STATE OF OREGON
DEPARTMENT OF GEOLOGY AND MINERAL INDUSTRIES
1069 State Office Building
Portland, Oregon 97201
Reprinted from Bulletin 77, pages 183-206 (Geologic Field Trips in Northern Oregon and Southern Washington)

GEOLOGICAL FIELD TRIP GUIDE

MOUNT ST. HELENS LAVA TUBES, WASHINGTON

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for the

GEOLOGICAL SOCIETY OF AMERICA
Cordilleran Section Meeting
Portland, Oregon March 1973

FIELD TRIP NO. 7

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INTRODUCTION

Abundant volcanic structures seen on high resolution pictures of the Moon and Mars has prompted interest in volcanic landforms as analogs to planetary surface features. Lava tubes have been of particular interest because they appear to be similar to sinuous rilles on the Moon (Greeley, 1971a) and structures associated with shield volcanos on Mars. In 1969 and 1970, the Cave Basalt (Greeley and Hyde, 1972) and associated lava tubes were studied extensively. These tubes are very well preserved and display structures (not generally seen elsewhere) that allow interpretations of lava-tube formation, morphology, and degradation. The lava tubes are on U.S. Forest Service and private lands and, after the spring snows melt, are readily accessible. Part of Ape Cave, a long lava tube segment, has been designated a Geologic Point of Interest by the Forest Service and a parking lot, restroom facilities, and ladders within the lava tube have been provided.

The field trip guide is divided into four sections: 1) road log from Portland to the lava tubes, 2) geological summary of the Mount St. Helens lava tubes, 3) guide to Lower Ape Cave, and 4) guide to Upper Ape Cave.

The highway distance between Portland and the lava tubes is about 96 km (60 miles) (Fig. 1) and requires a driving time of about 1.5 hours. The geology between Portland and the tubes is mentioned briefly to provide a regional geologic setting. The reader is referred to other papers in this guidebook and to publications listed here for more detailed descriptions of local geology. The tour of the Lower Ape Cave requires about one hour; the tour of Upper Ape Cave requires four to five hours.

Part of the original data was gathered during a U.S. Geological Survey investigation of the potential volcanic hazards of the area by Hyde. Greeley made the original study during tenure as a National Academy of Science National Research Council Associate at NASA-Ames Research Center.

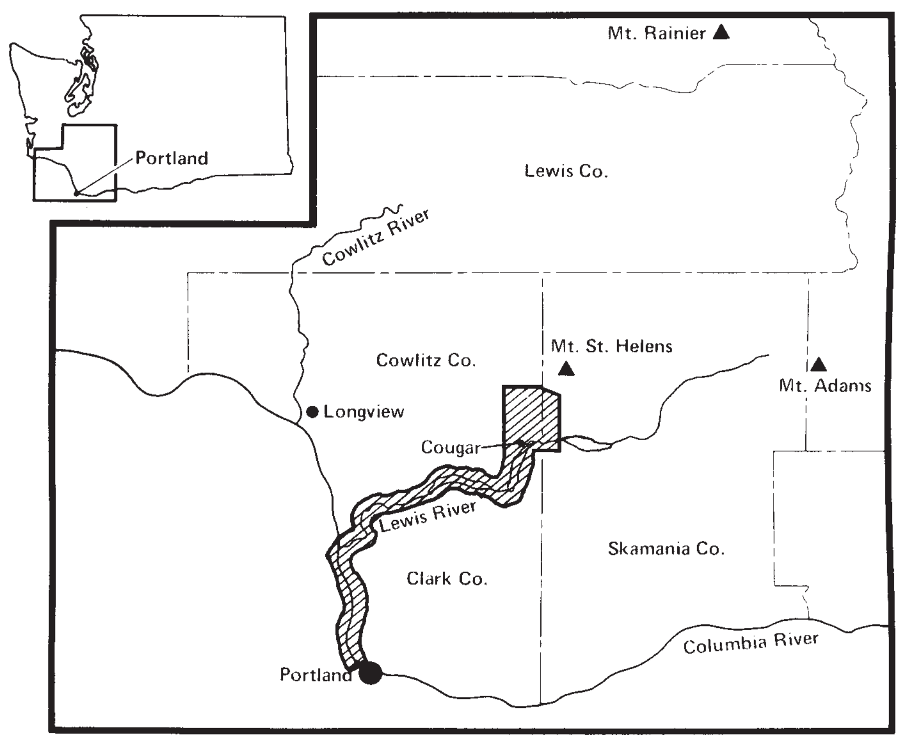

Figure 1. Location map; ruled portion outlines area discussed in guide. Straight-line distance from Portland to lava tubes is about 50 miles.

I. ROAD LOG, PORTLAND TO MOUNT ST. HELENS LAVA TUBES

Mileage (in miles)	
	Portland is built upon a broad, deltaic Pleistocene fill, formed during catastrophic floods from the Columbia River valley. Subsequently, part of the fill has been terraced and eroded. The deposits consist mostly of sand and gravel in the eastern part with sand, silt, and clay more common to the west and northwest.
0.0	North end Interstate 5 bridge over Columbia River. Follow freeway, which passes
(6.0)	from the trench of the Columbia River onto the delta surface.
6.0	Salmon Creek bridge, exposure of Troutdale Formation in gravel pit to west. The formation consists of siltstone, sandstone, and conglomerate more than 1100 feet thick, and is lower Pliocene based on fossil leaves (Trimble, 1957).
(3.0)	The abundance of micaceous sandstone and quartzite gravel, not derived locally, suggests that at least part of the sediment was derived from the upper part of the Columbia River drainage.
9.0	Mount St. Helens visible to the north.
(9.0)	
18.0	Bridge over East Fork Lewis River; rocks exposed to the east are assigned to the upper Eocene Goble Volcanic Series by Wilkinson, Lowry, and Baldwin (1946). This series
(1.5)	consists of volcanic breccia, lava flows, tuffs, mudflows, dikes, sandstones, and conglomerates. The lowest part of the formation is interbedded with marine sandstone.
19.5	Lewis River bridge.
(1.5)	
21.0	EXIT. Woodland; exit from freeway, proceed east on Highway 503 to Cougar and Swift Dam.
(3.1)	
24.1	To the south a gravel pit exposes sand and pumice that are the downstream equivalent of pyroclastic flows and lahars produced by eruptions of Mount St. Helens. The term lahar is used to designate deposits of debris that result from rapid mass flowage of water-mobilized material down the flanks of a volcano. It is also used to designate the flow-
(4.5)	ing mass. Small landslides are common in the deeply weathered older glacial drift exposed in road cuts for the next few miles.
28.6	Road to Salmon Hatchery, note large landslide.
(1.0)	
29.6	Crossing Lewis River terraces; note terraces across river.
(0.6)	
30.2	Small landslide to the north.
(0.3)	
30.5	Road cuts in volcanic breccias and lava flows assigned to the Goble Volcanic Series by Wilkinson, Lowry, and Baldwin (1946).
(0.8)	
31.3	Road to Merwin Dam.
(0.7)	
32.0	Road cuts in lava flows capped with fluvial gravel. Road cuts for the next several
(3.9)	miles expose interbedded sandstones and shales.
35.9	Bridge.
(1.7)	
37.6	Merwin Reservoir below.
(1.0)	
38.6	Bridge.

Figure 2. Oblique aerial overview of the Cave Basalt; Mount St. Helens in background; main entrance to Ape Cave in middle distance; spillway of Swift Reservoir and road N90 in foreground. Photo courtesy U.S. Forest Service

Mileage
(0.7)
39.3 Tumtum Mountain (visible ahead) is a cinder cone older than the last glaciation. (Fraser Glaciation)
(1.6)
40.9 Descending to the Lewis River valley; ahead is the relatively flat surface of lahar and fluvial deposits which represent the older episodes of explosive volcanism of Mount St. Helens.
(0.9) Road cuts to the north show interbedded sedimentary rocks and lava flows which may be part of the Ohanapecosh Formation.
41.8 Road to Speelyai Bay boat launch and picnic area.
(2.3)
44.1 Road to Yale Dam, Yacolt, and Amboy.
(0.3)
44.4 Summit of Mount St. Helens visible ahead.
(0.9)
45.3 Speelyai Creek Bridge.
(2.1)
47.4 Boat launching and picnic area to south. Sedimentary and volcaniclastic rocks exposed in road cuts are assigned to the Ohanapecosh Formation by Hopson (1971, personal
(1.2) commun.).
48.6 Road to Merrill Lake; good exposures of the Ohanapecosh Formation cut by a sill occur
(0.2) in road cuts between here and Merrill Lake (Hyde, 1970).
48.8 Lahars younger than those in the Speelyai Bay fill are exposed in the Highway Depart-
(0.5) ment gravel pit to the right. A weathered zone as thick as 8 cm (3 in.) separates the two youngest lahars.
49.3 Cougar Store; between here and Swift Dam as many as 8 terrace levels are present and
(2.2) record a complex sequence of valley filling and erosion.
51.5 Road to Beaver Bay campground. The terraces here conceal the western margin of the
(0.9) Cave Basalt flow (Fig. 2,3).

