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A Division in Transition

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My introductory column as the State Geologist focuses on transition. The new management team of the Division of Geology and Earth Resources is described elsewhere in this issue. The Division is facing significant challenges and opportunities because of changing circumstances on two fronts: funding and technology. The decade of the 1990s was a period of exceptional economic growth. During the same period, funding for the natural resource agencies in Washington from the state general fund declined from approximately 2.6 cents of every general fund dollar to less than 1.3 cents. Current fiscal projections for the near-term do not bode well for reversing this trend. In addition, at the beginning of the last decade most of the division's products and publications were printed and distributed as they have been for most of the 20th century. Now many of our customers, especially other government agencies, academic institutions, and technically sophisticated private sector organizations, want these products in digital formats for immediate incorporation into their electronic systems.

For the near-term, the division will focus its efforts on activities that enhance public safety, promote effective and efficient use of mineral resources in ways that minimize environmental impacts, and provide information on the earth sciences and the geology of Washington to educators and the public. We may see some negative adjustments to our fiscal year 2003 budget, and some continuing budget challenges for at least the subsequent two fiscal years. As a result, we will be looking for ways to reduce costs, especially non-staff costs. Ideas include moving more publications to electronic distribution as a way to reduce printing costs. The Division will be looking closely at opportunities to obtain outside grant funds to help us achieve our goals. Opportunities may include additional mapping of earthquake and landslide hazards in western Washington and the development of statewide earthquake hazard maps based on our existing 1:100,000 geologic maps to support a statewide hazard mitigation map. We will continue to participate in the federal–state cooperative geologic mapping program to the full extent possible with our general fund budget.

Longer term, we will be evaluating more effective ways to use technology to collect, process, compile, and publish geologic information, to make available more printing-on-demand, to use remote sensing technology for some regulatory compliance activities, and to improve our use of electronic technology to respond to public inquiries. Our overall goal of providing the public with up-to-date information on the geology, geologic hazards, and mineral resources of Washington remains. We also continue to look to our customers for their opinions on how we can best meet their needs. The pace of transition will not permit us to stand still. ■

Cover photo is Mount Rainier looming over the Wilkes Heritage Flotilla in Budd Inlet near Olympia, Washington. Harry Halverson took the picture from a neighbor's porch on Sept. 20, 1987. The flotilla commemorates the first American maritime exploration around the world by U.S. Navy Commander Charles Wilkes, who left Norfolk, Virginia, in 1838 to explore the South Seas and the west coast of North America. His expedition sailed into Puget Sound in 1841 and returned to Norfolk via the Cape of Good Hope in 1842. This photo was on bank calendars and on Harry's business card. See Harry's obituary on p. 26. *Photo courtesy of Halverson Fine Photos.*

1998 Debris Flows near the Yakima River, Kittitas County, Washington—Some Geomorphic Implications

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INTRODUCTION

The geomorphic consequences of debris flows and their associated storms have been documented in many parts of the United States. Few, if any, have been studied and documented in central Washington (Fig. 1). The importance of recurrent debris flows in sculpting Washington landscapes has not been generally recognized compared to other processes. Arid and semi-arid regions are particularly vulnerable to debris flows triggered by sudden intense thunderstorms. Most such areas are sparsely populated and eyewitnesses are uncommon. By contrast, semi-arid central Washington is relatively well populated, and there are likely to be people who have observed the storms. Such witnesses can help provide a better understanding of the role played by these storms in molding the landscape. What follows is an example.

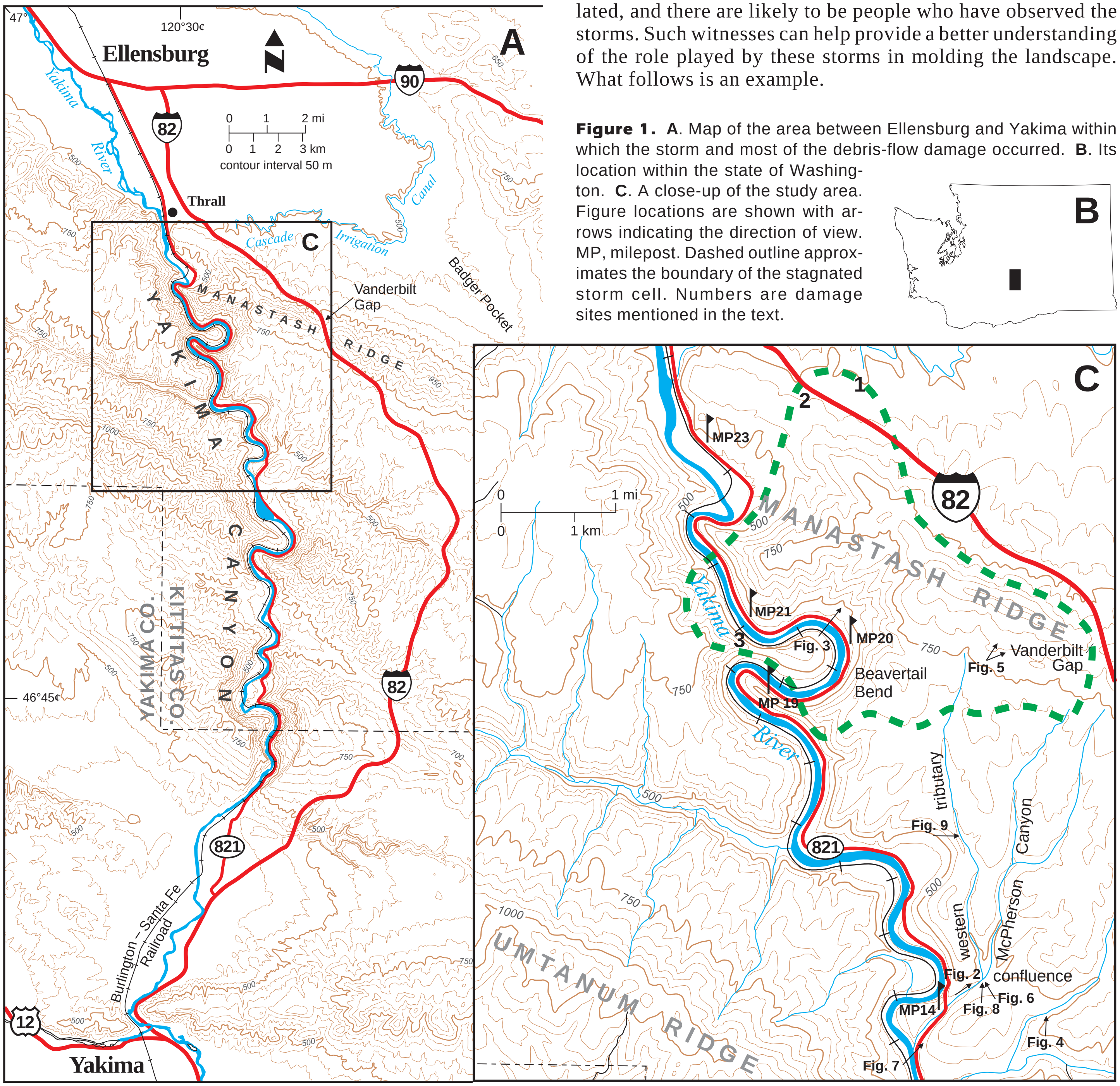


Figure 1. **A**. Map of the area between Ellensburg and Yakima within which the storm and most of the debris-flow damage occurred. **B**. Its location within the state of Washington. **C**. A close-up of the study area. Figure locations are shown with arrows indicating the direction of view. MP, milepost. Dashed outline approximates the boundary of the stagnated storm cell. Numbers are damage sites mentioned in the text.

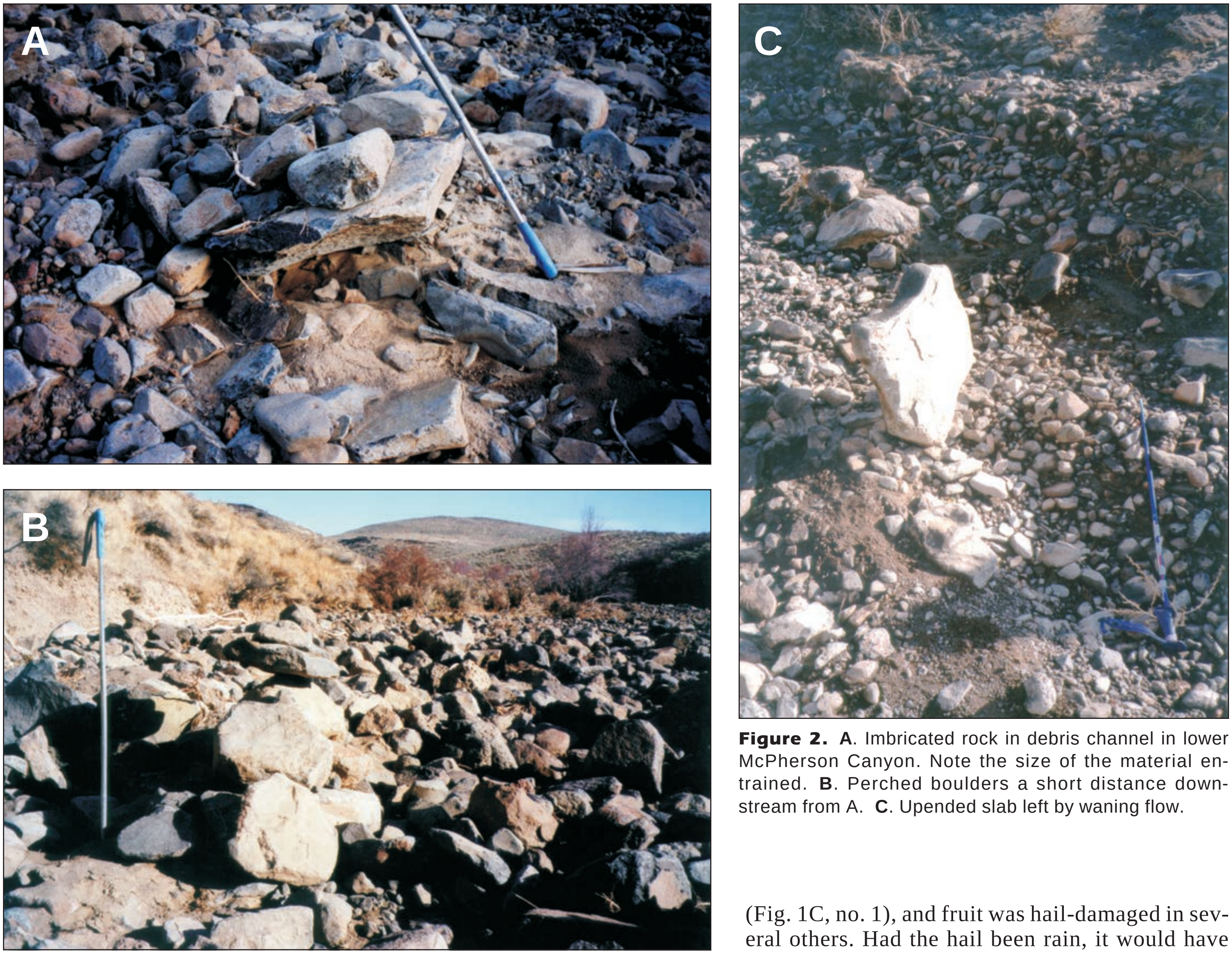


Figure 2. **A**. Imbricated rock in debris channel in lower McPherson Canyon. Note the size of the material entrained. **B**. Perched boulders a short distance downstream from A. **C**. Upended slab left by waning flow.

THE STORM

Between 2:00 and 3:00 p.m. on July 3, 1998, a severe thunderstorm from the west-northwest stalled intermittently over part of southeastern Kittitas County, Washington (Fig. 1). During the cloudburst, Ellensburg recorded 0.87 inches (2.21 cm) of rain in less than an hour. At about 2:15 p.m., witnesses southeast of Ellensburg in the Badger Pocket area reported a tornado-like cloud that appeared to touch down in the vicinity of Thrall near the north entrance to the Yakima River canyon. Some observers also reported an apparent convergence of winds from the northeast and southwest that may have preceded the funnel-like cloud. One observer said "the storm seemed to come in three waves, starting at about 2:30 p.m. Strong winds and rain out of the west hit the area first, and then very strong winds came. . . from the north, followed by a ten minute lull. . . then winds, rain and hail cascaded out of the southwest" (*Ellensburg Daily Record*, July 7, 1998).

As the generally southward-moving storm cell began ascending Manastash Ridge (Fig. 1), it intensified, probably from the uplift. When the cell reached the ridge top, it straddled the ridge and stalled for nearly an hour. Records from the automated weather recorder at Interstate 82 (I-82) on the northeast flank of Manastash Ridge indicate that more than 3 inches (7.6 cm) of rain fell in less than one hour. Much of one orchard was covered with an estimated 5 inches (13 cm) of hail (Fig. 1C, no. 1), and fruit was hail-damaged in several others. Had the hail been rain, it would have added measurably to erosion. Winds in excess of 21 mph were recorded on an agricultural anemometer 6.5 feet (2.1 m) above ground level.

When the storm lifted, it left the remainder of the upland surface rainless from about 1 mile south of the Manastash Ridge crest all the way to Yakima, 25 miles (40 km) farther south. There the cell touched ground and again stalled. In less than an hour, 3.2 inches (8 cm) of rain fell over the Yakima city area. The previous one hour record was 2.03 inches (5.16 cm).

According to the Pendleton National Weather Service office (Joe Solomon, Pendleton National Weather Service Meteorologist, oral commun., 2001), the atmospheric conditions on July 3 were as follows. Convection developed along west-to-east-oriented ridges of the east slopes of the Cascades west of Ellensburg around midday. A large upper-level low east of the Cascades was moving northwesterly upslope into the mountains. The presence of the low helped to facilitate an eastward push of marine air from western Washington through the passes. The marine push eventually overcame thermally produced upcanyon wind patterns associated with the mountain topography. The advancing marine air began to counter the flow pattern of the upper level low. Individual storm cells began to merge. As they combined, they stagnated into a single major cell that hovered for close to an hour over the steep terrain south of the Kittitas valley near the Yakima River canyon. Torrential rainfall, totaling 3 to 4 inches (8–10 cm), fell in a little over an hour.

Figure 3. Debris flows along the north side of Beavertail Bend of the Yakima River burying State Route 821 and debouching into the river. Note the small catchment areas of the ravines and their steep scoured channels. *Photo courtesy of the Washington State Department of Transportation.*

The boundary between the surfaces that experienced torrential precipitation and those that remained almost completely dry was especially well-defined on the southwest flank of Manastash Ridge. Here the edge of the less than 4-square-mile (10.6 km^2) catchment area was marked by rills and flattened grasses next to undisturbed surfaces.

DEBRIS FLOW DAMAGE

Undoubtedly there were variations in the amount and duration of the precipitation over the principal storm area on the flanks of Manastash Ridge, but the quantity and intensity of precipitation that occurred over very limited surface areas was impressive. The rate of precipitation vastly exceeded the rate of infiltration, producing damaging debris flows. The ratio of the supply of water to the supply of regolith determined flow viscosity, and, together with channel gradient and channel roughness, determined the speed of the debris flows. Surges or pulses in the flows were associated with significant sediment additions from undercut channel banks and temporary pondings of the flow. The downstream volume of debris flows is generally proportionate to the area drained, but the channels descending Manastash Ridge varied enough in some instances to make the gradient and the supply of debris available more determinant. (See discussions of debris flow characteristics in Costa, 1984, and Johnson and Rodine, 1984.)

