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VOLCANO HAZARDS IN THE MOUNT HOOD REGION, OREGON

By

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Cover photo: Mount Hood and Portland, Oregon. View is to east from the Washington Park Rose Garden.
Tom Iraci, USDA - Forest Service

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SUMMARY

Mount Hood is a potentially active volcano close to rapidly growing communities and recreation areas. The most likely widespread and hazardous consequence of a future eruption will be for lahars (rapidly moving mudflows) to sweep down the entire length of the Sandy (including the Zigzag) and White River valleys. Lahars can be generated by hot volcanic flows that melt snow and ice or by landslides from the steep upper flanks of the volcano. Structures close to river channels are at greatest risk of being destroyed. The degree of hazard decreases as height above a channel increases, but large lahars can affect areas more than 30 vertical meters (100 vertical feet) above river beds. The probability of eruption-generated lahars affecting the Sandy and White River valleys is 1-in-15 to 1-in-30 during the next 30 years, whereas the probability of extensive areas in the Hood River Valley being affected by lahars is about ten times less. The accompanying volcano-hazard-zonation map outlines areas potentially at risk and shows that some areas may be too close for a reasonable chance of escape or survival during an eruption. Future eruptions of Mount Hood could seriously disrupt transportation (air, river, and highway), some municipal water supplies, and hydroelectric power generation and transmission in northwest Oregon and southwest Washington.

INTRODUCTION

Snow-clad Mount Hood dominates the Cascade skyline from the Portland metropolitan area to the wheat fields of Wasco and Sherman Counties. The mountain contributes valuable water, scenic, and recreational resources that help sustain the agricultural and tourist segments of the economies of surrounding cities and counties. Mount Hood is also one of the major volcanoes of the Cascade Range, having erupted repeatedly for hundreds of thousands of years, most recently during two episodes in the past 1,500 yr. The last episode ended shortly before the arrival of Lewis and Clark in 1805. When Mount Hood erupts again, it will severely affect areas on its flanks and far downstream in the major river valleys that head on the volcano. Volcanic ash may fall on areas up to several hundred kilometers downwind.

The purpose of this report is to describe the kinds of hazardous geologic events that have happened at Mount Hood in the past and to show, in the accompanying volcano-hazard-zonation maps, which areas will be at risk when such events occur in the future.

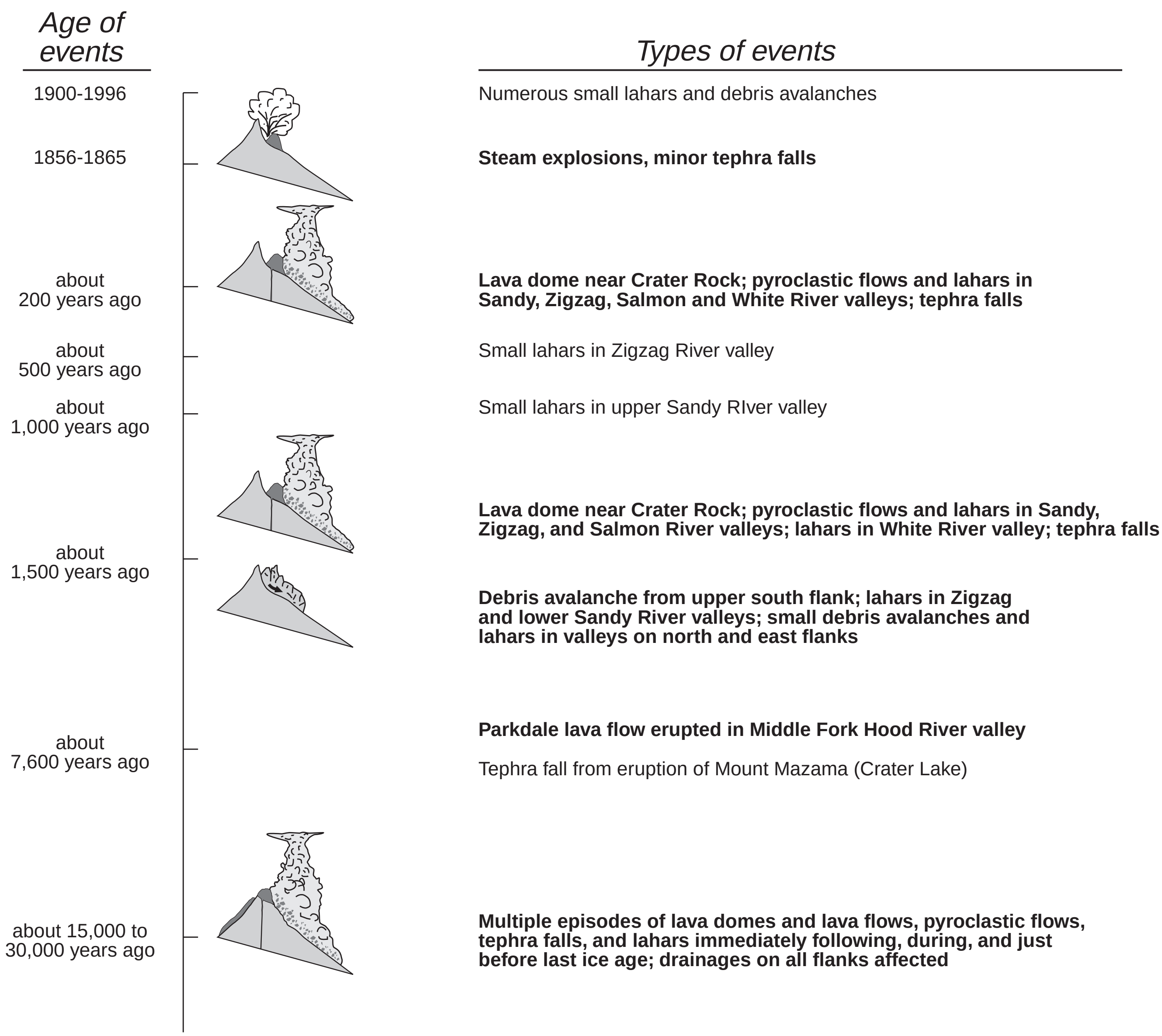
PAST HAZARDOUS EVENTS

Mount Hood has erupted intermittently for hundreds of thousands of years, but historical observations are meager, so most of our information about its past behavior comes from geologic study of the deposits produced by prehistoric events *[1; numerals in brackets refer to end notes listed at the end of the report]*. We also use observations of recent eruptions at other similar volcanoes around the world to better understand what future eruptions of Mount Hood might be like. A brief description of the kinds of events that have occurred at Mount Hood and are likely to happen in the future follows.