The Cave Basalt (Greeley and Hyde, 1972) is a high-alumina pahoehoe flow which originated at the southwest flank of Mount St. Helens and flowed south about 11 km (6.5 miles) down a stream valley cut into late Quaternary lahar and pyroclastic flow deposits. The upper part of the basalt is covered with younger lava and surficial deposits, but it is present at least as high as the 1,465 m (4,800 feet) elevation on the volcano. The flow terminates on the north bank of the Lewis River.

The basalt rests on river gravels exposed at the east end of the private logging road bridge across the Lewis River south of the main highway. The basalt-flow surface ranges from flat to hummocky over broad areas and is commonly broken into large tilted slabs. Common surface features include ropy or corded textures, pressure ridges, and tumuli that are often cracked or collapsed. The term tumulus is used here for any dome-shaped, circular or semicircular, solid or hollow surface feature. Many of the known hollow tumuli of the Cave Basalt are collapsed, leaving raised-rim craters up to 50 m (164 feet) in diameter. The age of the basalt flow is probably close to 1,900 years B.P. Charcoal from roots exposed in breakdown areas in both Lake and Ape Cave were dated by radiocarbon methods and are 1,900 years old.

Surface features of the lava flow are well-displayed between here and the margin of the basalt near the east entrance to the private logging road.

52.4 West entrance to private logging road.
(0.1)
52.5 East entrance to private logging road, well-developed pressure ridge to north (Fig.4).
(0.8)

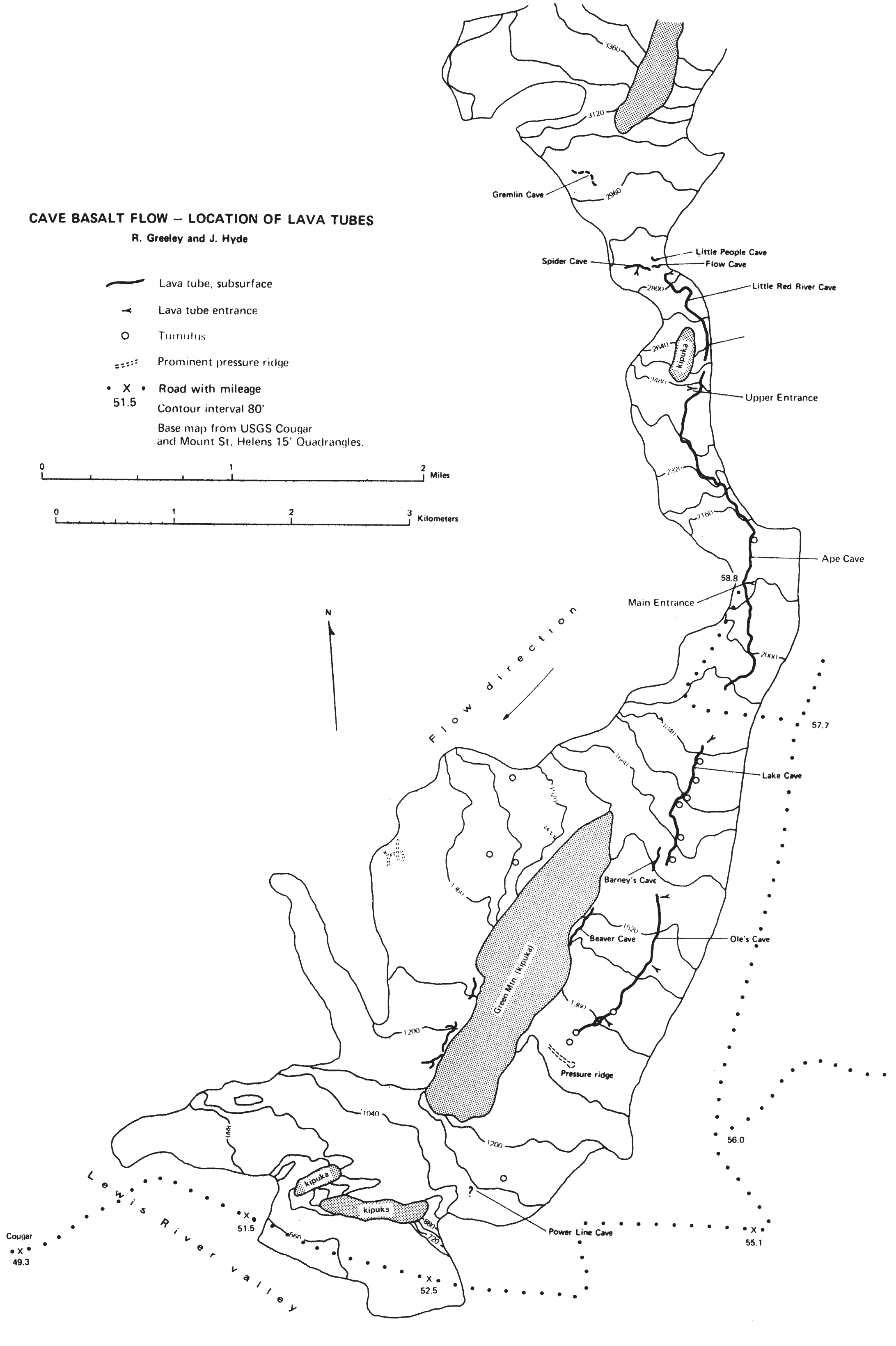

Figure 3. Map showing location of lava tubes and road to Ape Cave.

Figure 4. Pressure ridge with medial crack, mile 52.5.

Mileage	
53.3	Bridge across power canal. The oldest dated volcanic deposit at Mount St. Helens is a wood-bearing lahar (36,000 years old) exposed at river level. Road cuts between here
(1.8)	and dam viewpoint exposed portions of the valley fill which consists of fluvial sand and gravel, lahars, and (near the viewpoint) pyroclastic flow deposits.
55.1	Dam viewpoint. The viewpoint is located near the top of a thick sequence of volcanic debris which forms a large fan across the Lewis River at the mouth of Swift Creek. Pumice-flow deposits form the upper units in the fan.
(0.3)	In the gravel pit on the south side of the Lewis River valley the pumice flow contains charcoal which has been dated at about 20,000 years B.P.
55.4	Mount St. Helens viewpoint. Volcanic ash erupted as recently as 1842. In the last few hundred years there has been frequent violent volcanism accompanied by hot pyroclastic flows, lahars, pumice eruptions, and lava flows. The dark, fresh-looking lava
(0.6)	flows visible from this point are mainly younger than 450 years. Geologic studies on the volcano are listed at the end of the guide.
56.0	EXIT. Turn north on gravel road N83. The white pumice at the surface is Layer W,
(1.7)	erupted about 450 years ago. It is about 5 to 10 cm (2 to 4 in.) thick here, but in the vicinity of Spirit Lake on the north side of the volcano it is 30 to 100 cm (1 to 3 feet) thick. Older pumice layers are visible below Layer W.
57.7	Turn west on road N816.
(0.2)	
57.9	Lava Cast area. Vertical and horizontal tree molds are particularly well displayed here. The trail from the parking lot leads to the entrance of Lake Cave, part of the Mount
(0.4)	St. Helens lava-tube system.
58.3	Road cut is in a pyroclastic flow deposit similar to those exposed in collapsed wall sections in the lava tubes.
(0.5)	
58.8	Main Entrance, Ape Cave lava tube.

