

Post-Glacial Lahars of the Sandy River Basin, Mount Hood, Oregon

Abstract

Within the last 10,000 years, three significant lahar-producing periods have occurred at Mount Hood, Oregon. The Timberline eruptive period occurred between 1400 and 1800 years BP. It was by far the most voluminous of the three periods, producing enough clastic debris to bury the glacial topography of the southwest face of the mountain beneath a smooth debris fan. Smaller debris fans were formed in the upper reaches of the Sandy and Salmon Rivers. Timberline-age lahars traveled the length of the Zigzag and Sandy Rivers, a distance in excess of 90 km. These lahars and associated fluvial deposits helped form flat-floored valleys near the confluence of these rivers and created a delta at the mouth of the Sandy at the Columbia River. The flows probably attained depths of 9 to 12 m above modern river level for most of their passage. Pyroclastic flows of this age traveled at least 13 km from the vent area at Crater Rock along the Zigzag or Little Zigzag Rivers.

Between 400 and 600 years BP, the Zigzag eruptive period produced deposits along the middle reaches of the Zigzag River and the upper Sandy River. Bouldery lahars and fluvial deposits created a terrace 8 to 10 m above present river level along the Zigzag and veneered a Timberline-age terrace on the Sandy River. The Old Maid eruptive period occurred between 180 and 270 years BP. A single lahar flowed down the Sandy River at least as far as Brightwood, 30 km from Crater Rock. Sand deposits that may be related to this event are found down to the mouth of the Sandy River. A single lahar also flowed at least 18 km down the Zigzag River. The lahars, which were probably about 9 m deep, buried mature cedar forests along both rivers.

Introduction

Since the end of the Fraser alpine glaciation about 10,000 years ago, three significant lahar-producing eruptive periods have occurred at Mount Hood. The lahars were confined to river basins originating on the southwest flank of the mountain. The older, Timberline eruptive period occurred 1400 to 1800 years BP (Crandell, 1980), the Zigzag eruptive period 400 to 600 years BP, and the more recent Old Maid eruptive period occurred 180 to 270 years BP (Crandell, 1980). Deposits from the Timberline eruptive period (informally termed Timberline-age in this report) can be traced the length of the Zigzag and Sandy Rivers to the Columbia River. Flows from the Zigzag eruptive period (informally termed Zigzag-age in this report) have been identified only in the middle Zigzag basin and in the upper Sandy basin at Old Maids Flat. Deposits from the Old Maid eruptive period (informally termed Old Maid-age in this report) have been identified from the upper Sandy basin downstream to 2.5 km below the confluence of the Sandy and Salmon Rivers near the hamlet of Brightwood and at a single locality below the confluence of the Zigzag and Little Zigzag Rivers.

Although the lahars from the three eruptive periods affected all drainages on the southwest flank of Mount Hood, this paper will be limited

to a discussion of the deposits in the Sandy and Zigzag drainage basins (Figure 1). These basins were chosen due to the concentration of population and recent intense development, which would exacerbate the effects of future eruptions.

Crater Rock

A composite dome known as Crater Rock lies at the apex of the smooth debris fan which gives the southwest side of Mount Hood its distinctive profile (Figure 2). This mass of amphibole-rich phytic dacite sits atop the modern vent, and its extrusion was the probable causative force behind lahar generation.

Field studies and air-photo interpretation show that the Crater Rock dome is composed of at least three lobes (Figure 3). This is based upon degree of alteration, texture, and fabric contrasts between different areas of the dome. The dacite of Lobe 1 has an oxidized, brick red or pink colored matrix, but phenocrysts of plagioclase and amphibole are unaltered. Localized areas of high fumarolic activity have created patches of white and yellow alteration and encrustation. Spires of whitish, pumiceous rock rise 5 to 10 m above the surface of the dome on the north-northwest side of the lobe. The general surface is very irregular and angular with local relief of over 1 m. The lobe shows no obvious fabric.

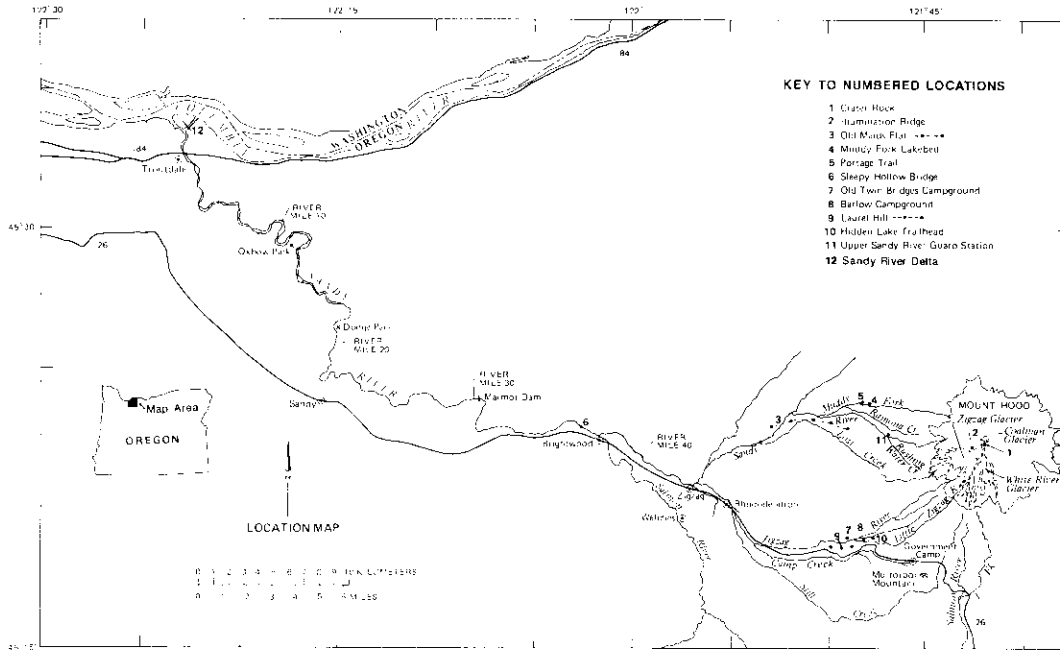


Figure 1. General location map for the Sandy and Zigzag River basins.

