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View west of a climber descending the 8,365-foot summit of Mount St. Helens. The mountain was recently re-opened to mountaineers by the U.S. Forest Service. Clouds of ash from debris avalanches obscure the crater walls. (See article, p. 3.)

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WASHINGTON GEOLOGIC NEWSLETTER

The Washington Geologic Newsletter is published quarterly by the Division of Geology and Earth Resources, Department of Natural Resources. The newsletter is free upon request. The Division also publishes bulletins, information circulars, reports of investigations, and geologic maps. A list of these publications will be sent upon request.

Mount St. Helens Scientific Advisory Board

by

Ray Lasmanis

The Mount St. Helens Scientific Advisory Board was established in 1983 to comply with Section 7 of Public Law 97-243, an act passed by the 97th Congress, designating the Mount St. Helens National Volcanic Monument. The provisions of Section 7 are:

Sec. 7. (a) There is hereby established the Mount St. Helens Scientific Advisory Board (hereinafter referred to as the "Board"). The Secretary [of Agriculture] *shall consult with and* ***seek the advice and recommendations of the Board*** *with respect to--*

(1) the measures needed to protect and manage the natural and scientific values of the Monument; and

(2) the administration of the Monument with respect to policies, programs, and activities which are ***specifically intended to retain the natural ecologic and geologic processes and integrity*** *of the Monument.*

The Board may make recommendations to the Secretary in regard to new research opportunities which may exist within the Monument designed to gain scientific information for future interpretation and enjoyment by visitors to the Monument. No recommendation by the Board shall be binding upon the Secretary.

(b) The Board shall be composed of nine members, who shall be individuals with recognized professional standing in appropriate scientific disciplines, as follows:

(1) three members appointed by the Secretary (one of whom shall be a professional employee of the Forest Service);

(2) two members appointed by the Secretary of the Interior (one of whom shall be a professional employee of the United States Geological Survey);

(3) two members appointed by the Governor of the State of Washington from among professional employees of the State of Washington; and

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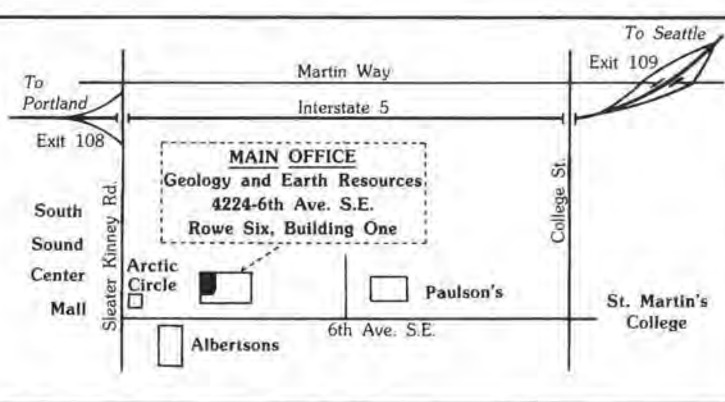

Geologic Guide to the Monitor Ridge Climbing Route, Mount St. Helens, Washington

by

William M. Phillips

INTRODUCTION

For nearly 7 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-foot 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-foot 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 6 or 7 hours.

This article presents a guide to geologic features along the popular Monitor Ridge climbing route (Figs. 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 feet (about timberline) on the mountain. The permits are valid for 36 hours: from 12 hours 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 miles west of Cougar, on Washington State Route 503 (Fig. 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 Yale Park. 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 feet, 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
(206)247-5473

Climbing Access

Climbing routes within the Mount St. Helens National Volcanic Monument are reached from the south side of the

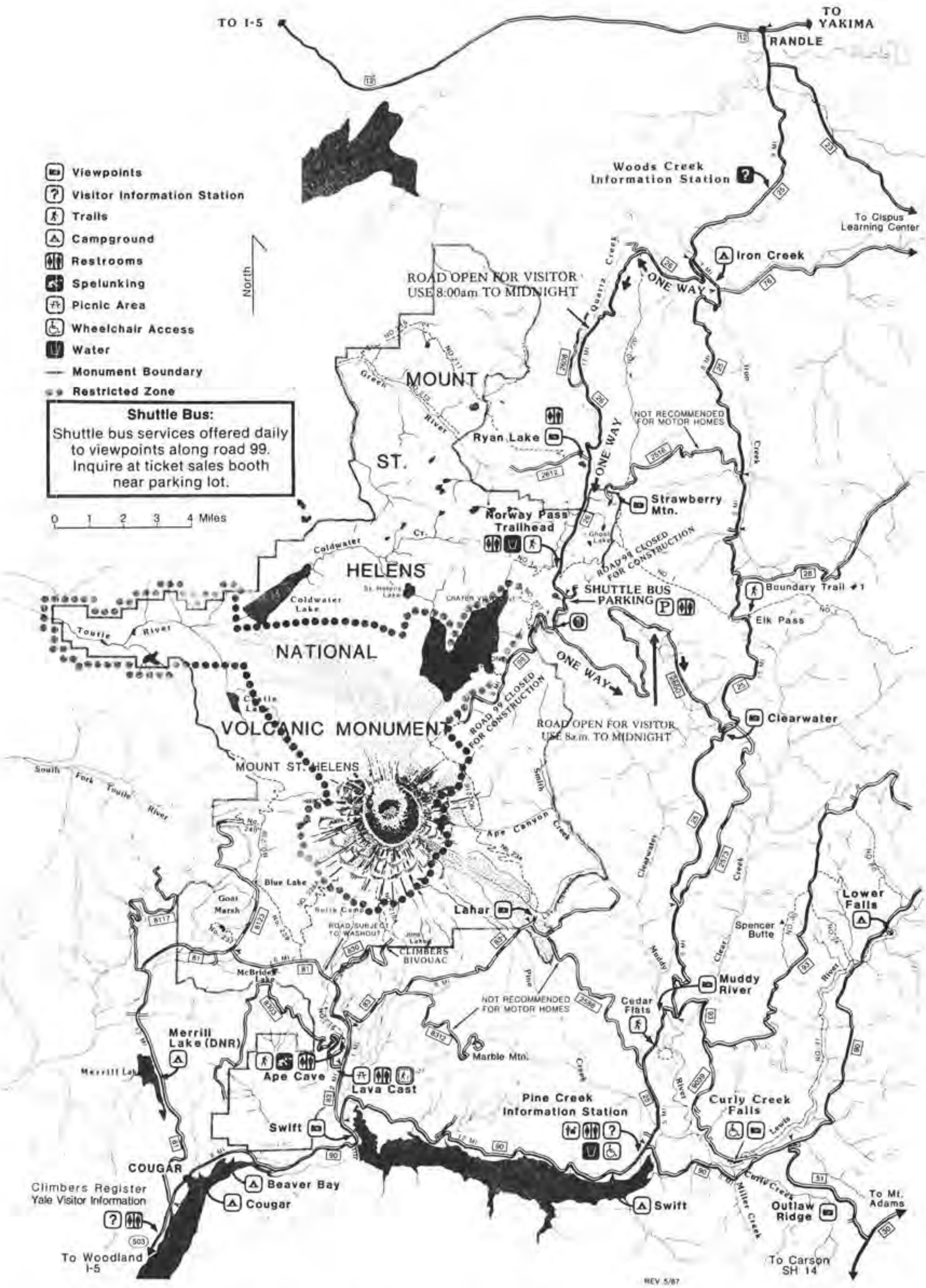

Figure 1:-Location map of the Mount St. Helens area. Road conditions are subject to change. Check with Mount St. Helens National Monument Headquarters for current conditions. (Map by permission of the Pacific Northwest National Parks and Forests Association.)