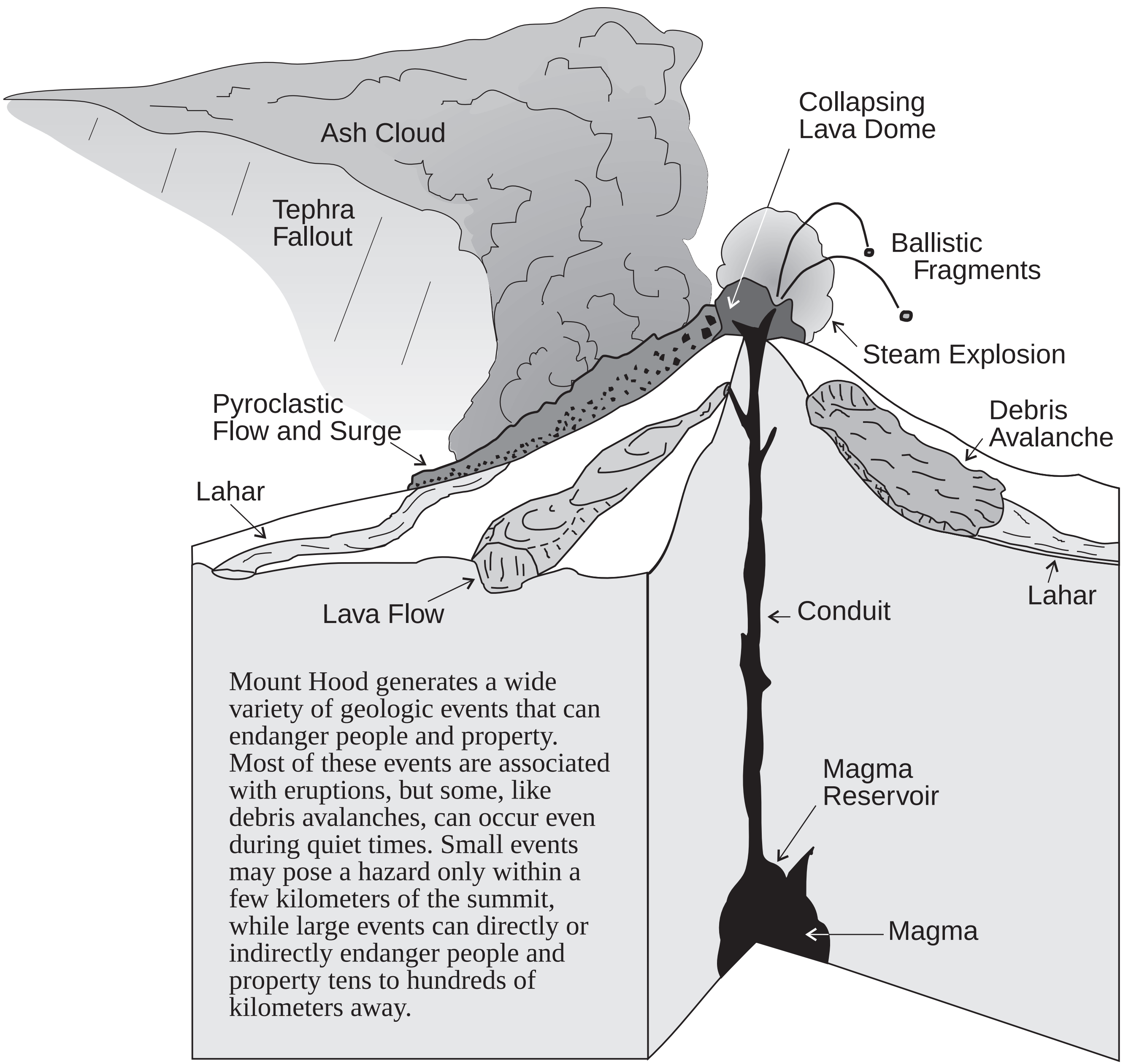
Lava Eruptions, Pyroclastic Flows, and Related Lahars

Lava has erupted at Mount Hood chiefly in two modes. Numerous ***lava flows*** issued from vents on the upper flanks and traveled up to 12 kilometers (7 miles) down valleys. Erosion of new valleys along flow margins has left many of these lava flows as ridges, such as Cathedral Ridge, that radiate out from the center of the volcano. Observations of lava flows at similar volcanoes suggest that Mount Hood flows move down valleys as tongues of fluid lava a few to tens of meters thick (10 to 200 feet) encased in a cover of hardened lava rubble. Such lava flows can destroy all structures in their paths, but they advance so slowly that they seldom endanger people. ***Lava domes*** formed stubby lava

Key geologic events in the Mount Hood region during the past 30,000 years



Hazardous Geologic Events at Mount Hood



masses on the upper flanks and summit of Mount Hood as lava welled out of a vent and piled up, too viscous to flow away. A recent example is the lava dome that grew in the crater of Mount St. Helens between 1980 and 1986. Past lava domes growing on the steep upper flanks of Mount Hood were typically unstable and collapsed repeatedly as they grew higher and steeper.

Collapse of a growing lava dome or the front of a thick lava flow generates landslides of hot rock called ***pyroclastic flows***. Pyroclastic flows are fluid mixtures of hot rock fragments, ash, and gases that sweep down the flanks of volcanoes at speeds of 50 to more than 150 kilometers per hour (30 to 90 miles per hour) destroying vegetation and structures in their paths. Most are confined to valley bottoms, but ***pyroclastic surges***, overriding clouds of hot ash and gases, are more mobile and can overwhelm even high ridge tops. At Mount Hood, pyroclastic flows have traveled at least 12 kilometers (7 miles) from lava domes; pyroclastic surges probably traveled even farther. Pyroclastic flows and surges also produce ash clouds that can rise thousands of meters (tens of thousands of feet) into the atmosphere and drift downwind for hundreds of kilometers (hundreds of miles). The consequences of this ash are discussed in a later section called ***Tephra Fall***.

Pyroclastic flows and surges can also melt snow and ice and generate ***lahars*** (also called volcanic mudflows or debris flows). Lahars are rapidly flowing, water-saturated mixtures of mud and rock fragments, as large as truck-size boulders, that range in consistency from mixtures resembling freshly mixed concrete to very muddy water. Lahars can travel more than 100 kilometers (60 miles) down valleys. They move as fast as 80 kilometers per hour (50 miles per hour) in steep channels close to a volcano, but slow down to about 15 to 30 kilometers per hour (10-20 miles per hour) on gently sloping valley floors farther away. Past lahars at Mount Hood completely buried valley floors in the Sandy and Hood River drainages all the way to the Columbia River and in the White River drainage all the way to the Deschutes River.