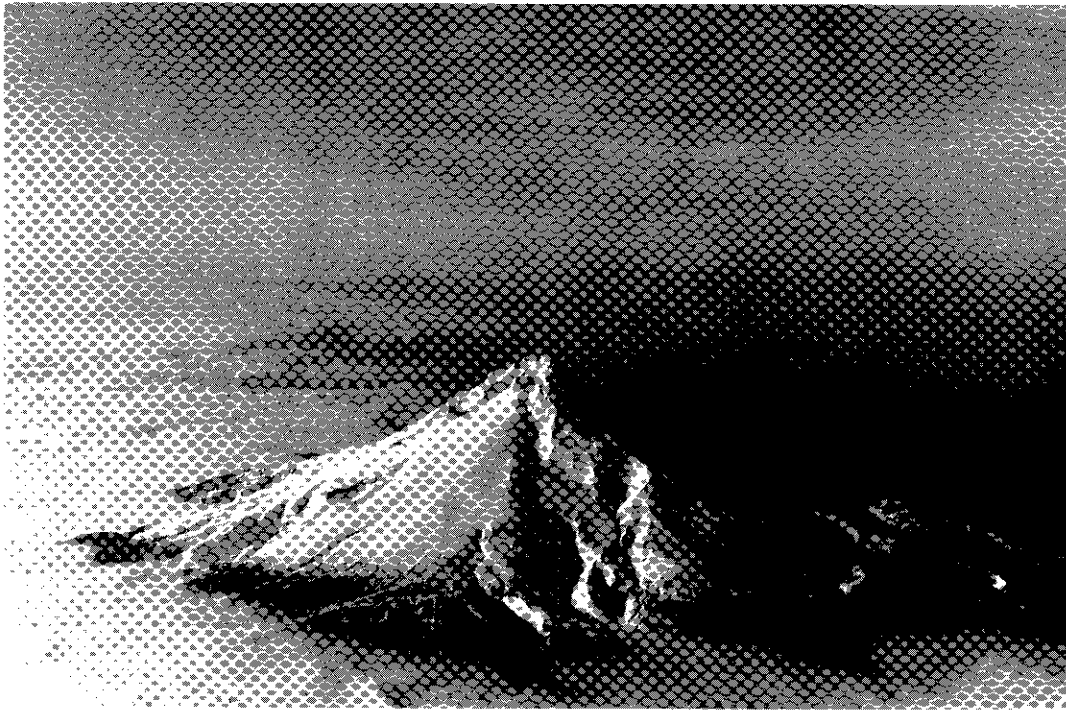


Figure 2. Southwest flank of Mount Hood showing the smooth surface of the main debris fan formed during the Timberline eruptive period, with Crater Rock at its apex. Mount Adams, Washington, is in the background. Photograph by Ellen Cameron.

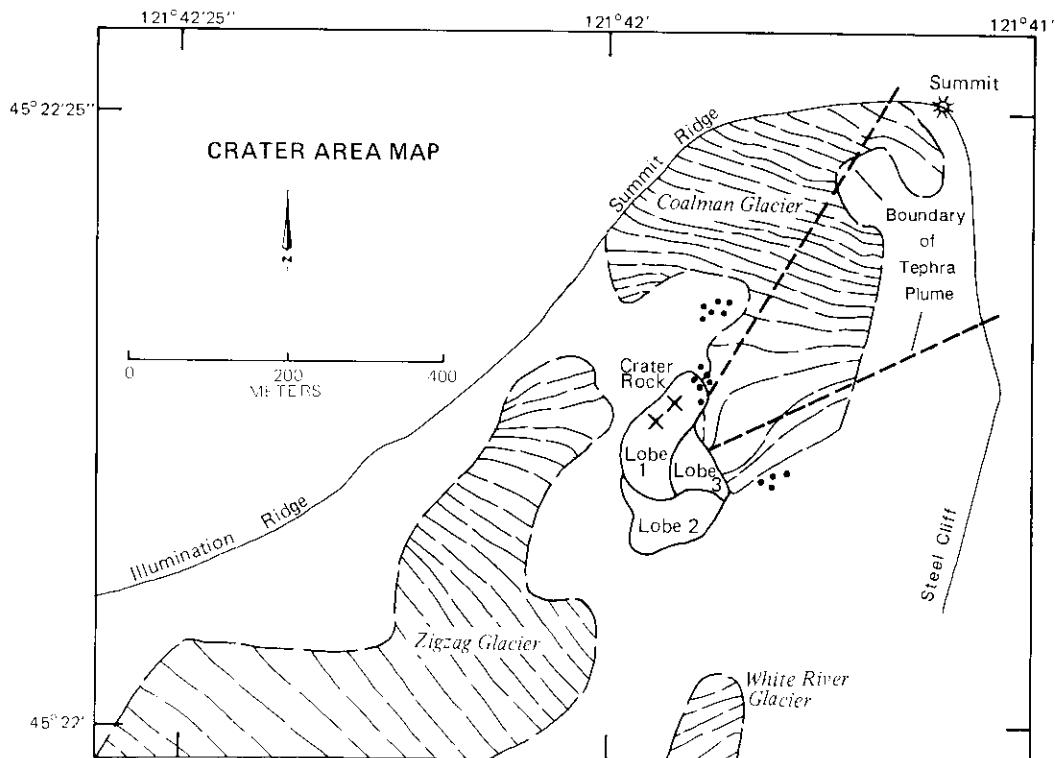


Figure 3. Map view of Crater Rock and surrounding area showing location of the three lobes. Dots represent fumarolic areas. "X" indicates spines on the dome. Dashed lines indicate inferred limits of the breadcrust-bomb tephra plume.

Lobe 2 has an unaltered grey matrix and a much smoother surface texture with local relief of under 1 m. It possesses a general fabric in the form of platy jointing that dips to the southwest (down slope) and is the result of flow within the lobe during extrusion. It is separated locally from Lobe 1 by deep crevasses eroded along the contact. No current fumarolic activity was seen on Lobe 2.

Lobe 3 appears to be the youngest area of the dome. Whether it is a true lobe with extensive talus cover or a deposit of angular clastic debris could not be determined due to snow cover and lack of penetrating exposures. Nevertheless, Lobe 3, as it will be called for convenience, is an area of grey, vesicular, unaltered, angular rubble. Individual clasts average 0.5 m in diameter, but a few range up to 2 m and all sizes commonly show thermally related prismatic fracture patterns. No current fumarolic activity was observed on this lobe.

Two main regions of fumarolic activity flank Crater Rock and bound Coalman Glacier (Figure 3). Temperatures of the fumaroles (84°C to 90°C) are at or below local boiling point. Hydrothermal alteration has reduced the surrounding fragmental debris to sticky yellow, red and blue-grey clay. Both fumarolic areas remain snow-free throughout the winter despite their elevation (3200 m) and prevent Coalman Glacier from joining Zigzag and White River Glaciers.