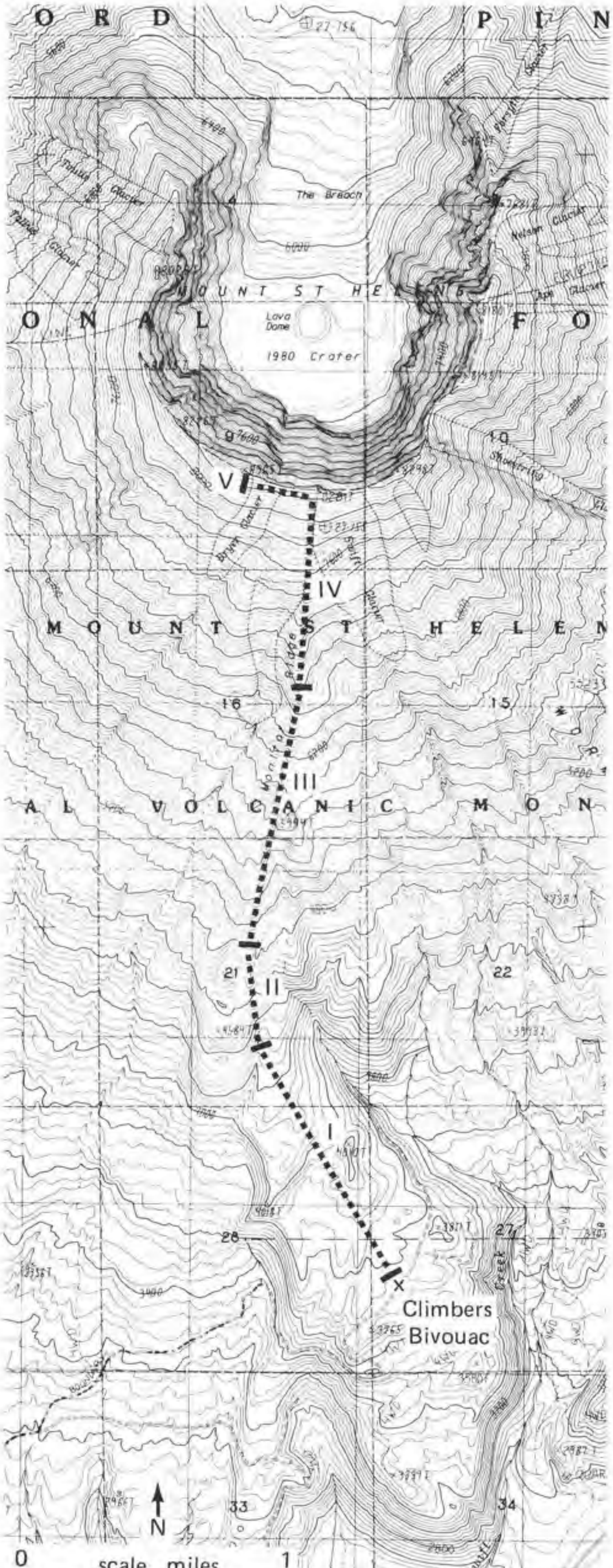

Figure 2:-Topographic map showing the Monitor Ridge climbing route. (From U.S. Geological Survey Mount St. Helens 1:24,000-scale quadrangle map.)

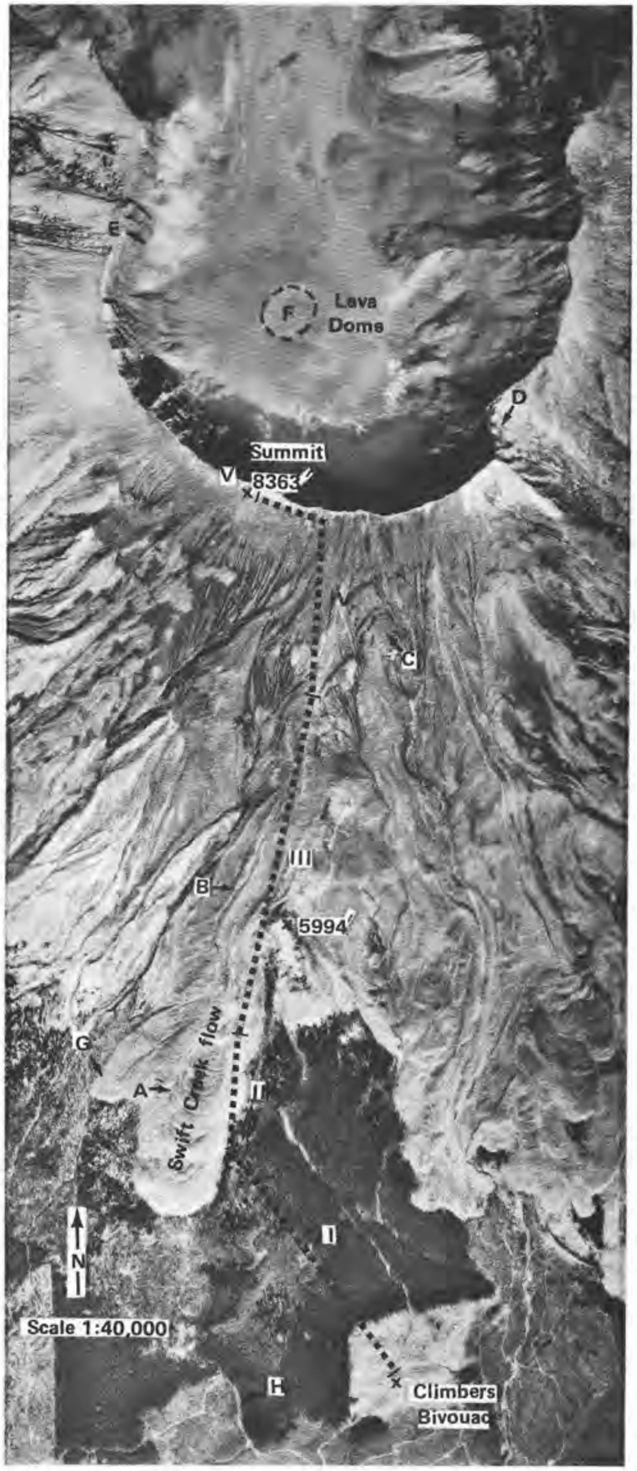

Figure 3:-Aerial photograph of the Monitor Ridge climbing route, fall 1980. Route approximately located. Numerals I-V refer to segments of the route discussed in the text. A, lateral pressure ridges; B, lava levee; C, crevasses on Swift Glacier; D, top of Shoestring Glacier; E, contact between white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

volcano, near Cougar, Washington (Fig. 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.