Eruptive activity at Mount Hood during the past 30,000 years has been dominated by growth and collapse of lava domes. The last two episodes of eruptive activity occurred 1,500 and 200 years ago. Repeated collapse of lava domes extruded near the site of Crater Rock, Mount Hood's youngest lava dome, generated pyroclastic flows and lahars and built much of the broad smooth fan on the south and southwest flank of the volcano.

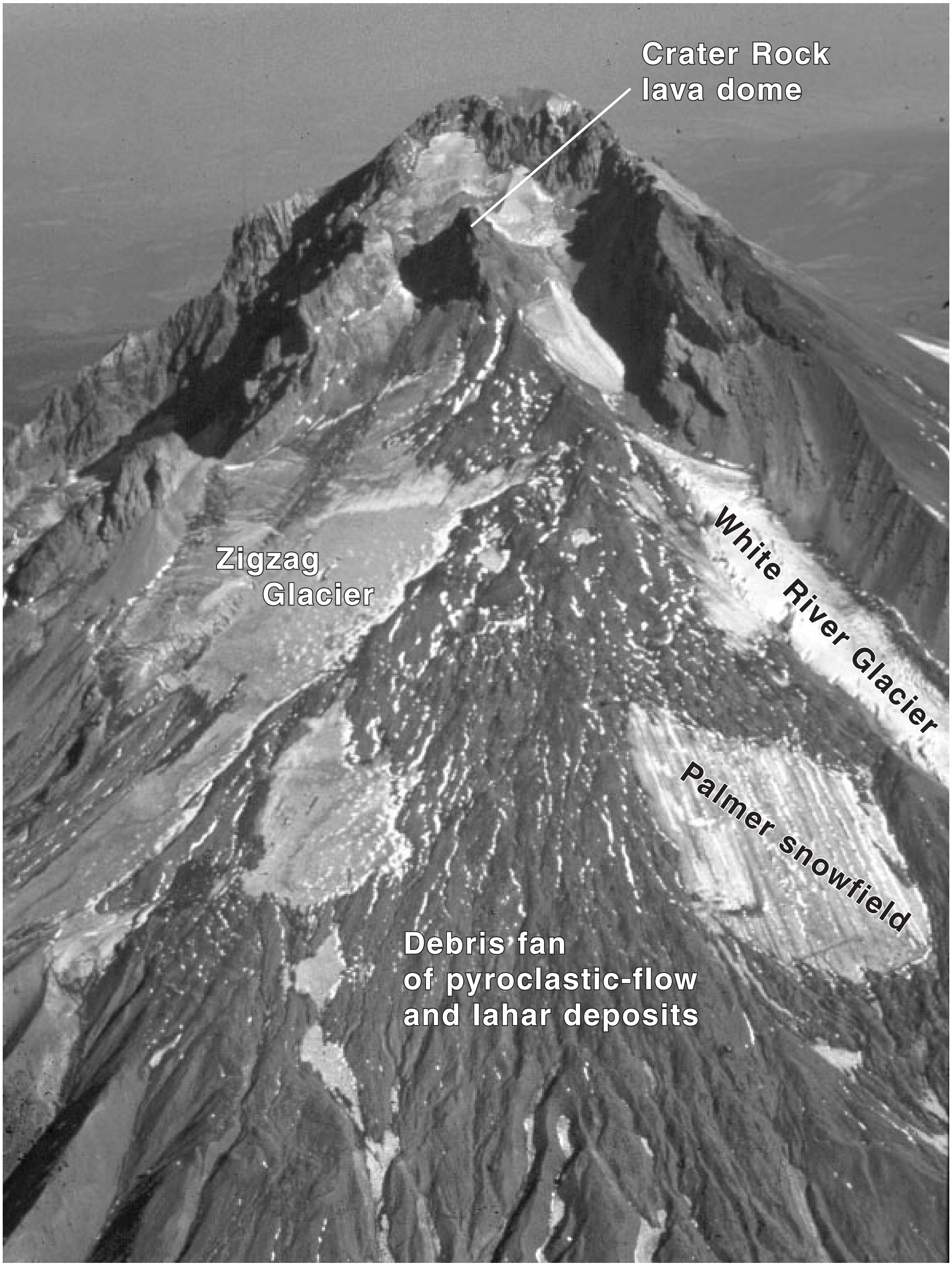
The newly formed fans of debris on the lower flanks of Mount Hood and deposits of lahars in river valleys were highly erodible, which caused additional impacts. Normal rainfall, snowmelt, and streams remobilized the sediment and continued to move it farther downstream for years after eruptions. For example, after the last eruptive period, the Sandy River became choked with sediment and within about a decade buried the preeruption valley floor over 20 meters (65 feet) deep between Sandy and Troutdale. Ultimately, much of the sediment from past eruptions entered the Columbia River. A recurrence of such events would greatly affect the Columbia River, its shipping channel, and, potentially, hydroelectric installations, such as Bonneville Dam.

Debris Avalanches and Lahars

Rapidly moving landslides, called ***debris avalanches***, occurred numerous times in the past when the steep upper parts of Mount Hood collapsed under the force of gravity. Warm acidic ground water that circulates in cracks and porous zones inside volcanoes alters strong rock to weak slippery clay, thereby gradually weakening them and making them more susceptible to debris avalanches than other mountains. Volcanoes are further weakened as erosion, especially by glaciers, oversteepens slopes. The destabilizing forces of ***magma*** (molten rock) pushing up into a volcanic cone prior to an eruption can trigger debris avalanches as occurred at Mount St. Helens in 1980. Unexpected earthquakes (both smaller local ones and larger distant ones) or steam explosions can also trigger debris avalanches. A debris avalanche can attain speeds in excess of 160 kilometers per hour (100 miles per hour); the larger the avalanche, the faster and farther it can move. Small-volume debris avalanches typically move only a few kilometers (1 to 3 miles), but large-volume debris avalanches are capable of reaching tens of kilometers (tens of miles) from the volcano. Debris avalanches destroy everything in their paths and can leave deposits 10 to more than 100 meters (30 to more than 300 feet) thick on valley floors. Depending upon their water content, debris avalanches can transform into lahars, which, like lahars formed by pyroclastic flows, can move down valleys for even greater distances.