Timberline Eruptive Period

Timberline-age lahars are the most voluminous of the post-glacial lahar sequences. They form the bulk of the valley-fill deposits in the Sandy and Zigzag basins and the broad fan that extends from Crater Rock to the base of the mountain. Pyroclastic flow deposits of this age have been found as far as Barlow Campground on the Zigzag River (E1/2 NE1/4 Sec 15 T3S R8E), 13 km from the vent area, and lahar and hyper-

concentrated runout deposits as far as the mouth of the Sandy River at the town of Troutdale, 80 km from the source area.

Age and Origin

Radiocarbon dating, of organic debris entrained in the lahars, dates the Timberline flows at 1440 ± 155 to 1780 ± 200 years BP (Table 1). Deposits of Timberline age are found in all drainages on the southwest side of the mountain from the Salmon River (upper reaches only) west to the Sandy River. The extrusion and mass wasting of Crater Rock produced the pyroclastic flows and lahars. Prismatically jointed boulders are common throughout the lower 75 percent of the sequence but rare in the upper 25 percent, suggesting that lahar generation accompanied dome building.

Areal Distribution and General Stratigraphy

The main debris fan (Figure 4) is bounded on the north by Illumination Ridge, on the east by the right lateral moraine of White River Glacier, on the south by Multorpor Mountain and on the southwest by Laurel Hill. The actual thickness of the deposits is unknown, but exposures of over 15 m occur along Highway 26 at Laurel Hill (SE1/4 SW1/4 Sec 14 T3S R8E). Exposures measured from aerial photographs at the headcuts of the Sandy River and Rushing Water Creek are in excess of 100 m in height. These thicknesses probably represent filling of the pre-eruption glacial valleys of the headwaters of these rivers.

Exposures at Laurel Hill (SE1/4 SW1/4 Sec 14 T3S R8E) and in the village of Government Camp next to the fire station (NW1/4 Sec 23 T3S R81/2E), show two discrete textural zones within the Timberline deposits. Matrix-rich, sandy lahars and fluvial deposits constitute approximately the lower one half of both outcrops. Cobble or larger clasts make up less than 10 percent of these flow units. (In all subsequent descriptions of deposits, the term "clast" will be used to mean lithic fragments obviously larger than the matrix material.) Maximum clast size is 10 to 20 cm in diameter. Thinly laminated and cross-bedded fluvial layers up to 10 cm thick intercalate with lahars that average 1.5 to 2 m thick. The sandy deposits of the lower half change

abruptly to bouldery lahars and flood deposits of the upper half of the sequence. Here clasts make up 40 to 70 percent of the flow units. Average clast size is 20 to 50 cm in diameter with rare boulders to 2 m. Individual flows are 1 to 1.5 m thick. Lenses of bedded fluvial sand and gravel 20 to 50 cm thick and 1 to 4 m long are occasionally found in the upper half. Weathering of the top unit extends downward for at least 40 cm at all sites measured on the fan, with 40 to 70 cm of weathering typical for deposits of this age in the Sandy River basin (Crandell, 1980).

The timberline-age deposits of the debris fan are veneered by sand- and gravel-sized angular particles of grey, phyrlic dacite. This is inferred to be air-fall material from small events reported to have occurred in the mid 1800's (Folsom, 1970). This deposit is rarely over 1 cm thick and lies directly on the ground surface.

Below the main debris fan and above Old Maids Flat the Sandy River flows through a narrow gorge cut through the Pliocene volcanic rocks of the Sandy Glacier volcano (Wise, 1969) and the Pleistocene and Holocene deposits of the Mount Hood cone. The high gradient and narrow nature of the gorge precludes the accumulation of more than a trace of deposits.

At the mouth of the canyon, a widening valley and decreasing gradient have allowed the formation of a debris fan at Old Maids Flat which is composed of Timberline-age deposits (Figure 4). The fan, covering an area 0.5 km wide by 1.5 km long, has been dissected by the Sandy River and yields exposures up to 60 m high. The deposits of the Old Maids Flat debris fan show a distinct textural variation similar to that of the main debris fan. The lower one-third is a sequence of sand-rich laharic and fluvial beds ranging in thickness from 1.5 to 3 m, which appear to contain less than 10 percent clasts. The upper two-thirds of the exposure is composed of intercalated cobble and boulder lahars and fluvial beds, with thicknesses ranging from 1.5 to 2 m. Clasts make up 20 to 70 percent of the lahars by volume, the remainder being a matrix of coarse lithic sand. The fluvial beds are generally thinner than the lahars and are composed of stratified sand and gravel. Most of the beds are laterally discontinuous and probably represent fill deposits within shallow, meandering channels on the aggrading fan surface. Cut and fill features are

TABLE 1. Radiocarbon dates from drainages on the southwest flank of Mount Hood.

Location and Setting	Age	Reference
Sandy River near Zigzag, charcoal in duff between lahars SE1/4 SE1/4 Sec 33 T2S R7E	200	Crandell, 1980
White River, terrace near timberline, limb in lahar N1/2 Sec 8 T3S R9E	185 ± 120	Cameron, Pringle
Sandy River, north bank, 2 km NW of Guard Station, Old Maids Flat, charcoal in lahar	220 ± 150	Crandell, 1980
Sandy River, margin of Old Maids Flat, exact location unknown, standing stump buried by lahar	250	Crandell, 1980
White River, upper canyon, standing stump buried by lahar N1/2 Sec 8 T3S R9E	250 ± 150	Lawrence, 1959
White River near Highway 35 crossing, wood in pyroclastic flow SW1/4 Sec 16 T3S R9E	260 ± 160	Crandell, 1980
Zigzag River at Twin Bridges, standing cedar snag killed by lahar NW1/4 Sec 15 T3S R8E	270 ± 150	Cameron, Pringle
White River at Tygh Valley, wood fragments in lahar N1/2 Sec 12 T4S R13E	425 ± 150	Cameron, Pringle
Sandy River at Old Maids Flat, "bayonet tree" buried by lahar NE1/4 Sec 23 T2S R8E	455 ± 135	Cameron, Pringle
Zigzag River near Twin Bridges, standing stump buried by lahar NW1/4 Sec 15 T3S R8E	550 ± 130	Cameron, Pringle
Muddy Fork Sandy River at Portage Trail crossing, Old Maids Flat, wood from ash layer below upper lahar	560 ± 150	Cameron, Pringle
White River at White River Station, charcoal in soil below lahar NW1/4 Sec 30 T4S R10E	1340 ± 160	Cameron, Pringle
Zigzag River at Barlow campground, charcoal from upper pyroclastic flow SE1/4 NE1/4 Sec 15 T3S R8E	1440 ± 155	Cameron, Pringle
Sandy River, south bank, 0.2 km SW of Guard Station, Old Maids Flat, log carried in lahar	1530 ± 200	Crandell, 1980
Near Government Camp, along road, charcoal in ash above glacial age deposits S1/2 Sec 18 T3S R9E	1610 ± 200	Crandell, 1980
Base of Multoppor Mountain, log carried in lahar N1/2 Sec 23 T3S R81/2E	1670 ± 200	Crandell, 1980
White River, top of left lateral moraine charcoal under ash layer NW1/4 SE1/4 Sec 16 T3S R9E	1690 ± 140	Cameron, Pringle
Sandy River near Zig Zag, log carried in lahar SE1/4 SE1/4 Sec 33 T2S R7E	1780 ± 200	Crandell, 1980
White River at Tygh Valley, charcoal in sands below lahar N1/2 Sec 12 T4S R13E	2080 ± 115	Cameron, Pringle
Sandy River 4 km from Brightwood, wood from lahar NE1/4 Sec 22 T2S R6E	40,000	Crandell, 1980