Forest Service officials expect a climbing route via June Lake (Fig. 1) to be popular during the winter months.

Climbing Hazards

While not considered a difficult mountain, scaling Mount St. Helens 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.

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.

GEOLOGIC 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 Period about 35 to 20 million years ago (Fig. 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 (Fig. 4). The uplift, together with alpine glaciation during the last ice age 10,000 to 20,000 year 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 (Fig. 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 (Fig. 5).

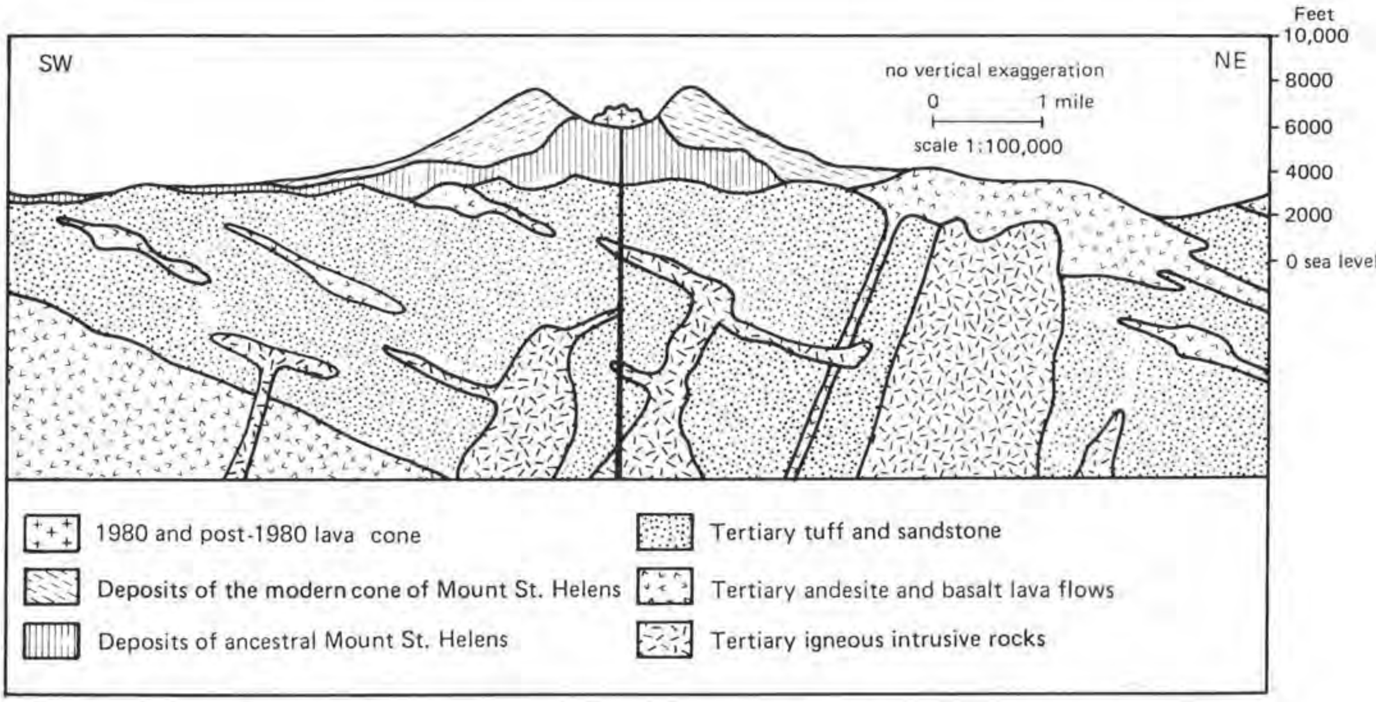

Figure 4:-Geologic cross section through Mount St. Helens (modified from Evarts and others, 1987). Geologic units are discussed in text.

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 miles away.

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 to 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 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 (Fig. 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 Fig. 3, Fig. 6.) On gentler slopes at the terminus of these flows, flowing lava piled-up and formed lateral pressure ridges (point A of Fig. 3).

Figure 6:-View south from an elevation of 6,000 feet 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, Fig. 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.

One of the more fluid Mount St. Helens lava flows, the Cave Basalt, flowed more than 9 miles from the volcano. The Cave Basalt is a pahoehoe flow with smooth, ropey 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 feet long. Ape Cave is open for public exploration and is conveniently located near climbing routes (Fig. 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-square-mile 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 feet, and a new 1,900-foot-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 explosive 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.

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.

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	

Start: Climbers Bivouac

Climbers Bivouac, near the end of USFS Road 830 (Fig. 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.

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 (Fig. 2). The abrupt flow margin is also traversed and then ascended by road 830 just before reaching Climbers Bivouac (point H on Fig. 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.

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

At about 4,120 feet 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 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 (Fig. 3) or on a topographic map (Fig. 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 (Fig. 6).

At its terminus, the Swift Creek flow is more than 200 feet thick. Lava streaming down the steep flanks of the cone ponded upon reaching gentler slopes. Distinctive crescent-shaped lateral pressure ridges (point A on Fig. 3) mark the toe of the flow. Flow lobes (point G on Fig. 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 (Fig. 6).

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 feet elevation signals the end of the multi-lobed toe of the Swift Creek flow. From here to the probable vent area at 6,900 feet, the Swift Creek lavas are contained within a series of levees. The lava levees consist of longitudinal rubble walls, 6 feet or more in height, stretching for hundreds of yards along the flow (Point B on Fig. 3). As many as four distinct levees are visible along portions of the route (Fig. 6). Travel in the central flow channel, particularly when 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 (Fig. 3).

At 5,280 feet 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. Each of many such sites on the volcano are resurveyed regularly, and the distances and angles between the stations 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 feet, the highest point of the ancestral Mount St. Helens lava flow traversed in segment I is visible immediately east of the route (Fig. 6). The prominent ridge has an elevation of 5,994 feet (Figs. 2 and 3).

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

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

From about 6,800 feet elevation to the crater rim at about 8,250 feet, the route traverses pyroclastic flow deposits (Fig. 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 feet elevation, remnants of a hydrogen gas monitoring station may be visible. Monitor Ridge was named in 1983 after the hydrogen sensor. Operated for several years as an experiment in eruption prediction, the station is slated to be removed soon by 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.

