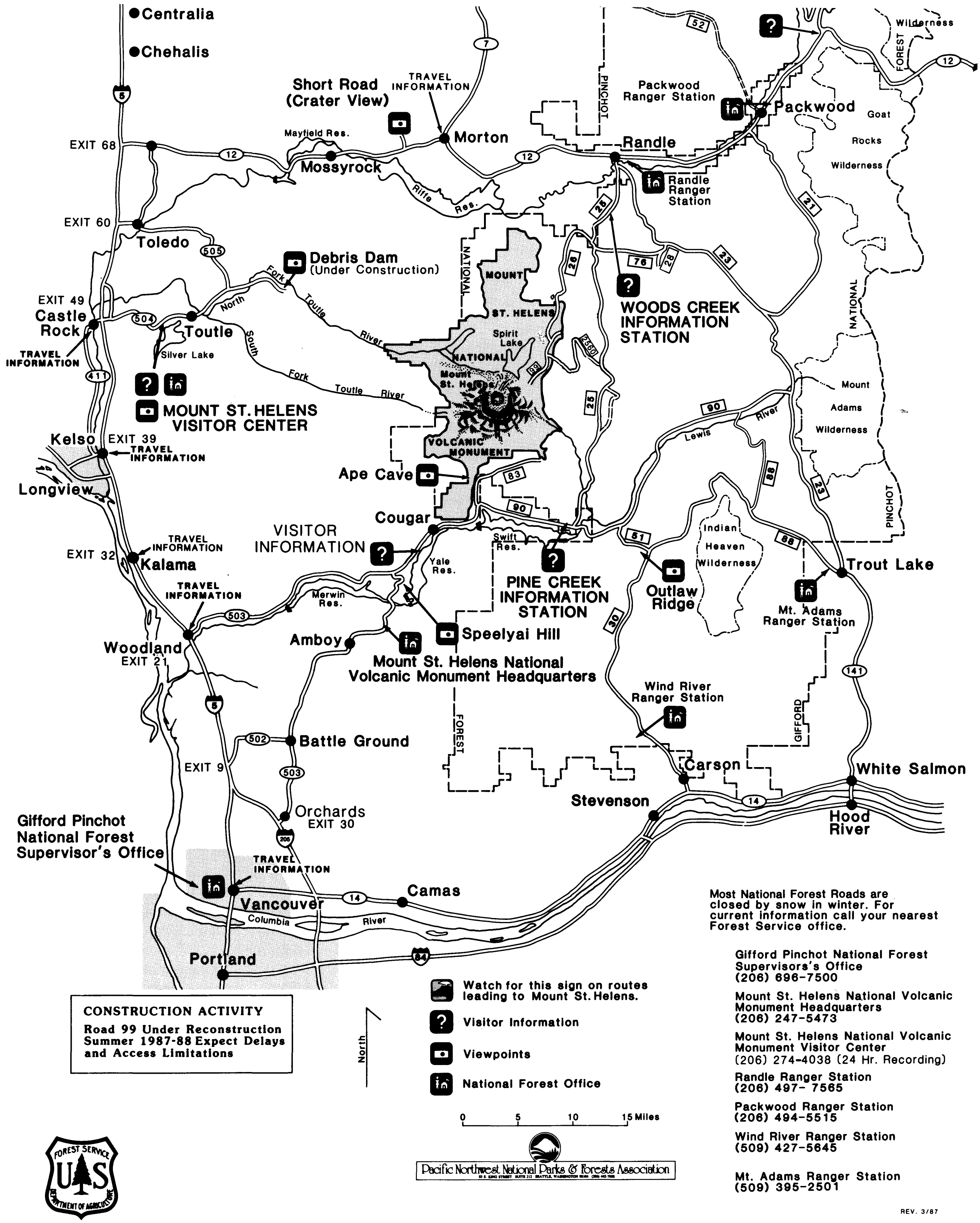

Figure 1. Location map of the Mount St. Helens area. Road conditions are subject to change. Check with Mount St. Helens National Monument Headquarters for current conditions (map by permission of the Pacific Northwest National Parks and Forests Association).