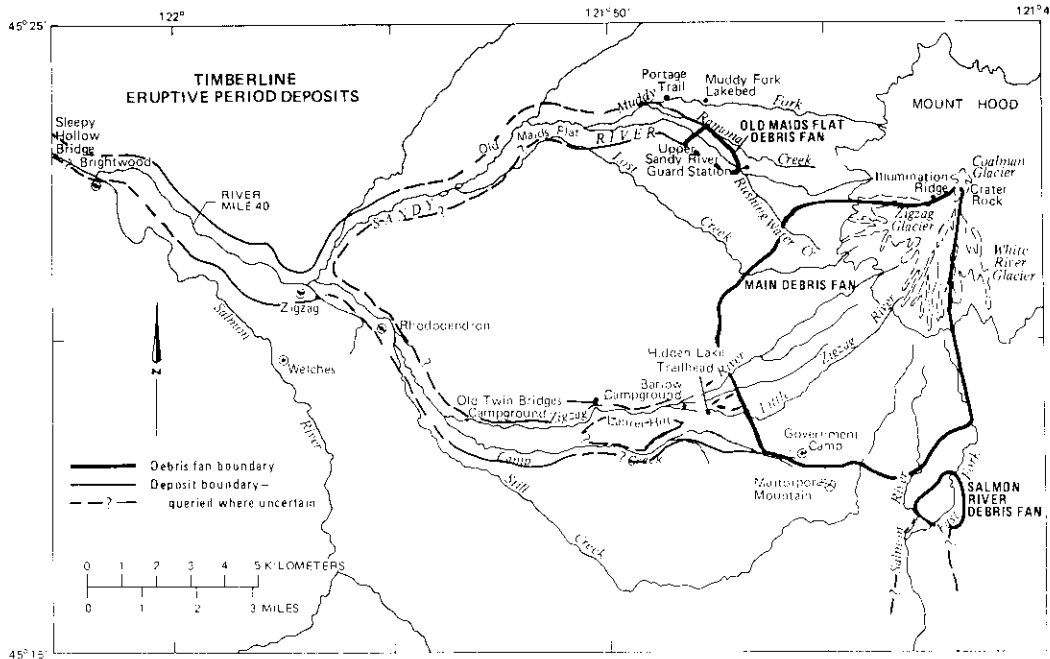


Figure 4. Inundation boundaries of the Timberline eruptive period.

common, with some channels being up to 4 m wide and 2 m deep.

Timberline-age lahars fill the Sandy River valley from the Old Maids Flat debris fan downstream to the power diversion dam at Marmot, forming a flat valley floor 0.5 to 3 km wide. The true thickness of the deposits is unknown, but well-logs from two geothermal test wells located on Old Maids Flat (NE1/4 SE1/4 Sec 15 T2S R8E and SW1/4 SE1/4 Sec 15 T2S R8E) list thicknesses of the mudflow sequence at 80 and 30 m, respectively (Priest and Vogt, 1982).

Exposures 1 to 2 km downstream of the Old Maids Flat debris fan show only the lower, sandy part of the Timberline-age sequence. Individual flows are 1 to 3 m thick and contain less than 10 percent cobble or larger clasts. Maximum clast size is 1 m. Beyond 2 km, only the upper, coarser portion of the sequence is found. The coarser lahars are generally matrix-supported cobble and boulder lahars with clasts composing 20 to 70 percent of the unit. Average clast size is 5 to 10 cm with a maximum of 80 cm. The flows are separated by fluvial sand and gravel. Individual flow deposits average 1 m thick with an observed minimum of 0.4 m and a maximum of

1.2 m. The uppermost unit of each exposure is oxidized to a depth of 40 to 60 cm.

The power diversion dam at Marmot (SE1/4 NE1/4 Sec 13 T2S R5E) marks the transition from valley filling by Timberline-age lahars to migration of the lahars along the river with little deposition. The river flows through narrow, bedrock gorges between river miles 3 and 8, and between 15 and 30. (River miles are marked on most quadrangles for this region and this use is the reason for citing the English measurement rather than the metric equivalent.) Deposits within these reaches are limited to point bars and veneers on lower terraces.

Between the dam and the mouth of the Sandy River Timberline-age deposits were positively identified at only four locations: near the town of Troutdale (NW1/4 Sec 25 T1N R3E), Oxbow Park (SW1/4 Sec 10 T1S R3E), Dodge Park (NE1/4 Sec 36 T1S R4E), and at Marmot dam (NE1/4 Sec 13 T2S R5E) (Figure 1). At each site a maximum of two lahars was found. Average thickness of each lahar deposit was just over 0.5 m with a maximum of 1.5 m at Troutdale. The lahars are generally separated by fluvial or hyper-concentrated runout deposits. Average clast size

is from 2 to 5 cm, with a maximum of 10 cm. All lahar deposits are matrix-supported with clasts composing 30 to 70 percent of the unit.

A well-developed delta occurs at the mouth of the Sandy River which, until the construction of a rockfill dam, split the river into two channels. The surface of the delta is veneered by modern flood deposits from both the Sandy and the Columbia Rivers but it is assumed to be cored by Timberline-age deposits.

As with the Sandy River, the Zigzag and Little Zigzag Rivers pass through narrow, deep canyons in their upper reaches that preclude the accumulation of large deposits. Below the rivers' confluence, Timberline-age lahars have filled the valley to an unknown depth, producing a flat-floored valley extending to the Sandy River valley.