The Monitor Ridge route passes close to three small glaciers between an elevation of 6,200 feet and the summit.

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.

From west to east, the glaciers are Dryer Glacier, a small unnamed glacier, and Swift Glacier (Fig. 2). Between about 7,000 to 7,400 feet 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 Fig. 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 foot elevation, the crater rim is reached. 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-foot summit of Mount St. Helens. The route passes over the top of Dryer Glacier (Fig. 2). Glacial ice and small crevasses may be visible.

V. Summit (End of guide)

In clear weather, three other nearby Cascade stratovolcanoes are visible from the summit. They are, on 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 feet taller (Fig. 8).

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 (Fig. 9). Composed of gray dacite with a rough, fractured surface and a dense, columnar-jointed interior, the 920-foot-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 (Figs. 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

Figure 8:-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 feet higher.

Figure 9:-View north from the crater rim of the lava dome. Mount Rainier is in the background. Spirit Lake and the area devastated by the May 18, 1980, lateral blast lie north of the dome. See Figure 10 for dome details.

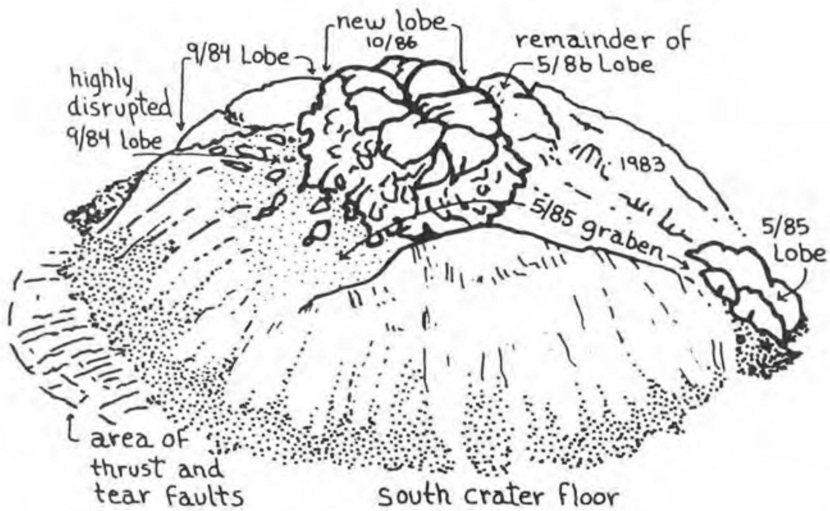

Figure 10:-Sketch of dome from photographs taken October 28, 1986. View roughly north from above the south crater rim. (Sketch by Bobbie Meyers, USGS, David A. Johnston Cascades Volcano Observatory.)

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 October 21, 1986. An irregular lobe, still visible on the top of the dome (Fig. 10), was produced along with injection of magma into the interior of the dome. The new lobe is more than 800 feet long and 330 feet wide, and it added about 85 feet 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-foot 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.

Acknowledgements

Thanks to Matt McClincy, Karl Swanson, Barry Chrestensen, and Steve Grayson for being such good climbing partners. Roland Emetaz of the U.S. Forest Service kindly assisted with helpful maps.

Recommended Reading

Beckey, Fred, 1987, Cascade alpine guide, climbing and high routes—1. Columbia River to Stevens Pass: [Seattle] The Mountaineers, 2nd edition, 337 p.

The classic guide to climbing in the Southern Washington Cascades. Newly edited to reflect the drastic changes at Mount St. Helens.

Brugman, M. M.; Post, Austin, 1981, Effects of volcanism on the glaciers of Mount St. Helens: U.S. Geological Survey Circular 850-D, 11 p.

A concise, nontechnical description of what happened to the glaciers of Mount St. Helens during and following the eruption of May 18, 1980.

Evarts, R. C.; Ashley, R. P.; Smith, J. G, 1987, Geology of the Mount St. Helens area—Record of discontinuous volcanic and plutonic activity in the Cascade Arc of southern Washington: Journal of Geophysical Research, v. 92, no. B10, p. 10,155-10,169.

A technical but up-to-date description of the Tertiary geology around Mount St. Helens.

Lipman, P. W.; Mullineaux, D. R., editors, 1981, The 1980 eruptions of Mount St. Helens: U.S. Geological Survey Professional Paper 1250, 844 p.; 1 plate.

The single best technical volume available on the geologic history of Mount St. Helens and details of the events of May 18, 1980. Describes geodetic survey stations and the hydrogen monitor on Monitor Ridge. Contains many excellent photographs.

Phillips, W. M., 1987, Geologic map of the Mount St. Helens quadrangle, Washington and Oregon: Washington Division of Geology and Earth Resources Open File Report 87-4, 59 p., 1 plate.

Detailed overview of the geology in and around Mount St. Helens.

Tilling, R. I., 1984, Eruptions of Mount St. Helens—Past, present, and future: U.S. Geological Survey, 46 p.

Nontechnical but complete account of the eruptive history of Mount St. Helens with emphasis on the events of May 18, 1980. Contains numerous high-quality photographs.

Mount St. Helens Scientific Advisory Board

(Continued from page 2)

(4) two members appointed by the Chairman of the National Science Foundation.

(c) Each member shall be appointed to serve for a term of three years, except that one of the initial appointees of each appointing official shall serve an initial term of four years, one of the initial appointees of each appointing official shall serve an initial term of two years, and one of the initial appointees of the Secretary shall serve an initial term of one year.

(d) The members of the Board shall be appointed within ninety days of the date of enactment of this Act. The members of the Board shall, at their first meeting, elect a chairman.

(e) The Secretary, or a designee, shall from time to time, but at least annually, meet and consult with the Board on matters relating to the protection of the Monument and potential and ongoing research programs within the Monument.

(f) Members of the Board shall serve without compensation as such, but the Secretary is authorized to pay, upon vouchers signed by the Chairman, the expenses reasonably incurred by the Board and its members in carrying out their responsibilities under this Act.

(g) Any vacancy in the Board shall be filled in the same manner in which the original appointment was made.

(h) The Board shall terminate ten years from the date of its first meeting.

[Bold italics are author's emphasis.]

The chairman of the Board is Dr. Jack K. Winjum, of the U.S. Environmental Protection Agency in Corvallis, Oregon. Other members of the board are:

Mr. Raymond Lasmanis - State Geologist,
Washington Department of Natural Resources
Olympia, WA

Mr. Bruce Crawford - Regional Manager
Washington Department of Wildlife
Vancouver, WA

Dr. Jerry F. Franklin, Professor
College of Forest Resources
University of Washington
Seattle, WA

Dr. Estella B. Leopold, Professor
Quaternary Research Center
University of Washington
Seattle, WA

Mr. Robert W. Williams - Forest Supervisor
Gifford Pinchot National Forest
Vancouver, WA

Mr. Frank H. Dunkle, Director
U.S. Fish and Wildlife Service
Washington, D.C.