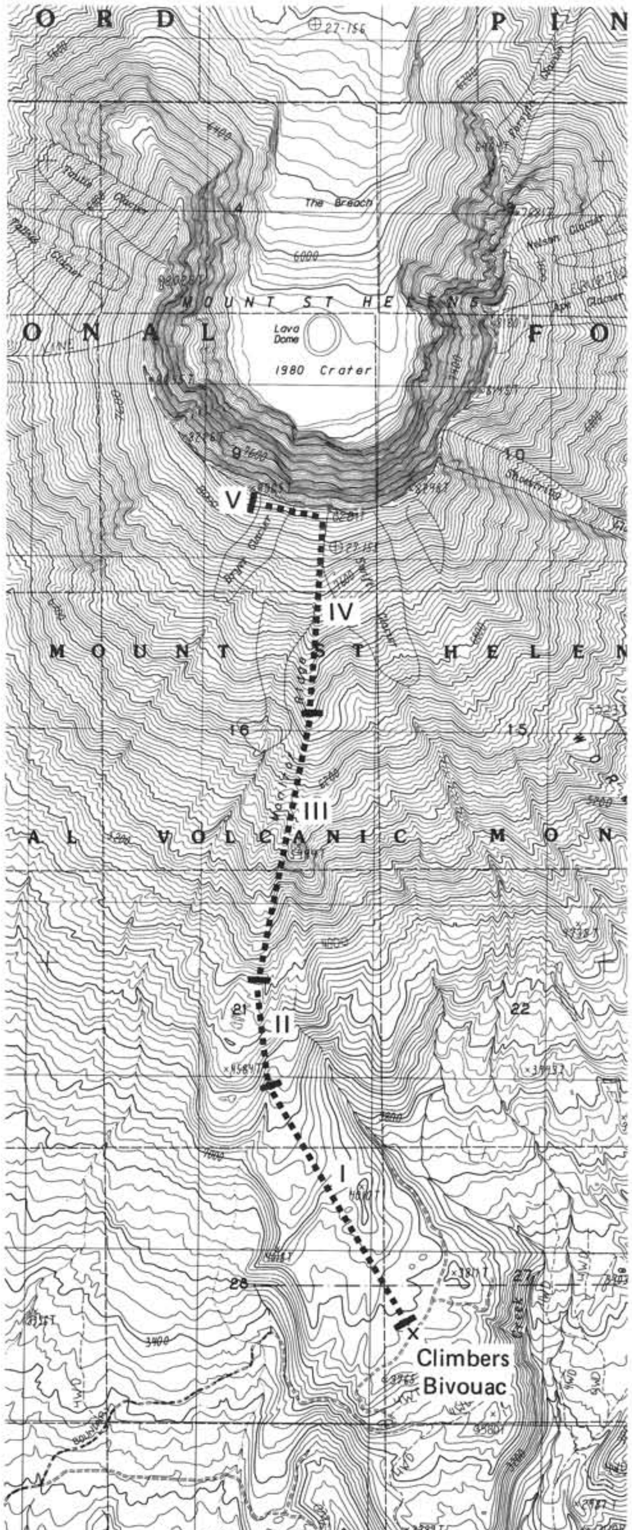

Figure 2. Topographic map showing the Monitor Ridge climbing route (from U.S. Geological Survey Mount St. Helens 1:24,000-scale quadrangle map).