Exposures are rare in the valley below the canyons. The rivers are not actively incising or side cutting, and vegetation extends to the water's edge. A 10 m thick sequence of cobble and boulder lahars is exposed in a road cut at the abandoned bridge over the Little Zigzag River (SW1/4 NW1/4 Sec 14 T3S R8E). These flows came down the Little Zigzag River or spilled over the low saddle divide from the upper Camp Creek area of the main debris fan. Here the lower, sandy portion of the Timberline-age sequence is not present. A quarry near the Hidden Lake trailhead (SE1/4 NE1/4 Sec 15 T3S R8E) exposes at least 8 m of pyroclastic flow and lahar deposits. Two pyroclastic flows are separated by a discontinuous gravel layer and overlie at least one sandy lahar. The upper pyroclastic flow was dated at 1440 ± 155 years BP (Table 1) which places it near the end of the Timberline eruptive period. This exposure is in a 10 to 15 m high terrace formed along a 1 km reach below the confluence of the Little Zigzag and the Zigzag River. It is not known down which river the flows came. The height of the terrace and the thickness of the pyroclastic flow deposits is inconsistent with the lack of downstream deposits. Either erosion has removed the deposits or the flows simply did not extend any farther. A flattening of the valley gradient combined with a constriction in valley width at this point might have caused ponding of the flow.

The only other known Timberline-age deposits found in the Zigzag basin are in shallow

exposure of 1 m or less in road cuts and drainage ditches (SW1/4 NE1/4 Sec 16 T3S R8E, road cut; SE1/4 NE1/4 Sec 17 T3S R8E, road cut; NE1/4 SE1/4 Sec 18 T3S R8E, road cut; NE1/4 NE1/4 Sec 19 T3S R8E, drainage ditch).

Timberline-age deposits have been identified only in the upper reaches of the Salmon River, including a well-defined alluvial fan (Figure 4) at the mouth of the upper Salmon River canyon (Sec 19, 20, 29, 30 T3S R9E). Numerous meadows, ponds and bogs occupy a large, low-gradient reach of the river immediately below the fan. No phytic rock types indicative of a Crater Rock origin were found in stream bank deposits in the canyon below the low-gradient reach. Evidently the Timberline-age lahars in the Salmon River were neither voluminous nor energetic enough to cross the low-gradient reach below the alluvial fan.

Physical Characteristics

Timberline-age lahars, exclusive of the debris fans, are generally interbedded with fluvial sands and gravels, this feature becoming more pronounced as distance from the mountain increases. The fluvial interbeds probably represent lahar material reworked by floods that followed shortly after the lahars. Lack of soil horizons between the lahar and fluvial material shows that the time span between the events was minimal. Observations of the lahar deposits of the Toutle River system at Mount St. Helens show that rivers affected by lahars carry large sediment loads until the thalweg has been flushed of sediment. Until then, aggradation of the river bed in low-energy reaches can greatly decrease the carrying capacity of the river channel, making floods more common and severe.

The textural variation of the Timberline-age deposits, with a lower sandy portion and an upper coarser portion, suggest early, fine-grained-producing events and later, coarse clastic material production. The extrusion of the Crater Rock dome might have been preceded by ash emissions and ash-rich pyroclastic flows which, because of the high gradient and available water source in the form of snow and glacier ice, produced the sandy lahars that form the lower portion of the Timberline-age deposits. Once the dome became established, mass wasting or collapse of the growing extrusion would have

supplied the coarse clastics of the upper portions of the sequence.

Clast size generally decreases downstream. Average clast size in the bouldery section of the main debris fan 8 km from the source is 20 to 50 cm in diameter with a maximum of 2 m. On Old Maids Flat, 12 km from the source and downstream from the Old Maids Flat debris fan, the average size is 10 to 20 cm with a maximum of 1 m. Near Brightwood, 40 km from the source, the average clast size is 8 to 15 cm and the maximum is 50 cm. At Troutdale, 80 km from the source, the average size is 1 to 3 cm and the maximum is 10 cm.

Generation of lahars by the extrusion and mass wasting of Crater Rock should have produced a clast lithology predominantly the same as Crater Rock. Samples of average sized clasts were taken from three sites along the Sandy River and the clasts divided into lithologic groups based upon "hand lens" petrology. Sample sites were near Brightwood (SW1/4 NW1/4 Sec 22 T2S R6E, two lahars sampled), Marmot Dam (NW1/4 NE1/4 Sec 13 T2S R5E, one lahar sampled) and Oxbow Park (SW1/4 SW1/4 Sec 10 T1S R4E, one lahar sampled). The sites are 25, 30 and 45 km by river from the source area on the mountain.

Clasts were divided into three dominant rock types: grey-matrix phyrlic dacite, red-matrix phyrlic dacite, and "other rocks." Both phyrlic dacite rock types are similar in gross petrology to lithologic types found on Crater Rock. Phenocrysts comprise 20 to 40 percent of the dacites, with an aphanitic or phaneritic matrix. Phenocrysts are predominantly (80 percent) euhedral plagioclase 1 to 3 mm across with accessory subhedral amphibole 0.5 to 3 mm across. The matrix varies from being truly aphanitic to possessing discernible microlites of plagioclase set in an aphanitic groundmass. Oxidation, which gives a reddish color to some of the clasts, is confined to the aphanitic portions of the matrix with neither microlites nor phenocrysts showing any alteration. At the dome on Mount St. Helens this type of matrix oxidation has at times occurred within months of the extrusion of a lobe. Angular voids less than 1 mm across form up to 5 percent of the volume of some of the clasts.

The "other rock" category includes all rock types other than the phyrlic dacite. Included are tabular to rounded clasts of aphyric andesite, in-

trusive rocks from small stocks to the west and southwest of the mountain, and very scoriaceous and altered rocks from lava flows. These "other" clasts are assumed to have been incorporated into the lahar as it moved down stream channels.

Relative percentages among the rock types vary somewhat from site to site, which may be a function of the small sample size (usually 15 to 20 clasts, or all that would fit into an easily carried sample bag). A few trends, however, are distinguishable. Crater Rock-type lithologies generally make up about 60 percent of the clasts by number. This indicates that incorporation of material during flow played an important role in determining the actual volume of the lahar. The rock types represented in the "other rocks" category are found only high on the slopes of the mountain and not from the formations exposed in the valley walls away from the cone, such as olivine basalt of the Sandy River Glacier Volcano, altered basalt of the Miocene Rhododendron Formation, and flows of the Yakima Basalt Subgroup of the Miocene Columbia River Basalt Group. Incorporation of exotic clasts must have occurred primarily high on the cone of the mountain. This premise is supported by personal observations at Mount St. Helens of recent, small scale lahars that showed the lahars to be erosional only in the early stages of flow and to rapidly become depositional.