About 1,500 years ago, a moderate-size debris avalanche originating on the upper southwest flank of Mount Hood (see photograph) produced a lahar that flowed down the Zigzag and Sandy River valleys. It swept over the entire valley floor in the Zigzag-Wemme-Wildwood area, and inundated a broad area near Troutdale, where the Sandy flows into the Columbia River—a total distance of about 90 kilometers (55 miles). More than 100,000 years ago, a much larger debris avalanche and related lahar flowed down the Hood River, crossed the Columbia River, and flowed several kilometers up the White Salmon River on the Washington side. Its deposit must have dammed the Columbia River at least temporarily.

During noneruptive periods, relatively small lahars present a hazard along channels and on



Photograph of upper south flank of Mount Hood showing the lava dome of Crater Rock and the head of the fan of pyroclastic-flow and lahar deposits below it. The steep scarp above Crater Rock was formed by a landslide (debris avalanche) about 1,500 years ago.

floodplains on the flanks of Mount Hood. Although of modest size compared to lahars generated by eruptions or large debris avalanches, they occur much more frequently. Twenty-one lahars, including single flows as large as several hundred thousand cubic meters (cubic yards), whose effects were chiefly limited to areas within 15 kilometers (9 miles) of Mount Hood's summit, are reported in the historical record. Most occurred during autumn and early winter rains. Glacial outburst floods caused at least two and probably as many as seven others. A highly damaging lahar occurred in December 1980 when intense warm rain (with rapid snowmelt) triggered a flow in Polallie Creek that killed a camper at the creek mouth and temporarily dammed the East Fork Hood River. The ensuing dambreak flood destroyed about 10 kilometers (6 miles) of Oregon Highway 35 and other downstream facilities and caused about $13 million in damage.

Tephra Falls

Mount Hood has typically not produced thick, extensive deposits of ***tephra*** (fragmented solidified lava that rises into the air, is carried by winds, and falls back to the ground) as has nearby Mount St. Helens. Rather, relatively modest amounts of tephra were produced during past lava-flow and lava-dome eruptions. Most tephra fallout was caused by clouds of sand- and silt-size particles that rose from moving pyroclastic flows produced by lava-dome collapse. Tephra was also generated by explosions driven by volcanic gases. Both types of tephra clouds probably reached altitudes of 1,000 to 15,000 meters (3,000 to 50,000 feet) above the volcano and were then carried away by the prevailing wind, which blows toward sectors northeast, east, or southeast of Mount Hood about 70 percent of the time. Winds that would carry tephra toward the Portland

Large boulders in Wemme transported by a lahar that originated from a debris avalanche on the upper southwest flank of Mount Hood about 1,500 years ago.

metropolitan area are rather uncommon, occurring only a few percent of the time. On the flanks of the volcano, each event deposited, at most, a few centimeters (inches) of tephra. Thickness of tephra fallout decreased rapidly downwind to probably just a few millimeters (one-tenth inch) or less at 100 to 200 kilometers (60-120 miles) from the volcano. During future explosions at Mount Hood, large, dense ***ballistic fragments*** (more than 5 cm (2 inches) in diameter) that can damage structures and kill or injure people may be thrown up to 5 kilometers (3 miles) from vents.

Tephra fallout produced by future eruptions of Mount Hood poses little threat to life or structures in nearby communities. But tephra clouds can create tens of minutes or more of darkness as they pass over a downwind area, even on sunny days, and reduce visibility on highways. Tephra ingested by vehicle engines can clog filters and increase wear. Deposits of tephra can short-circuit electric transformers and power lines, especially if the tephra is wet and thereby highly conductive, sticky, and heavy. This effect could seriously disrupt hydroelectric power generation and transmission along the Columbia River and powerline corridors north and east of the volcano. Tephra clouds often spawn lightning, which can interfere with electrical and communication systems and start fires. A serious potential danger of tephra stems from the grave effects of even small, dilute tephra clouds on jet aircraft that fly into them. Major air routes pass by Mount Hood, and tephra clouds produced repeatedly during an eruptive episode would interfere greatly with air traffic.

Lessons learned in eastern Washington during the 1980 eruption of Mount St. Helens can help prepare governments, businesses, and citizens for future tephra falls. Communities experienced significant disruptions in transportation, business activity, and services during fallout of from 0.5 to 8 centimeters (1/4 to 3 inches) of tephra and for several days thereafter. The greater the amount of tephra that fell, the longer the recovery time. As perceived by residents, tephra falls of less than 0.5 centimeter (1/4 inch) were a major inconvenience, whereas falls of more than 1.5 centimeters (2/3 inch) constituted a disaster. Nonetheless, all communities resumed normal activities within about two weeks. On the basis of the type and magnitude of tephra production we would expect *from Mount Hood* in the future, only nearby communities, such as Government Camp, Rhododendron, and Parkdale, would likely receive a tephra thickness approaching 1.5 centimeters (2/3 inch) in any one event. However, *some other nearby volcanoes* in the Cascade Range do produce large explosive tephra eruptions that could affect the Mount Hood region.

VOLCANO-HAZARDS-ZONATION MAP

The accompanying volcano-hazards zonation map shows areas that could be affected by future hazardous geologic events at Mount Hood *[2; numerals in brackets refer to end notes listed at the end of the report]*. Hazardous areas are divided into ***proximal*** and ***distal hazard zones*** depending on distance from the volcano. Some zones are split further on the basis of their relative degree of hazard. Zone boundaries are based on (1) the frequency and magnitude of past events at the volcano, as recorded by their deposits, (2) computer models that predict the extent, depth, and travel time of future lahars, and (3) our experience and judgment derived from observations and understanding of events at other volcanoes. Other hazard zones shown on inset maps include zones for tephra fall, for lava flows from other vents scattered through the Mount Hood area, and for very large-magnitude, but highly unlikely, events at Mount Hood.

Most future events will affect only part of a hazard zone. The location and size of an affected area will depend on the location of the erupting vent or landslide, the volume of material involved, the snow and ice conditions around and down slope from the vent, and the character of an eruption, especially its explosivity. For lava domes, the duration of an eruptive episode is also important. Long-lived dome extrusion with numerous collapses can fill entire valleys on the flanks of the volcano with debris and form broad fans that eventually can affect large parts of a hazard zone.

Although we show boundaries of hazard zones by lines, the ***degree of hazard does not change abruptly at these boundaries***. Rather, the hazard decreases gradually as distance from the volcano increases and decreases more rapidly as elevation above the valley floor increases. Areas immediately beyond outer hazard zones should not be regarded as hazard-free, because the boundaries can only be approximately located, especially in areas of low relief. Too many uncertainties exist about the source, size, and mobility of future events to locate the boundaries of zero-hazard zones with confidence.