II. MOUNT ST. HELENS LAVA TUBES

General description

The Cave Basalt contains sections of lava tubes extending nearly the entire length of the flow. The principal lava tube system in the flow is composed of Little Red River Cave, Ape Cave, Lake Cave, and Ole's Cave (Table 1).

Table 1. Physical characteristics of lava tubes in the Cave Basalt

Name	Length* (m)	Maximum Height (m)	Maximum Width (m)	Average Slope
Ape Cave	3,400	11.6	12.2	3.3°, 1 m/17.2 m
Barney's Cave	56	2.7	3.6	2.0°, 1 m/27.8 m
Bat Cave	330	3.7	16.2	-- --
Beaver Cave	477	9.1	15.2	3.0°, 1 m/19.6 m
Dollar-Dime Cave	---	----	----	-- --
Flow Cave	99	2.4	4.6	3.2°, 1 m/17.4 m
Gremlin Cave	---	----	----	-- --
Lake Cave	1,248	15.5	9.1	2.6°, 1 m/22.2 m
Little People Cave	143	4.6	7.9	1.3°, 1 m/47.7 m
Little Red River Cave	1,032	9.1	11.9	4.5°, 1 m/11.7 m
Ole's Cave	1,592	7.6	13.1	2.1°, 1 m/27.4 m
Powerline Cave	---	----	----	-- --
Prince Albert Cave	480	6.1	15.0	-- --
Spider Cave	271	4.6	11.4	-- --

* For lava tubes with multiple passages, length represents main passage only.

Although the system begins in the constricted northern part of the flow, it probably originated upslope, above Little Red River Cave. The system trends southward along the east flow margin and apparently terminates in collapsed tumuli east of Green Mountain kipuka*. Ape Cave, with a passage length of 3,400 m (11,330 feet), is one of the longest uncollapsed lava-tube segment known.

Lava-tube formation is apparently controlled primarily by lava flow viscosity, which in turn is related to the chemistry, dissolved gasses, temperature, and flow velocity of the lava. At least two modes of tube formation are displayed in the Cave Basalt, and both may occur within a single tube in different localities. Most of the tubes apparently formed between shear planes that developed within laminar flow of the molten lava (Fig. 5), similar to the mode of formation described by Ollier and Brown (1965). Where the flow gradient increased, however, the active flow probably became turbulent, destroying the laminar flow and shear planes, and the tube roof probably formed by accretion of spattered lava on lateral levees as observed in active lava flows (Greeley, 1971b, 1972).

Lava flows and tubes are controlled to some degree by pre-flow topography and are usually situated in topographic depressions. Lava tubes represent the zone of highest flow velocity within the overall flow body, analogous to a hydrologic thalweg; as such, the axis of the developing tube may migrate in a sinuous pattern within active flows. Some sections of the Cave Basalt tubes, however, appear to occupy the bed of a former stream, indicated by exposures of country rock where sides of the tube have collapsed. These exposures also reveal that lava flows are capable of eroding pre-flow surfaces, shown by undercut sections of country rock and country rock inclusions in the basalt (Fig. 6).

* Island of older rock surrounded by younger lava.

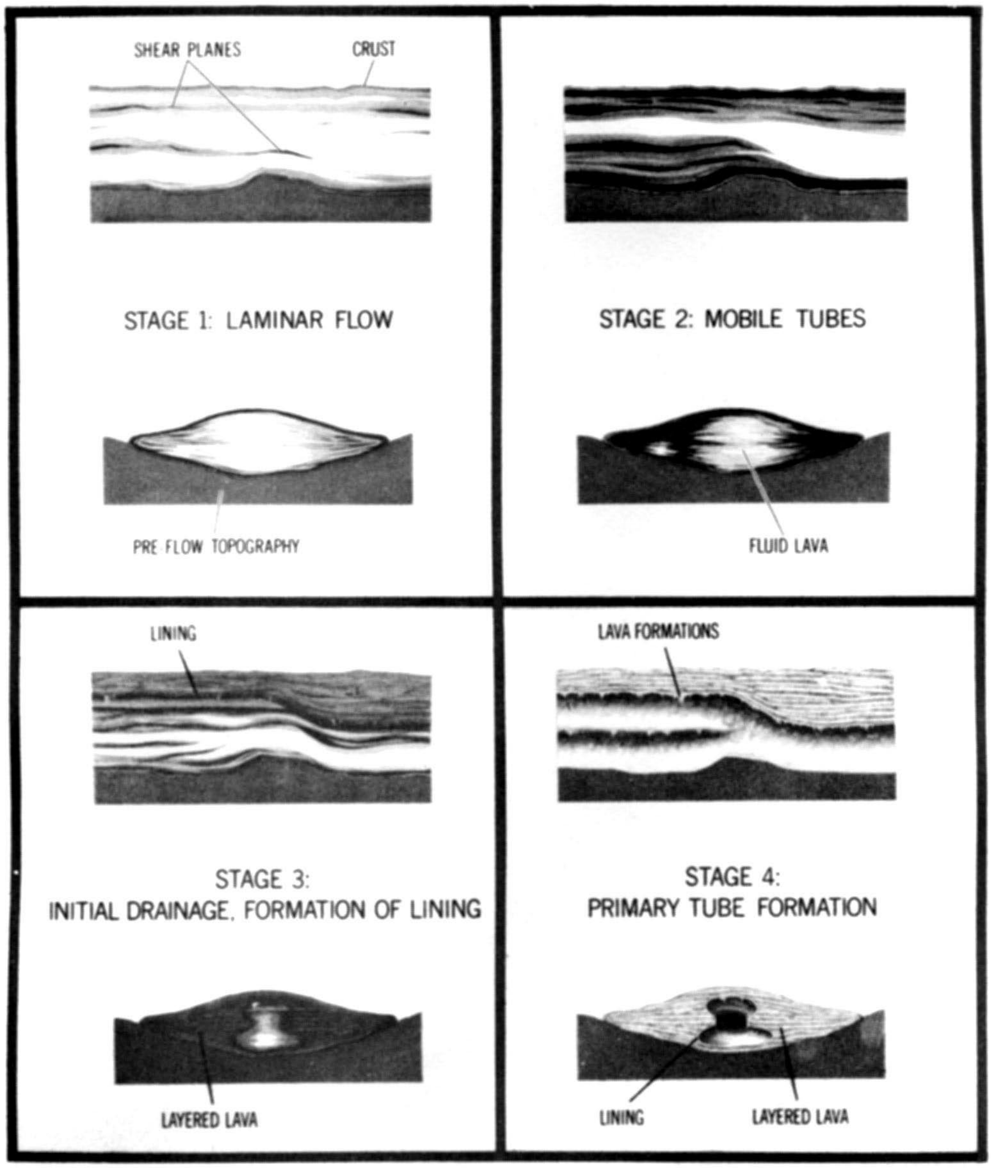

Figure 5. Diagrams illustrating lava-tube formation associated with shear planes developed in laminar lava flow. Each stage is shown in longitudinal profile (parallel to flow axis, top diagram) and in transverse cross section (normal to axis, lower diagram). The tube cross section in stage 4 is shown with an hourglass outline to emphasize that noncircular tubes may form within a single flow (after Greeley and Hyde, 1972).