Dr. Richard V. Fisher, Professor
Department of Geological Science
University of California, Santa Barbara
Santa Barbara, CA

Dr. Dallas L. Peck, Director
U.S. Geological Survey
Reston, VA

Because the Board is to advise the Secretary of Agriculture with respect to administration of the monument, it is pertinent to note what the act directs the monument manager to accomplish. Parts of Section 4 of the act are of particular interest:

Sec. 4. (a) The Secretary acting through the Forest Service shall administer the Monument as a separate unit within the boundary of the Gifford Pinchot National Forest, in accordance with the appropriate laws pertaining to the national forest system, and in accordance with the provisions of the Act.

(b)(1) The Secretary shall manage the Monument to protect the geologic, ecologic, and cultural resources, in accordance with the provisions of this Act ***allowing geologic forces and ecological succession to continue substantially unimpeded.***

(c) The Secretary shall permit the full use of the Monument for ***scientific study and research****, except that the Secretary may impose such restrictions as may be necessary to protect public health and safety and to* ***prevent undue modification of the natural conditions*** *of the Monument.*

(e)(1) The Secretary shall provide for ***recreational use*** *of the Monument and shall provide recreational and interpretive facilities (including trails and campgrounds) for the use of the public which are compatible with the provisions of this Act, and may assist adjacent affected local governmental agencies in the development of related interpretive programs.*

(h) The Secretary shall ***permit hunting and fishing*** *on lands and waters within the Monument in accordance with applicable Federal and State law, except that the Secretary may designate zones within the Monument where, and establish periods when, no hunting or fishing shall be permitted for reasons of public health and safety, the protection of resources, scientific research activities, or public use and enjoyment. Except in emergencies, any regulations issued by the Secretary under this subsection shall be put into effect only after consultation with the appropriate State agencies responsible for hunting and fishing activities. Nothing in this subsection shall be construed as affecting the jurisdiction or responsibilities of the State of Washington with respect to wildlife and fish within the Monument.*

Examination of the statutory provisions shows that a delicate balance has to be present in the monument. The protection of natural ecologic and geologic processes [Sec. 7(a)(1) and (2)] and allowing geologic forces and ecological succession to continue substantially unimpeded [Sec. 4(b)(1)] conflicts with development of the monument for tourism, hunting and fishing [Sec. 4 (e)(1) and (h)]. The Board is the group that attempts to resolve these conflicts.

The first difficult issue before the Board was a request by the Washington Department of Game to stock lakes within the monument. The Board sought a legal opinion on the words "substantially unimpeded" from both the U.S. Forest Service legal counsel and Congressional staff. The Board was informed that its role was to define the balance through its recommendations to the Regional Forester. The resolution was a 5-year moratorium on fish stocking, effective May 18, 1983.

A chronological list of other items reviewed by the board leading to recommendations follows:

- With regard to operations of U.S. Army Corps of Engineers within the monument related to the Spirit Lake containment project, the Board has consulted and coordinated plans among the U.S.Forest Service, U.S.Geological Survey, and other agencies to ensure protection of landscape from unauthorized vehicle and heavy equipment use.

- After reviewing the U.S. Army Corps of Engineers comprehensive plan to lower Spirit Lake, the Board recommended the Coldwater tunnel option.
- The Board has worked to define research opportunities in aquatic ecology and to find personnel to do the studies.
- The Board recommended the establishment of a Monument Scientist position. Peter Frensen now fills that post.
- Following a review of the comprehensive monument management plan, the Board endorsed Alternative D with several qualifications. The plan is described in "Mount St. Helens National Volcanic Monument—Final Environmental Impact Statement Comprehensive Plan", released in 1985.
- The Board prepared a vision statement: "Management of Mount St. Helens Scientific Values" to facilitate decision making.
- The Board has recommended a plan for stocking fish in some lakes in the monument after May 17, 1988.

Some other issues reviewed by the Board were: a proposed fish ladder by modification of Green River Falls; research road access to Spirit Lake; protection of research plots; and the impact of work U.S. Corps of Engineers sediment retention structures.

The next agenda item will be the review of various alternatives presented by the Corps of Engineers to stabilize Castle Lake.

All meetings of the Board are announced in advance and are open to the public. If you wish to attend, please send your request to be placed on the mailing list to:

Secretary, Mount St. Helens Scientific Advisory Board
Joan K. Ruthford, Administrative Services Manager
Centralia Research Center
Weyerhaeuser Company
505 N. Pearl Street
Centralia, WA 98531

American Geophysical Union Regional Meeting

by

Timothy Walsh

The 34th annual meeting of the Pacific Northwest Region of the American Geophysical Union (PNAGU) was held at The Evergreen State College in Olympia, Washington, on September 2-4, 1987. The meeting was convened by geologists Tim Walsh and Bill Phillips of the Division of Geology and Earth Resources (DGER). Walsh is Secretary-Treasurer of PNAGU.

On the first morning of the meeting, discussion centered on Mesozoic and lower Tertiary accretionary tectonics of the Washington Cascades and Olympics. Mesozoic melanges and large-scale Mesozoic structures in the Cascades were described. A possible accreted Eocene seamount was proposed for the Crescent Formation near Bremerton, as was a new scheme for grouping Cascade plutons. The afternoon session began with several papers on Tertiary volcanic stratigraphy in the southern Washington Cascades. That session concluded with posters describing the distribution of Quaternary volcanic vents, Columbia River basalts, and upper Eocene forearc-generated volcanics of southwest Washington, as well as presentation of a new bibliography of the geology of Mount St. Helens in preparation by DGER librarian Connie Manson and her colleagues with the U.S. Geological Survey.

The second day's papers included discussions of groundwater in Columbia River basalt in north-central Oregon and erosion along the lower Columbia River. The potential for major subduction-zone seismicity was described, and a preliminary evaluation of earthquake hazard micro-zonation in the Puget Sound area was given. Other presentations discussed microearthquake swarms in the Columbia Basin, Quaternary structural geology near Tacoma, Washington, the use of tracers to model glacial drainage during surges, and the use of paleomagnetism for the correlation of Quaternary lacustrine sediments on Vancouver Island. DGER librarians Connie Manson and Virginia Taken presented preliminary bibliographies of seismic hazards in western Washington and mineral resources of the Exclusive Economic Zone off the coast of Washington, respectively.

Following the meeting, DGER biostratigrapher Weldon Rau led a 1-day field trip to the Miocene Hoh melange on the Washington coast near Taholah.