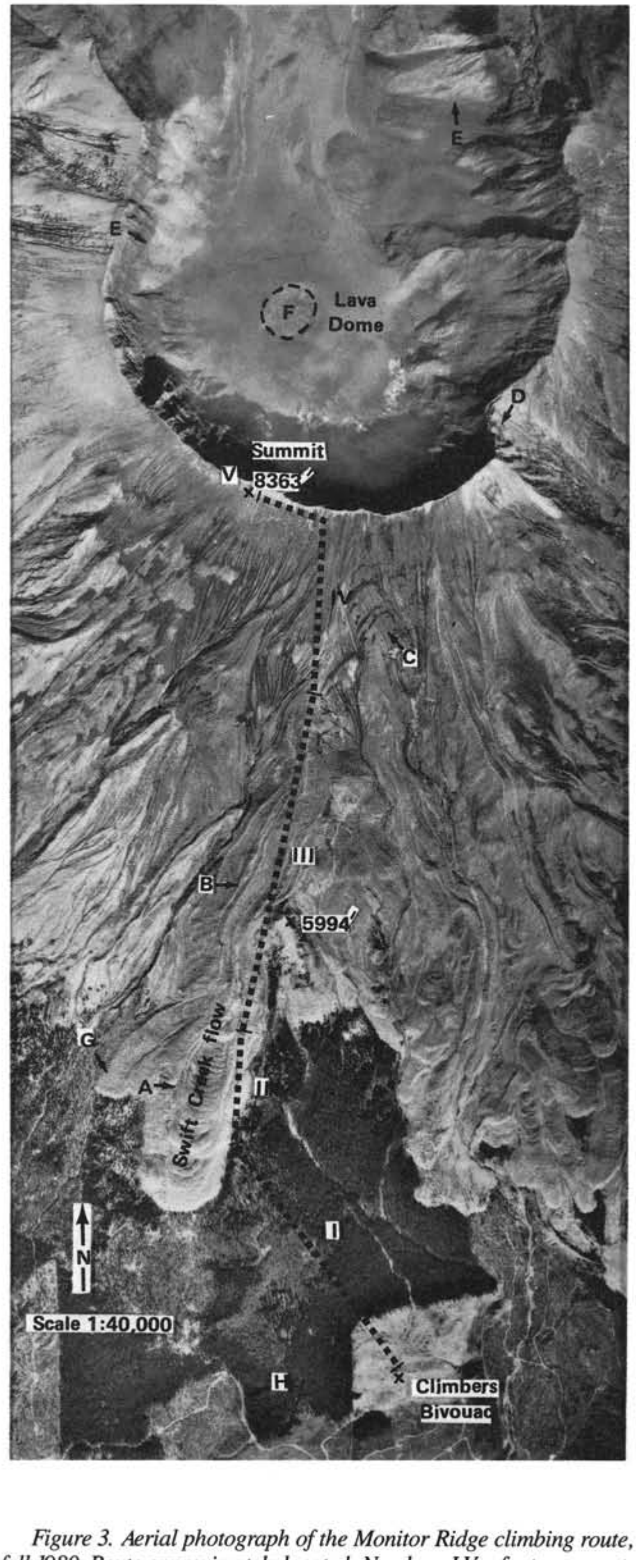

Figure 3. Aerial photograph of the Monitor Ridge climbing route, fall 1980. Route approximately located. Numbers I-V refer to segments of the route discussed in the text. A, lateral pressure ridges; B, lava levee; C, crevasses on Swift Glacier; D, top of Shoestring Glacier; E, contact between white ancestral Mount St. Helens dacite and younger pyroclastic and lava deposits; F, 1980 lava dome; G, margin of old andesite flow; H, point where Road 830 traverses margin of old andesite flow.

In addition, climbers must recall that Mount St. Helens is still an *active* volcano. Sudden explosive activity in the lava dome is possible and may not be predicted by scientists monitoring the volcano. In the case of eruption, the Forest Service recommends immediate descent from the mountain, avoiding gullies and ravines. If caught in an ash-fall, breathe through a moist cloth and protect your eyes.

During the winter, large snow cornices build out over the crater rim. The cornices may fail at any time, and climbers should avoid travel over them, even when roped-up.

The Mount St. Helens climbing experience changes radically as snow melts from the stratovolcano's cone. Early-season ascents (approximately pre-July or post-October) are largely over snow fields. While often plagued by bad weather, the early-season climb delights well-prepared mountaineers with exciting glissades, telemark skiing, and most importantly, ash-free conditions.

As the snow melts, an extremely dusty environment may be encountered. Climbers should protect cameras and other sensitive gear from swirling ash. At the summit, sudden intense "dust-devils" may rip hats from the heads of the unwary and coat everyone and everything with fine ash.

GEOLOGICAL HISTORY OF THE MOUNT ST. HELENS AREA

Tertiary rocks older than Mount St. Helens

The oldest rocks in the Mount St. Helens area record volcanic eruptions occurring during the Tertiary about 35 to 20 million years ago (Figure 4). The Tertiary volcanoes were unrelated to present-day Mount St. Helens and produced interbedded pyroclastic materials (tuffs) and lava flows. Also common are sandstone, conglomerate, and siltstone derived from erosion of the volcanic units during the Tertiary.

Most of the Tertiary volcanic rocks are andesites. Basalt and dacite are also present in lesser quantities. These three igneous rock types are typical products of volcanic arcs like the Cascade Range. Basalts are, generally, dark-colored rocks that are relatively fluid when molten. As a result, basalts often flow great distances and form low, broad shield volcanoes. Lighter colored dacites are products of more viscous magma and typically pile up to form steep lava domes or plugs subject to catastrophic collapse. Dacitic magma also tends to trap volcanic gases and therefore often produces explosive eruptions of pumice and ash. The physical and chemical properties of andesites are intermediate between those of basalt and dacite.

Numerous igneous intrusions also cut the Tertiary section. In many instances, the intrusions mark the location of the subsurface conduits through which magma rose to the Earth's surface during an eruption.

Millions of years intervened between the last eruption of the Tertiary volcanoes and volcanism related to Mount St. Helens. During that time, folding accompanying uplift of the Cascade Mountains tilted the Tertiary rocks eastward (Figure 4). The uplift, together with alpine glaciation during the last ice age 10,000 to 20,000 years ago, caused deep erosion and incision of the Tertiary rocks by rivers, streams, and ice.

Ancestral Mount St. Helens

Beginning about 40,000 years ago and continuing to about 2,500 years ago, explosive dacitic eruptions built (and destroyed) lava domes and possibly one or more stratovolcano cones on top of the eroded Tertiary rocks. The eruptions widely distributed volcanic ash over Washington. Volcanic activity was episodic with hundreds or even thousands of years between eruptions.

Characteristic products of ancestral Mount St. Helens include hornblende-rich dacite lava domes, pyroclastic flows, and lahar deposits. The Butte Camp area (Figure 1) contains an excellent example of the dacite lava domes. Additional light-colored lava domes of ancestral Mount St. Helens can be seen from the summit in the base of crater walls (Figure 5).

Pyroclastic flows—hot, gas-rich torrents of pumice, dense dacite fragments, and crystals—streamed into and filled valleys surrounding ancestral Mount St. Helens. Explosive eruptions may have caused large portions of volcanic cones or domes to collapse, causing debris avalanches. The debris avalanches and pyroclastic flows dammed drainages and created lakes like Spirit Lake. Rapid breaching of the dams, along with melting of snow or ice during eruptions, generated lahars (sediment-rich floods). Some of the lahars produced by ancestral Mount St. Helens were huge, inundating floodplains as far away as the Columbia River, more than 40 mi away.