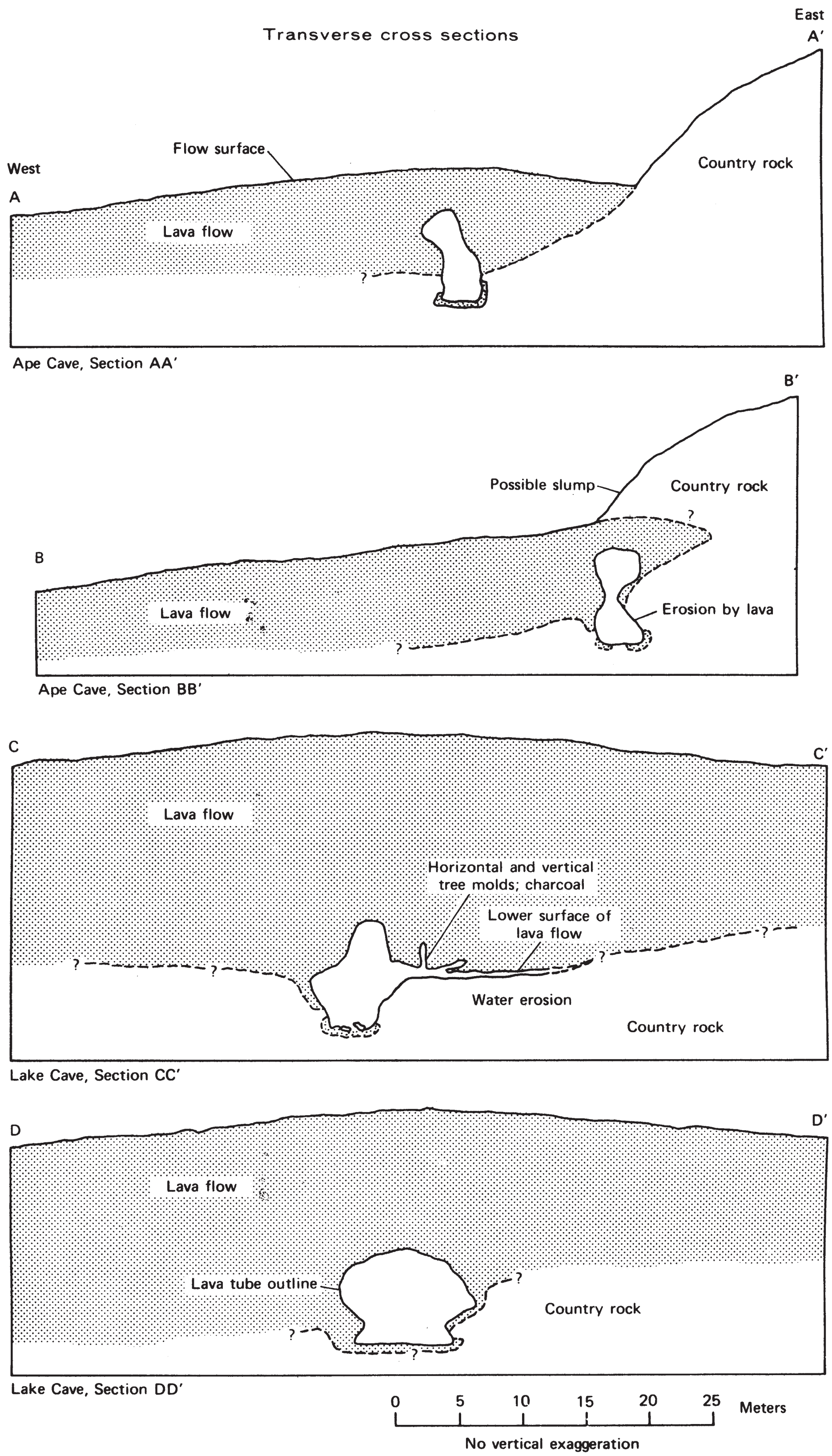

Figure 6. Transverse cross sections, Mount St. Helens lava-tube system, showing relations of lava tube to lava flow and preflow country rock. In these sections, the lava tube is interpreted to occupy a former stream channel (after Greeley and Hyde, 1972).

Ape Cave

Ape Cave was named for a group of local cave explorers who called themselves the St. Helens Apes, after large, hairy, ape-like creatures which were reported in the early 1920's to have attacked a group of miners working on the east side of the volcano.

The tour of Ape Cave is divided into two parts; the segment of the tube downslope (south) from the main entrance is 1,330 m (3,910 feet) long and requires about 1 hour for a round trip. This segment is easily travelled, but there is no lower exit and the return is made back through the tube. The portion of the tube upslope (north) from the main entrance is more interesting geologically, but a few areas of breakdown (collapse-block from the ceiling) are present, necessitating short crawls. An exit is present at the end of the upper segment and the surface of the lava flow can be followed for a return to the parking lot at the main entrance. The upper segment is 2,470 m (7,420 feet) long and requires a roundtrip of 4 to 5 hours.

For safety and enjoyment we recommend that you have a lantern in addition to a flashlight, warm clothes, boots, hard hat, and gloves. The upper segment of the lava tube should not be travelled alone. Standard caving practice calls for three independent light sources (e.g. lantern, flashlight, candle with matches).

Distances to localities within the tube are necessarily approximate and are given in paces (one pace equals five feet, or two steps). The tube walls are referred to as either the east wall or west wall (the tube is assumed to run north-south with upslope to the north).

Tube entrance

The entrance to the tube is a collapsed tumulus which once formed a chamber above the main lava tube. Layered lava is visible in the walls of the entrance.

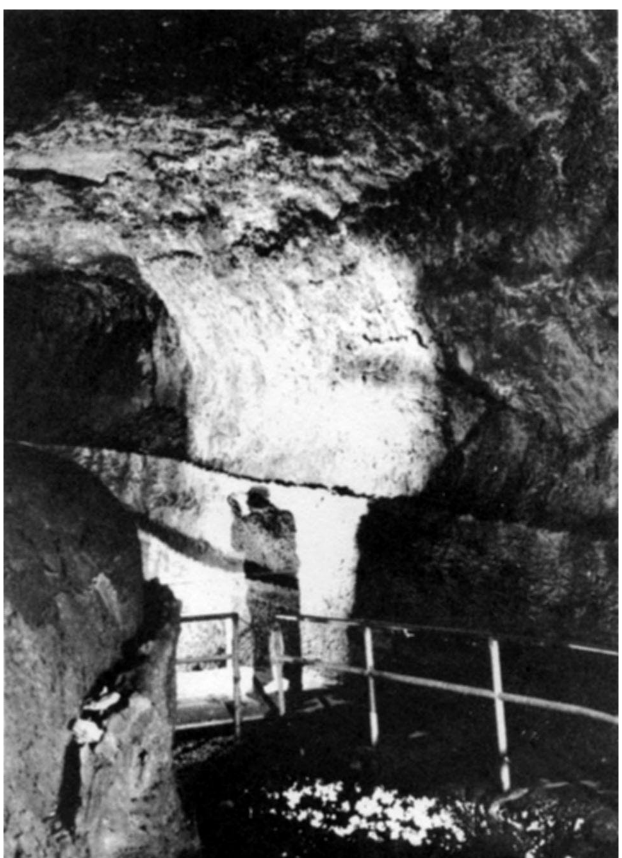

Figure 7. Lava-tube interior near top of stairway, main entrance to Ape Cave, showing lava flow gutters. View downtube. Photo courtesy F. Dippolito

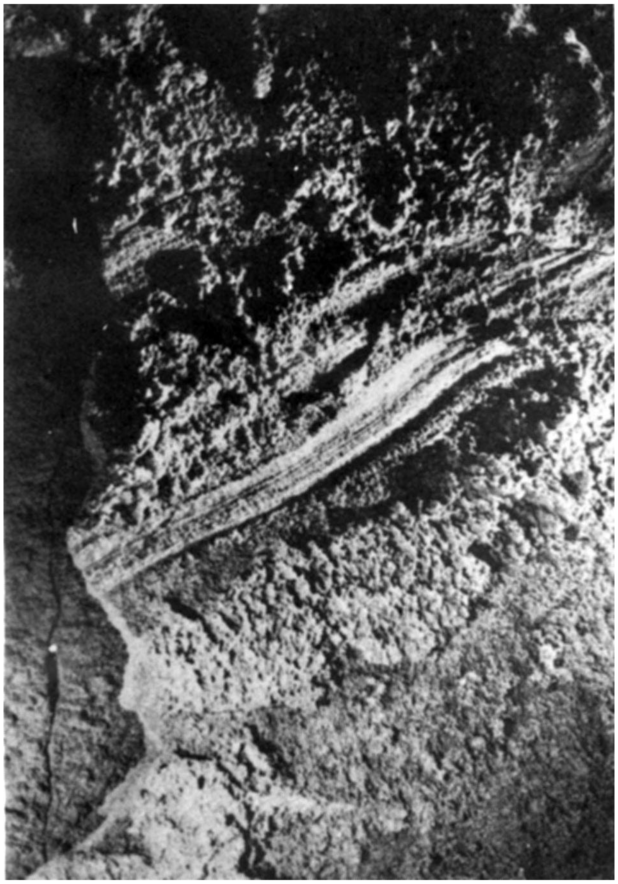

Figure 8. Drag mark on west wall, near main entrance to Ape Cave, caused by a block carried by the lava stream and coming in contact with the still plastic tube lining. Mark about 1 m (3 feet) long.