Estimated Depth of Timberline-age Lahars During Flow

Depth of the lahars during peak flow cannot be determined from the height of deposits above river level, but personal observations of lahars and their deposits at Mount St. Helens provides a basis for some interpretations. On the Toutle River and its North Fork, which resemble the Sandy River below the Old Maids Flat debris fan in channel and valley morphology, the height of the lahar deposits above river level varies between 20 and 70 percent of the true depth of the lahar at peak flow as determined by mudlines and trimlines. In constricted reaches, deposits ranged from 20 to 40 percent of the peak flow height. In more open reaches, deposits ranged from 50 to 70 percent of the peak flow height. In very narrow, steep reaches, such as in the headwaters of the South Fork of the Toutle and in Sheep Canyon, the height of the deposits is less than 1 to 10 percent of the peak flow height.

Deposit height on the Sandy River on Old Maids Flat is 7.3 m above water level; at the confluence with the Zigzag River, 8.5 m; at Sleepy Hollow bridge, 8.5 m; at Oxbow Park, 7.0 m; and at Troutdale, 5.8 m. All of these sites are in open reaches; therefore, it can be conservatively estimated that peak flow heights of the lahars approached one and a half times the height of the deposits. This would produce a peak stage 9 m above the present river level at Troutdale and 10 to 12 m at the upstream sites.

Zigzag Eruptive Period

Deposits from a previously undescribed sequence of lahars and associated fluvial deposits form an 8 m high terrace along a single reach of the Zigzag River just below its confluence with the Little Zigzag River (Figure 5) and caps part of a 30 m high erosional terrace in the Old Maid debris fan. This sequence has the lowest volume and extent of the three major post-glacial lahar sequences. Within this paper it will be referred to as the Zigzag eruptive period.

Age and Origin

Along the Zigzag River (N1/2 Sec 15 T3S R8E) the flows buried a stream-bank forest of mature Douglas fir, and standing trunks still exist that are at least 2 m tall. The bark from one of these stumps has been dated at 550 ± 130 years BP (Table 1). This date corresponds well with the 560 ± 150 years BP age of wood from a tephra layer in the upper Sandy River basin and suggests an eruption which produced both lahars and air fall material. On the Old Maid debris fan 1 km downstream from the Upper Sandy River Guard Station (NE1/4 Sec 23 T2S R8E) a single sandy, cobble lahar caps an erosional terrace 30 m above present river level. The flow overran and charred a stand of young Douglas fir trees 5 to 10 cm in diameter. These trees are aligned in downstream orientations similar to the "bayonet" trees flattened by the lahars at Mount St. Helens (Janda and others, 1980). Wood from these trees has been dated at 455 ± 135 years BP.

Areal Extent and Stratigraphy

Laharic deposits of this age are restricted to a terrace on the right bank of the Zigzag River

below its confluence with the Little Zigzag River and veneer a terrace in the Timberline-age deposits of the Old Maid debris fan (Figure 5). The Zigzag basin terrace is at least 1 km long and averages 100 m wide. It merges with the valley wall at its upstream end and terminates abruptly downstream in a series of erosional terraces. The valley narrows considerably at this point and may have caused ponding of the flows, creating the thick, localized deposits and may explain the lack of any exposures downstream. It is in this reach that the thick but not laterally extensive Timberline-age pyroclastic flows are found. They, too, may have ponded behind this valley constriction.

The terrace is composed of a lower, bouldery deposit 3 to 4 m thick that is massive and made up of rounded clasts up to 0.5 m in diameter set in a sandy matrix. Portions of the deposit are clast-supported. The flows engulfed a forest of mature Douglas fir trees up to 0.5 m in diameter but left the bark intact on the upstream sides and undamaged brushy branches wrapped around the trunks. The rooted bases of some of these stumps are at the modern river level and show that the Zigzag River has returned to the base level which existed before the formation of the terrace.

Overlying the bouldery deposit are 2 to 3 m of intercalated lahar, hyperconcentrated runout and fluvial sand deposits. These units are generally less than 1 m thick and are not laterally traceable. They represent thin flows which washed over the flat surface of the fill material immediately after its emplacement. The thin units are topped by 10 cm of soil and forest duff which is in turn overlain by a lahar of Old Maid-age.

The deposit on the Old Maid debris fan terrace is 0.9 m thick and represents a single, sandy cobble lahar. The height of the terrace above river level at the time of the lahar is unknown, but it is 30 m above modern levels. The deposit now supports a Douglas fir forest of greater density and size than elsewhere on the Old Maids Flat surface. This vegetative difference is readily apparent on air photos and shows that the deposit is limited to a terrace 0.5 km long and 100 m wide. No other evidence of this flow is found in the Sandy basin.

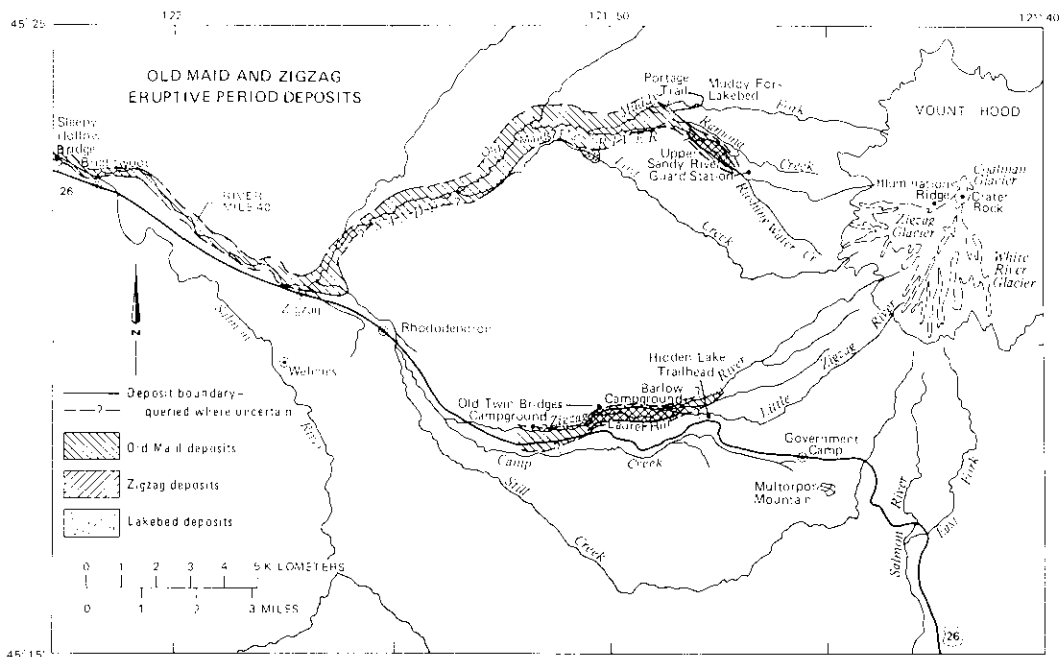


Figure 5. Inundation boundaries of the Zigzag and Old Maid eruptive periods and the location of two Old Maid age lakes.