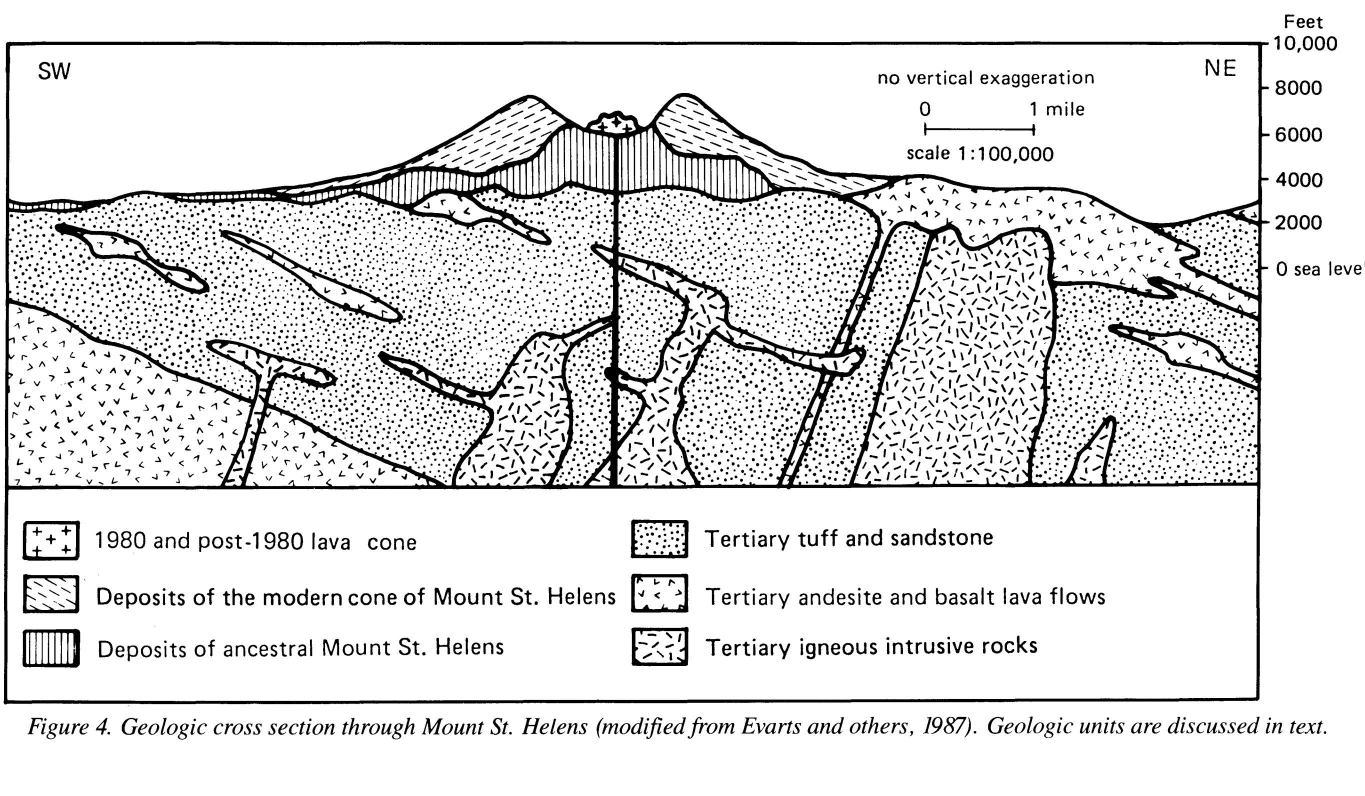

Figure 4. Geologic cross section through Mount St. Helens (modified from Evarts and others, 1987). Geologic units are discussed in text.

Figure 5. View northwest from crater rim showing west crater wall. Photograph taken August 7, 1987. Light-colored deposits at base of crater walls are dacite domes from ancestral Mount St. Helens. To the east, right, is the lava dome. Note ash clouds derived from small avalanches into the crater.

Building of the pre-1980 cone of Mount St. Helens

About 2,500 years ago, the present-day cone of Mount St. Helens began to grow. Because most of the cone was built after the extensive alpine glaciation of the last ice age (about 10,000 years ago), pre-1980 Mount St. Helens had a beautifully symmetrical profile. Neighboring older stratovolcanoes such as Mount Rainier or Mount Adams are heavily scarred from glacial erosion and therefore present steeper, more demanding climbing routes.

During this growth stage in the development of the volcanic center, both dacitic pyroclastic deposits and andesitic and basaltic lava flows were erupted. Once again, eruptions were episodic. Often, long dormant intervals occurred between periods of intense activity. Before 1980, the last eruptions of Mount St. Helens were between 1831 and 1857.