Christine Reinhard Named New Washington State Cartographer

Christine Reinhard has been hired by the Department of Natural Resources to fill the newly created position of Washington State Cartographer. Reinhard, who will work in DNR's Division of Engineering, Resource Mapping Section, is scheduled to start September 1, 1987.

"Reinhard has been the assistant state cartographer in Wisconsin since 1975, and played a key role in developing the Wisconsin Land Records program," said Engineering Division Manager Grant Fredricks when making the announcement of the appointment. "She will bring a wealth of public and professional experience to the department."

Reinhard's responsibilities as state cartographer will include assessing, developing, coordinating, and implementing multi-agency mapping and geographic information systems projects statewide in an effort to avoid duplication. She will also serve as executive secretary of the State Mapping Advisory Committee.

Reinhard has replaced Gary Calder, who served as the U.S. Geological Survey (USGS) Resident State Cartographer for the last two years. Calder recently returned to his field duties with the USGS.

Reinhard is currently president of the North American Cartographic Society—an organization she founded in 1980. A graduate of the University of Wisconsin at Madison, Reinhard holds advanced degrees in Cartography and Library Sciences.

[From Department of Natural Resources press release.]

Smithsonian Research Fellowships in Science

The Smithsonian Institution announces its research fellowships for 1988-1989 in Earth Sciences. Smithsonian Fellowships are awarded to support independent research in residence at the Smithsonian, in association with the Research staff and using the Institution's resources. Predoctoral and postdoctoral fellowship appointments for six to twelve months, senior postdoctoral appointments for three to twelve months, and graduate student appointments for ten weeks are awarded. Proposals for research in the following areas may be made:

Meteorites, mineralogy, paleobiology, petrology, planetary geology, sedimentology, and volcanology.

Applications are due January 15, 1988. Stipends supporting these awards are $25,000 per year plus allowances for senior postdoctoral fellows; $19,000 per year plus allowances for post-doctoral fellows; $12,000 per year plus allowances for predoctoral fellows; and $2,500 for graduate students for the ten week tenure period. Pre-, post-, and senior postdoctoral stipends are prorated on a monthly basis for periods less than one year.

Awards are based on merit. Smithsonian fellowships are open to all qualified individuals without reference to race, color, religion, sex, national origin, age, or condition of handicap of any applicant. For more information and application forms, please write Smithsonian Institution, Office of Fellowships and Grants, 7300 L'Enfant Plaza, Washington, D.C. 20560. Please indicate the particular area in which you propose to conduct research and give the dates of degrees received or expected.

Staff Notes

Raymond Lasmanis was reappointed by Governor Gardner in July to the Mount St. Helens Scientific Advisory Board. His term expires in December 1990.

Governor Booth Gardner has authorized **Raymond Lasmanis** and **William Lingley** as Washington's designees to access privileged or proprietary information about oil and gas resources of the continental shelf. Mr. Lasmanis is the authorized state official to receive, upon the Governor's request, privileged or proprietary geological and geophysical data or information on leased and unleased lands on the Outer Continental Shelf administered by the federal Minerals Management Service. Mr. Lingley is authorized to inspect data on currently leased lands.

William M. Phillips lectured November 2 at Clark College, Vancouver, Washington, on the geology of the Vancouver area. The presentation initiated "Geology Week", which included speakers and films exploring geology.

Republic Fossil Locality Open to Public

by

Nancy Joseph

"Gee whiz, I found a fossil!" exclaimed Simeon Taylor. He was one of a group of people "fossil hunting" during the August open house at the Stonerose Interpretive Center in Republic. The center, a community effort, was established in 1986 as a research and tourist facility for scientists studying Eocene fossil plants, fish, and insects and for educational groups and other visitors. (See Washington Geologic Newsletter, October 1986.)

On display at the center are well-preserved locally collected Eocene flora and fauna, including the oldest known member of the rose family. The enclosing rocks are believed to be about 47-50 m.y. old. This site is important because it contains some of the best preserved upland Eocene fossils in the United States. Many of the species found at the site are extinct or have restricted natural ranges today—for example, in the case of the ginkgo, in only one area of the Peoples Republic of China.

The interpretive center is at the south end of the town. Visitors are permitted to collect fossils at a second locality, named the Boot Hill site, which is about one-half mile northwest of the interpretive center. Necessary collecting equipment, such as chisels and hammers, can be rented from the center. Fossil hunters are asked to check in at the center before and after collecting. Interpretive guides, who will identify fossils and help novices with their hunt, are available at 10 a.m. and 2 p.m. until December, weather permitting. The center will re-open in May 1988.

For more information, contact the Stonerose Interpretive Center, P.O. Box 331, Republic, Washington 99166; (509) 775-2295 or 775-3216 (town hall).

Simeon Taylor (left photo) and Mel Ashwill at the Boot Hill site, Republic fossil locality. The town, visible in the right photo, is southeast of the site.

New U.S. Geological Survey Projects in Washington

Four new research projects have been started by the U.S. Geological Survey in Washington in 1987. All are being conducted by branches of the Office of Earthquakes, Volcanoes and Engineering. Following are brief descriptions of project work and plans.

Earthquake-resistant design and structure vulnerability

Project chief: Edgar V. Leyendecker (Denver, CO)

The need for realistic and consistent estimates of losses caused by earthquakes is widely recognized. Estimation depends on the range of hazards posed by ground motion and soil behavior and an inventory of what is at risk and its vulnerability. Because of the numerous approaches to studying hazards, results may have only local application and be substantially different from place to place.

This project has several objectives, among them:

- To evaluate parameters involved in estimating casualties and monetary losses.
- To participate in developing optimal measures of ground motion and using these measures to develop vulnerability relationships.
- To develop means of inventorying critical elements in urban areas.
- To improve methods of measuring structural vulnerability.
- To develop a consistent methodology for estimating loss that can be applied nationwide.
- To prepare recommendations for disaster mitigation.

During this project's first year, project members will work with the USGS Urban Hazards Program and will emphasize the Puget Sound area, particularly Seattle. By the end of its first year, the project hopes to have completed a preliminary damage survey and inventory acquisition procedure, preliminary procedures for training personnel to inventory conditions and damage, and a trial use of the survey procedures. Also anticipated is a plan to integrate losses related to ground motion with those related to ground failure.

The project is funded by the National Earthquake Hazards Reduction Program.

Volcanic hazards of Washington

Project chief: Richard Hoblitt (Vancouver, WA)

The project will assess volcanic hazards, specifically the type, frequency, magnitude, and extent from future eruptions, particularly at Mount St. Helens. Maps and reports will delineate areas subject to the various kinds of hazards and means of mitigation. Coupled with this will be improvement of hazard appraisal techniques and maintenance of a current data base relating to volcanism in the state.

First-generation hazards assessments have been completed for the major volcanoes in Washington. Refinement of volcanic histories will allow improvement of these assessments. During the first year of the project, Mount Rainier will be the focus of the first reassessment. Holocene activity at Mount Baker will be examined. However, Mount St. Helens remains the point of project emphasis.