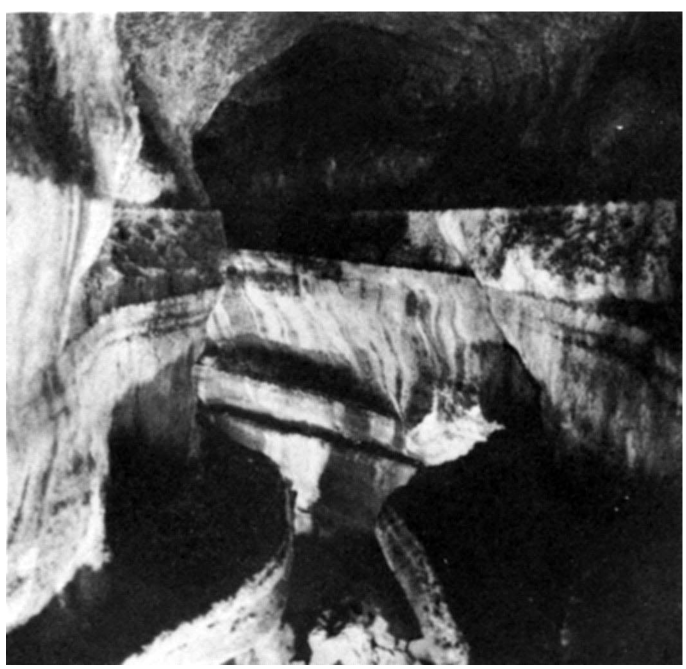

Figure 9. Lava-tube interior near main entrance, Ape Cave, showing complex cross section, multiple "flow" lines, and meandering nature of lava tubes. Tube is about 13 m (40 feet) high.

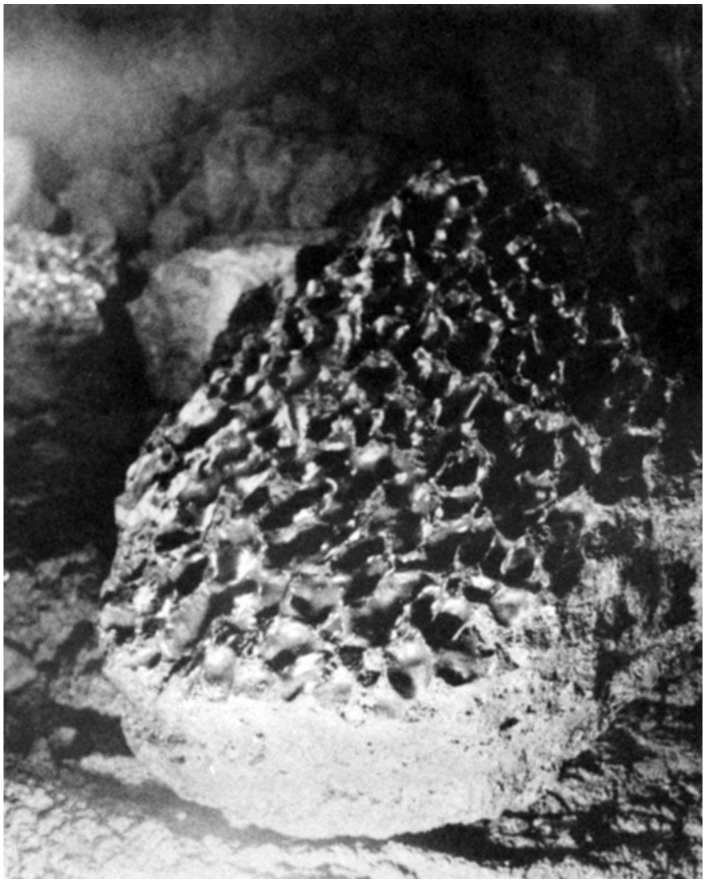

Figure 11. A fallen roof block similar to those at pace 0 (and elsewhere) showing development of a glassy surface. Block about 1 m (3 feet) in maximum dimension. Photo courtesy F. Dippolito

Figure 12. Wall section of lower Ape Cave at pace 44, showing where wall collapsed, allowing the country rock (a pyroclastic flow deposit) to slump into the tube. Molten lava which dripped on the material, and the fusion of the slumped sediment to the tube lining, shows that collapse occurred before the lava flow had completely cooled. Pack gives scale. Photo courtesy F. Dippolito

Top of lower stairway

Lines and ledges caused by partial cooling of the surface during temporary halts in the lava flow are visible on the sides of the tube (Fig. 7). Remnants of later lava flows that moved through the tube are present on the tube floor. The drag mark (Fig. 8) on the west wall was caused by a block being carried on the surface of the lava stream and coming in contact with the still plastic tube lining. The tube here (Fig. 9) is about 13 m (40 feet) high and appears to have been modified by subsequent flow alteration. Apparently two or more lava surges flowed both through an existing tube and over the surface of the tube. These later flows apparently remelted the existing roof to extend the tube vertically, forming a vertically elongate cross section. An alternative explanation for multiple-level tubes and vertically elongate cross sections is that individual conduits of lava developed within a single massive flow. As cooling progressed, the conduits may have merged to form single, elongate tubes, or may have developed as individual tubes stacked vertically. In come areas, the conduits merged and separated alternately along the course.

Bottom of lower stairway

The sand and pumice on the tube floor have been carried in from the outside by streams and, in some areas, completely plug the tube. Where the sand surface is undisturbed, patterns have been sculptured by water dripping from the roof.

The luminescence of the walls is due to light reflecting from water droplets and "cave slime."

In the later stages of tube formation, probably during drainage, a layer of lava is accreted along the walls and ceiling to form a lining. Lava-tube linings range from less than 1 cm to more than 1 m thick and are generally somewhat more vesicular than the main body of the lava flow. Vesicularity within the lining may increase toward the tube, possibly representing outgassing into the tube. During or after drainage, parts of the lining may develop a glassy surface. Glaze that is deformed must have developed while the lining was still plastic and subject to movement. Formation of glaze is not well understood; however, it appears to develop as a thin coating over the outer vesicular zone of the lining, possibly as a result of rapid cooling by air currents in the lava tube.

Longitudinal profiles of Mount St. Helens lava tubes (Figure 10) in pocket.

III. LOWER SEGMENT TOUR - APE CAVE

Paces (5 feet)	
0	Bottom of lower stairway, main entrance (Fig. 10). Proceed downtube (south). The blocks lying on the floor have spalled from the roof of the tube (a continuing process).
(44)	Note the development of a glassy surface (Fig. 11).
44	Here the west wall of the tube collapsed, allowing the country rock (a pyroclastic flow deposit) to slump into the tube (Fig. 12). Molten lava which dripped on the country rock and then cooled and fusion of the slumped material to the tube lining show that collapse occurred during or immediately following drainage of lava from the tube. The country rock is baked a brilliant red.
(6)	
50	Step down, watch head; fallen roof block.
(28)	
78	Note the presence of a small subsequent lava flow. Many good examples are present in this tube segment of deformation of the visco-elastic semimolten lava-tube lining, which produces wall drapery.
(90)	
168	Discontinuous exposures on both walls of brick-red lava clinkers (autobrecciated lava) between the lining and the massive basalt of the flow. Differential movement of the lining and massive basalt may produce a shear zone along which the autobrecciated lava forms. Brecciation may also have occurred by vesiculation into possible voids and low-pressure areas between the lining and the body of the flow, similar to the process described by Parsons (1969) for lava flows in general.
(142)	