The Monitor Ridge route on Mount St. Helens passes almost entirely over products of the cone-building stage. Dacitic volcanism during this stage produced lava domes, pyroclastic flows, and lahars. Near the end of the climb, the route crosses such pyroclastic flows (see route segment IV below). Other dacite structures, such as the old summit dome and Goat Rocks dome on the north side of the mountain were casualties of May 18, 1980.

The lava flows of Mount St. Helens were extruded mostly from vents high on the south slopes of the volcano. The Monitor Ridge route takes advantage of the relatively smooth central flow channel of one of the andesite units, the Swift Creek flow (Figure 3).

Andesites, not as viscous as most dacites, are still relatively "sticky" compared to many basalts. At Mount St. Helens, the andesitic lavas form short, narrow, stubby flows with surfaces composed of blocky lava rubble. Beneath the rubble, the flow interior is massive with platy to roughly columnar jointing.

Lava levees—low walls of rubble which confined flowing lava into central flow channels—are common and well-exposed along the steep portions of Mount St. Helens andesite flows (see point B of Figure 3, Figure 6). On gentler slopes at the terminus of these flows, flowing lava piled up and formed lateral pressure ridges (point A of Figure 3).

One of the more fluid Mount St. Helens lava flows, the Cave basalt, flowed more than 9 mi from the volcano. The Cave basalt is a pahoehoe flow with smooth, ropy surface textures and numerous lava tubes. Lava tubes form from the roofing over of lava channels by flowing lava. During an eruption, molten basalt is carried from the vent area to the advancing toe of the flow via lava tubes. The longest and best known Mount St. Helens lava tube is Ape Cave, which is more than 11,000 ft long. Ape Cave is open for public exploration and is conveniently located near climbing routes (Figure 1). Climbers may want to bring a lantern for a quick caving experience after the ascent of the mountain.

The 1980 eruptions of Mount St. Helens

After more than 100 years of dormancy, Mount St. Helens resumed activity on March 20, 1980, with a swarm of earthquakes. Between late March and May 18, a dacitic magma body (cryptodome) was emplaced into the cone of the volcano, causing a significant "bulge" or swelling.

On May 18, a 5.1-magnitude earthquake triggered enormous debris avalanches on the north side of the mountain, and the "bulge" slid northward toward Spirit Lake. The debris avalanches exposed the magma body and abruptly reduced the confining pressure in the surrounding geothermal system. The cryptodome exploded, producing a destructive, northward-directed lateral blast that wiped out timber, wildlife, and the human beings caught within its 156-mi^2 extent.

Following the lateral blast, vertically directed ash clouds soared into the stratosphere, blanketing much of eastern Washington with volcanic ash. Ultimately, some of the ash traveled around the world. Pyroclastic flows also spread out through the breach in the cone and formed a thick pumice blanket on the north side of the mountain.

Lahars occurred on most of the rivers ringing Mount St. Helens. The largest, along the North Fork of the Toutle River, may have been produced by liquefaction of a portion of the debris avalanche by earthquakes. Lahars on the south side consisted of hot pyroclastic-flow material mixed with melted glacial ice, snow, and perhaps magmatic water.

Mount St. Helens was drastically altered by these volcanic events. The summit was lowered by more than 1,300 ft, and a new 1,900-ft-deep crater exposing the core of the cone was formed. Cherished climbing routes on the north side of the mountain, such as the Lizard and Dog's Head routes, were destroyed or severely altered. About 70 percent of the volume of glacial ice on the mountain vanished. All of two glaciers and most of a third were blasted apart or were carried in landslides into the North Fork Toutle River (see route segment IV for more discussion of the remaining glaciers on Mount St. Helens).

So far, the current eruptive cycle has produced only typical ex-

Figure 6. View south from an elevation of 6,000 ft on Monitor Ridge. Note longitudinal lava levees (low ridges) and blocky surface of Swift Creek lava flow. Peak in background is marked "5994T" on topographic map, Figure 2, and is the top of the ancestral Mount St. Helens andesite flow traversed in segment I of the climb. Toe of the Swift Creek flow is visible to the right of the peak.

plosive dacitic products such as pyroclastic flows, a debris avalanche, lahars, and lava domes. Table 1 illustrates eruptive activity since 1980. Lava dome growth (and occasionally, explosive destruction) has been the primary action on the volcano. Perhaps the dome will ultimately fill the crater and rebuild Mount St. Helens to its former (or a greater) height. Perhaps dome growth will stagnate, leaving the gaping crater. Other alternatives include explosive destruction of the dome—possibly producing further pyroclastic flows and lahars—or extrusion of andesite or basalt lava flows. Geologists are presently unable to determine which is more likely.