The summit area of Manastash Ridge and the drainages south of the summit have a cover of discontinuous loess and relatively thin colluvium, with many outcrops of weathered basalt bedrock (see Figs. 5 and 6). Storm-induced torrents raced down northeast-facing ravines on the flank of the ridge between Yakima River and Vanderbilt Gap (where I-82 crosses the ridge) (Fig. 1). The ensuing debris flows overtopped ditches and damaged irrigation canals and roads. The Kittitas Reclamation District Mainline Cascade Irrigation Canal suffered one 40-foot (12 m) and one 12-foot (3.6 m) washout (Fig. 1, no. 1). Part of a 50-foot (15-m) long, 4.5-foot (1.6 m) square irrigation tunnel beneath I-82 was plugged with debris (Fig. 1, no. 2). Roadside ditches overflowed, piling debris on to the roads.

West of the Yakima River, a small area that received less sustained precipitation extends a short distance upslope, but not far enough upslope to provide a catchment capable of producing the scale of debris flows that occurred east of the river. The one exception is a flow that buried the Burlington–Santa Fe railroad tracks (Fig. 1, no. 3). On the left bank of the river, concentrated and sustained rainfall flushed out several ravines, some of whose drainage basins are better measured in acres (hectares) than square miles (kilometers).

After the storm, a landscape of scoured and scarred channels remained, commonly eroded to bedrock. Devastated vegetation adjacent to channels

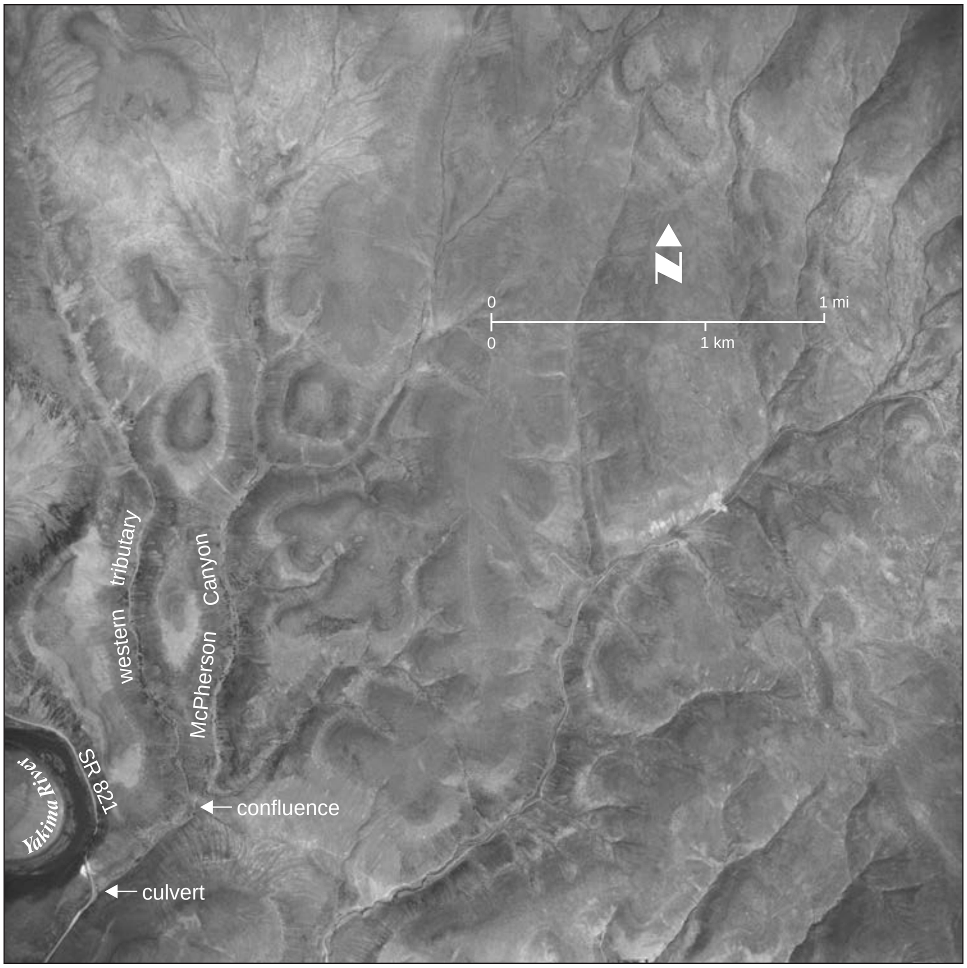
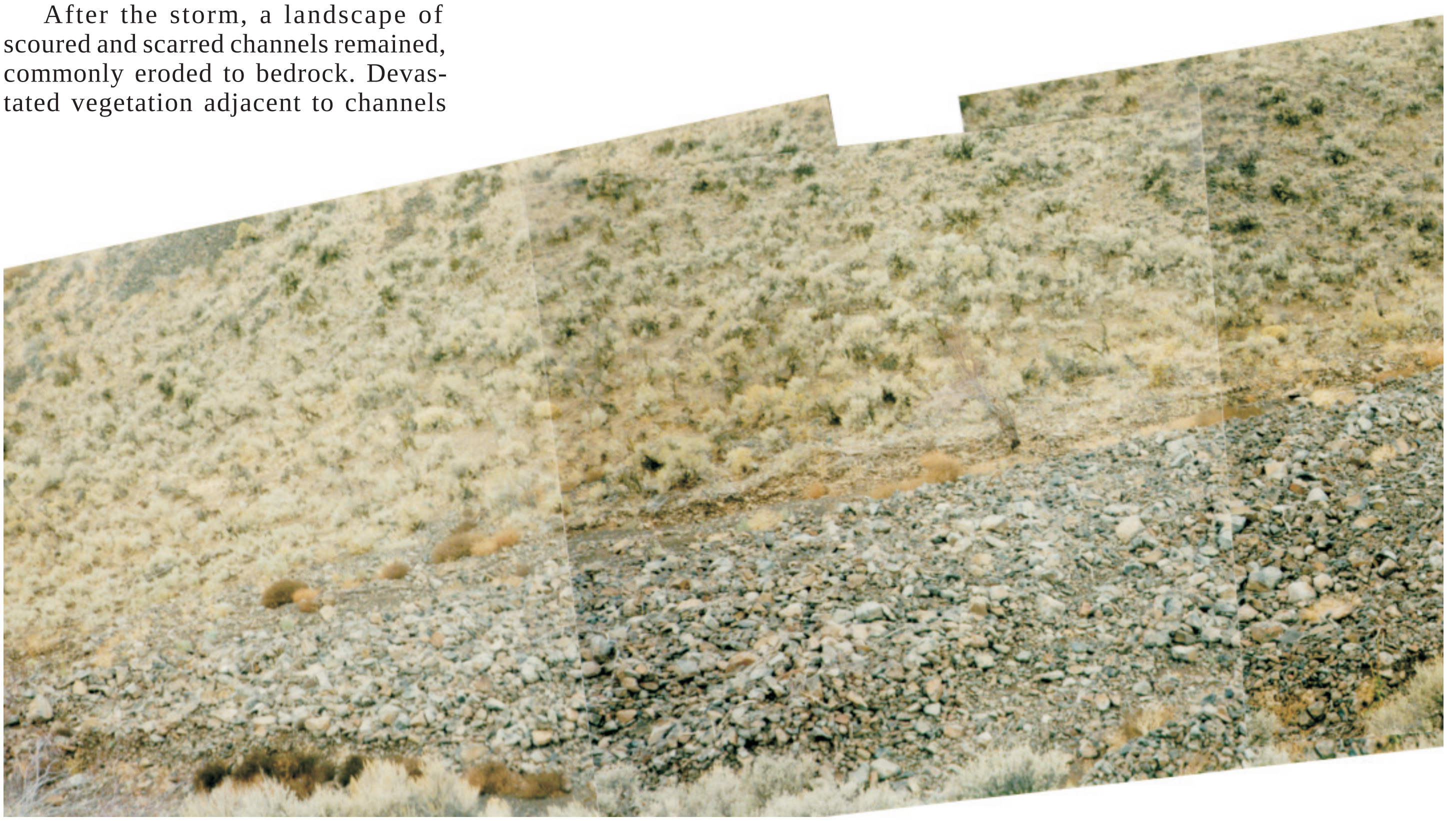


Figure 4. A 1942 air photo of the McPherson Canyon catchment area. Note the bare summits. The erosion illustrated in Fig. 5 occurred a very short distance above the top edge of the photo. The view in Fig. 7 runs approximately from the lower left to the upper right of Fig. 4. *Photo courtesy of the U.S. Department of Agriculture.*



and intermittent lobes of cobbles and boulders were typical. Fresh percussion marks on rocks testified to the force with which some of the entrained rocks struck one another. Debris suspended on bankside shrubs indicated that some flows had depths greater than 6 feet (1.8 m). Debris levees formed intermittently along channel flanks. Lobes of debris occurred wherever the velocity was so diminished that the slurry conveying the debris could no longer maintain its momentum. Deposition was especially favored where channel gradients and channel confinement or constriction lessened significantly. Some of the rock deposits show imbricate bedding, a few with basalt slabs a foot (30 cm) or more in diameter. Here and there, rocks remained perched precariously after their supporting slurry drained away (Fig. 2).

Ravines draining westward from the southwest flank of Manastash Ridge directly into the Yakima River canyon discharged rocky debris that quickly buried portions of State Route (SR) 821, depositing debris fans into the adjacent river channel. The deposits generally lie downstream of the principal precipitation catchment area. Every ravine abutting SR 821 between mileposts 19 and 23 (Fig. 1), a straight-line distance of about 2.6 miles (4.2 km), was affected to some degree by the torrents. Major debris deposits covered SR 821 in eight separate places between mileposts 19 and 21 opposite Beavertail Bend. Six reached well into the river. One of these buried the highway with debris more than 15 feet (4.6 m) deep and continued nearly 60 percent of the way across the river channel (Fig. 3). The ravines, all less than one mile (1.6 km) long,

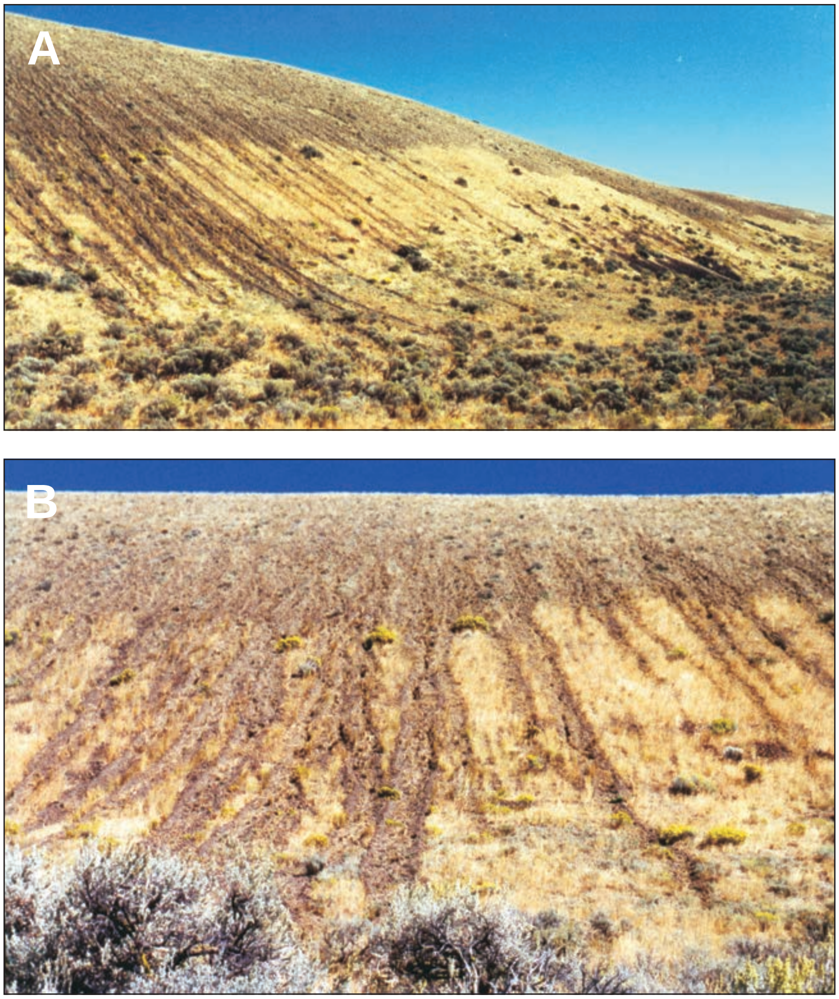


Figure 5A and B. *(top and middle, this page)* Streaked southwest flank of Manastash Ridge following the July 1998 storm. The streaks are furrows eroded through the loess (silt) mantle down to bedrock. *Photo courtesy of Will Johnson.*

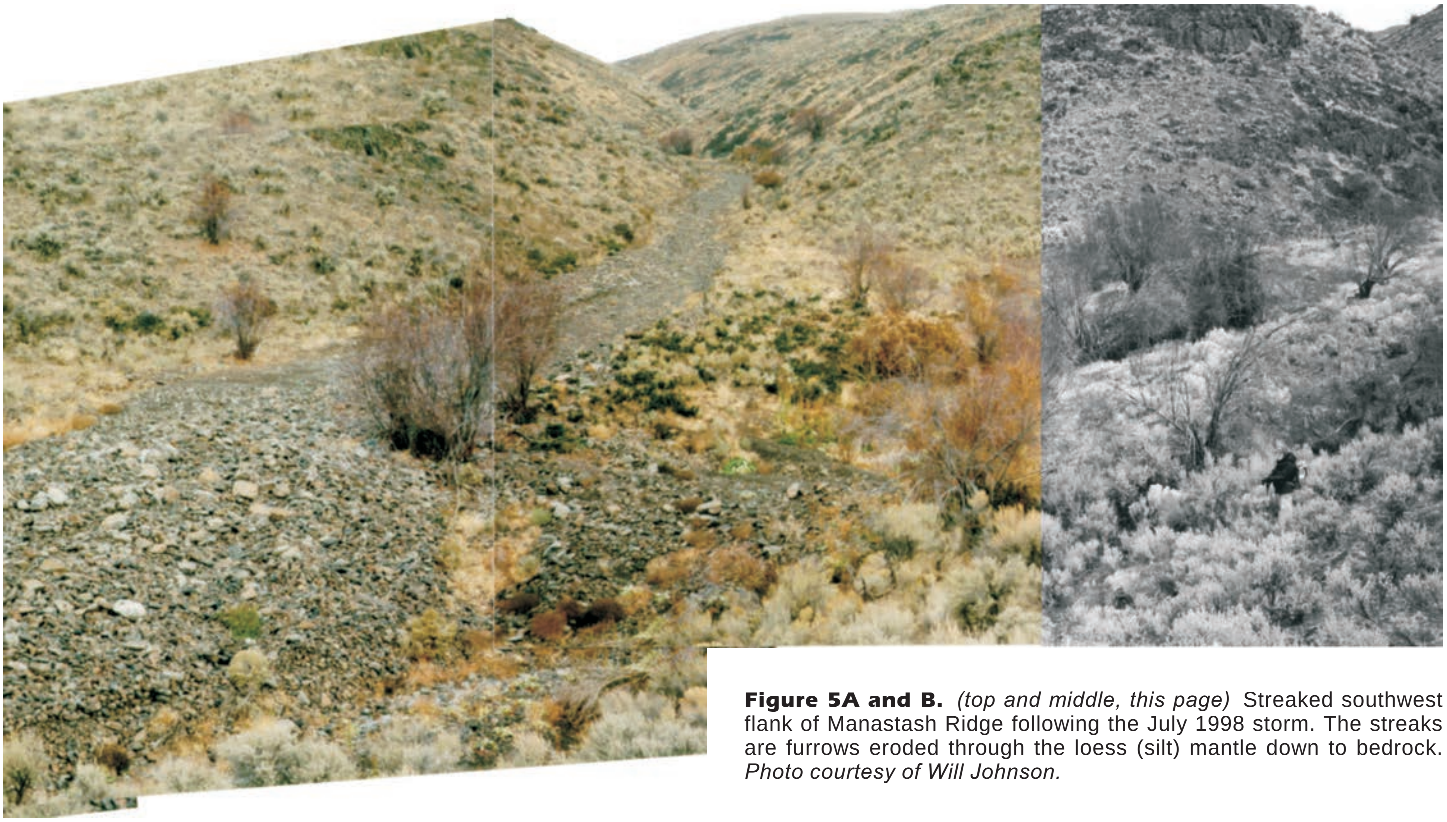


Figure 6. *(preceding page and bottom, this page)* Debris lobe at the confluence of the unnamed western tributary, upper right, and the main McPherson Canyon channel in the foreground.