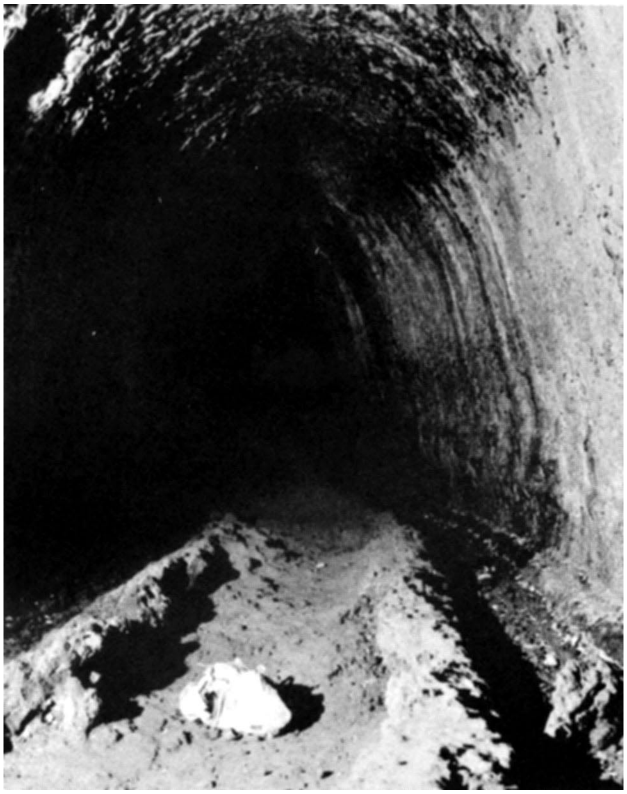

Figure 13. Lava levees developed on small subsequent lava flow at pace 425, lower Ape Cave. View uptube, pack gives scale. Photo courtesy F. Dippolito

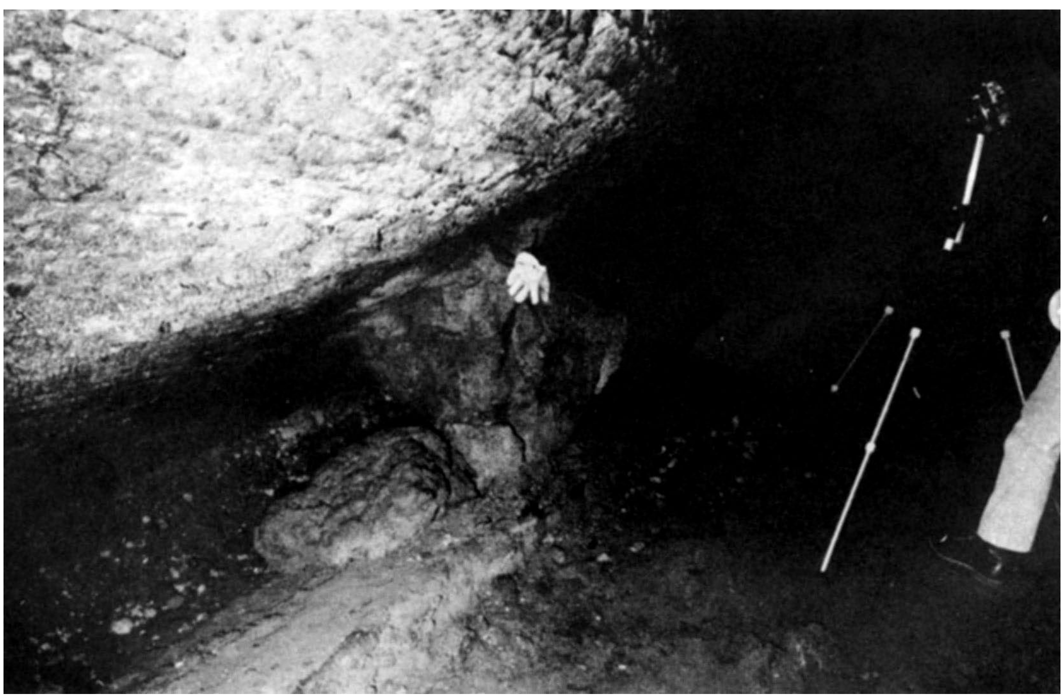

Figure 14. Block rafted to its present position by a small floor flow and fused to tube lining, pace 450, lower Ape Cave. Tripod gives scale.

Figure 15. Balls of lava wedged between and fused to the tube walls during drainage of molten lava from the tube. Note well-developed wall drapery. View uptube at pace 468, lower Ape Cave.

Figure 16. Tube interior at pace 481, lower Ape Cave, showing a ball of lava similar to those at pace 468. Note the flow lines near the base of the walls and the scattered white pumice fragments on the floor.

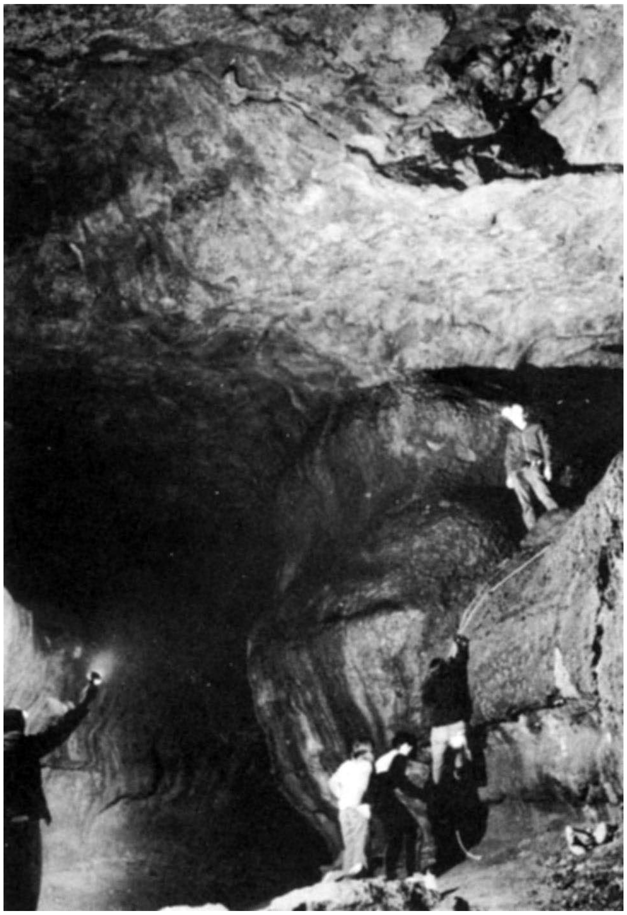

Figure 17. Tube interior at pace 690, lower Ape Cave, showing development of a short upper passage. View uptube. Photo courtesy P. Clee

Figure 18. A small lava tube developed in a subsequent floor flow resulting in a tube-in-tube structure. View uptube about 10 paces north of main entrance, Ape Cave.

Paces (5 feet)

310 A cupola (a bulbous chamber in the ceiling) is present at this point; its surface expression is a dome 20 m (60 feet) in diameter. The roof is about 5 m (15 feet) thick here.
(30) The cupola probably formed by hydrostatic pressure within the closed tube systems and outgassing into the tube interior. In some places, pressure apparently was great enough to rupture the roof.

340 Well-formed wall drapery.
(40)

380 Floor steepens.
(45)

425 Well-developed lava levees on small floor flow (Fig. 13).
(25)

450 Tube narrows; note the block near the base of the east wall (Fig. 14).
The block is fused to the tube lining and, since at this point there is no obvious source for it on the roof, it must have been rafted to its present position by a subsequent floor
(18) flow or during final drainage of the tube.

468 Tube narrows, note several balls of lava wedged between and fused to the tube walls
(13) during drainage of molten material from tube (Fig. 15).

481 Single ball of lava wedged and fused to walls (Fig. 16).
(25)

506 Start of discontinuous exposures of red lava clinkers in west wall caused by collapse of
(94) tube lining. Exposures continue downtube for about 85 m (255 feet).

600 The sand and pumice fill becomes thicker here and a well-developed terrace is present, presumably caused by the reduced velocity of the stream as it encountered the wider
(52) cross-section of the lava tube.

652 Cupola; the tube is about 12 m (35 feet) high here. The roof is 3 to 5 m (9 to 15 feet)
(38) thick.

690 A short upper level is present (Fig. 17); note the well-developed lava stalactites. The
(72) section between this point and the end of the tube contains a sand and pumice fill which in some places is more than 1 m (3 feet)thick.

762 End of tour. The upper level is passable for a short distance; the roof of the lower level meets the sand fill and the tube becomes impassable about 30 m (100 feet) farther.
(20) A small cave with a slight breeze at the entrance is located on the surface at about this point, which is 300 m (900 feet) north of the Forest Service road at the Lava Cast area.