Proximal Hazard Zones

Proximal hazard zones include areas from the summit out to 24 km (15 miles) along major valleys and out to about 12 kilometers (7 miles) in between major valleys. These zones are subject to several types of rapidly moving, devastating flows. Pyroclastic flows and surges will travel out to a maximum distance of about 12 kilometers in less than 10 minutes, whereas lahars and debris avalanches can travel out to the 24-km hazard boundary in as little as 30 minutes *[3]*. Areas up to 5 kilometers (3 miles) from a vent could also be subject to showers of large (more than 5 centimeters or 2 inches) ballistic fragments within a few minutes of an explosion. Owing to such high speeds, escape or survival is unlikely in proximal hazard zones. Therefore, evacuation of proximal hazard zones prior to onset of an event is realistically the only way to protect lives. Lava flows issuing from vents on the upper flanks of Mount Hood would be largely restricted to proximal hazard zones, but they would move much more slowly than these other types of flows.

During the past 1,500 years, lava-dome growth has been localized in the area around Crater Rock, the youngest lava dome on Mount Hood, which lies in a steeply sloping, breached crater south of the summit ridge. We think that this same area is the most likely vent location during the next eruption as well. Therefore, we define a ***proximal hazard zone A (PA)***, which encompasses those areas that could be affected by events accompanying dome growth at or near Crater Rock. A less likely event is the opening of a vent elsewhere on the upper east, north, or west flank. Should this occur, the corresponding hazard zone would be all or part of ***proximal hazard zone B (PB)***. Depending on vent location, especially if at the summit, all or part of zone PA also could also be at risk. On the lower south and west flanks, hazard zone PB extends beyond the limit of zone PA because a lava dome growing at the summit would be at a higher altitude than Crater Rock and would have the potential to generate farther-reaching pyroclastic flows. On the basis of past eruption frequency, we estimate the probability of an eruption impacting part of zone PA in the next 30 years (the 30-year probability) to be about 1 in 15 to 1 in 30 *[4]*. In contrast, the 30-year probability of part of zone PB being affected is on the order of 1 in 300 *[4]*. We caution that these probabilities are based solely on the long-term behavior of the volcano. Any signs of increased restlessness at Mount Hood will increase these probabilities dramatically.

Several major valleys within the proximal hazard zones are highlighted on the map by a hachured line pattern because they are more likely than others to be affected by future pyroclastic flows and lahars related to collapse of growing lava domes, especially during initial stages of dome building. These valleys, along with Polallie Creek valley, are also areas subject to frequent small lahars, floods, and debris avalanches triggered by storms or other noneruptive causes. If a lava dome grows near Crater Rock, the White and Zigzag River valleys and the valley of Zigzag Glacier and its meltwater stream, an unnamed tributary of the upper Sandy, are the most likely pyroclastic-flow and lahar paths. If an eruptive episode continues for a long enough time period that debris fills the heads of these drainages, pyroclastic flows and lahars will be able to sweep over a broader area, which could include the Little Zigzag River, Still Creek (including the area around Government Camp), and Salmon River valleys. Likewise in zone PB on the north or east flank, the main valleys below a growing lava dome would initially be the most likely flow paths. For example, dome growth on the upper northeast flank would initially affect the valleys of Newton Creek and Eliot Branch. The large area in the proximal hazard zone between these valleys that is drained by Polallie and several other creeks does not presently head directly on the upper flanks and probably would not be affected initially. Before these drainages could be inundated by pyroclastic flows, the valley heads of Newton Creek and(or) Eliot Branch would have to be partly filled with debris.

While the subdivision of the proximal area into zones PA and PB based on vent location applies well to pyroclastic flows and lahars produced by lava dome collapse, several other types of events are not so neatly restricted by this hazard zonation. First, the earthquakes and deformation associated with future intrusion of magma into Mount Hood can trigger landslides of fractured and weakened rock from the steep upper slopes. Therefore, even though dome building is localized at one site, landslides elsewhere on the upper flanks can generate debris avalanches and related lahars in valleys not otherwise affected by dome growth. Such events, largely restricted to the hachured areas in zone PB, occurred on the east, north, and west flanks during the past 1,500 years, while dome growth and collapse affected valleys on the south and southwest flanks. Furthermore, owing to the pronounced filling of valleys on the south side by debris during the past 1,500 years, the majority of high cliffs and spurs subject to landsliding lie on other flanks. Thus, regardless of which zone a dome is growing in, potential hazards from debris avalanches and lahars exist in other parts of the proximal zones. Second, explosive eruptions driven by volcanic gases can also affect both proximal zones. Explosions can generate highly mobile pyroclastic flows as material falls back to the ground and can hurl large ballistic fragments outward up to 5 kilometers (3 miles). Such events are less constrained by topographic features than are pyroclastic flows from dome collapse, so explosions at a vent in one proximal zone could impact parts of the other proximal zone, especially with ballistics.

Distal Hazard Zones

Distal hazard zones lie beyond proximal zones and include the major river valleys draining Mount Hood that can be swept by lahars and debris avalanches. Depending on distance from the volcano, these areas will be affected 30 minutes to several hours after the onset of an event, and escape is possible given sufficient warning.

Sandy River drainage

Numerous lahars inundated the Sandy River valley and its tributaries that head on Mount Hood during the two eruptive episodes of the past 1,500 years. Thus, plentiful deposits are available for study so that we can reconstruct extent and depth of past flows. Areas most likely to be affected by future events are included in ***distal hazard zone A (DA)***, which encompasses areas known to have been inundated by these prehistoric flows and adjacent areas up to 12 meters (40 feet) higher. Deposits do not always record the highest level of inundation, and we use our judgment based on experience with historical lahars to locate the boundaries higher on valley walls where the valley is relatively narrow and flows would deepen, or where flows sweeping around bends would run up higher on the outside of a bend. In zone DA, the probability of areas being inundated by a lahar or debris avalanche depends on such factors as height above the river channel, distance downstream from Mount Hood, and valley shape. The 30-year probability of areas in zone DA being inundated by lahars is the same as that for renewed dome growth near Crater Rock, about 1 in 15 to 1 in 30 *[4]*.

Lahars that flow south from the Crater Rock area can also enter the valleys of other Sandy River tributaries, such as Still Creek and Salmon River. During an eruptive period, we consider these tributaries less likely to be inundated than the upper Sandy and Zigzag Rivers, at least initially, because the topography of the upper debris fan will funnel future lahars toward the upper Sandy and Zigzag valleys. Furthermore, events of the past 1,500 years suggest that only small lahars will enter the lower canyons of Still Creek and Salmon River, and these should transform into muddy floods before traveling far down either channel.