Table 1. *Eruptive activity at Mount St. Helens since May 18, 1980 (data from a summary of eruptive activity prepared by the U.S. Geological Survey, October 1986).*

Date	Explosive activity	Pyroclastic flows	Dome-building	Mud-flows
5/25/80	x			
6/12/80	x	x	x	
7/22/80	x	x		
8/07/80	x	x	x	
10/16/80	x	x	x	
12/27/80			x	
2/05/81			x	
4/10/81			x	
6/18/81			x	
9/06/81			x	
10/30/81			x	
3/19/82	minor		x	x
5/14/82			x	
8/18/82			x	
2/03/83	minor		x	x
2/83-2/84	continuous dome-building activity			
3/29/84			x	
6/17/84			x	
9/10/84			x	
5/30/85			x	
5/08/86			x	
10/21/86			x	

GUIDE TO THE GEOLOGY OF MONITOR RIDGE

In the following guide, segments of the climb to the summit of Mount St. Helens along the Monitor Ridge route are described. Figures 2 and 3 show the route and the segments, numbered I through V. After the name of each segment, the estimated distance and elevation gain are given. This guide is designed to be used during the ascent of the mountain.

Start: Climbers Bivouac

Climbers Bivouac, near the end of USFS Road 830 (Figure 1), is the starting point for most Mount St. Helens climbers. The bivouac area lacks water and developed camping facilities. An emergency telephone there provides a quick link to authorities in case of an accident.

Segment I. Climbers Bivouac to base of Monitor Ridge via the Ptarmigan Trail (0.9 mi, 260 ft)

The Ptarmigan Trail (Trail 216A) rises from Climbers Bivouac to the base of Monitor Ridge. The trail is on the hummocky surface of an ancient (ancestral Mount St. Helens) andesitic lava flow. Although not easily seen by the hiker, the steep margins and lobate form of the lava flow are easily recognized on a topographic map (Figure 2). The abrupt flow margin is also traversed and then ascended by Road 830 just before reaching Climbers Bivouac (point H on Figure 3).

The unnamed flow consists of several thick flow lobes of andesite. As the forest cover and deep soils suggest, the flow is older than the nearby sparsely vegetated lavas. While the precise age of the andesite is not known, it predates the 2,500-year-old or younger eruptive products of the cone of Mount St. Helens. This lava flow is exceptional in that it records a rare eruption of andesitic lava at a time when explosive dacitic volcanism dominated ancestral Mount St. Helens.

Segment II. Base of Monitor Ridge to beginning of the lava levees (0.7 mi, 800 ft)

At about 4,120 ft of elevation, the forest cover thins, and climbers enter meadows at the base of Monitor Ridge. Here, the well-maintained, gently ascending Ptarmigan Trail ends, and the first steep portion of the climb begins with a scramble up the toe of the Swift Creek lava flow. The route over the lava is marked with widely spaced red flagging. Beware of falling rocks set in motion by other climbers scurrying up steep slopes.

The ridge is composed of the andesitic Swift Creek lava flow. Formally named in 1983 for the adjacent drainage on the east, the Swift Creek flow was previously known as "The Mitten" because of its distinctive shape when viewed from the air (Figure 3) or on a topographic map (Figure 2). The climbing route traverses the 350- to 450-year-old andesite lava flow most of the way up the volcano.

The Swift Creek flow is typical of the many andesite lava flows on the south flank of Mount St. Helens. Erupted from vents high on the volcano, these relatively viscous lavas formed stubby, narrow block flows. The surface of a block lava flow is composed of angular chunks or rubble of andesite (Figure 6).

At its terminus, the Swift Creek flow is more than 200 ft thick. Lava streaming down the steep flanks of the cone ponded upon reaching gentler slopes. Distinctive crescent-shaped lateral pressure ridges (point A on Figure 3) mark the toe of the flow. Flow lobes (point G on Figure 3) record successive eruptions of lava—probably separated by no more than hours or days—and are responsible for the mitten shape of the flow. As many as six lobes are present in the Swift Creek flow.

While easily visible on an aerial photo, features such as pressure ridges and flow lobes may be a challenge to recognize while trudging up the mountain over loose blocks of andesite. The ridges and lobes are best viewed from above, either during a rest stop near the beginning of the next climbing segment or on the descent of the mountain (Figure 6).

Segment III. The lava levees of Monitor Ridge to upper pumice slopes (1.0 mi, 2,100 ft)

An abrupt steepening of slope at about 4,800 ft of elevation signals the end of the multi-lobed toe of the Swift Creek flow. From here to the probable vent area at 6,900 ft, the Swift Creek lavas are contained within a series of levees. The lava levees consist of longitudinal rubble walls, 6 ft or more in height, stretching for hundreds of yards along the flow (point B on Figure 3). As many as four distinct levees are visible along portions of the route (Figure 6). Travel in the central flow channel, particularly when it is snow-covered, is pleasant compared to that on the rugged toe of the flow.

The levees are the consequence of the flow of a viscous material—lava—down a slope. In order to move, the lava must form a layer deep enough to overcome resistance to motion. At the center of the flow, this is easily accomplished. Along flow margins, however, the lava thins, and a "dead zone" develops where stationary material accumulates to form walls. Construction of the walls or levees is accentuated by cooling of the lava. Blocks of congealed magma pile up at a much faster rate on the margins than in the central flow channel. The levees force the lava to occupy a narrower area than at the flow toe. Succeeding eruptions produce levees of different heights depending on the volume of lava extruded. Excellent examples of levees are common in the andesite flows of the south flank of Mount St. Helens (Figure 3).