782 End of tube; retrace route to EXIT.

IV. UPPER SEGMENT TOUR - APE CAVE

Paces (5 feet)

0 Bottom of lower stairway,main entrance. Proceed uptube (north). Well-developed levees and gutters, formed by subsequent lava flows, are located 5 to 15 paces uptube. A floor flow displays a small lava tube, resulting in a tube-in-tube structure (Fig.18).
(96) Note that the surface of the flow is broken into plates which were rafted from uptube. The blocks that have spalled from the ceiling show development of a glassy surface.

96 Large breakdown area; the roof is about 7 m (21 feet) thick here. Lava-tube collapse after cooling begins with spalling of the tube lining. This is followed by spalling and collapse of basalt blocks from the roof, eventually forming a small opening (termed a skylight) to the surface. Some parts of lava tubes are marked by extensive collapse,
(36) as here, (not necessarily breaking through to the surface, however) that may completely

Figure 19. Interior of lava tube at pace 522, upper Ape Cave, showing a floor flow which poured over an abrupt rise in the tube floor. Notebook gives scale; view uptube.

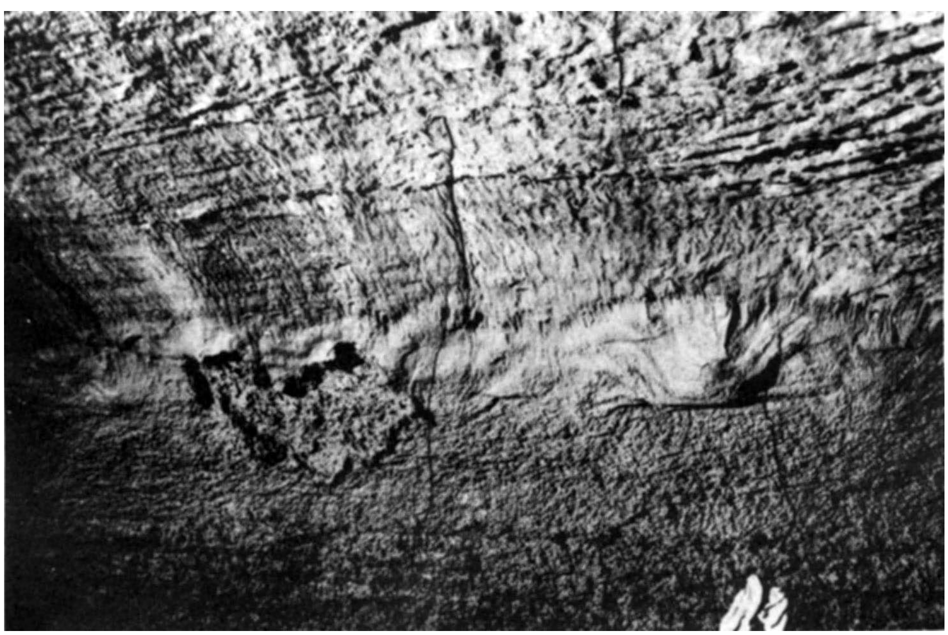

Figure 20. Tube wall near pace 526, upper Ape Cave, showing ruptured blister and a possible nonruptured blister probably caused by gas collecting behind the semimolten tube lining. Note wall drapery and "flow" lines; glove gives scale.

Figure 21. The terminus of a small subsequent aa lava flow similar to those at pace 668 and 801, upper Ape Cave. View uptube; width of tube about 2 m (6 feet).

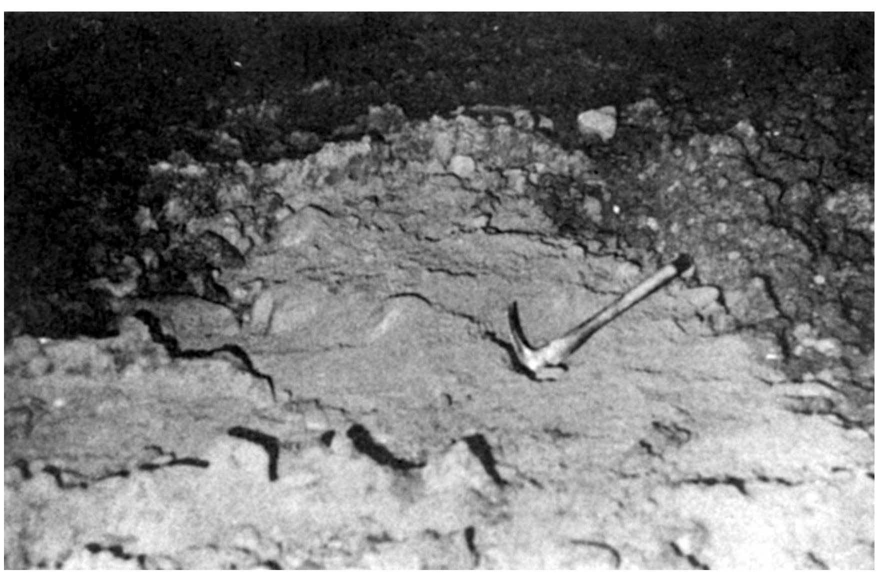

Figure 22. Lava tube floor showing probably exposure of country rock, pace 731, upper Ape Cave. Pick handle about 45 cm (18 inches) long.

Paces (5 feet) block the interior passage. The small tube on the west side of the chamber is about 25 m (75 feet) long. Note the development of the wide shelves on both sides of the main tube. The best path over the breakdown area follows the east wall.

132 Large roof breakdown area. Several smaller intermittent sections of roof breakdown
(118) occur in the next 197 m (590 feet).
250 End of roof breakdown area. The floor flow here is aa lava.
(272)
522 Tube narrows and floor rises 1.7 m (5 feet) (Fig. 19). Lava stalactites are well developed here. A series of ruptured blisters occur on the west wall of the tube, probably caused by gas collecting behind the semimolten tube lining.
(94) A possible nonruptured blister is present on the west wall about 7 m (21 feet) uptube (Fig. 20).
616 Rise in floor.
(52)
668 Terminus of small floor flow (Fig. 21).
(10)
678 An area of wall breakdown about 35 m (105 feet) long has exposed the valley wall at this point. The country rock (a pyroclastic flow deposit) is baked a brilliant red and
(53) contains fragments of charcoal which were radiocarbon dated at 1,900 years B.P.
731 Country rocks (?) exposed in floor (Fig. 22).
(19)
750 Wall breakdown area, exposing country rock. On the west wall directly opposite the breakdown area, silt- to sand-sized particles of the country rock are fused to the tube
(40) lining, showing that the wall rupture was explosive. The explosion was probably caused by interaction of molten lava with stream water, snow, or ground water (Hyde and Greeley, 1971), although generation of hydrocarbon gasses by destructive distillation of vegetation buried by lava flow is known. The particles are fused to the downtube side of protuberances on the tube lining for at least 500 m (1,500 feet) uptube. A block of dacite which has melted and flowed downward is visible on the west wall at the uptube (north) end of the breakdown area.
790 Breakdown area; country rock exposed in both walls. Near the northern end of the breakdown area, on the east wall, blocks of dacite contained in the pyroclastic flow deposits have melted and flowed out through breaks in the lava-tube lining. The melted
(5) material is light tan and in one example formed a molten stream 20 cm (8 inches) wide and 1 m (3 feet) long (Fig. 23).
795 Rise in floor of 2 m (6 feet).
(6)
801 Terminus of floor flow, note particles of country rock fused to the flow.
(54)
855 Note the exposure of country rock in the east wall at the uptube end of the breakdown area. Here the country rock is overhanging the lava tube. It is unlikely that this was the original configuration of the topography in an area of easily eroded unconsolidated deposits; this and other overhangs in the tube probably represent erosion by the lava flow. Sections of Little Red River Cave, for example, undercut parts of the eastern, preflow hillside. Thus, to some degree the position of the tube is determined by the erosive capability of the lava flow.

Wall breakdown areas and exposures of country rock deposits (rare in most other areas) provide a unique opportunity to study relations of lava tubes and flows to preflow topography. From exposures available in Ape Cave and in other parts of the tube system, we conclude that parts of the lava tube are situated in a prelava-flow stream
(23) channel. This channel is about as deep and wide as the present stream channel of Panamake Creek, a small stream a few miles west of the Cave Basalt but unaffected by Holocene volcanic eruptions.