Figure 7. Looking northeast from the mouth of McPherson Canyon to the summit of Manastash Ridge. Note the scoured channel between the highway crossing of McPherson Canyon and the confluence debris lobe. Erosion from the overflow of the culvert can be seen paralleling the highway downstream to the Yakima River. The catchment area for the debris flow in McPherson Canyon lies beyond the left side of the photo (Fig. 4). *Photo courtesy of the Washington State Department of Transportation.*

concentrated the flows and provided a very steep gradient. Channel incision was initiated at about 1,000 feet (300 m) above Yakima River level. Were there no maintained highway in place, there would have been steep alluvial aprons at the ravine mouths, accumulations testifying to past debris flows. Some would have coalesced, forming compound fans projecting into the river channel and deflecting it, at least temporarily.

What happened in lower McPherson Canyon and its upstream unnamed western tributary illustrates the nature and power of cloudburst-generated debris flows particularly well. Portions of the southbound lane of SR 821 at milepost 14 were washed out by inundation from an overwhelmed culvert that carries the ephemeral stream in McPherson Canyon beneath the roadbed. (The name 'canyon' is deceiving. Only a few hundred yards of McPherson Canyon's stream channel are canyon-like.)

The damage here was about 3 straight-line miles (5.4 km) beyond the limit of the storm's catchment area. Less than one third of McPherson's 5.5-square-mile (14.3 km^2) watershed, which originates on the southwest slope of Manastash Ridge, collected the storm's precipitation. The catchment area is covered, more or less, by sagebrush-steppe vegetation and a discontinuous, often thin, loess (silt) blanket (Fig. 4). From the ridge summit west of I-82, fresh, naked rows of loose rock interspersed with sparsely vegetated strips (stone stripes) extend downslope (Fig. 5). This loose rock and loess, augmented with debris gathered by sheetwash and rilling on the ridge's mid flanks, was the initial source of storm-delivered sediment to first-order channels of McPherson Canyon. The slurry that formed from the sediments had the velocity needed to entrain cobbles and boulders up to about 1.5 feet (0.5 m) in diameter (Fig. 3). Most of the discharge of water, entrainment of debris, and erosion occurred in the western tributary to McPherson Canyon. Only the upper portion, about one square mile (2.6 km^2), of the tributary's watershed was entirely within the catchment area.

A very large lobe of rocks (Fig. 6) was deposited by the debris flow where the western tributary joins the main channel of McPherson Canyon. Its volume and size approximates that of the largest of the deposits, estimated to be 50,000 cubic yards (38,227 m^3) in volume and more than 15 feet (4.5 m) deep, that flowed onto SR 821 near milepost 20 (Fig. 3). A widening of the valley floor, a decrease in channel gradient, and a change in channel direction combined to decrease flow velocity and deposit the debris lobe at the confluence.

The channel discharge that followed the loss of load at the confluence caused extensive downstream erosion and highway damage (Fig. 7). The now-more-liquid slurry was able to speed downstream, relatively unencumbered, to a culvert beneath SR 821. It overwhelmed the culvert and turned the highway embankment above the culvert into a 150-foot (46 m)-wide dam, temporarily ponding the surging water for a distance of 700 feet (220 m) upstream. When the impounded water overtopped the embankment barrier, it eroded a double cataract into the pavement where it plunged back into its channel adjacent to the highway's southbound lane. Other segments of the road were undermined as the flood continued down the channel to its confluence with the Yakima River. Subsequently, a narrower, deeper channel trenched this reach, a response to at least one last surge of essentially debris-free water.

The confluence debris lobe is the only major debris flow deposit that has remained undisturbed since the storm occurred. Those deposited on SR 821 were removed or bulldozed aside to maintain traffic through the Yakima River canyon. The configuration, composition, and other characteristics of the confluence debris plug suggest the sequence and some of the dynamics associated with the debris flows. The sequence appears to have been: (1) An initial, relatively sediment-poor flow came down the main channel of McPherson Canyon, and perhaps its western tributary as well. It was not associated with significant evidence of deposition. (2) A

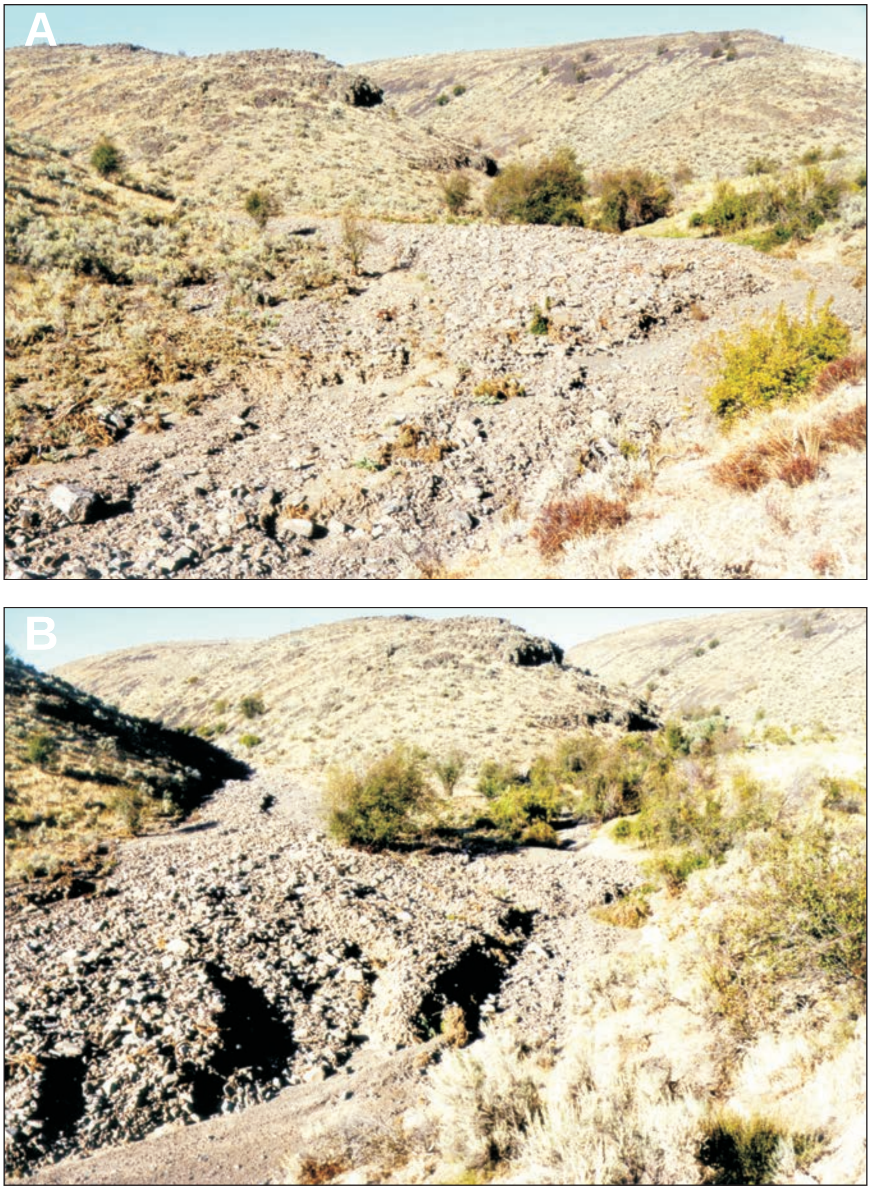


Figure 8. **A**. Toe of the confluence debris lobe showing incision by flooding following initial deposition. **B**. Incision on debris lobe south flank. The western tributary, the source of virtually all of the debris, is on the upper left; the main McPherson Canyon channel is on the upper right.

Figure 9. *(right)* Stratigraphy of alternating cobbles and fines in incised channel of the western tributary indicates the occurrence of previous debris flow events.

subsequent flow down only the western tributary deposited the debris lobe. (3) A final(?) flow down the western tributary continued to the outlet of McPherson Canyon. The debris lobe is scarred by at least three gullies (Fig. 8) partially incised into its distal flank, suggesting that the lobe was overtopped after its initial deposition.

That this happened when less than 25 percent of the entire McPherson Canyon watershed lay in the catchment area illustrates the extraordinary amount of erosion that a cloudburst may generate even when it occurs over a very limited portion of a watershed.

PREVIOUSLY RECORDED DEBRIS FLOWS

Nothing in the preceding account is particularly unusual relative to the behavior of debris-flow-producing storms. There have been many previous debris-flow-producing storms in the general vicinity of the 1998 event. One on June 21, 1967, produced debris flows in two of the same ravines affected by the 1998 storm. Another, on Aug. 10, 1952, initiated debris flows in drainages west of the Yakima River near the 1998 site. A July 26, 1977, storm generated debris flows several miles to the east. Elsewhere in Kittitas County, intense summertime storms were recorded on Sept. 14, 1940, Aug. 20–21, 1990, and July 24, 1991. Some of the channels affected by the 1998 storm have very old debris flow levees that are much larger than the new ones. These are indicative of powerful storms in the past for which there are no written records (Fig. 9). The normal flow associated with these ephemeral streams is not capable of generating the significant channel erosion that is associated with debris flows.

CONCLUSION

Catastrophic events on a small, relatively localized scale may be significant to understanding the geomorphology in portions of upland semi-arid central Washington (Beatty, 1974). Cloudburst-generated debris flows are sudden, spasmodic events recurring at irregular intervals over limited surface areas. Their work is rarely observed, and their geomorphic importance in sculpting the landscape in central Washington is rarely appreciated.

Previously, periglacial activity during the late Pleistocene has been cited as the primary agent for loess segmentation and removal in much of central Washington (Kaatz, 1959). There is no reason to dispute that role. Periglacial processes were critical to the initiation of upland loess dissection. In post-glacial times, however, evidence indicates that summer cloudbursts may have supplanted frost action as a dominant landscape-shaping process.

During the Pleistocene, periglacial denudation proceeded in a rather steady incremental manner over extensive, largely contiguous areas that were either underlain by permafrost or exposed to deep seasonal frost (Clark, 1988). Holocene cloudbursts, on the other hand, occur over limited areas. For example, although at least seven cloudburst-like storms are known to have occurred in eastern Kittitas County in the last 50 years or so, only one has occurred in the area delineated in this paper.

It is unlikely that winter events, such as rain on snow, generate enough runoff on the ridges that separate Ellensburg from Yakima to produce debris flows. The south-facing slopes of the ridges are especially vulnerable to poor snow retention during frequent sunny winter days, hence there is usually insufficient snow to provide enough meltwater to combine with steady, prolonged, low-intensity rainfall (typical of local winter rain) to cause debris flows. Therefore summer cloudburst-generated debris flows should be considered a dominant agent of upland landscape change in the region between Ellensburg and Yakima during the Holocene.

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This study benefitted from field observations and review of the manuscript by Lisa Ely, Department of Geology, Central Washington University; Karl Lillquist, Department of Geography, Central Washington University, and Will Johnson, M.S. Resource Management. Photographs taken by Will Johnson shortly after the storm were particularly helpful. Jari Roloff edited the article and also did the graphics; Karl Wegmann and Karen Meyers reviewed the article.

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Debris Flows Websites

Debris-Flow Hazards in the United States [http://geohazards.cr.usgs.gov/factsheets/html_files/debrisflow/fs176-97.html]

Mudflows, Debris Flows, and Lahars [http://vulcan.wr.usgs.gov/Glossary/Lahars/framework.html]

History of Landslides and Debris Flows at Mount Rainier [http://wa.water.usgs.gov/fs_landslide.html]

New Liquefaction Website

The University of Washington has a new website about soil liquefaction with animation, photos, and discussions of liquefaction in major earthquakes—http://www.ce.washington.edu/%7Eliquefaction/html/main.html. The website was developed to provide general information for interested lay persons, and more detailed information for engineers. Visitors who are not familiar with soil liquefaction can find answer to typical questions below.

What is soil liquefaction?

When has soil liquefaction occurred in the past?

Where does soil liquefaction commonly occur?

Why does soil liquefaction occur?

How can soil liquefaction hazards be reduced?

More detailed information, presented at a level that does require an engineering background, can be obtained by following the links labeled “More” at the end of each section. There are also links to other sites on soil liquefaction research and earthquake and soil liquefaction information.

Dating the Bonneville Landslide with Lichenometry

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ABSTRACT

The Bonneville landslide, located on the Washington shore of the Columbia River Gorge, is a recent geologic feature, most likely deposited within the last 800 years. Due to its modern status, typical radiometric methods of dating landforms fail to date the event with precision. This study uses lichenometry to estimate the age of the Bonneville landslide deposit. I measured lichens in the Columbia River Gorge at sites where the ages of substrates were known. The regression of *lichen size* and *years since establishment* produced a linear equation. Using lichen measurements obtained from atop the Bonneville landslide, I rearranged the regression equation to extrapolate a population of ages for the landslide. This population yields a mean age of 287 years for the emplacement of the deposit, with a conservative 2 standard deviations (SD) confidence interval of ±43 years. Conversion to calendar dates (rounded to the nearest decade) indicates that the landslide likely occurred between 1670 A.D. and 1760 A.D. These dates corroborate recent radiocarbon dates presented for the age of the Bonneville landslide by Pringle and Schuster (1998). In addition, they provocatively bracket the 1700 A.D. date of the last great Cascadia subduction zone earthquake, though no causal relationship between the Cascadia earthquake and the Bonneville landslide can be determined by this research.

INTRODUCTION

The small town of Stevenson, Washington, stands just east of a remarkable landscape. From town, your eyes are quickly drawn to the improbably precipitous scarp below the summit of Table Mountain (Fig. 1). Over 400 m (1300 ft) of sheer vertical relief is exposed in this face, and its total relief approaches 1020 m (3350 ft). Beneath this cliff lies more than 14 km^2 (5 mi^2) of rumpled landscape that was once orderly mountain strata. Commonly known as the Bonneville landslide, the deposit is composed of odd hummocks and ponded depressions, all with a complex patterning of disparate rock types distributed across the surface. This landslide is believed to have achieved a velocity of more than 10 m/s (33 ft/s) (Palmer, 1977), and the rapidly emplaced deposit completely dammed the Columbia River (Fig. 2). Subsequent breaching of the dam occurred nearly 1.5 km (1 mi) to the south of the original river channel and created a series of huge rapids (later called ‘The Cascades’) that immediately became an important fishing ground and portage point for Native American cultures (Bourdeau, 1999).

Wise (1961) and Waters (1973) determined from surficial geology that the landslide deposit is a composite feature that resulted from several distinct events. They mapped individual lobes of the landside complex and calculated the total area of the composite landslide as 30 to 36 km^2 (11–14 mi^2) and the areas of the individual landslides as from 5 to 14 km^2 (2–5 mi^2) (Palmer, 1977). The Bonneville landslide is merely the most recent event to occur and possibly the largest in what is now known as the Cascades landslide complex.