Lahars and sediment-rich floods that flowed to the Columbia River during and immediately after past eruptive periods built the delta at the mouth of the Sandy River near Troutdale. The delta area is in hazard zone DA because its low relief offers little protection from lahars or from the shifting of channels that can occur during periods of high sedimentation. Sediment deposition at the edge of the delta has narrowed the Columbia River and pushed it against the Washington shore. Future lahars and eruption-induced sedimentation are likely to build the delta farther out into the Columbia River and narrow the existing channel, which could lead to progressive bank erosion and inundation of land in the Camas-Washougal area.

The hazard zone on the north side of the river outlines areas thought to be vulnerable to these processes. More specific forecasts are impossible other than to note that areas close to the river and land composed of erodible deposits are the most vulnerable.

White River drainage

Lahars spawned by lava-dome collapses swept through the White River valley about 200 years ago and inundated large parts of Tygh Valley. Hazard zone DA encompasses these deposits as well as adjacent areas that lie up to 12 meters (40 feet) higher depending on valley width (see discussion in *Sandy River drainage*). Lahars of this magnitude would inundate the broad flood plain of White River in Tygh Valley, but probably not reach the town itself. Lahars that reach the Deschutes River probably would be diluted to muddy floods that would transport large amounts of sediment into the Columbia River upstream from The Dalles Dam. The 30-year probability of an area in zone DA along White River being inundated by a debris avalanche or lahar is about 1 in 15 to 1 in 30 *[5]*.

Hood River drainage

The Hood River and its tributaries drain about one-half of Mount Hood, but have apparently not been affected by lahars that extended outside of the proximal hazard zone, or substantially out of channels, during the past 15,000 years. Recent eruptions that produced pyroclastic flows and lahars in the Sandy and White River valleys only indirectly affected upper parts of the Hood River basin by producing modest debris avalanches and related lahars. However, dome growth on the east or north flank, a condition that we consider of lower probability than renewed activity near Crater Rock, would substantially impact Hood River and its tributaries.

Owing to the lack of evidence of young events in the Hood River Valley, we include areas along Hood River in distal hazard zone DB, and estimate a 30-year probability of inundation by lahars or debris avalanches on the order of 1 in 300 *[4]*. We consider two types of events. First, several masses of partly altered and highly fractured rock on the steep upper east and north flanks could generate a debris avalanche and related lahar with a volume of about 50 million cubic meters (65 million cubic yards), which is roughly the volume of the largest debris avalanche and lahar generated in the Sandy River valley during the past 1,500 years. Second, dome growth on the upper east or north flank could generate lahars similar to those produced by dome growth and collapse near Crater Rock during the past 1,500 years. We use a computer model calibrated from analysis of these Sandy River events to simulate flows in the three forks of Hood River and to define hazard zone DB *[6]*.

Tephra-Hazard Zones

Mount Hood has produced relatively modest tephra falls, but it is not the only source of tephra fall in the region. For example, Mount St. Helens, which lies 100 kilometers (60 miles) northwest of Mount Hood has been the most prolific producer of tephra in the Cascades during the past few thousand years. The accompanying maps indicate the 30-year probability of tephra fall affecting the Mount Hood region from all Cascade sources. The maps are based on the combined likelihood of tephra-producing eruptions occurring at Cascade volcanoes, the relationship between thickness of a tephra-fall deposit and distance from its source vent, and regional wind patterns *[7]*. Probability zones extend farther east of the range because winds blow from westerly directions most of the time. One map shows 30-year probabilities for a fall of one centimeter (about 0.4 inch) or more and the other for a fall of 10 centimeters (about 4 inches) or more. The map pattern illustrates clearly the dominating influence of Mount St. Helens.

Most of the region around Mount Hood has a 30-year probability of about 1 in 30 of receiving one centimeter or more of tephra; for 10 centimeters or more the 30-year probability is about 1 in 150. In detail, the probability of such thicknesses accumulating on the flanks of Mount Hood and a short distance beyond are somewhat higher owing to the additional probability of multiple tephra falls from ash clouds of pyroclastic flows being produced at Hood during an episode of lava-dome growth. This area of higher probability is too small to show at the scale of the figures, but includes the Upper Hood River Valley around Parkdale, the upper parts of Bull Run and The Dalles Watersheds, and the upper Sandy and

Zigzag River valleys, including Rhododendron and Government Camp.

Regional Lava-Flow Hazard Zone

In addition to Mount Hood, other volcanoes in the region from the Portland metropolitan area to the east flank of the Cascade Range have erupted during the past two million years. The most recent such event, about 7,500 years ago, produced a small tephra fall and a 6-kilometer-long (3.7-mile-long) lava flow in the valley of the Middle Fork of Hood River, west of Parkdale. Some older events built large shield volcanoes composed chiefly of lava flows, such as Mount Defiance, Lost Lake Butte, and Clear Lake Butte. Future eruptions will probably occur at new vents within this same broad region, rather than at existing vents. On the basis of the rate at which past events have buried the landscape with lava flows, the 30-year probability of a given site within the hazard zone (excluding the proximal hazard zones of Mount Hood) being buried by a lava flow is estimated to be on the order of 1 in 100,000, a very low probability indeed *[8]*.

How Large an Event Is Possible at Mount Hood?

The largest magnitude event that is possible at Mount Hood is one of very low 30-year probability —less than 1 in 10,000—but one that would have very serious consequences. Although preparing for such a rare event probably is not warranted, understanding the worst-case scenario is nonetheless prudent. As demonstrated by Mount St. Helens' catastrophic eruption on May 18, 1980, two types of large-scale hazardous events can occur at volcanoes like Mount Hood—a *large-volume debris avalanche and lahar* and a large *directed blast* (a type of highly mobile pyroclastic flow). Hazard zones for a large-volume debris avalanche and lahar are shown on the hazard map, and the hazard zone for a directed blast is shown on an inset map.

Debris avalanches and lahars of much greater size than those considered in constructing hazard zones DA and DB have occurred in the past and are possible again at Mount Hood. The hazard map portrays the potential extent of a debris avalanche and lahar of about 500 million cubic meters in the Sandy and Hood River valleys *[9]*. (The limited sector of the volcano drained by the White River precludes a landslide of this volume being confined to the White River.) An event of this size or larger has happened at least once in both the Sandy and Hood River valleys during the past 500,000 years. Such an avalanche today would entail removal of a significant portion of the upper part of Mount Hood. Sizable deformation driven by intrusion of magma into the volcano (and thus a warning period) would probably be a necessary condition to generate such an event.