At 5,280 ft of elevation, climbers may notice a U.S. Geological Survey (USGS) geodetic survey station. The station consists of a metal tower on which is mounted a prism used to reflect the laser light used in high-precision surveying. Many such sites on the volcano are resurveyed regularly, and the distances and angles between the stations are precisely calculated. The surveys are designed to detect swelling or collapse of the cone—a probable sign of magma injection into the stratovolcano. In March-May 1980, growth of such a "bulge" on the north side of Mount St. Helens led to the catastrophic eruption of May 18.

Do not disturb survey stations or any other monitoring equipment found on the volcano. The safety of climbers on Mount St. Helens depends on the ability of geologists to accurately detect signs of impending eruption.

At 5,800 ft, the highest point of the ancestral Mount St. Helens lava flow traversed in segment I is visible immediately east of the route (Figure 6). The prominent ridge has an elevation of 5,994 ft (Figures 2 and 3).

Between 6,600 and 6,800 ft of elevation, the lava levees narrow and coalesce. The vent for the Swift Creek lava flow probably lies within this area.

Segment IV. Upper pumice slopes to the summit (0.8 mi, 1,465 ft)

From about 6,800 ft of elevation to the crater rim at about 8,250 ft, the route traverses pyroclastic flow deposits (Figure 7). These flows were produced by the old summit dome of Mount St. Helens (destroyed on May 18, 1980) about 500 to 350 years ago. The pyroclastic flows are slightly older than the Swift Creek lava flow. Because of a thick cover of 1980 ash, features of the flows are not easily viewed by climbers at the time of writing.

At about 6,900 ft of elevation a hydrogen gas monitoring station was in place until not long ago. Monitor Ridge was named in 1983 after the hydrogen sensor. Operated for several years as an experiment in eruption prediction, the station has been removed by the USGS.

Hydrogen gas is present in most magmas. Because hydrogen gas is light and mobile in earth materials, anomalous quantities of the gas could signal the presence of hidden magma. Experiments at Mount St. Helens indicate that hydrogen monitoring is not as sensitive an indicator of impending eruptions as seismic activity, crater or dome deformation, and sulfur-dioxide gas concentration.

Figure 7. Climbers arriving at the crater rim. View east with Mount Adams in the background. The climbers are traversing pyroclastic flows covered with a thick layer of 1980-vintage ash.

Figure 8. View west of a climber descending the 8,365-ft summit of Mount St. Helens. Clouds of ash from debris avalanches obscure the crater walls.

The Monitor Ridge route passes close to three small glaciers between an elevation of 6,200 ft and the summit. From west to east, the glaciers are Dryer Glacier, a small unnamed glacier, and Swift Glacier (Figure 2). Between about 7,000 and 7,400 ft of elevation, the surface of the unnamed glacier forms a convenient snow-covered surface for glissades during descent of the mountain.

Dryer Glacier commemorates Thomas J. Dryer, an early Portland journalist and businessman. In 1853, Dryer led the first recorded party to climb the mountain and probably passed close to the glacier.

Normally, these glaciers are heavily covered with 1980-vintage ash and other volcanic debris and are usually difficult to detect. However, by late summer, crevasses in snow and ice may break through the overlying ash cover, revealing the presence of glacial ice (point C on Figure 3).

Prior to 1980, Mount St. Helens supported 11 named glaciers: Wishbone, Loowit, Leschi, Forsyth, Nelson, Ape, Shoestring, Swift, Dryer, Toutle, and Talus. The May 18 eruption removed about 70 percent of the ice volume on the volcano. Loowit and Leschi glaciers and nearly all of Wishbone were blasted away together with most of the snow-accumulation areas for Forsyth, Nelson, Ape, and Shoestring. Hot pyroclastic flows melted or eroded snow and firn from the surfaces of Shoestring, Nelson, and Ape Glaciers, producing the Muddy River, Pine Creek, and Smith Creek lahars.

The beheaded glaciers of Mount St. Helens may ultimately stagnate, retreat, and finally vanish. However, the insulating effect of the thick ash cover prolongs the existence of the glaciers. And at least one glacier, Shoestring, appears to have revived. Following a year (1981) in which the lower part of Shoestring was nearly stagnant and moving at less than 20 percent of its pre-eruption velocities, glacial ice has rapidly regenerated, and a wave of increased motion has begun moving down the glacier.

At about 8,250 ft of elevation, the crater rim is reached (Figure 8). Be sure to maintain a safe distance from the edge of the rim and avoid travel over cornices. Continue 0.2 mi west along the crater rim to the 8,365-ft summit of Mount St. Helens. The route passes over the top of Dryer Glacier (Figure 2). Glacial ice and small crevasses may be visible.