The occurrence of the Bonneville landslide is well established. Native Americans were certainly present on the landscape at the time of the event, and the landslide was captured in the mythology of regional cultures as the legend of the “Bridge of the Gods” (Lawrence and Lawrence, 1958), which uses the geologic event as a key component. Lewis and Clark recorded the first written observations of the landslide, noting in 1806, “…the river has been obstructed at the rapids by the rocks which have fallen into that channel within the past twenty years; the appearance of the hills at that place justify this opinion” (Strong, 1967). The precise year that the Bonneville landslide occurred is not known, although many potential dates have been suggested.

DATING THE BONNEVILLE LANDSLIDE

Lawrence and Lawrence (1958) noted that explorers in the early 1800s believed the pristine state and original position of

Figure 1. Aerial-oblique photo of the Bonneville landslide. View is to the northeast with Mount Adams volcano in the distance. Table Mountain with its triangular scarp is in the upper left of the photo. Bonneville Dam and its powerhouses (lower left) and the “Bridge of the Gods” highway bridge (far right) flank the landslide. *Photo courtesy of Derek Cornforth, Landslide Technology.*

drowned trees still extant in the river upstream of the landslide area indicated the river-damming event must have occurred around 1750. The Lawrences also reported that ring counts of large trees, cut in 1912 from locations on the slide, showed that the slide had occurred before 1562. In an attempt to discern the age of the landslide, they used radiocarbon dating on two samples of wood from drowned trees, obtaining values of 670 ±300 yr B.P. and 700 ±200 yr B.P. Like Wise (1961) and Waters (1973), the Lawrences reported that the landslide deposit exhibited the characteristics of a composite feature. However, they appear to have incorrectly interpreted adjacent lobes in the Cascades landslide complex as 'secondary' to the Bonneville landslide, rather than as predating the Bonneville event.

Minor (1984) presented five radiocarbon dates from wood debris found within and below the landslide during the 1978 excavation for the second powerhouse at Bonneville Dam. Three of the samples were more than 3,000 years old. He reported the date of another sample, taken from the outer rings of a Douglas fir (*Pseudotsuga menziesii*) log unearthed during the excavation, as 830 ±60 yr B.P. The last of the five samples returned a radiocarbon date of 400 ±70 yrs B.P. This sample, BDH-1094, was a small piece of wood obtained from a Becker hammer drill core at a depth of approximately 30 m (98 ft) (U.S. Army Corps of Engineers, 1976). Minor initially reported that this sample was obtained from sand deposits below the landslide debris, but later in the same paper said that the sample "may date a later secondary slide on top of the Bonneville deposits" and that the date of the sample was "too recent to relate to the main Bonneville Landslide." Minor believed that the date of 830 ±60 yr B.P. from the Douglas-fir log correlated well with the radiocarbon dates previously presented by the Lawrences and concluded that the Bonneville landslide occurred between 1060 A.D. and 1180 A.D. His estimate of 1100 A.D. has often been cited.

In 1998, Pringle and Schuster presented a new radiocarbon age for the Douglas fir log originally sampled by Minor. They analyzed two samples from different areas of the log, which yielded ages of 410 ±80 yr B.P. (120 rings in from bark) and 360 ±80 yr B.P. (20 rings in from bark), less than half of the age presented by Minor. Pringle (Wash. Divn. of Geology and Earth Resources, written commun., 2001) noted that he "cannot explain the discrepancy in the results" between the Minor date and the Pringle/Schuster date.

LICHENOMETRY AS A DATING TOOL

In an attempt to resolve the debate over the age of the event, I used lichenometry to estimate the age of the landslide. Lichenometry has been used since the early 1950s to date both geomorphic events and archaeological features. Historically, the science has been hindered by a "paucity of widely accepted measurement and analytical procedures" (Bull and Brandon, 1998). Many workers have estimated event ages based upon the diameter of the single largest or mean of the five largest lichens in the study area. However, larger sample sizes and refined measuring techniques have recently yielded robust analyses (McCarroll, 1994; Bull and Brandon, 1998; Winchester and Harrison, 1999).

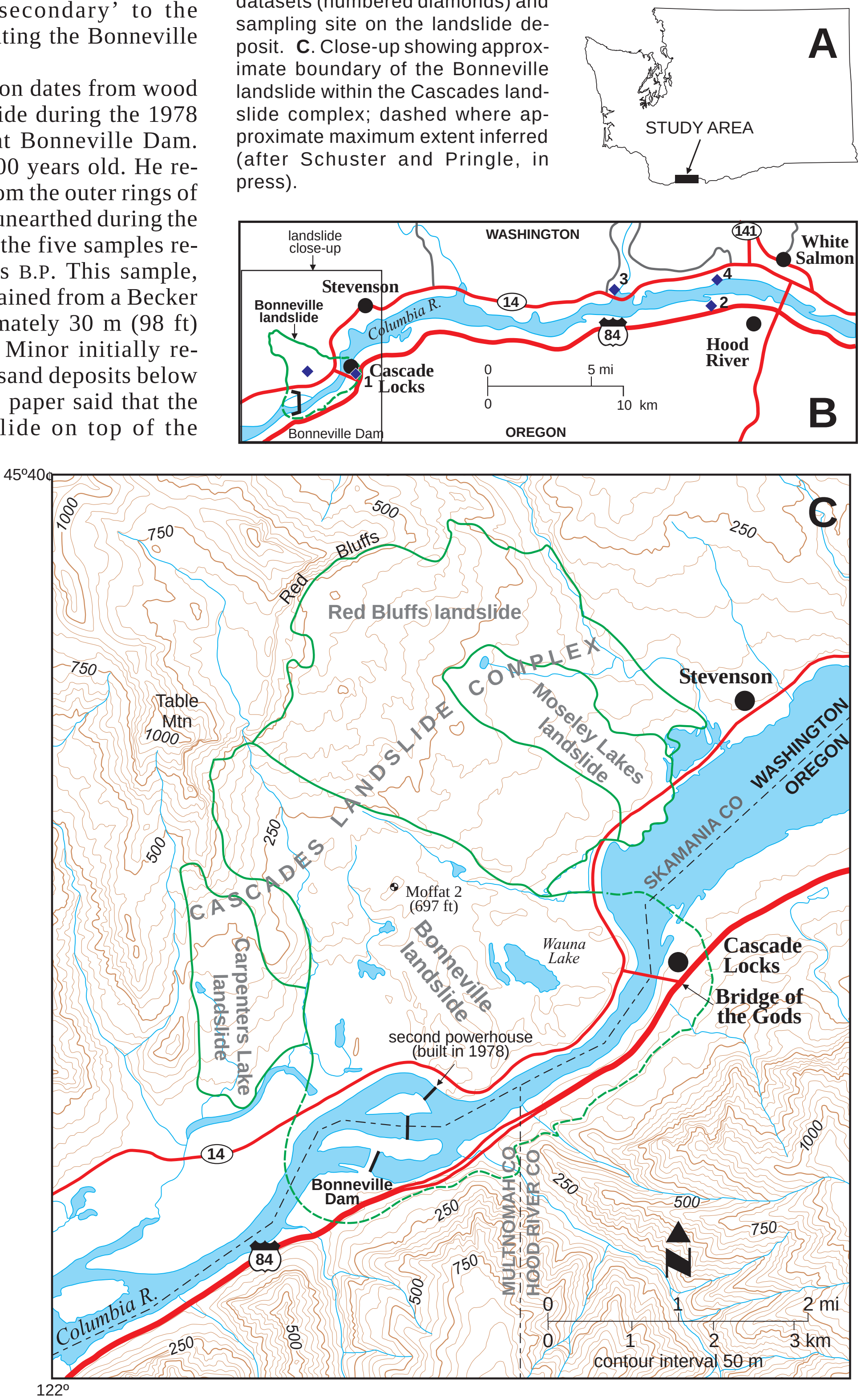

Figure 2. **A**. Location of study area within Washington State. **B**. Study area with sampling site locations of the four reference datasets (numbered diamonds) and sampling site on the landslide deposit. **C**. Close-up showing approximate boundary of the Bonneville landslide within the Cascades landslide complex; dashed where approximate maximum extent inferred (after Schuster and Pringle, in press).

Lichens are a very slow-growing life form. Crustose lichens growing closely appressed on rocks become virtually inseparable from the surface of the rock. Growth in crustose lichens is commonly observed or measured only as an increase in the diameter of the *thallus*, the body of the lichen. Some alpine lichens may live more than 1,000 years, possibly as much as 4,500 years (Purvis, 2000), putting them on par with the oldest of the vascular plants and making them useful for dating recent geologic events.

A fresh rock surface, created by a landslide, flood scour, or volcanic event is immediately open to colonization by lichens. Thallus size of a crustose species is therefore proportional to the time elapsed since disturbance. If a growth rate can be systematically determined by examining reference sites (substrates of known ages), the time elapsed since disturbance at the target site can be determined.

Previous lichenometry studies have focused on the genus *Rhizocarpon* (Porter, 1981; Burbank, 1982; Innes, 1983), and in particular, *Rhizocarpon geographicum* (L.) DC., commonly known as *map lichen*. Poelt (1988) expressed concern that *R. geographicum* may actually represent a group of species that remain insufficiently described to separate. Recent studies (Bull, 1996; Winchester and Harrison, 1999) have used other species of crustose lichens including *Pleopsidium chlorophanum* (Whalb.) Zopf., *Lecidea atrobrunnea* (Raymond ex. Lam. & DC.) Schearer, and *Lecanora sierrae* B.D. Ryan & T. Nash. However, Bull and Brandon's significant 1998 treatise on lichenometric methods used the entire yellow *Rhizocarpon* group without differentiating individual species.

This study is one aspect of a multifaceted attempt to use biometric methods to date the Bonneville landslide. The results of this inquiry provide an age estimate that may help resolve the Bonneville landslide controversy and better direct future research.

METHODS

I began sampling on a boulder field generated by the Bonneville event. Slopes at this site are below the angle of repose, and the site is the highest point on the deposit in the immediate vicinity (an area of approximately 2.5 km^2 or 1 mi^2) (Fig. 2). This site is immediately east of the Moffat 2 benchmark. According to Palmer (1977), the Bonneville landslide deposit has settled due to "reconsolidation and compaction", but it is probable that no deposition of new landslide debris has occurred at this site since the original emplacement of the deposit. Vegetation at the site is limited—a few storm-weathered Douglas fir, scattered ocean spray (*Holodiscus discolor*), and poison oak (*Rhus diversiloba*) patches are the predominant woody plants. Herbaceous vegetation is largely nonexistent, and a thick layer of moss (*Racomitrium elongatum*) covers the surface of the landslide deposit (Fig. 3). Several small outcrops of consolidated rock protrude from the loose debris at the 210 m (670 ft) high point of this boulder field. These rocks are Grande Ronde Basalt of the Columbia River Basalt Group and originally capped Table Mountain (Korosec, 1987). I targeted these outcrops for sampling because they appeared to be the most stable features in the sampling area (the least likely to have settled or moved) and should therefore provide the oldest substrate.

I measured the lichens using a variation of the FALL technique, which is the 'Fixed Area Largest Lichen' method described by Bull and Brandon (1998). I considered each face of an outcrop a discrete sampling area and measured, using digital calipers, the diameter of the largest *Rhizocarpon* occurring on each face (Fig. 4). Bull and Brandon (1998) demonstrated that digital calipers are an effective tool for measuring the diameter of lichen thalli with high precision, strong replication, and minimization of observer bias. I examined the least friable faces, including the tops of the outcrops, taking precautions to ensure that no face was examined twice. I recorded measurements without regard to microsite environmental conditions—dry and moist faces, windward and leeward sides, high and low light conditions, and horizontal and vertical faces.

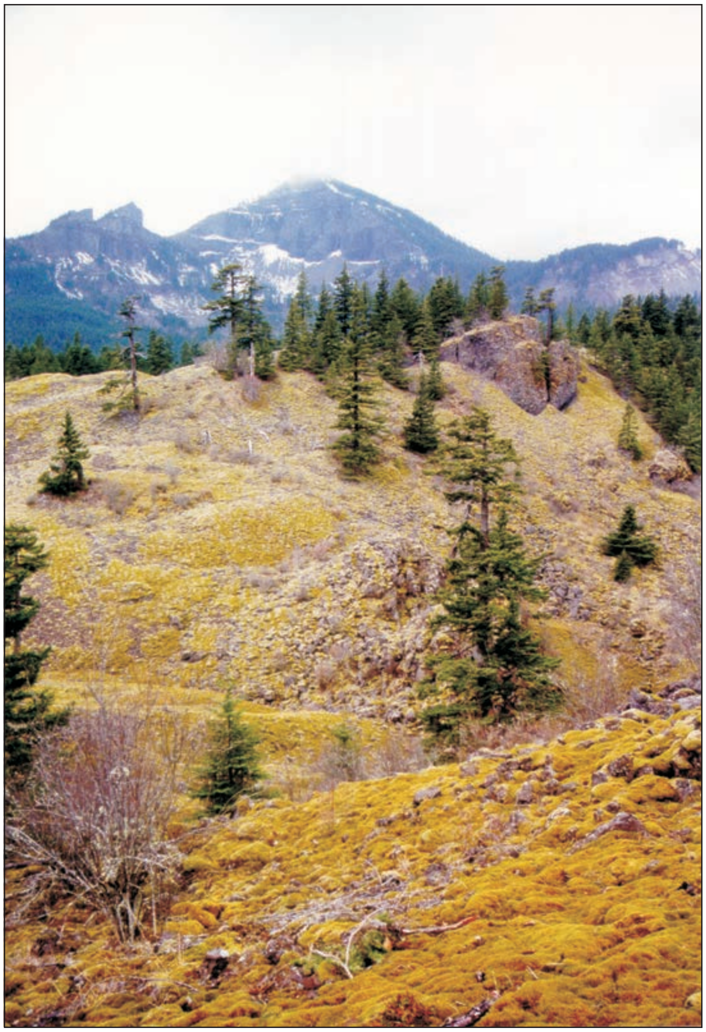

Figure 3. Looking northwest up the Bonneville landslide toward Table Mountain from near the Moffat 2 benchmark. The top of Table Mountain is obscured by clouds.

Lichens that appeared to be merged individual thalli or that wrapped around the edge of any rock face were not included. Similarly, any lichen that was distinctly noncircular was not included. I took measurements across the longest axis, as it is assumed to represent the highest potential growth (Bull and Brandon, 1998). Measurements included the *prothallus*, the black margin of the thallus. I recorded 30 measurements from the landslide site.

During sampling (all of which occurred during the spring of 2001), I collected representative *Rhizocarpon* specimens at study sites, which I forwarded to a professional lichenologist for verification. Two species were reported: *Rhizocarpon geographicum* and *Rhizocarpon macrosporum* Räsänen. Separation of these species is labor and time intensive, requiring microscopic examination of reproductive structures. Like Bull and Brandon (1998), I did not separate species but used the entire yellow *Rhizocarpon* group. I assumed that any growth dif-

Figure 4. Measuring *Rhizocarpon sp.* with digital calipers.

ference existing between these species is small enough to be obscured by the normal variation in thallus diameter due to environmental factors.

Reference Curve

In order to establish a lichen growth reference curve that could be used to correlate size with date, I subsequently investigated 27 sites in the Columbia River Gorge that appeared suitable for *Rhizocarpon* species, including cemeteries, landscape walls, road cuts, bridge abutments, and riprap. Sites were targeted using a combination of map work, historical research, and field forays. Linear features such as landscaping walls, cut-banks, and rock faces were treated in the same manner as transects, where the surface area of each linear meter along the feature was considered a discrete sampling area. I located *Rhizocarpon* and collected data at 14 sites. Unfortunately, the data from several sites had to be abandoned when later inquiry revealed strong human intervention in lichen growth processes in the form of herbicide application and pressure washing. This was not initially apparent, but only came to light during supplemental research and interviews (Larry Cotton, Director of Vista House, Crown Point State Park, oral commun., 2001; Herb Hamblyn, Skamania County Cemetery caretaker, oral commun., 2001).