Old Maid Eruptive Period

More than 20 exposures of Old Maid age lahar deposits have been located in the Sandy and Zigzag River drainages. Although a succession of Old Maid age lahars is found in the White River canyon on the south side of Mount Hood, only a single lahar unit has been identified in the Sandy and Zigzag basins in any one exposure. Old Maid age deposits essentially form a veneer on the surface of the voluminous Timberline-age deposits and on the Zigzag-age deposits along the Zigzag River (Figure 5). No deposits of Old Maid age were identified in the Little Zigzag and Salmon Rivers or in Still and Camp Creeks.

Age and Origin

Radiocarbon dating of wood samples suggests that the Old Maid eruptive period occurred between 200 and 300 years BP (Table 1). Historical accounts and dendrochronological work extend the lower limit to about 180 years BP.

In November of 1805 and April of 1806, Lewis and Clark explored a river they named Quick-sand River. Captain Clark described it as follows

in his journal (Thwaites, 1959), reproduced here with original spellings:

"... I arrived at the entrance of a river which appeared to scatter over a Sand bar, the bottom of which I could see quit across and did not appear to be 4 Inches deep in any part; I attempted to wade this Stream and to my astonishment found the bottom a quick Sand, and impassable... this river which we found to be a very considerable Stream Discharging its waters through 2 channels which forms an Island of about 3 miles in length on the river and 1 1/2 miles wide, composed of coarse sand which is thrown out of this quick sand river compressing the waters of the Columbia and throwing the whole current of its waters against its Northern banks... This stream has much the appearance of the River Platt, roleing its quick sands into the bottoms with great velocity after which it is divided into 2 channels by a large sand bar before mentioned, the narrowest part of this River is 120 yards." (3 Nov. 1805) "... above the point which it divided itself into two chanel, it is about 300 yards wide tho' the chanel is not more than 50 yards, and only 6 feet deep. the other part of the river from 2 to 4 inches water, the head of this river is formed entirely of quick sand; its banks are low and at present overflow. the water is turbed and current rapid." (1 April 1806)

The name of this river was shortened in later years to the Sandy River. The Sandy River is now

a boulder-armored river and the channel immediately above the delta is at least 3 to 4 m deep. Modern fall and spring floods do not generally overtop its banks. The expedition appears to have arrived while the river was still flushing the sediment of the Old Maid event through the system. Taking into account the rapidity with which some of the streams surrounding Mount St. Helens have recovered from damage induced by the 1980 eruption (staff members of the Cascades Volcano Observatory, personal communications, 1984), it is possible that the Lewis and Clark Expedition arrived within 5 to 10 years after a laharcic event.

Dendrochronologic samples were taken in the vicinity of Old Maids Flat in an attempt to refine the age range established by radiocarbon analysis and suggested by historical accounts. At Mount St. Helens, trees at the periphery of the May 18, 1980 mudflows commonly had large patches of bark removed on their upstream sides by abrasion but managed to survive. It is assumed that damage of this magnitude would affect the growth rate of the tree and cause an abrupt narrowing of the annual rings.

About 20 old growth fir and cedar trees were cored around the edges of Old Maids Flat. Several trees near the confluence of the Muddy Fork and the Sandy River show a consistent narrowing of rings between 1760 A.D. and 1805 A.D. with a possible drastic thin sequence starting about 1794 A.D. and lasting for an average of 10 years. The ensuing rings also show the presence of traumatic resin canals, which have been associated with the recovery response of a tree to physical injury. Trees higher on the hillslopes do not show the narrowing or the concentration of resin canals. These preliminary findings suggest that a tree-damaging event, possibly a lahar, occurred around the year 1794 A.D. The narrow rings starting in 1760 A.D. may indicate the beginning of ash falls in the basin which slowed the growth rate of the trees. Ring counts in 1984 on stumps rooted in the Old Maid-age surface show maximum ages of 173 years in the Sandy basin and 190 years in the Zigzag basin, or 1811 A.D. and 1794 A.D., respectively.

The formation of lobe 3 of Crater Rock is a possible method of generation for the Old Maid lahars. The very angular nature of the lobe material and its complete lack of oxidation and

weathering provide evidence for a recent origin. The close proximity of the lobe to Coalman Glacier (Figure 3) and the normal snowpack expected at this elevation would provide the water needed for lahar generation through melting of the snow and glacial ice.

A deposit of grey tephra mantles the normally light colored material of the summit ridge. From its shape, the deposit had its origin at Crater Rock. The tephra has a maximum observed thickness of 20 cm at the summit and exhibits some stratification that may be due to reworking by wind. Breadcrust bombs are common throughout the deposit, averaging 15 cm across but with occasional bombs up to 0.8 m. The actual age of this ash is not known, but the fact that the loose ash is still quite visible in a very windy location and that the highly fractured surfaces of the breadcrust bombs are sharp and unaltered by the freeze-thaw cycle requires a relatively young age. The Old Maid eruptive period is the last of the major eruptions at Mount Hood; the ash and bomb deposit may be contemporaneous with it.

Areal Distribution

The highest irrefutable exposure of Old Maid age deposits in the Sandy River basin was found about two km downstream from the Upper Sandy Guard Station. At this point the lahar ceased being channelized and began overbank deposition across most of the surface of Old Maids Flat. A possible Old Maid age deposit is found in the very high-gradient upper and middle reaches of Rushing Water Creek. This grey, sandy deposit is found in patches along low ridge crests and terraces.

In the Old Maids Flat area, the Old Maid age lahar forms a veneer from 0.2 to 1 m thick on pre-existing terraces and over most of the surface of the Flat. Most of the exposed sections range between 0.5 and 0.8 m thick. Deposits up to 3 m thick are found along the stream channel of the Muddy Fork of the Sandy River downstream from the Portage Trail crossing (E1/2 Sec 15 T2S R8E). The pre-lahar channels of the Muddy Fork and Ramona Creek were incised into the Timberline age surface of the Flat and lined with old growth cedar trees up to 2 m in diameter. The Old Maid age lahar filled these channels and adjacent low areas, killing the trees. Their remains are still apparent in the form of tree wells

and standing snags up to 30 m tall. Inferred depths of the pre-lahar channels of 1.6 to 6.5 m were obtained by sounding tree wells and the interiors of hollow snags.