Coastal tectonics, western USA

Project chief: Kenneth Lajoie (Menlo Park, CA)

Project objectives are to determine (a) rates of vertical and horizontal Pleistocene and Holocene crustal movement, (b) rates and ages of last movement on coastal faults, and (c) Holocene paleoseismicity.

Mapping marine strandline and shore sediments will be assisted by using amino-acid, radiocarbon, electro-spin and paleontologic studies. During the first year, project work will concentrate on mapping and improving the resolution and economical application of electro-spin techniques. Reports summarizing preliminary data on general tectonics of the West Coast are planned, and early emphasis will be on the southern part of the study area. Only about 5 percent of the project efforts will involve Washington.

Volcano-plutonic magmatic evolution

John S. Pallister (Denver, CO)

The project's two main emphases are (a) studies of comagmatic volcanic and plutonic rocks and (b) examining young volcanic rocks as interpretive windows into plutonic processes. The Basin and Range area of southern Arizona is a natural laboratory for studies of the various levels in magmatic systems. Studies there will involve mapping, chemical (trace element and isotopic) analysis, and petrologic work to better define magmatic history. The Turkey Creek caldera will be the site of detailed study of the relation between the hypabyssal rocks and intercaldera ash flows. Samples will also be taken from the Chiricahua Mountains.

Modelling of the magmatic processes at Mount St. Helens will be a second focus of the project. Time-stratigraphic constraints here provide a means to evaluate magmatic processes and comparison with experimentally and theoretically determined diffusion and crystallization rates. In the project's first year, modelling and evaluation of geochemical data from the volcano will continue, and microprobe studies of Kalama rocks will begin, particularly on mixed-magma pumice and scoria.

Mineral Industry News Notes

Echo Bay Mines Ltd. announced that the company will spend $2.5 million over the next year conducting a feasibility study and expanding the exploration at their Kettle River project in Ferry County. This gold project includes the Granny deposit, which is 1 mile west of Curlew, and the Key West, Key East, and Overlook deposits, 9 miles northeast of Republic. The gold properties are operated by Echo Bay, Ltd., in a joint venture with Crown Resources Corp. and Gold Texas Resources Ltd.

At the Granny deposit Echo Bay plans to drive a 3,000-foot underground ramp to a depth of 400 feet, from which they will begin underground drilling. The underground access will enable the company to drill low-angle holes into the near-vertical vein system. This will allow collection of more accurate data, leading to a determination of whether a minable ore body is present. The evaluation of the property should be completed by the end of the second quarter of 1988. Rotary drilling continues at the Overlook deposit, discovered in 1986, to define the extent of the deposit.

If the feasibility study indicates that minable ore is present, Echo Bay officials have indicated that the Granny will be exploited by underground methods, whereas the Key and Overlook deposits will be mined by open pit methods, with possible underground operations on a deeper, higher grade portion of the Overlook deposit. One mill, likely located near the Key deposits, will serve the four mines. Should a mine be feasible, Echo Bay will employ about 100 persons.

Tacoma Lime, a division of Continental Lime, Inc., began production in September at their precipitated calcium carbonate (PPC) plant. PPC, which is made by adding carbon dioxide (CO_2) to lime (CaO), will be produced a rate of 125 tons per day. This facility is one of three in the nation and was specifically built for off-site consumption of the product. The company has been running a pilot plant for several years.

The limestone used at the plant is mined at Texada Island in southwesternmost British Columbia and is calcined at the Tacoma plant. The product's average particle size will be 1 to 2 microns, and the material will be of white paper grade.

Additions to the Division of Geology and Earth Resources Library

July-October, 1987

THESES

Batchelor, C. F., 1982, Subsidence over abandoned coal mines—Bellingham, Washington: Western Washington University Master of Science thesis, 122 p.

Bazard, David R., 1987, Paleomagnetism of the late Cretaceous Ventura Member of the Midnight Peak Formation, Methow-Pasayten belt, north-central Washington: Western Washington University Master of Science thesis, 168 p.

Bigelow, P. K., 1987, The petrology, stratigraphy and basin history of the Montesano Formation, southwestern Washington and southern Olympic Peninsula: Western Washington University Master of Science thesis, 263 p.

Buddington, A. M., 1986, Petrography and petrology of the Methow stock, Okanogan County, Washington: University of Washington senior thesis, 31 p.

Furlong, Edward Thomas, 1986, Sediment geochemistry of photosynthetic pigments in oxic and anoxic marine and lacustrine sediments—Dabob Bay, Saanich Inlet, and Lake Washington: University of Washington Doctor of Philosophy thesis, 214 p.

Groffman, Louis H., 1986, Stratigraphy, sedimentology, and structure of the upper Proterozoic Three Sisters Formation and lower Cambrian Gypsy Quartzite, northeast Washington: Washington State University Master of Science thesis, 208 p., 1 plate.

Jaeger, David J., 1986, Paleomagnetic and geochemical correlation in the high Cascade, Indian Heaven volcanic field, south-central Washington: Michigan Technological University Master of Science thesis, 63 p.

Kuivila, Kathryn Marie, 1986, Methane production and cycling in marine and freshwater sediments: University of Washington Doctor of Philosophy thesis, 170 p.

Lindsey, Kevin A., 1987, Character and origin of the Addy and Gypsy Quartzites, central Stevens and northern Pend Oreille Counties, northeastern Washington: Washington State University Doctor of Philosophy thesis, 256 p.

Lim, Jose Bernardo R., 1986, Paleomagnetism of the Pomona-Weippe basalt flow in southeastern Washington and west-central Idaho: Washington State University Master of Science thesis, 181 p.

Magloughlin, Jerry Francis, 1986, Metamorphic petrology, structural history, geochronology, tectonics and geothermometry/geobarometry in the Wenatchee Ridge area, north Cascades, Washington: University of Washington Master of Science thesis, 343 p., 2 plates.

Mitchell, Robert J., 1986, Paleomagnetism of the Indian Heaven volcanic field, southern Washington: Michigan Technological University Master of Science thesis, 57 p.

Murphy, S. A., 1981, Coping with stress following a natural disaster—The volcanic eruption of Mt. St. Helens: Portland State University Doctor of Philosophy thesis, 240 p.

Oliver, Linda Ann, 1986, Geology and mineralization in the Republic district, Ferry County, Washington: University of Washington Master of Science thesis, 97 p., 2 plates.

Parkinson, David Lamon, 1985, U-Pb geochronometry and regional geology of the southern Okanogan Valley, British Columbia—The western boundary of a metamorphic core complex: University of British Columbia Master of Science thesis, 149 p., 1 plate.