Crustose lichens undergo three phases of growth: colonization, great-growth, and uniform growth (Bull and Brandon, 1998). The colonization phase is defined as the average amount of time from exposure of the substrate to the initial appearance of the first lichen. The great-growth phase is represented by an early period of exponential growth, which commonly ends when the thallus reaches a diameter of 10 to 15 mm (0.39–0.59 in.). Porter (1981), Bull (1996), and Bull and Brandon (1998) maintain that a simple linear growth model will accurately describe lichen growth during the uniform growth phase.

Although I did not attempt to identify specific growth phases, I ruled out some lichens using criteria from previous studies. Porter's (1981) growth curves for *Rhizocarpon* at Mount Rainier show the great-growth phase ending at a thalli diameter of approximately 12 mm (0.47 in.). Bull and Brandon (1998) noted that the great-growth phase in New Zealand (which has a temperate climate comparable to western Washington and Oregon) concluded at a thalli diameter of 9.4 mm (0.37 in.). For this study, I arbitrarily defined the end of the great-growth phase as 10 mm (0.39 in.) and considered all lichen growth above this size to be in the uniform growth phase. As a result, all data sets whose mean was less than 10 mm (0.39 in.) were removed from further analysis.

This two-part winnowing process resulted in a final reference set of 149 measurements, with replicate measurements representing four ages (Table 1). Reference sites are shown in Figure 2.

Although some lichenologists have used one linear equation to represent lichen growth across a broad region, this tightly constrained set of reference points minimizes variation arising from the dramatic ecological gradients of the Columbia River Gorge. I obtained all reference measurements from sites 200 m (656 ft) or less in elevation, within a narrow east–west band approximately 30 km (19 mi) in length (Fig. 2). All reference sites had similar basaltic substrate lithology and macrosite exposure. Consultations and site visits with professional lichenologists determined that *Rhizocarpon* growth rates most likely vary only minimally among reference sites.

Statistical Analysis

I performed statistical tests on the data using *Minitab* version 13.1. The equation describing lichen growth was determined using simple linear regression. Regression analysis is a statistical technique used to examine the relationship or correlation between sets of data. I used regression to mathematically describe the relationship between the age and size of *Rhizocarpon* lichens. I then extrapolated proportional ages for each Bonneville landslide lichen measurement, based upon a rearranged version of the regression equation. I examined the mean and standard deviation of these dates to estimate an age and confidence intervals for the Bonneville landslide deposit.

In order to satisfy the assumptions of simple linear regression (normal distributions, equality of variances), I analyzed each set of reference data independently, using the Ryan/Joiner test (similar to the Shapiro/Wilk test) to test for normal distribution. All four datasets are normally distributed ($P_1 >$ 0.10, $P_2 > 0.10$, $P_3 > 0.10$, $P_4 = 0.09$) (Table 2).

I examined reference data sets for equality of variance. Results indicated that variance between reference sets of data was not significant (Bartlett's Test: P = 0.504, Levene's test: P = 0.447).

To determine the lichen growth curve, I regressed *lichen size (mm)* and *years since establishment* (Fig. 5). This regression yielded the equation:

$$\text{lichen size (mm)} = 0.093 * \text{years} + 8.076$$
$$(R^2 = 58.8\%, F = 209.41, P < 0.000).$$

This equation describes variance occurring among the reference datasets. Another source of variance originates from the landslide dataset. In order to identify the potential for this second source of variance to affect the analysis, I examined the

Table 1. Reference locations, sample sizes, and associated dates for reference lichen datasets

Set	Location	Second identifier	Sample size (n)	Date
1	Cascade Locks	railings and lock structure	24	1896
2	Hood River	Columbia Gorge Hotel	6	1921
3	White Salmon	Drano Lake highway tunnel	26	1937
4	White Salmon	Spring Creek fish hatchery	93	1971

Table 2. Descriptive statistics and normality test results for reference lichen datasets. SD, standard deviation; R, correlation coefficient; P, probability

Set	Sample size (n)	Mean	SD	R	P
1	24	17.08	2.34	0.99	> 0.10
2	6	14.77	2.17	0.98	> 0.10
3	26	15.84	1.71	0.97	> 0.10
4	93	10.61	2.08	0.98	= 0.09

lichen measurements from the landslide. They were non-normally distributed, appearing leptokurtic or narrowly distributed ($n = 30$, $R = 0.9476$, $P < 0.01$). Mean lichen size was 34.79 mm ±1.99 mm (SD) or 1.370 in. ±0.078 (SD). McCarroll (1994) stated that sampling methods designed to capture only the largest lichen on each boulder may result in near-normal distributions of data. However, linear regression has been demonstrated as robust enough to withstand modest violations of normality (Underwood, 1997). Proceeding, I grouped the landslide measurements with the reference datasets and tested all five datasets for equality of variance. The tests indicated that variance of the landslide measurements is not significantly different from the variances of the reference datasets (Bartlett's test: $P = 0.658$; Levene's test $P = 0.552$).

I algebraically rearranged the reference equation to estimate lichen age, since I knew the size of the landslide lichens precisely, but did not know the age of the substrate:

$$\text{years} = (\text{lichen size (mm)} - 8.076) / 0.093$$

Results

I entered each measurement from the landslide deposit into the rearranged regression equation to determine the year proportional to lichen size. This created a population of potential ages for the landslide ($n = 30$, mean = 287.11 years, SD = 21.40 years). Although confidence limits for a population mean are typically calculated using Student's t-statistic and standard error of the population (Zar, 1999), my limited number of reference sites and intermediate R^2 value required a conservative estimate of confidence limits. I estimated confidence limits around the mean using 2 SD. This analysis indicates that the Bonneville landslide event occurred approximately 287 years ago, with a confidence interval of ±43 years. Conversion to calendar dates (rounded to the nearest decade) indicates that the landslide likely occurred between 1670 and 1760 A.D.

DISCUSSION

In this study, lichenometry successfully serves as a biometric measure, indicating that the Bonneville landslide most likely occurred between 1670 A.D. and 1760 A.D. Furthermore, these results appear to corroborate the radiocarbon ages recently presented by Pringle and Schuster (1998), which differ from both the earlier radiocarbon ages reported by Lawrence and Lawrence (1958) and the date promoted by Minor (1984). These results demonstrate that the Bonneville landslide may have occurred more recently than previously believed. Furthermore, the dates generated by this research provocatively bracket the last great Cascadia subduction zone earthquake of 1700 A.D. Although earthquakes have been demonstrated to trigger rockslides and debris avalanches (Keefer, 1984; Pringle and others, 2000), no causal relationship between the 1700 A.D. Cascadia earthquake and the Bonneville landslide can be determined from the results of this study alone.

Discrepancies among previous dating attempts and methods may have arisen because the site of the Bonneville landslide was not initially recognized as a composite, multi-event landform. Tree ring counts used to estimate the maximum age of the landform (Lawrence and Lawrence, 1958) may not have been taken from directly atop the Bonneville landslide deposit, but from atop adjacent but older components of the Cascades landslide complex. Furthermore, radiocarbon dating techniques have seen a great refinement in laboratory methods since the early efforts of the late 1950s, resulting in higher levels of accuracy and precision for geologically recent dates.

Other lichenometric research (Porter, 1981; Bull and Brandon, 1998) illustrates that large sample sizes and replication of studies can narrow the range of variance to ±15 years. Although beyond the scope of this study, future intensive sampling of lichens at historic sites in the Columbia Gorge, combined with similar studies at other landslides whose ages are precisely known (dendrochronologically or historically) may serve to narrow the range of variance described here.

It is important to acknowledge the assumption that lichen growth in the uniform phase is truly linear, and, therefore, it is allowable to violate standard statistical procedure and extrapolate outside the reference dataset using the regression equation. Underwood (1997) notes, "Extrapolation outside the range of the dependent variable is an unwise procedure." Generally, equations generated by regression analyses should be used

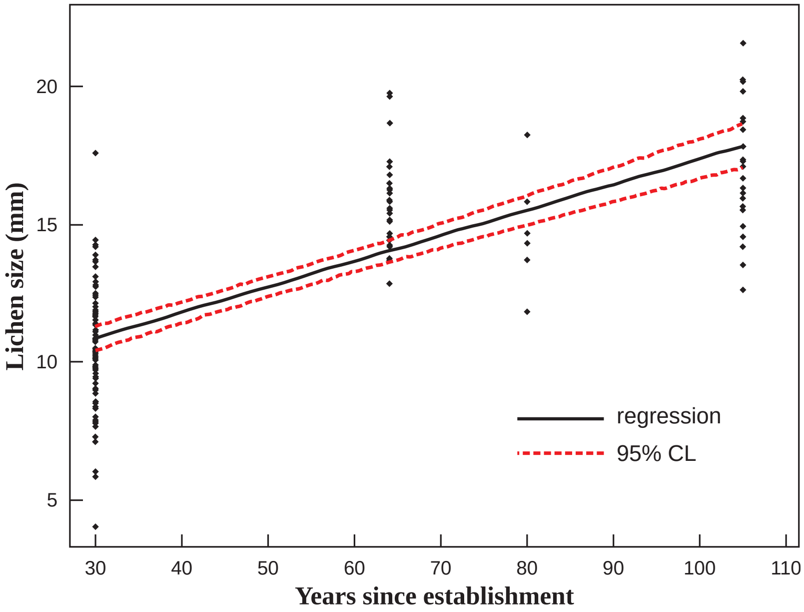

Figure 5. Regression graph reference curve for the uniform growth phase. Numbers are reference dataset numbers from Tables 1 and 2; CL, confidence limit. *Years since establishment* equals 2001 minus the date listed in Table 1.

only for interpolation. Nonetheless, I extrapolated based upon the linear relationships that have been described in lichenometric literature (Porter, 1981; Bull and Brandon, 1998).

If ongoing studies independently corroborate the date of the Bonneville landslide as determined by lichenometry, there may be large implications concerning the anthropology and archaeology of the Portland basin (Bourdeau, 1999). The downstream size and effects of an outburst flood from the Bonneville landslide are not yet well established, and the role of the Cascade rapids in both the pre- and post-settlement economy of the Pacific Northwest cannot be overlooked.

Additionally, this research may prove valuable in dating other geomorphic events within the same region. Palmer (1977) reported that more than 130 km^2 (50 mi^2) of landslide deposits have been mapped in the Columbia Gorge, including landslides as large as 50 km^2 (20 mi^2). The Columbia Gorge is home to significant rail and highway transportation corridors as well as important hydropower facilities. Accurately comprehending the scale, causes, and frequency of large landslides may help the region prepare for potential future events.

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Skolithos in a Quartzite Cobble from Lopez Island— Are Western Washington's Oldest Fossils Canadian Emigrants?

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INTRODUCTION

Quartzite cobbles are a common minor constituent of late Pleistocene deposits in the San Juan Islands and Puget Lowland of Washington, but their origin has long been enigmatic. The discovery of a cobble containing several trace fossils of *Skolithos* (Fig. 1) suggests that these clasts were transported from Lower Cambrian outcrops in the Selkirk and Purcell Mountains of British Columbia by a combination of fluvial and glacial processes. In addition to serving as a clue to the wide reach of glaciofluvial transport and allowing us to trace the possible path of the quartzite cobbles, these fossils are the oldest evidence of life yet found in western Washington.

GEOLOGIC SETTING

Fossilized remains of plants and animals that inhabited the Pacific Northwest during the Cenozoic Era are relatively abundant, but older fossils are rare. One explanation of the rarity is that the processes of assembling and docking much of the pre-Tertiary bedrock in western Washington to the continent destroyed most organic remains. The pre-Tertiary rocks are tectonic mélanges, juxtaposed fragments of oceanic crust and islands, that were carried to and then welded to the continental margin. Elevated pressures and temperatures caused by the assembling of the arriving fragments, combined with heating from later igneous intrusions, produced metamorphism that destroyed fossils. Most Paleozoic and Mesozoic plant and animal fossils in the Pacific Northwest originated far from the places in which they are found today.

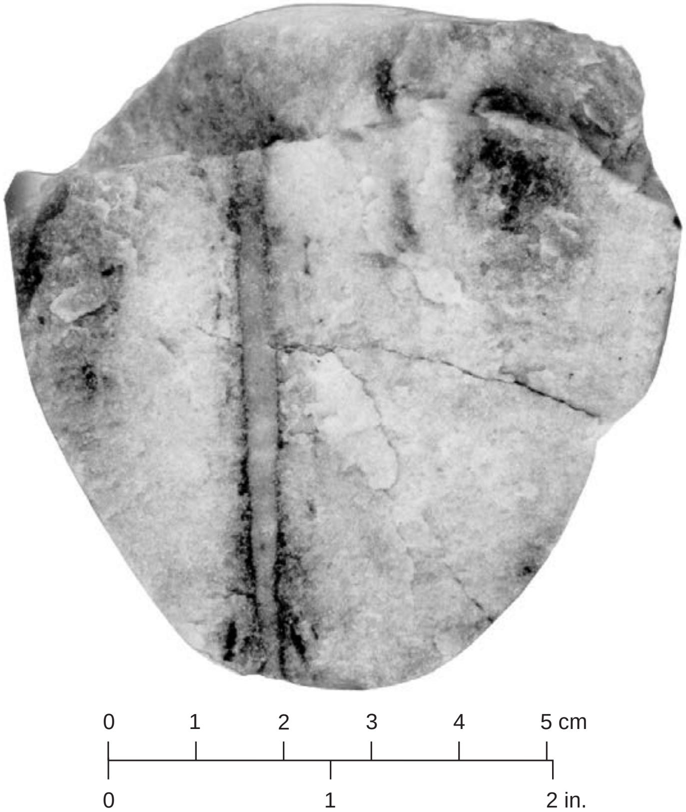

Figure 1. Quartzite cobble from Lopez Island, Washington, showing one of its three *Skolithos* trace fossils.

The region's oldest sedimentary rocks date from the late Precambrian. Approximately 1 billion years ago, the west coast of North America was created by the breakup of a supercontinent. One fragment may have been transported west to form the Siberian platform, or perhaps it became a subcontinent that later split to create Antarctica, Australia, India, and China (Orr and Orr, 1996). This breakup produced a late Precambrian shoreline that extended through what is now British Columbia, Idaho, Nevada, and southern California. Fine terrestrial sediments were deposited in shallow marine basins along the new continental margin. These sedimentary rocks are known as the Windermere and Purcell Supergroups in Canada and as the Belt Supergroup in the U.S. Outcrops of these rocks in Idaho, Montana, and British Columbia contain stromatolites, layered limestone trace fossils produced by colonies of algae, which constitute the earliest evidence of life in the region. Belt Supergroup beds extend into the northeast corner of Washington. The oldest animal fossils they contain are the trilobites, brachiopods, and mollusks, found in Upper Proterozoic–Lower Cambrian strata of the Gypsy Quartzite and Addy Quartzite, and archaeocyathids, found in the Lower Cambrian Maitlen Phyllite in Stevens and Pend Oreille Counties (McLaughlin and Enbysk, 1950; Lindsey and others, 1990). These fossils are evidence of creatures that inhabited that area during the Cambrian explosion of marine life, when marine basins occupied the land where mountains exist today.

The situation is quite different west of the Cascade Range where Paleozoic and early Mesozoic fossils occur in sedimentary sequences that have been tectonically transported from distant locations. The oldest fossils previously reported from western Washington are crinoids, corals, brachiopods, and protista from Devonian to Early Permian limestones of the Chilliwack Group in Whatcom County and in correlative beds in southwest British Columbia (Danner, 1966). These specimens are generally considered to be local fossils even though the organisms lived several thousand kilometers away from where their remains are found today.