Sections (Fig. 24) of the tube along the presumed stream channel assume a skull-

Figure 23. Tube wall showing flowage of melted dacite block down tube wall at pace 790, upper Ape Cave. Glove gives scale. Photo courtesy P. Clee

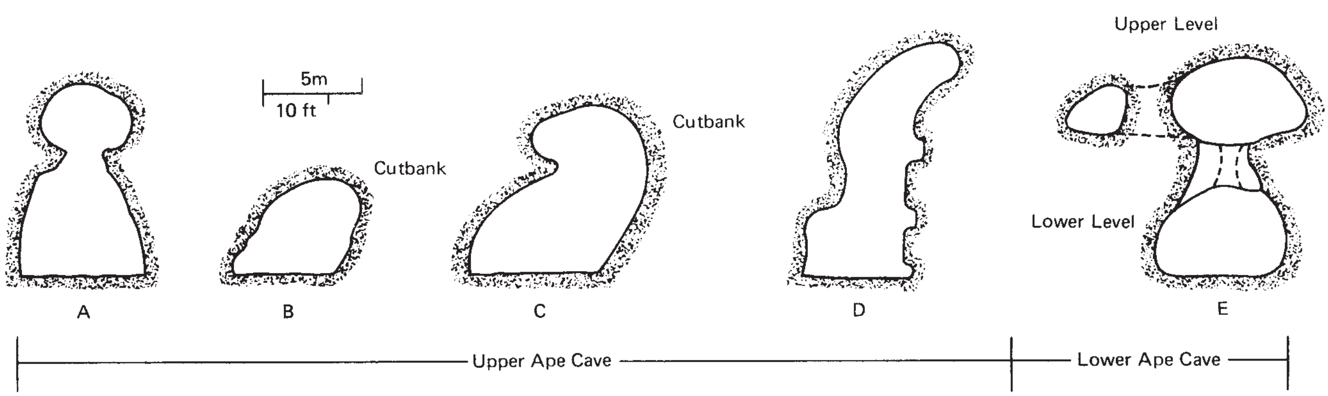

Figure 24. Transverse cross sections of Ape Cave lava tube showing "cutback" configurations and multiple-level development. Stippled area represents lava containing the tube: A. lower Ape Cave near main entrance (about pace 50); view uptube; B. upper Ape Cave (about pace 300); view uptube; C. upper Ape Cave (about pace 400); view uptube; D. upper Ape Cave (about pace 225); view uptube; E. lower Ape Cave (about pace 445); view uptube.

shaped cross section; undercutting by the flow may form asymmetric sections. Some sections in the middle of the flow on gentle gradients have horizontally oval sections which may be due, in part, to lateral erosion. Tube configurations in meander bends are often asymmetric, forming cutbanks similar to stream beds. Further evidence of erosion by lava is found in the form of inclusions of country rock in the lava flow.

Paces	
878	The tube lining has ruptured near the base of the wall and molten lava behind the lining, and (at some points) melted dacite blocks have spilled over the lining and into the tube interior.
(7)	
885	Breakdown area.
(11)	
896	Short upper tube present.
(24)	
920	Small rise in floor; large breakdown blocks fused to floor and walls. Note the fused particles of country rock (result of phreatic explosion).
(27)	
947	Breakdown area, exposures of country rock. A ball of lava is wedged between and fused to the tube walls near the uptube end of the breakdown area.
(80)	
1027	Breakdown area, many exposures of country rock and melted dacite blocks.
(21)	
1048	Breakdown area; it is possible to crawl for about 8 m (24 feet) along the contact between the lava flow and the country rock.
(69)	
1117	Small breakdown area.
(35)	
1152	Skylight and short upper tube. A floor flow with well-formed levees, ropy texture, and slabs is present in the section uptube from the skylight. In this section and uptube from the next small breakdown area, the tube lining has ruptured near the base of the east wall and molten lava has spilled into the tube.
(74)	
1226	Area of small breakdown, lava clinkers exposed in west wall in segment uptube.
(54)	
1280	Large breakdown area, the roof is about 10 m (30 feet) high here.
(24)	
1304	Rise in floor. The segment between this point and the skylight shows well-developed side shelves and ruptured wall lining.
(76)	
1380	Skylight.
(10)	
1390	Skylight, EXIT. The Ape Cave lava tube segment terminates about 157 m (470 feet) beyond (north of) the skylight.
(94)	
1484	End of tube: the terminus of the next lava tube segment (Little Red River Cave) is about 60 m (180 feet) upslope (north).

The east side of the lava flow surface offers the best return path. Many surface features of lava flows are well displayed along the return path. A large crater is present at the point where the path intersects a logging road near the parking lot.

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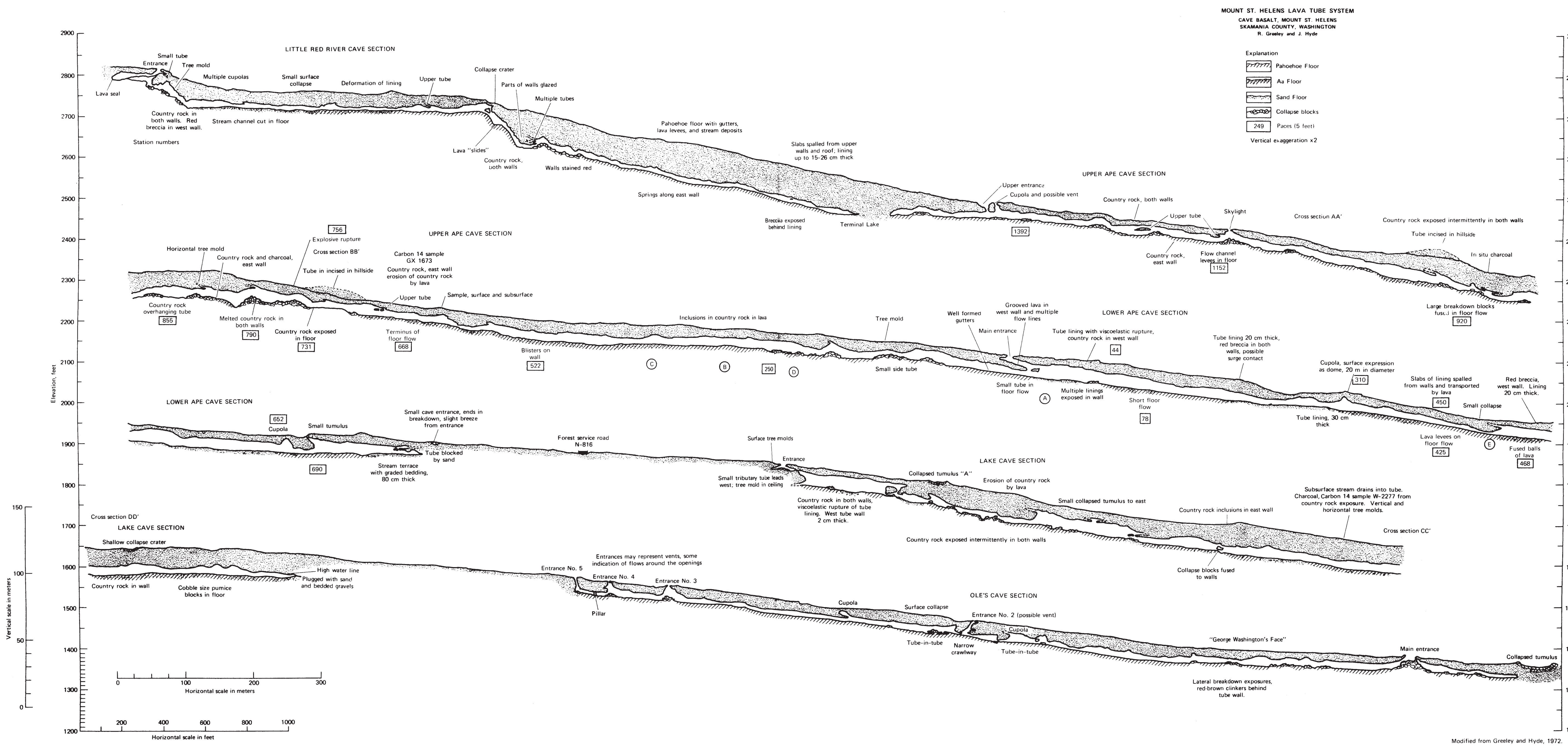

Figure 10. Longitudinal profiles of Mount St. Helens lava tubes.

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