None of the exposures of the Old Maid age lahar within the Sandy River drainage provides evidence of multiple flows. Apparent stratification in a deposit forming the north bank of Muddy Fork 100 m downstream from the crossing of the Portage Trail may reflect individual surges of pulses as a single flow spilled into and flowed down the old channel. A thin (2 to 6 cm) layer of moderately well sorted sands, possibly the sole or basal layer (Kevin Scott, personal communication, 1983), underlies the above unit.

At least one and possibly two temporary lakes were formed along the margins of Old Maids Flat through damming of tributaries by the Old Maid age lahar (Figure 5). The largest and best defined of the temporary lakes formed at the mouth of the Muddy Fork valley where it joins the main Sandy River valley (Sec 14 and 15 T2S R8E). Over 1 m of lacustrine deposits in the form of interbedded sand, silt and organic debris indicates that the lake existed for at least a few years. The fine-grained sediment supports a dense growth of deciduous trees, mostly alders, very different from the dominant fir cover of the surrounding region, making the extent of the lake readily apparent. This broad-leaf forest covers about 0.3 km². The valley floor of the Muddy Fork was carpeted by a mature cedar forest before the formation of the lake and over a hundred 30 to 50 m high snags drowned by the impounded water are found within the lake deposit boundaries.

The second lake, at the mouth of Lost Creek (Sec 21 T2S R8E), is not nearly as well defined as the Muddy Fork lakebed. Its existence is suggested by sand and silt deposits that appear to be of lacustrine rather than fluvial origin. Lost Creek is much steeper in gradient than the Muddy Fork so the lake would have covered less area. No snags were found in the area but logs were found buried in the lacustrine deposits.

No Old Maid-age lahar deposits were positively identified below Marmot Dam. However, thick sand beds found near Dodge Park, Oxbow Park and near Troutdale may be terraces formed by a lahar runout or post-lahar flow with high sediment concentration. The deposits at Trout-

dale are up to 6 m above modern water level, much higher than normal flood deposits, and are at least 3 m thick.

Along the Zigzag River deposits of an Old Maid age lahar mantle the terrace of the Zigzag-age lahar sequence to an average depth of about 1 m and a maximum depth of 1.8 m. This sandy-matrix cobble lahar contains clasts up to 30 cm with an average clast size of 5 to 10 cm. As in the Old Maids Flat area, the lahar buried and killed a mature cedar forest, leaving standing snags up to 5 m tall. These snags have been dated at 270 ± 150 years BP. This date is from the outermost layer of wood from one of these snags, but the bark and an unknown number of annual rings have been lost to decay. The actual age of the lahar is therefore younger by an undetermined amount.

Downstream from the terrace, where the Zigzag River valley broadens and flattens, there is an obvious vegetation zone very different from the surrounding forest. Unlike the surrounding flora of Douglas fir, ferns, rhododendrons and huckleberry, this zone is sparsely covered by stunted pines 10 to 15 cm in diameter with little or no undergrowth. This type of vegetation is very similar to that found growing on the Old Maid-age lahar surface on Old Maids Flat. It is the result of lack of soil formation owing to its youth and the relatively dry subsurface conditions caused by drainage through the sandy lahar deposit. This "dry" vegetation zone extends for about 1 km onto the flat area of the Zigzag River valley (Sec 17 T3S R8E) and probably represents the path of the distal portion of the Old Maid age lahar.

Physical Characteristics

Although only a single lahar is recorded in deposits along the Sandy and Zigzag Rivers, it was not necessarily the same lahar in both rivers. Radiometric dating of wood from the lahars gives about a 50-year range for emplacement (250 and 220 ± 150 years BP for the Sandy River deposits and 270 ± 150 years BP for the Zigzag River deposits) and the dendrochronologic and historical material extends that range to 90 to 100 years. It is possible that multiple Old Maid-age lahars were produced over a span of time and that only two, along separate rivers, produced over-bank deposits which have survived to the present.

The smaller size and extent of the Old Maid age lahar (compared to the Timberline age lahars) produces a corresponding smaller clast size and range. Maximum clast size in the Old Maid age lahar is 0.5 m in the upper reaches of Old Maids Flat and 0.3 m near Brightwood, at the distal portion of the lahar. Average clast size for the two locations is 0.2 and 0.1 m, respectively.

Clast lithology was subdivided into 3 groups based on "hand lens" petrology: grey matrix dacite, black matrix dacite and "other rocks." Both types of dacite are aphanitic-porphyrific with phenocrysts of plagioclase and amphibole. Maximum phenocryst size is 3 to 5 mm for the plagioclase and bimodal 1 to 2 and 3 to 5 mm for the amphibole needles. The grey matrix dacite is generally more vesicular with up to 10 percent void space, some of the voids being plastic pull-aparts with numerous glass needles. Grey matrix dacite makes up 30 percent of the clasts by number. The black matrix dacite generally has 0 to 5 percent angular void space and makes up 65 percent of the clasts by number. Clasts with poorly developed breadcrust or radially fractured textures are common in both dacites. The remaining 5 percent of the clasts are classed as "other" rock types and include red matrix dacite and highly altered rock types incorporated into the lahar during flow, probably as it passed over the upper reaches of the main Timberline-age debris fan.

Depth of Old Maid age Lahar During Flow

All Old Maid age lahar deposits are veneers on pre-existing terraces and represent open-reach-type deposition. Actual peak-flow height was

probably 1.5 to 2 times the deposit thickness. In virtually all locations this would give a flow depth of 0.8 to 1.5 m above the terrace surface. The bulk of the flow remained within the channel. The flat-topped nature of the terraces allowed the flow to travel up to 0.5 km beyond the channel in some places on Old Maids Flat.

Summary

During the last 10,000 years, at least 3 major eruptive periods have occurred at Mount Hood. The oldest, and volumetrically largest, the Timberline eruptive period, occurred between 1400 and 1800 years BP. The Zigzag eruptive period, volumetrically the smallest of the three, occurred between 400 and 600 years BP. The Old Maid eruptive period occurred between 180 and 270 years BP and its aftereffects may have been witnessed by early explorers.

The combined clastic debris from these periods buried the southwest flank of the mountain, producing a smooth debris fan. Lahars travelled at least 90 km and pyroclastic flows at least 13 km from their source area near Crater Rock. Flow-depths of the lahars probably averaged 8 to 12 m in most cases.

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