MYSTERIOUS QUARTZITE COBBLES

In May of 2000, I was given the opportunity to examine cobbles collected by Lopez Island resident Robert Carter from a beach at Bayshore Road. These specimens included several pieces of white and pink quartzite, a rock type that is not common in the bedrock of the North Cascades or San Juan Islands. Quartzose units in these metamorphic terranes are too small and localized to account for the abundance and geographic range of quartzite clasts in Pleistocene alluvial deposits. Well-rounded pieces of quartzite are ubiquitous in late Pleistocene deposits in the Puget Lowland, but they typically comprise no more than a few percent of cobble-sized clasts. Larger glacial erratics consist of diverse metamorphic and crystalline igneous rocks, but no boulder-sized quartzite erratics have been found to date. Although many geologists have noticed these cobbles, I can find no published discussion of their occurrence, and in casual conversation the usual response is “they must come from Canada somewhere”. Trace fossils in one of the Lopez Island specimens allow us to more accurately deduce the geological history of these clasts.

The broken surface of the 270 g (9.5 oz) quartzite cobble reveals a cylindrical trace fossil cast 61 mm (2.4 in.) in length and 3.5 mm (0.14 in.) in diameter (Fig. 1). The opposite surface exposes two adjacent 28 mm (1.1 in.) by 3 mm (0.12 in.) cylindrical casts spaced 40 mm (1.6 in.) from the single burrow. These three trace fossils are incomplete segments of parallel burrow casts, and their original lengths are unknown. These fossils belong to the ichnogenus *Skolithos*, a form genus that describes unbranched, unadorned vertical burrows that have circular or subcircular cross sections 3 to 9 mm (0.12–0.35 in.) in diameter. Burrows of this type are believed to have been created by soft-bodied suspension feeders that inhabited shifting sands in littoral and very shallow sublittoral zones where they obtained security by penetrating deeply and remaining stationary for long periods. *Skolithos* has worldwide distribution in rocks that range in age from upper Precambrian to Cretaceous, but are most commonly found in Early Cambrian strata (Alpert, 1974; Frey, 1975; Crimes and others, 1977). Some investigators believe that *Skolithos* and *Monocraterion* are generic names applied to two types of burrows produced by a single type of organism, the shape being controlled by variations in rates of sedimentation or erosion (Hallam and Swett, 1996; Goodwin and Anderson, 1974). The ichnogenus *Monocraterion* consists of cylindrical vertical burrows that extend downward from funnel-shaped depressions.

POSSIBLE SOURCES

The pale color and well-sorted texture of the quartzite suggest that the cobbles were not derived from the late Precambrian Belt Supergroup rocks, which typically have finer grain size and a distinctive reddish color. The scarcity of quartzite cobbles on beaches of Vancouver Island and the western Olympic Peninsula eliminates the British Columbia Coast Mountains and Insular belt as a source. Their abundance in the Puget Lowland hints that these cobbles came from an area where quartzite is a major bedrock unit. A likely hypothesis is that these clasts have been transported from outcrops of the Purcell Supergroup on the western slope of the Selkirk Mountains. The Puget Sound cobbles are lithologically similar to Lower Cambrian quartzites of the Hamill Group of interior British Columbia, a correlation that is supported by the presence of *Skolithos* burrows in these Canadian rocks

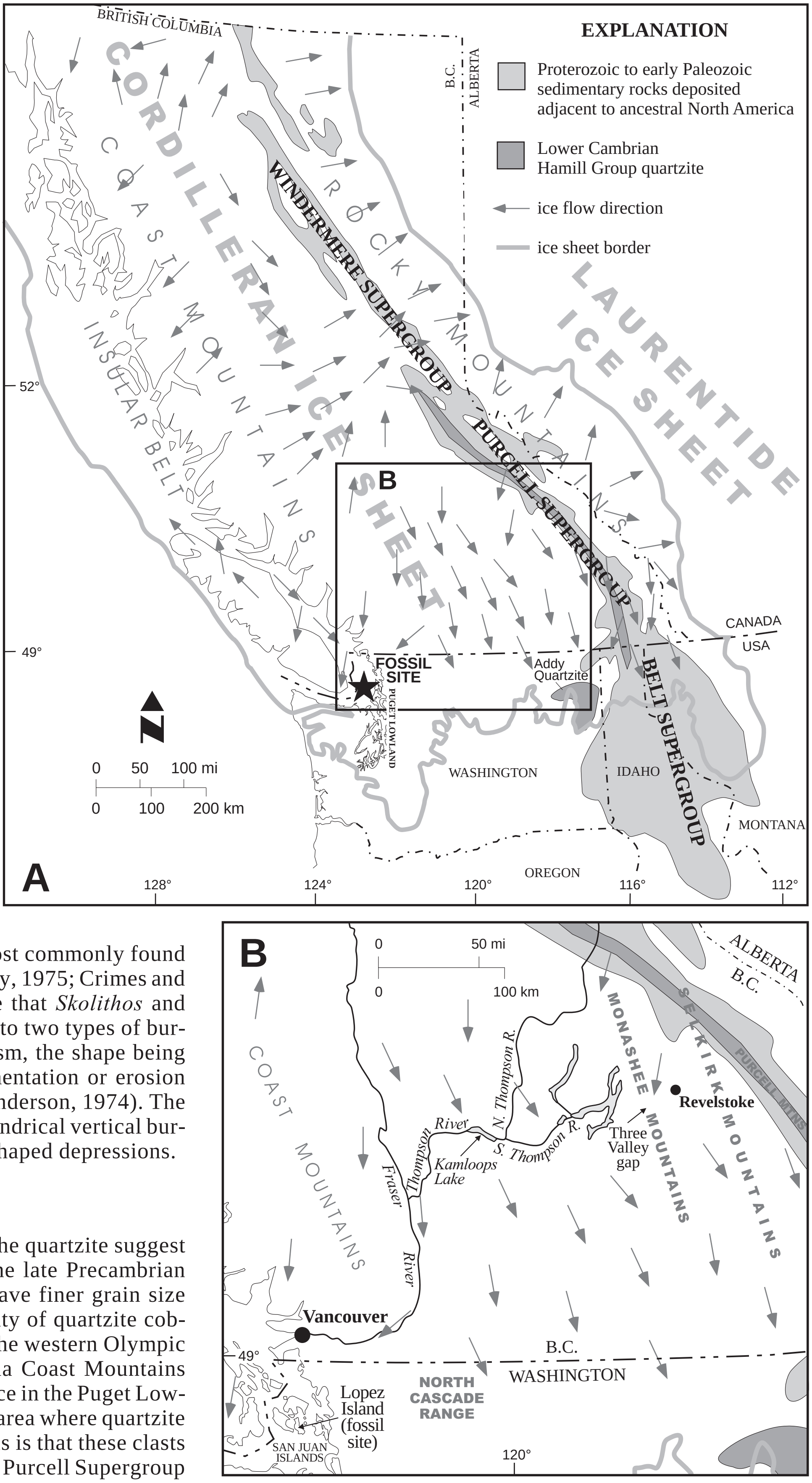

Figure 2. **A**. Map showing present extent of Proterozoic to early Paleozoic bedrock exposures and extent of the Cordilleran ice sheet in British Columbia and Washington during the maximum advance at circa 12,000 yr B.P. Box encloses transport area. **B**. Close-up of transport area. Data from Clague (1989) and Devlin (1989).

Lower Cambrian quartzites of the Hamill Group form a 400 km long belt that extends from the northeast corner of Washington to latitude 51°41′ in the southern Canadian Cordillera, cropping out in the Purcell and Selkirk Mountains. Deposited along the ancient passive margin during a period of transition from rifting and thermal subsidence to post-rift tectonic stability, the oldest sediment accumulated as shallow marine and braided fluvial deposits and have been preserved as cross-bedded coarse-grained feldspathic and quartzose arenites and fine conglomerate (Devlin and Bond, 1988; Devlin, 1989). A middle unit contains greenstones that originated during a period of volcanism. The upper Hamill Group consists of mature quartz arenites that were deposited in a shallow marine environment. *Skolithos* and *Planolites* fossils are present in these beds. *Planolites* consists of horizontal or gently inclined tunnels, some of which are branched, that may be straight or sinuous (Ekdale, 1977).

Although *Skolithos* is a common trace fossils in Addy Quartzite, a Hamill Group correlative in central and southern Stevens County (Lindsay and others, 1990), the North Cascades provide a topographic barrier for transporting cobbles westward to Puget Sound. Transport of Hamill Group quartzite to the San Juan Islands and Puget Lowland can be explained by a combination of glacial and fluvial processes. Late Pleistocene ice flow directions (Fig. 2) would have allowed rock fragments to have been deposited in the Thompson River watershed, a major tributary of the Fraser River. This route involves only a relatively modest topographic barrier offered by a low divide in the Monashee Mountains in the Three Valley region west of Revelstoke that separates the Selkirk Mountains from the Fraser/Thompson River lowlands. During subsequent interglacial episodes, fluvial transport would have continued to move this sediment southward, remobilizing the quartzite cobbles during subsequent glacial advances. The well-rounded clast shapes, the absence of quartzite erratics, and the geographic distribution of these cobbles in regions south of the Fraser River watershed all suggest that fluvial transport was involved, but the presence of similar quartzite clasts in glacial drift deposits south of the 49th parallel indicates that these rocks were carried to their final destination by flowing ice. If this interpretation is correct, the quartzite clasts should become increasingly abundant as we follow the course of the Fraser and South Thompson Rivers upstream toward their headwaters.

This hypothesis cannot be tested, however, because of rapid post-Pleistocene uplift rates. The Fraser/Thompson Rivers have carved deep canyons, creating an environment where older fluvial sediments are not preserved. Instead, present riverbank deposits predominantly consist of material derived from the valley walls. Farther upstream, the topography bordering the South Thompson River is more gentle, but here the valley is blanketed with thick sand and silt beds deposited in ancient Lake Thompson and its modern counterpart, Kamloops Lake (Fulton, 1969). These geologic restrictions prevent us from directly tracing quartzite cobbles in Puget Sound deposits to their source area.

ACKNOWLEDGMENTS

This study was initiated by specimens provided by Robert Carter. Don Easterbrook, James Talbot, Clark Blake, Pat Pringle, and Peter Mustard shared geologic opinions regarding the distribution of quartzite in local glacial deposits, and James Monger first suggested the Hamill Group as the most likely source. Kitty Reed, Chuck Gulick, and Joe Dragovich reviewed this manuscript.

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Links to Pub Pages of State Geological Surveys

A web resource you might find useful is Links to Publications Pages of the State Geological Surveys at http://www.library.uiuc.edu/gex/StateSurveyPubs.html. The site was created by Lura Joseph, a geology librarian at the University of Illinois at Urbana-Champaign, who got tired of having to hunt around for the pub pages of state surveys.

Port Townsend's Marine Science Center Expands

Katherine M. Reed; 927 56th St; Port Townsend, WA 98368

In September 2001, the Port Townsend Marine Science Center (PTMSC) capped more than a year of renovation and building by opening its new Natural History Center (Fig. 1). The center is in a transformed machine shop near the store at the Point Wilson campground at Fort Worden. It houses public exhibits and a gift shop, as well as a classroom and office. The exhibits cover local birds and mammals and geology, and the center complements the hands-on and up-close marine-life facility on the dock, also newly remodeled. The new center and improvements are the result of a creative partnership among the Washington State Parks and Recreation Commission, the Thomas C. Burke Museum of Natural History on the University of Washington campus, subject experts, and many dedicated volunteers.

In the middle of the well-lit natural history center is a low table that presents a 'geo-puzzle' (Fig. 2), a moving model that incrementally 'assembles' Washington over geologic time, placing the old terranes[1] and geologic events in chronologic and geographic order. The model also shows the extent of the Miocene basalt flows and the ice sheet maximum. This is a large version of a popular paper model conceived by Washington State Department of Natural Resources geologist Jack Powell. It was built with his active participation.

A central wall display (Fig. 3) features Cenozoic marine fossils from western Washington (most donated by the Burke Museum). Walls flanking the entrance will have temporary exhibits. One case is dedicated to fossil skulls of marine mammals from the Olympic Peninsula, including the so-called beach bear. The other case guides visitors through the science behind an interpretation of the geology on the north shore of Point Wilson and the drowned trees exposed there at low tides.

Fossils that document climate change over the last 60 million years are presented in a case next to a wall-high scale model of the Vashon glacier that covered the Port Townsend area about 15,000 years ago (Fig. 4). Next to that is a large model of a local bluff, showing the sequence of sediments. Drawers in the bluff reproduction encourage visitors to touch typical glacial sediments—outwash, glaciomarine drift, till, clay, silt, and sand—and peat and topsoil (Fig. 5).

On the opposite wall of the Center is a display of beach sands from around the world. Visitors can examine the sands with magnifying glasses to determine sand grain texture and components.

Skulls, skeletons, and models of local birds and mammals complete the displays. The back wall of the main room is covered with a large mural of sea mammals and fish. The wall can be moved so that the display space can be enlarged for classes or meetings. Behind the wall is a room being prepared as a laboratory. Docents and local experts will soon be offering classes in the building and in the field. Upcoming Saturday lectures will be held in the main room (see PTMSC website). Lectures begin at 1:30 p.m. Cost is $5 for nonmembers and $3 for members and active volunteers.

The PTMSC is building a collection of specimens for display and teaching, as well as a library. A small gift shop offers guidebooks as well as educational books and toys for children.

Figure 1. The new Natural History Center is a former machine shop whose exterior has been renovated in accordance with historic guidelines. *Photo by Libby Palmer.*

Figure 2. Center volunteers examine the 'geo-puzzle', a moving model that incrementally 'assembles' Washington over geologic time. *Photo by Keith Pace.*

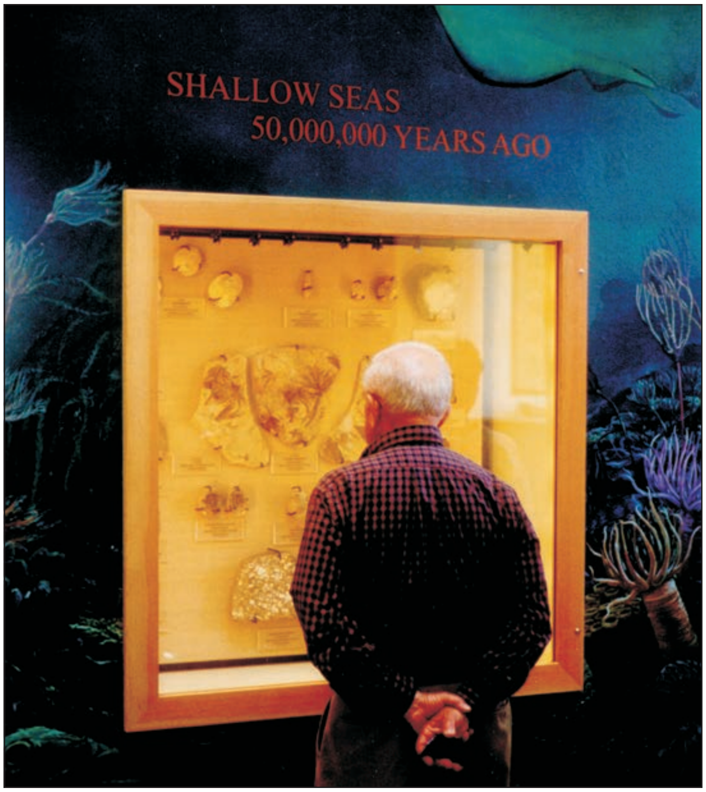

Figure 3. Display of fossils showing shallow sea life in the middle Cenozoic in western Washington surrounded by a mural depicting sea life 50 million years ago. *Photo by Keith Pace.*

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[1] *terrane* – a fragment of a colliding tectonic plate added to the continental margin at a converging plate boundary.