A directed blast devastated more than 500 square kilometers (200 square miles) north of Mount St. Helens on May 18, 1980. A directed blast of similar size and mobility at Mount Hood could engulf a broad sector of the hazard zone outlined in the inset figure on the hazard-zonation map *[10]*. The irregular shape of the hazard zone reflects the topography of the surrounding area. The zone extends farther from the volcano where elevations drop more steeply, as down the Hood River Valley toward the Columbia River.

HAZARD FORECASTS AND WARNINGS

Scientists recognize several signs of impending volcanic eruptions. The upward movement of magma, or molten rock, into a volcano prior to an eruption causes changes that can usually be detected by geophysical instruments and visual observation. Swarms of small earthquakes are generated as rocks break to make room for rising magma or as heating of fluids causes underground pressures to increase. Heat from the magma can increase the temperature of ground water and boost temperatures and steaming from fumaroles; it can also generate small steam explosions. The composition of gases emitted by fumaroles can change as magma nears the surface. Injection of magma into the volcano can cause swelling or other types of surface deformation.

A regional seismic network operated jointly by the U.S. Geological Survey and the Geophysics Program at the University of Washington detects and locates earthquakes around Mount Hood. As many as 50 earthquakes have been recorded in one year, but the events are seldom strong enough to be felt by people on the volcano. Most occur in swarms of several events that are located below the summit area or the south flank at depths of less than 10 kilometers (6 miles). An increase in this level of earthquake activity would be noticed quickly. At monitored volcanoes similar to Mount Hood, a notable increase in seismicity has occurred days to months before the onset of eruptions.

Scientists have conducted other surveys aimed at detecting precursory activity at Mount Hood. A network of precisely surveyed points has been remeasured several times. Gases from fumaroles are analyzed periodically. An increase in seismicity would prompt deployment of additional seismometers to better locate earthquakes, the resurvey of the deformation network to detect slight ground movements, and the analysis of volcanic gases. Changes in some or all of these baselines might indicate intrusion of new magma into the volcano.

Periods of unrest at volcanoes are usually times of great uncertainty. Although outstanding advances have been made in volcano monitoring and eruption forecasting over the past few decades, scientists are often able to make only very general statements about the probability, type, and scale of an impending eruption. Precursory activity can go through accelerating and decelerating phases, and sometimes die out without leading to eruption. Government officials and the public must realize the limitations in forecasting eruptions and be prepared for such uncertainty.

Once lava-dome growth begins, scientists will be able to detect most collapses that could generate pyroclastic flows, lahars, and tephra falls by using a combination of visual observations, seismic monitoring, flow detectors, and weather radar. Warnings that an event is in progress could then be broadcast by emergency-response agencies. At times when darkness or clouds hamper visual observations, great uncertainty will probably exist about the character and size of an event. Specific, *advance* warning of individual dome-collapse events probably would not be possible; however, seismic or other evidence would signal the onset of a period of dome growth, during which dome collapses would be likely.

Some other hazardous events at Mount Hood, including debris avalanches and related lahars, may occur with little or no advance warning. However, the onset of earthquakes and ground deformation related to magma intrusion would increase the probability of debris avalanches, especially those of large size that have the greatest chance of inundating developed areas.

PROTECTING OUR COMMUNITIES AND OUR FAMILIES FROM VOLCANO HAZARDS

Communities, businesses, and citizens need to plan ahead to mitigate the effects of future eruptions, debris avalanches, and lahars. Long-term mitigation includes using information about volcano hazards when making decisions about land use and siting of critical facilities. Development should avoid areas judged to have an unacceptably high risk or be planned to reduce the level of risk. For example, a real-estate development along a valley could set aside low-lying areas at greatest risk from lahars for open space or recreation, and use valley walls or high terraces for houses and businesses.

When volcanoes erupt or threaten to erupt, emergency responses are needed. Such responses will be most effective if citizens and public officials have an understanding of volcano hazards and have planned the actions needed to protect communities. Mount Hood has a settlement (Government Camp), major highways (US 26 and OR 35), and popular tourist and recreation areas (Timberline Lodge and Mount Hood Meadows Ski Area) on its flanks. Furthermore, several thousand people live within 35 kilometers (22 miles) of Mount Hood along the channels and flood plains of rivers that drain the volcano. Such areas are at greatest risk from lahars and debris avalanches and could be inundated within one hour of an event's onset.

Because an eruption can occur within days to months of the first precursory activity and because some hazardous events can occur without warning, suitable emergency plans should be made before hand. Public officials need to consider issues such as public education, communications, and evacuations. Emergency plans already developed for floods may apply, with modifications, to hazards from lahars.

Businesses and individuals should also make plans to respond to volcano emergencies. Planning is prudent because once an emergency begins, public resources can often be overwhelmed, and citizens may need to provide for themselves and make informed decisions. The Red Cross recommends numerous items that should be kept in homes, cars, and businesses for many types of emergencies that are much more probable than a volcanic eruption. A map showing the shortest route to high ground will also be helpful.

The most important additional item is knowledge about volcano hazards and, especially, a plan of action based on the relative safety of areas around home, school, and work. Lahars pose the biggest threat to people living in valleys that drain Mount Hood. The best strategy for avoiding a lahar is to move to the highest possible ground. A safe height above river channels depends on many factors including size of the lahar, distance from the volcano, and shape of the valley. For areas beyond the proximal hazard zone, few lahars will rise more than 30 meters (100 feet) above river level. Be aware that an approaching lahar will cause a loud roaring noise like a gradually approaching jet plane. Once audible, a lahar may be only a few minutes away.

REFERENCES AND SUGGESTED ADDITIONAL READING

Brantley, S.R., and Scott, W.E., 1993, The danger of collapsing lava domes: Lessons for Mount Hood, Oregon: Earthquakes and Volcanoes, v. 24, no. 6, p. 244-269.