Purdy, J. W., 1987, Paleomagnetism and tectonic interpretation of the Crescent and Blakeley Formations of Kitsap Peninsula, Washington: Western Washington University Master of Science thesis, 138 p.

Simkover, Elizabeth Gail, 1986, A groundwater flow model of the aquifer intercommunication area, Hanford site, Washington: Portland State University, 120 p.

Spicer, Richard Campbell, 1986, Glaciers in the Olympic Mountains, Washington—Present distribution and recent variations: University of Washington Master of Science thesis, 158 p., 1 plate.

Volk, Jeffrey Alan, 1986, Structural analysis and kinematic interpretation of rocks in the southern portion of the Okanogan gneiss dome, north central Washington: Washington State University Master of Science thesis, 156 p.

Wallace, R. Scott, 1987, Quantification of net shore-drift rates in Puget Sound and the Strait of Juan de Fuca, Washington: Western Washington University Master of Science thesis, 58 p.

U.S. GEOLOGICAL SURVEY REPORTS

Celebi, Mehmet; Safak, Erdal; Brady, A. G.; Maley, Richard; Sotoudeh, Vahid, 1987, Integrated instrumentation plan for assessing the seismic response of structures—A review of the current USGS program: U.S. Geological Survey Circular 947, 37 p.

Chrzastowski, J. J., compiler, 1980, Documentation of the initial phase of a Puget Sound submarine slide hazard assessment—The 1977 hydrographic survey at Nisqually Reach: U.S. Geological Survey [Seattle, Wash.] unpublished report, 65 p.

Dion, N. P., 1987, Geohydrologic reconnaissance of a ground-water contamination problem in the Argonne Road area near Spokane, Washington: U.S. Geological Survey Water-Resources Investigations Report 86-4173, 37 p.

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Gori, P. L.; Hays, W. W., editors; Kitzmiller, Carla, compiler, 1987, Proceedings of conference XL—A workshop on "The U.S. Geological Survey's role in hazards warnings": U.S. Geological Survey Open-File Report 87-269, 1 v.

Hays, W. H.; Schuster, R. L., 1987, Maps showing ground-failure hazards in the Columbia River Valley between Richland and Priest Rapids Dam, south-central Washington: U.S. Geological Survey Miscellaneous Investigations Series Map I-1699, 2 sheets.

Lee, M. P.; Guild, P. W.; Schruben, P. G., 1987, Preliminary metallogenic map of North America—A listing of deposits by commodity: U.S. Geological Survey Circular 858-C, 138 p.

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Upcoming Meetings

- **Northwest Mining Assoc. 93rd Annual Convention**
  Nov. 30-Dec. 5, 1987
  Spokane, Washington.

Convention activities include these short courses: "Assays to Assets, Recent Feasibility Case Histories," directed by Bruce K. McKnight; "Contract Mining Workshop," led by Donald D. Haas; and "Gold/Silver Hedging and Trading," taught by Paul Sarnoff.

Information from:
Northwest Mining Association
414 Peyton Bldg.
Spokane, WA 99201
(509) 624-1158

- **American Geophysical Union Fall Meeting**
  Dec. 7-11, 1987
  San Francisco, California

For further information, contact:
Brenda Weaver, AGU
2000 Florida Avenue N.W.
Washington D.C. 20009
(202) 462-6903

- **American Mining Congress MINExpo International '88**
  April 24-28, 1988
  Chicago, Illinois

Exhibits of mining and processing equipment and 20 session on technical topics.

Obtain further information from:
American Mining Congress,
Suite 300
1920 N. Street N.W.
Washington, D.C. 20036

Short Summer Courses in X-Ray Spectrometry offered by State University of New York at Albany

X-Ray Spectrometry
June 6-10, 13-17, August 15-19, 1988

The course is tutorial and covers the entire field of chemical analysis by means of x-ray spectrometry, from elementary principles to the latest practices. The session in August will concentrate on mathematical and computer methods to solve the matrix problem and will examine problems of the advanced spectroscopist.

X-Ray Powder Diffraction
June 20-24, June 27-July 1, 1988

This course is also tutorial and develops the field of chemical analysis by means of X-ray powder diffraction, from beginning principles to the most recent developments. The second week emphasizes quantitative methods of analysis.

Registration may be made for one or both weeks, each week for $1,100. For further information about either course and to register, write or call:

Professor Henry Chessin
State University of New York at Albany
Department of Physics
1400 Washington Avenue
Albany, NY 12222
(518) 442-4512
(518) 442-4513

Anderson Joins DNR Staff

Garth Anderson comes on line as the Northwest Region's Geologist II on November 9. He received his B.S. in Geology from the University of Illinois and his M.A. in Geology from the University of North Dakota. He has had several years experience working as environmental scientist for the State of North Dakota, regulating and managing reclamation projects. Garth will be taking over the Region's Surface Mining Program and will provide his expertise to the Forest Practices and Timber Sales Programs. With his background in the technical aspects of geology, administration, and environmental concerns, he will be an asset to the Department.

Second Cartographic Information Center Established in Washington

The state of Washington has established a second cartographic information center linked to the National Cartographic Information Center (NCIC) of the U.S. Geological Survey.

NCIC is an information clearinghouse for organizations and persons who acquire or produce maps and other cartographic data and those who need the maps and data. NCIC's computerized files contain information on location and availability of maps and other cartographic products held by federal, state, and local governments, as well as by private firms and organizations.

The second office is at the Map Collection and Cartographic Information Center of the Suzzalo Library on the campus of the University of Washington in Seattle. The first NCIC affiliate was established in 1981, in the Washington State Library in the State Capitol complex in Olympia. These offices are part of a system that includes affiliated offices in 46 states and regional offices in Alaska, California, Colorado, Mississippi, and Missouri.

As NCIC affiliates, the cartographic centers are able to fill requests for cartographic and geographic information. They have quick access to information about the availability and source of maps, charts, digital cartographic data, air photos, satellite and radar images, photos from manned spacecraft, as well as other types of data. Under the agreement with the Geological Survey, NCIC supplies catalogs, indexes, and microfilm and microfiche of cartographic reference aids. The two affiliated offices in turn make this information available to the public. The state's cartographic records will become part of the nationwide information system.

The university's collection is the largest such collection in the state, with more than 200,000 maps and charts, 50,000 aerial photographs, and 2,000 atlases. The center is also a state regional map depository for Washington and automatically receives copies of all published U.S. Geological Survey maps for the United States.

Both NCIC affiliates in Washington are open from 8 a.m. to 5 p.m. Mondays through Fridays. The Seattle center can be reached at (206) 543-9392; its mailing address is University of Washington, Suzzalo Library, Map Collection and Cartographic Information Center, FM-25, Seattle, WA 98195. The Olympia center's phone number is (206) 753-4027. Its mailing address is Washington State Library, Information Services Division, Olympia, WA 98504.

(Information from USGS press release, Aug. 14, 1987)

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