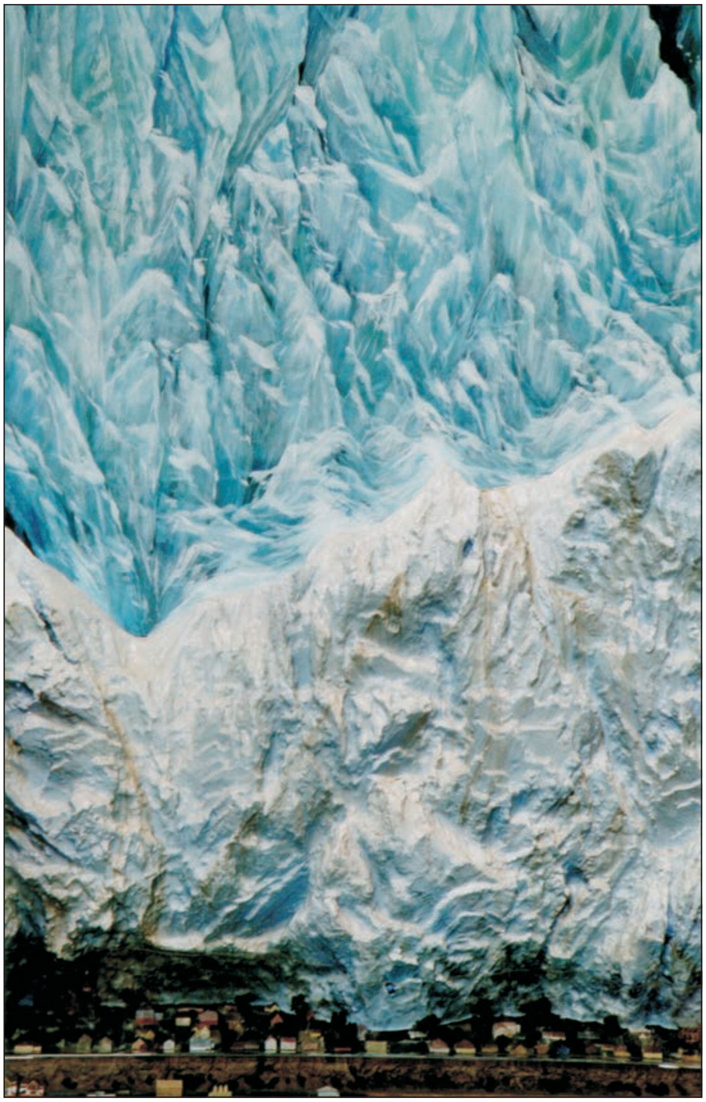


Figure 4. A 12-foot-high model of the most recent (Vashon) glaciation, which covered the Port Townsend area about 15,000 years ago, shows the thickness of the ice relative to the size of present-day buildings, shown to scale at the bottom of the photo. *Photo by Libby Palmer.*

Figure 5. Model of a local bluff, showing the sequence of sediments. In the model are drawers that contain touchable samples of typical glacial sediments. *Photo by Keith Pace.*

The PTMSC thanks the Burke Museum, especially Liz Nesbitt, curator, Invertebrate Paleontology; Ron Eng, collections manager; Bruce Crowley, fossil preparator; and Wes Wehr, affiliate curator, Paleobotany, for their help in developing the fossil exhibits. Thanks to Chuck Gulick, DGER geologist, for suggesting that I write this article and to Libby Palmer co-founder of the center (with Judy D'Amore) and text writer for the exhibit and now educational consultant on contract, for her help. Jerry Thorsen, retired DGER geologist; Jack Powell; Casey Burns, vice president, Northwest Paleontological Association; and the late Bob Forbes have been active advisors.

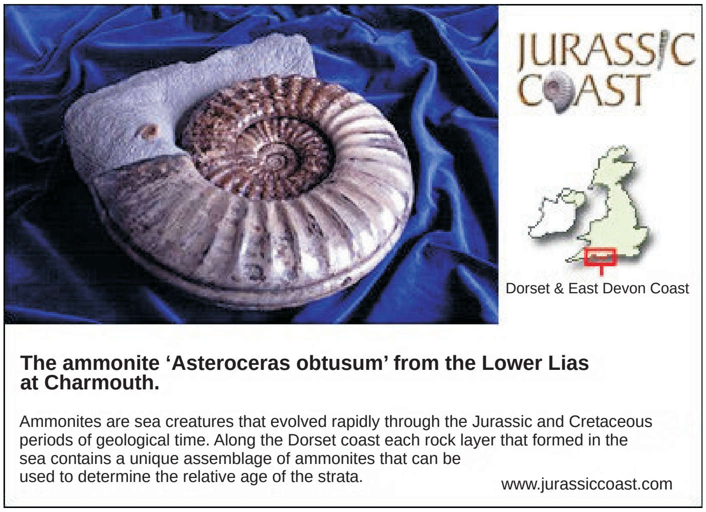
Put this new facility on your list of sites to visit. Winter hours are noon to 4:00 p.m., Friday through Monday. For seasonal schedules and further information, visit the PTMSC website at http://www.ptmsc.org/ or the Burke website at http://www.washington.edu/burkemuseum/.

For information on other geology-related displays in our state, see the article "Guide to geologic, mineral, fossil, and mining history displays in Washington" by David A. Knoblach in *Washington Geology*, v. 22, no. 4, Dec. 1994, p. 11-17. ■

EXCITING NEW GEOLOGY WEBSITE

A new and exciting website about the internationally important geology and fossils of the Dorset and East Devon coast of England, site of Lyme Regis, is at http://www.jurassiccoast.com. The website has sections on fossils, building stone, dinosaur footprints, and the geology of the landscape, and special features that allow you to send postcards, such as the one to the right, to your friends and to view the coast in wide screen. This coastline has been granted World Heritage Site status, which means that UNESCO has officially ranked it alongside the Great Barrier Reef and the Grand Canyon as one of the natural wonders of the world. The coast contains a near-complete sequence of rocks through 185 million years of Earth history during the Triassic, Jurassic, and Cretaceous periods of geological time. It contains a number of outstanding fossil localities that have played, and continue to play, an important role in the science of paleontology. This coast has been a crucible of Earth science investigations for 300 years.

("The French Lieutenant's Woman", a circa-1980 book by John Fowles and movie starring Meryl Streep and Jeremy Irons, was set on this coast during Victorian times. The hero was an amateur paleontologist.)



The ammonite 'Asteroceras obtusum' from the Lower Lias at Charmouth.

Ammonites are sea creatures that evolved rapidly through the Jurassic and Cretaceous periods of geological time. Along the Dorset coast each rock layer that formed in the sea contains a unique assemblage of ammonites that can be used to determine the relative age of the strata.

www.jurassiccoast.com

EARTH CONNECTIONS

Resources For Teaching Earth Science

MUDPILE MOUNTAIN

The erosion of a mountain by water can be demonstrated by pouring water on a mudpile. This makes it easy for students, even in flat country, to get a better understanding of mountains, their erosional and depositional landforms, and the processes that form them. This outdoor lesson plan is good for groups of any size. Students will construct a 'mountain' of dirt, pour water over it, and identify landforms caused by erosion and deposition.

Caution students not to carry the comparison of mountain to mudpile too far. Mountains are not just piles of dirt but consist chiefly of bedrock. The bedrock is weathered and transported in several different ways and not just simply eroded away by water. (For more information about weathering, see Earth Connections no. 4 in *Washington Geology*, v. 28, no. 3, p. 38-39, May 2001; online at http://www.wa.gov/dnr/htdocs/ger/pdf/earthcn4.pdf).

EROSION AND DEPOSITION

Weathering breaks up rocks, but what process carries the pieces away? Erosion. It breaks down the Earth's crust and carries away the pieces to deposit them elsewhere. The three main agents of erosion are water, ice, and wind.

Running water (rivers and streams) is the most common agent of erosion. Glaciers, immense sheets of moving ice, slowly grind away and carry off large chunks of the Earth's crust. The wind carries sand and dust, which act like sandpaper to wear down the rocks it contacts.

Erosional landforms illustrated by this activity include streams, canyons, and waterfalls. Depositional landforms illustrated include alluvial fans and deltas. This exercise also demonstrates the selective transport of materials by water. Fine particles are carried farther than coarse particles. Fast-moving water carries heavier particles than slow-moving water.

GLOSSARY

Discuss the new vocabulary before starting the activity:

alluvium – silt, sand, clay, gravel, and other loose rock material deposited by flowing water, as in a riverbed or delta.

alluvial fan – the fan-shaped deposit of alluvium left by a stream where it issues from a canyon onto a plain.

bedrock – the solid rock underlying the soil and other loose rock material on the Earth's surface.

canyon – a narrow valley with steep walls, formed by running water.

delta – a triangular alluvial deposit formed where a river enters a large body of water.

deposition – the laying down of material carried by water

erosion – the wearing away of the soil and rock of the Earth's crust

landforms – any physical, recognizable form or feature of the Earth's surface having a characteristic shape and produced by natural causes. Examples include mountains, valleys, deltas, and canyons.

sediment – fragmented rock material, such as silt, sand, clay, gravel, carried and deposited by water, wind, or ice.

silt – sediment made up of fine mineral particles smaller than sand and larger than clay.

transport – to carry from one place to another.

weathering – the mechanical and chemical processes by which rock exposed to the weather turns into soil.

ESSENTIAL ACADEMIC LEARNING REQUIREMENTS

1.2 Students will recognize the components and organization of systems and the interconnections within and among them.

1.3 Students will understand that interactions in the physical environment may cause changes in matter and energy.

2.2 Students will apply science knowledge and skills to solve problems or meet challenges.

3.2 Students will know that science and technology are human endeavors, interrelated to each other, to society, and to the workplace.

GRADE LEVELS

Grades 6–10

SUBJECTS

Earth science and geomorphology

CONCEPTS

Erosion and deposition

SKILLS

Observation, inference, and measurement

OBJECTIVES

Students will learn to identify landforms caused by erosion and deposition.

MATERIALS

3 popsicle sticks or tongue depressors per student

red, green, orange, blue, yellow, and purple crayons

shovel and watering can

TIME NEEDED

1 to 3 hours

Adapted, with permission, from Glacier National Park Electronic Field Trip [http://www.sd5.k12.mt.us/glacierefｔ/ Click on Lesson Plans; then click on Geology.]

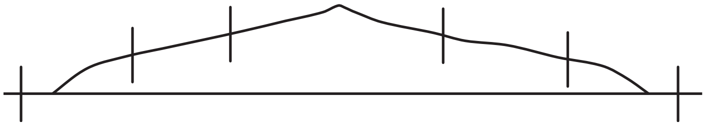
Earth Connections No. 6

PROCEDURE

1. Have each student rule lines 1 centimeter apart across both sides of a popsicle stick, starting from one end. Then have them crayon centimeter-wide bands, neatly, in this order: red, green, orange, blue, yellow, and purple.

2. Take the class outside to a patch of bare ground and dig up dirt, removing larger pebbles and stones. Dump the dirt in a pile and tamp it down to make a 'mountain' about half a meter high.

3. Have the students push their sticks into the 'mountain' and the surrounding 'land', red ends out, so that the sticks are vertical and evenly distributed. (See drawing below) The boundary between the orange and blue bands should be even with the mudpile surface.



4. Have one student sprinkle the 'mountain' with a watering can so that the 'rain' falls straight down. Let everyone in the class have a chance to be the rainmaker, while the others observe and chart the results.

5. After the 'mountain' is well eroded, ask the following questions:

   Do some markers indicate where erosion is taking place? Where is the material being removed?

   Do some markers indicate where deposition is taking place? Where is dirt being deposited?

   Which of these landforms can you identify: streams, canyons, waterfalls, lakes, deltas, alluvial fans?

   Which is carried farther by the water: sand or silt or rocks?

   What, if anything, seems to slow erosion on the 'mountain'?

6. Have the students identify as many of the erosional and depositional landforms on the 'mountain' as they can.

7. Have the students hypothesize why some areas moved at different rates and where the best places to build a house or a waterslide park would be.

8. Let the class continue to erode the 'mountain' and observe it for several days. Measure and record changes in erosion. Draw pictures each day and record measurements in a table.

9. Give extra credit for any photographs of erosional or depositional landforms from magazines or books that are brought to class and correctly identified.

from Schmidt, V. E.; Rockcastle, V. N., 1982, Teaching science with everyday things; 2nd ed.: McGraw-Hill, 210 p.

SUGGESTED READING

DK Publishing, Inc., 1993, The visual dictionary of the Earth: DK Publishing, Inc. Eyewitness Visual Dictionaries, 64 p.

RELATED WEBSITES

Erosion (K–4th grades) http://www.col-ed.org/cur/sci/sci03.txt

Changes Due to Erosion (2nd grade) http://www.uen.org/cgi-bin/websql/lessons/l4.hts?id=84&core=3&course_num=3020&std=6

Erosion in the Wind (3rd grade) http://www.uen.org/cgi-bin/websql/lessons/l4.hts?id=108&core=3&course_num=3030&std=3

Erosion Lab (3rd–4th grades) http://student.biology.arizona.edu/sciconn/earthscience/erosion.html

Identifying Erosion (3rd–5th grades) http://atozteacherstuff.com/lessons/Erosion.shtml

Demonstrating Erosion in Action (3rd–12th grades) http://btc.montana.edu/nten/trc/lesson30/lesson30_text.shtml

Weathering and Erosion (4th–6th grades) http://btc.montana.edu/nten/trc/eslab_text.shtml#weathering

Gravity and Erosion (8th grade) http://www.lessonplanspage.com/ScienceGravityErosionMassWasting8.htm ■

RADIO SHACK DONATES EMERGENCY RADIOS TO SCHOOLS. Don Miller (right) of Washington State Emergency Management Division (WADEM) gives Rex Kerbs, principal of Ptarmigan Ridge Elementary School in Orting, nine programmable weather radios. Don is manager of the Telecommunications and Warning Project for WADEM. Radio Shack Corporation donated the radios for use by the Orting and Sumner school districts. Both cities are located in the Puyallup River valley, which is underlain by extensive lahar deposits from Mount Rainier. The weather radios can provide alerts in the event of a volcanic emergency, such as the detection and confirmation of a lahar (volcanic debris flow) in upper regions of the Puyallup or Carbon River valleys. In 1998, the U.S. Geological Survey, in conjunction with the State of Washington and Pierce County, installed a network of acoustic flow detectors in those valleys to better detect lahars. In the event of a confirmed lahar, a warning message could be broadcast within minutes. *Photo by Rob Harper, WADEM.*

Student Website Design Contest

Technology savvy students can show off their web design skills and win prizes in the 2002 "Nature Greets Technology" contest sponsored by the Department of Natural Resources (DNR), the Department of Information Services, and the Office of Superintendent of Public Instruction.

Now in its fifth year, the contest offers Washington students ages 9 to 19, who are enrolled in public, private, or home school programs, the opportunity to build their own website based on one of two themes: "Forest Fire Prevention is Everyone's Responsibility" or "Conserving Washington's Water."

DNR started this contest to promote wildfire prevention awareness among teenagers. The number of entries has doubled each year, and the quality and sophistication of the entries has also improved.

Entries will be accepted until April 19, 2002. To view specific contest details and the websites of last years' winners, go to http://www.k12.wa.us/webcontest.