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END NOTES

[1] The geologic data upon which this report is based comes from reports and maps published during the past 35 years, as well as from our ongoing investigations of Mount Hood. Sources include: D.E. Trimble, 1963 , Geology of Portland, Oregon, and adjacent areas: U.S. Geological Survey Bulletin 1119; W.S. Wise, 1969, Geology and petrology of the Mt. Hood area: A study of High Cascade volcanism: Geological Society of America Bulletin, v. 80, p. 969-1,006; D.R. Crandell, 1980, Recent eruptive history of Mount Hood, Oregon, and potential hazards from future eruptions: U.S. Geological Survey Bulletin 1492; K.A. Cameron and P.T. Pringle, 1986, Postglacial lahars of the Sandy River basin, Mount Hood, Oregon: Northwest Science, v. 60, p. 225-237; K.A. Cameron and P.T. Pringle, 1987, A detailed chronology of the most recent major eruptive period at Mount Hood, Oregon: Geological Society of America Bulletin, v. 99, p. 845-851; and unpublished work by former and present U.S. Geological Survey staff (J.E. Costa, C.A. Gardner, J.J. Major, T.C. Pierson, W.E. Scott, D.R. Sherrod, R.I Tilling, and J.W. Vallance).

[2] The hazard map that accompanies this report differs in several respects from the map produced by D. R. Crandell in his 1980 hazard map of Mount Hood (see **REFERENCES AND SUGGESTED ADDITIONAL READING**). In part this reflects differences in the amount of detail that can be shown at the different scales of the maps. For example the larger-scale 1980 map subdivides what on this map is distal hazard zone DA along Sandy River into two zones. Other differences reflect new information and interpretations and the inclusion of low probability-high consequence events.

[3] Approximate travel times of lahars from their initiation high on Mount Hood comes from an analysis of historical lahars at volcanoes in the Cascades and elsewhere. The 30-minute time used to separate proximal and distal zones and travel-time marks shown along distal valleys is a minimum estimate for flows of the size used to define zones DA and DB. The travel time for an event of larger size could be shorter.

[4] We estimate the probability of future events by determining their average frequency of occurrence over a given time period from the geologic and historical record of past events. We assume that the average frequency of future events should be about the same as the average frequency of past events, which we determine by dividing the time period of record by the number of events. The probability or likelihood of an event in the future derives from this average frequency. For instance, much of hazard zone PA was affected by at least two episodes of eruptive activity centered near Crater Rock during the past 1,500 years, an average frequency of one episode every 750 years, or roughly one episode every 500 to 1,000 years. For relatively rare events such as volcanic eruptions, we commonly report probabilities for a time interval of 30 years rather than one year, because the longer time perspective pertains to such human milestones as the span of a generation, the term of a home mortgage, or a substantial portion of the useful life of public structures such as schools and hospitals. The probability is about 1 in 15 to 1 in 30 that an episode of lava-dome growth will commence near Crater Rock in the next 30 years. Zone PB has not been extensively affected during the past 10,000 years, but has on numerous occasions between 10,000 and 100,000 years ago. Therefore we estimate the 30-year probability of lava-dome growth shifting to the east, north, or west flank and extensively affecting zone PB to be on the order of 1 in 300. For comparison, the 30-year probability of a given house being damaged by fire in the United States is about 1 in 90. We caution that these probabilities are based solely on the long-term behavior of the volcano and that they will rise dramatically with any sign of increased restlessness at Mount Hood.

[5] Essentially all of hazard zone DA along White River has been inundated during both eruptive episodes of the past 1,500 years and therefore is assigned the same 30-year probability as that for renewed dome growth near Crater Rock, 1 in 15 to 1 in 30.

[6] We use one-dimensional hydraulic flood-routing models, calibrated for lahar flows, to predict lahar depth and extent in downstream valleys. Two different models were used for this analysis: a USGS model called HYDRAUX and a National Weather Service model called DAMBRK. Both models are fully dynamic, one-dimensional, unsteady-state, finite-difference mathematical models developed to simulate floods, but were calibrated with data from actual lahars at Mount Hood and other Cascade volcanoes in order to get realistic values for flow resistance. We assume a debris avalanche of 50 million cubic meters, which would entail the removal of a mass measuring about 800 meters long 400 meters wide and 150 meters thick (2600 by 1300 by 500 feet) from the upper flank. In running the model, we assume that this initial volume of 50 million cubic meters moves past the first upstream valley cross section as a triangular-shaped hydrograph with a peak discharge of 70,000 cubic meters per second and a duration of 0.4 hour.

[7] Maps were generated by computer program developed by R.P. Hoblitt (U.S. Geological Survey, Cascades Volcano Observatory, written communication, 1996).

[8] Distribution of volcanic vents is modified from Sherrod and Smith (1989), U.S. Geological Survey Open-File Report 89-14, and Sherrod and Scott (1995), U.S. Geological Survey Open-File Report 95-219. Hazard-zone boundary was made by assuming that future vents could be located anywhere within the broad region defined by vents of the past two million years and that lava flows can extend up to 15 kilometers (9 miles) from vents, where permitted by topography.

[9] Estimate of extent of 500 million cubic meter debris avalanche and lahar was obtained by using relationship of lahar volume to cross-sectional area of flow that was developed by R.M. Iverson and described in W.E. Scott and others, 1995, Volcano hazards in the Mount Adams region, Washington: U.S. Geological Survey Open-File Report 95-492. The zone on this map represents the projection of a cross-sectional area of about 33,000 square meters (355,000 square feet) down the Sandy and Hood River valleys. A volume of 500 million cubic meters was selected to represent a large-volume debris avalanche based on the following comparison to the 1980 debris avalanche at Mount St. Helens. The 1980 avalanche removed about 2,300 million cubic meters from an area on the north flank that had a surface slope of 0.5. The avalanche removed about 25% of the cone's volume above the altitude at which the failure plane intersected the lower north flank. In contrast to St. Helens, Mount Hood has much more concave flanks so that slopes steeper than 0.5 are chiefly confined to the upper part of the volcano except in the heads of a few canyons on the west flank. Thus, there is less volume available in the upper edifice from which to generate a large debris avalanche. The 25% value from Mount St. Helens applied to Hood yields potential avalanche volumes of several hundred million cubic meters from south and east flanks, 500 million cubic meters from the north flank, and up to 1000 million cubic meters or more from the steep valleys on the west flank. Structural (presence of a pre-Mount Hood edifice forming much of the steep valley heads) and topographic (narrowness of west flank canyons would probably result in a large failure not being restricted to a single drainage) considerations probably reduce the potential volume on the west flank to less than 1000 million cubic meters. Thus we regard 500 million cubic meters as a reasonable maximum volume for a debris avalanche but caution that, under extreme conditions, avalanches up to twice as large might originate on the west flank.

[10] A ratio of height of drop (measured from the summit of Mount Hood) to length of runout of 0.09, similar to that of the 1980 directed blast at Mount St. Helens, was used to estimate the potential extent of a directed blast at Mount Hood.