Segment V. Summit (End of guide)

In clear weather, three other nearby Cascade stratovolcanoes are visible from the summit. They are, to the south, Mount Hood, to the east, Mount Adams, and to the north, Mount Rainier.

On the crater rim to the east-northeast, note the cleft in the cone carved by Shoestring Glacier when the mountain was 1,300 ft taller (Figure 9).

Figure 9. View east of the crater rim. Mount Adams is in the background. To the left of the center of the photograph is a prominent valley that was carved by Shoestring Glacier when Mount St. Helens was 1,300 ft higher.

Avalanches. The crater rim is extremely unstable. Avalanches of rock and tephra cascade every few minutes into the crater, feeding large piles of talus that partially surround the lava dome. The avalanche activity decreases during the winter because ice tends to cement loose rubble on the crater walls. However, snow avalanches are common in the winter. Eruptive activity, such as dome growth, increases avalanching, as small earthquakes shake loose unstable portions of the crater walls. The extremely high avalanche potential makes any crater wall climbing excessively hazardous.

Following the May 18, 1980, eruption, large ice avalanches from beheaded glaciers frequently fell into the crater. As remaining glacial ice moved away from the rim due to glacier flow and melting, the ice falls diminished. Currently, the avalanches are dominantly composed of pyroclastic material and lavas from the crater rim and walls.

Lava dome. The lava dome dominates the view from the summit (see cover illustration). Composed of gray dacite with a rough, fractured surface and a dense, columnar-jointed interior, the 920-ft-high dome grows both by surface extrusion of new flow lobes and by swelling as new magma is injected internally. The dome is presently much larger than shown on available topographic maps or aerial photos (Figures 2 and 3).

USGS geologists and a host of instruments closely monitor the dome. The dome is "wired" to detect small earthquakes, changes in dome and crater dimensions, temperature, gas concentrations, and magnetic field changes. Climbers may see helicopters landing on or near the dome, and with binoculars, some of the instrument stations can be viewed.

The geologists primarily use crater and dome deformation rates, earthquake activity, and sulfur-dioxide gas concentrations to predict dome-building eruptions. Their success in anticipating major eruptions led to reopening Mount St. Helens to climbing.

The last dome eruption occurred on the evening of Octob er 21, 1986. An irregular lobe, still visible on the top of the dome (see cover illustration), was produced along with injection of magma into the interior of the dome. The new lobe is more than 800 ft long and 330 ft wide, and it added about 85 ft to the height of the dome. The eruption was heralded by swarms of small earthquakes. Emissions of sulfur dioxide increased from about 50 tons per day on October 20 to about 675 tons per day on October 21. Sulfur-dioxide concentrations quickly diminished after the eruption.

Perhaps of greater interest to climbers and hikers are the events of October 5, 1986. An earthquake on that night dislodged a large piece of the lava dome. The resulting dome explosion produced a pyroclastic flow that destroyed an instrument station north of the dome, partially melted telemetry cables, and sent an ash cloud to lightly dust Cougar, Woodland, and north Vancouver, Washington. This episode—which was not predicted by monitoring scientists—illustrates that small explosions, pyroclastic flows, or ash clouds may occur at any time within the crater.

Given current growth rates, the dome could rebuild Mount St. Helens to the former 9,677-ft elevation in about 200 years. However, many scenarios are possible, including stagnation of the dome and other eruptive features, explosion of the dome with attendant pyroclastic flows and lahars, or extrusion of andesite or basalt lava flows.

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Oil and gas well records listed in new DOGAMI release

The Oregon Department of Geology and Mineral Industries (DOGAMI) has published an updated list of all available records and samples it keeps on oil and gas exploration wells drilled in Oregon.

The new report is entitled *Available Well Records and Samples of Onshore and Offshore Oil and Gas Exploration Wells in Oregon* and has been released as DOGAMI's Oil and Gas Investigation 16. It was compiled by DOGAMI Petroleum Geologist Dan E. Wermiel.

The 25-page publication lists the well records in two tables, one listing onshore, the other offshore well records. The tables provide such information as well and company names; date, depth, and location of the wells; types of available logs and samples; and literature references. The onshore records are grouped by county. An introduction includes descriptions of the legislative history and current nature of DOGAMI's recordkeeping. Additional tables provide a key to abbreviations, a list of commercial firms offering well histories and logs, and a list of selected DOGAMI publications on oil and gas. Finally, the report contains a glossary explaining the different types of logs and a list of the references to which the well-record tables are keyed.

The publication is the first printed product derived from newly established computerized data bases of DOGAMI's oil and gas files. This will, in the future, enable the Department to provide the public with continually updated information, both of the well records and of the literature references to them.

The new release, DOGAMI Oil and Gas Investigation 16, is available now at the Oregon Department of Geology and Mineral Industries, 910 State Office Building, 1400 SW Fifth Avenue, Portland, OR 97201. The purchase price is $5. Orders under $50 require prepayment. □

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