Get Your Geology License Now—Don't Procrastinate

Wendy J. Gerstel
Washington State Department of Natural Resources
PO Box 47007; Olympia, WA 98504-7007

By now it should be old news to most geologists that Washington State has passed the geologist licensing law (Chapter 18.220 RCW; Chapter 308-15 WAC). We are more than half way through the grandparenting period, which began July 1, 2001. This is the year that allows applicants to be granted a license without testing, provided they meet the requirements of the law. After July 1, 2002, testing will be required, and it will be illegal to practice geology without a license (or without being under the direct supervision of someone who is licensed). The law, qualifications, application forms, and much other useful relevant information can be found at the Washington State Department of Licensing (DOL) website at http://www.wa.gov/dol/bpd/geofront.htm. Check it out, if you haven't already. The application forms are in PDF format, which you can access using the free download of Acrobat Reader. You will need to download the forms, fill them out, and print them, one page at a time. (Unless you have the full version of Adobe Acrobat, you cannot save the filled out forms!)

If you're already licensed, congratulations. If not, time is running out! Don't plan to wait till the last month to send in your application. Decide now whether the work you do falls under the legal bounds of a general geology license or one of the specialty licenses—engineering geology or hydrogeology (see the DOL website). You will need to arrange for college/graduate school transcripts to be sent to the DOL, to contact those who can verify your job experience (do this *before* sending them the verification forms, which they must submit directly to DOL), and, if you are applying for a specialty, gather all your project information to demonstrate your professional experience. All this takes time—and you may want to allow for extra time to gather and submit any additional information DOL may find necessary to process your application. Don't think that because the deadline is June 30, you can get your application in by June 30 and be okay. You must have your *license* in hand by June 30.

If you think you may want to wait and take the exam, consider this—the exam is not easy. (See the "Professional Geologists Candidate Handbook" on the ASBOG website at http://www.asbog.org/ for an explanation of the examination and sample exam questions. Exam takers have said that the actual exam is much harder than the exam questions.) Failure is not uncommon, and exams are scheduled only twice a year. Specialty exams are now being written by committees appointed by the Washington State Geologist Licensing Board. They should be ready by July 1, 2002. Looking at the fee schedule, you can see that the cost of taking the exams drastically increases the cost of the license.

A point in favor of taking the exam is that it will be needed if you want to get licensed in another state under reciprocity. Most states do not recognize grandparenting for this purpose. You may take the test at any time, even if you don't meet the other requirements. If you are just out of school, you might want to take the exam while everything is still fresh in your mind. If not, there are review courses.

Another point to consider: Your license renewal date will be your first birthday after July 1, 2002. However, if that birthday is within three months of the initial date of issuance of the license, your license will expire on the second birthday following issuance of your original license. You would save the first year's renewal fee, but this is a very narrow (and moving) window of opportunity, and there are no guarantees as to how long the application process will take.

One last thing: Represent your experience and skills as thoroughly as possible. You want to make sure all your hard work and training pays off. However, a license does not bestow permission to practice skills for which the license holder has little or no training or experience, even if the specific task is listed as an example under the language of the law.

Remember, licensing implies credibility, but it also obligates accountability. ■

Geologist Licensing Fee Schedule

Please note: Only those fees with an asterisk (*) will apply during the grandparenting period of July 1, 2001 through June 30, 2002.

Geologist License	Amount
Application fee	$100.00*
Application fee – reciprocity	$200.00
Initial license	$100.00*

Examination Fees	Amount
Fundamentals of Geology (vendor charge)	$125.00
Practice of Geology (vendor charge)	$150.00
Administration fee for re-examination	$ 65.00
Review of examination: Manual regrade (vendor charge) Administrative fee for regrade	 $ 50.00 $ 15.00
Late fee if examination scheduled fewer than 30 days prior to examination date (vendor charge)	$ 25.00

Specialty Fee (if you are applying for geologist license at the same time)	Amount
Application fee – 1 specialty	$200.00*
Application fee – 2 specialties	$300.00*
Application fee – reciprocity – 1 specialty	$350.00
Application fee – reciprocity – 2 specialties	$500.00
Initial license – 1 specialty	$185.00*
Initial license – 2 specialties	$270.00*

Fee per Specialty (if you are already a licensed geologist in Washington)	Amount
Application fee	$100.00*
Application fee – reciprocity	$150.00
Initial license	$ 85.00
Examination fee per specialty	$300.00
Examination review	$100.00

Renewal Fees	Amount
Annual renewal fee (geologist)	$100.00
Additional fee for late renewal (geologist)	$100.00
Annual renewal fee (geologist + 1 specialty)	$185.00
Additional fee for late renewal (geologist + 1 specialty)	$185.00
Annual renewal fee (geologist + 2 specialties)	$270.00
Additional fee for late renewal (geologist + 2 specialties)	$270.00

Miscellaneous Fees	Amount
Duplicate license or wall certificate	$ 25.00*
Certification of license records to other jurisdictions	$ 45.00
Proctor examination in another jurisdiction	$100.00

GEOLOGIST LICENSING REQUIREMENTS

1. *WHO IS REQUIRED TO OBTAIN A LICENSE?*

Any person who practices, or offers to practice, geology for others in this state, or who uses in connection with his or her name or assumes or advertises any title or description tending to convey the impression that he or she is a licensed geologist. This includes geologists working for businesses, non-federal government agencies, or nonprofit organizations, or who are self-employed. Those who have a specialty in the fields of engineering geology or hydrogeology must obtain an additional speciality license. A seven-member Geologist Licensing Board reviews applications, approves the exams, and helps administer the licensing program with DOL staff.

RCW 18.220.190 provides a listing of geological work activities that do not require a certificate of licensing.

2. *WHAT ARE THE LICENSING REQUIREMENTS?*

See RCW 18.220.060 for a more extensive listing of detailed requirements but, in general, the requirements are as follows:

- The applicant must be of good moral character as attested to by letter of reference.
- The applicant must have graduated from a course of study in geology or a related field (as determined by the Board).
- The applicant must have a documented record of a minimum of five years of experience obtained subsequent to academic credentials. Three years of the experience must be under the supervision of a geologist licensed in this or any other state or others deemed qualified to have responsible charge of geological work.
- The applicant must have passed an examination prescribed by the Board. Starting on July 1, 2002, applicants will be required to pass the National Association of State Boards of Geology (ASBOG) examination to obtain a license. ASBOG maintains the national geologic examinations used by state licensure boards for assessing the candidate's competency. To prepare for the exam, ASBOG recommends that candidates review the examination information presented on their website at http://www. asbog.org/. Review courses are available. ASBOG recommends that candidates obtain information regarding the quality and content of available programs from colleagues and professional organizations.
- For licensure in a specialty of geology, an applicant must demonstrate the same conditions relative to the experience and examination in that specialty field and pass an additional board-approved examination in the specialty. The specialty exams are currently being written.

3. *HOW CAN I OBTAIN A LICENSE?*

There are three ways:

- *Examination:* Take the examination as prescribed by the Geologist Licensing Board (effective July 1, 2002).
- *Grandparenting:* Through June 30, 2002, applicants may be grandparented into a license. They are not required to pass the Board-approved exams if they have a minimum of five years experience in geology or the specialty field, have a degree in geology or a related field approved by the board or have taken the required course work for a major in geology, and can provide verification of work experience and moral character from at least two individuals.
- *Recognition of out-of-state licensing:* A license can be issued without examination beginning July 1, 2002, provided the applicant holds a license or certificate of qualification issued by any state, territory or possession of the U.S. or foreign country, if the applicant's qualifications meet the requirements of this law. See RCW 18.220.100.

An application, list of requirements, and links to the RCW can be found on DOL's website at http://www.wa.gov/dol/bpd/geofront.htm. A new feature, Professional Licensing Internet Query, an Internet-based application, allows you to search the professional licensing database using full and partial name, license number, and other search criteria. In the future, additional resource information will be added to the website, including the exam schedule. For more information about the geologist licensing program, call (360) 664-1497.

Foreign Applicants: If you received your degree outside the U.S. or Canada, you will need to have your transcript evaluated to qualify for licensure in the state of Washington. Please contact the Geologist Licensing Program for more information at (360) 664-1497.

Adapted from the Geologist Licensing Program website at http://www.wa.gov/dol/bpd/geofront.htm

MARK YOUR CALENDAR—HYDROGEOLOGY SYMPOSIUM SCHEDULED FOR APRIL 2003

The Fourth Symposium on the Hydrogeology of Washington State will be held April 8–10, 2003, at the Sheraton Convention Center in Tacoma. The symposium will cover issues and topics involving both ground and surface water, as well as the respective geology. It will include a variety of field trips, workshops, panel discussions, and evening forums by regionally and nationally recognized experts. The program will be structured to maximize the potential for you to network with others. As in the past, the goal is to provide an affordable technical forum where hydrogeologic issues can be shared and discussed. The future of these symposiums continues to rest on strong partnerships and committed individuals.

While the 2003 symposium may seem a long way off, please mark your calendar so potential conflicts will be avoided. A call for presentations will be sent out in April of 2002. Sign up for the mailing list at http://www.ecy.wa.gov/events/hg/mailing_list.htm. For more information, see http://www.ecy.wa.gov/events/hg/index.htm.

GLACIER PEAK WEST SEISMOGRAPH IS WORKING!

Stephen D. Malone
University of Washington Geophysics Program
Box 351650; Seattle, WA 98195

Telemetry has now been connected to the Glacier Peak West (GPW) seismic station, which was originally installed in early September at an elevation of about 8,000 feet on the west flank of Glacier Peak volcano. This is the newest station in the Pacific Northwest Seismograph Network (PNSN). The signals look quite good, and a couple of earthquakes and rockfalls have already been recorded. The radio path into microwave telemetry near Concrete, Wash., is pretty solid. The Puget Sound Energy people went out of their way to facilitate the hookup on short notice. Many thanks to all of the people, particularly in the U.S. Forest Service, who made it possible. This is one of the most remote, and third highest, seismic stations in the PNSN. Let's hope that it can survive our lovely winter weather.

The PNSN gathers information on Pacific Northwest earthquake activity from its seismograph stations and locates earthquakes in Washington. It is operated jointly by the University of Washington and several other Northwest institutions and funded by the U.S. Geological Survey, the Department of Energy, and the State of Washington. The PNSN is based at the Department of Earth and Space Sciences at the University of Washington.

To see actual waveforms from this new station, go to http://www.ess.washington.edu/SEIS/PNSN/WEBICORDER/ and

GSA Cordilleran Section Meeting and Third Decadal Symposium on the Geology of Washington

The 98th annual Cordilleran Section Meeting of the Geological Society of America will be held May 13–15 in Corvallis, Oregon, which is close to the North America–Juan de Fuca Plate boundary. The active volcanic arc is visible to the east, and Corvallis is on the edge of the outer-arc high (Coast Range) to the west. The theme of the meeting is "Where Plates Collide."

The meeting promises to be a great opportunity to present new syntheses of ongoing efforts to map Cascadia convergent margin structure and topography. In recent years, the USGS, state surveys, and the academic community, in cooperation with the private sector, have been working to create seamless coverages of bedrock and surficial geology, potential field and velocity structure, and physiography of the convergent margin. This work is critical for understanding Cascadia's crustal deformation, hazards, and resources. A theme session of special interest in this regard is the Architecture of Cascadia: A Synthesis of New Geologic and Geophysical Mapping along the Convergent Margin. There will also be a session on another recent manifestation of the plate margin—the Nisqually earthquake of February 28, 2001.

Another important theme session is the Third Decadal Symposium on the Geology of Washington: In Honor of Rowland W. Tabor.

Preregistration deadline is April 5, 2002. The February 2002 issue of *GSA Today* has the registration form. You can also register online at http://www.geosociety.org/sectdiv/cord/02cdmtg.htm.

IN MEMORIAM: Harry T. Halverson

On October 13, 2001, the Division of Geology and Earth Resources lost a good friend when Harry Halverson died in Olympia, Washington, at the age of 82. Harry was a retired founder and vice-president of world sales for Kinemetrics, Inc., the world's leading manufacturer of seismographs, in Pasadena, California. He was the one who encouraged Kinemetrics to donate the seismograph in the Natural Resources Building rotunda. He was enthusiastic about seismology and brought in seismic records from his home instruments whenever there was a significant earthquake anywhere in the world.

Harry was born in Spanish Fork, Utah, on August 11, 1919. Several years later, his family moved to Glendale, California, where Harry was raised. He took trumpet lessons and played in the high school orchestra, later playing in small dance bands around town and finally touring several states. He played trumpet professionally for six years during the Big Band Era, prior to World War II. He was called to serve his country with the U.S. Army in the spring of 1941.

Harry's company trained in the desert and was then sent, in their desert uniforms, to fight in the Aleutian Islands, where it was very cold. He later landed with the marines on Okinawa. Harry returned home with many medals, including a Silver Star and a Purple Heart, after completing five years of service.

Growing up, Harry always thought he'd major in music. He was an excellent musician, his music sweet and smooth. But when he went back to school at the University of California at Berkeley, he decided to be more practical and major in engineering. To keep up his music, Harry played in the university symphony and, on weekends, in a dance band at a small club on the Russian River, where his future wife Marjorie would dance to his music. Harry hated to dance! Harry and Marjorie were married during those college years. The two of them had actually met 13 years before at a church event in Glendale, when Marge was 9 and Harry was 15. Harry got his engineering degree at Berkeley in 1950.

The Halversons' life has been one of achievement and adventure. They raised five children and entertained scientists from all over the world in their various homes while Marge remodeled, decorated, and landscaped. Later Harry was an international lecturer on earthquakes and earthquake technology. For his contributions to earthquake hazard mitigation, he was elected an honorary member of the Seismological Society of America in 1994, one of only two individuals from industry to be so honored. During his travels, Harry also took pictures.

By 1987, Harry had become known throughout Washington as the man who photographed the State Capitol Campus. His photographs are in the Governor's Office, the State Capitol Museum, private collections, banks, government offices, the Olympia Chamber of Commerce, and even on chocolate bars and note cards. Harry's photography and Marge's art have been exhibited several times in the Governor's Conference Room. Perhaps his best known work is the one on our cover—Mount Rainier looming over the Wilkes Regatta in Budd Inlet. Several of Harry's photos can be seen at the City of Olympia website at http://www.ci.olympia.wa.us/information/gallery/. Harry's photos may be purchased by calling (360) 866-9137.

NEW STATE GEOLOGIST AND ASSISTANT STATE GEOLOGIST CONFIRMED

Commissioner of Public Lands Doug Sutherland has appointed Ron Teissere as State Geologist and head of the Geology and Earth Resources Division for the Washington Department of Natural Resources (DNR) and Dave Norman as Assistant State Geologist. Ron succeeds Ray Lasmanis, who has been appointed Region Manager of DNR's Southwest Region office in Castle Rock. Dave succeeds Eric Schuster, who retired, but is still working with us several days a week to finish the 1:250,000-scale geologic map of the northwest quadrant of the State of Washington.

As Washington State Geologist, Ron oversees the support sections of the Division. He serves on the state Geologist Licensing Board and has been appointed co-vice chair of the state's Seismic Safety Committee. At the national and regional level, Ron represents both the state and DNR as a member of the Association of American State Geologists and as a representative to the Western States Seismic Policy Council. He is also a member of several environmental assessment and regulatory program standards committees with American Society for Testing and Materials (ASTM).

Ron has worked for DNR for the past 16 years, first as a geologist specializing in upland mineral, oil, and gas resources, then as Aquatic Resources Division Assistant Manager for submerged lands issues. His experience also includes mine operations and mineral land acquisition. Ron joined Geology and Earth Resources Division in 1999 as Assistant State Geologist for regulatory programs. He received his bachelor of science degree in geology from California State University at Los Angeles and his master of science degree in geological sciences from the University of California at Riverside.

As Assistant State Geologist, Dave oversees the Geologic Hazards, Regulatory, and Geology and Resources Sections of the Division. He has worked for DNR since 1989 and was the Chief Geologist of the Reclamation Program before being promoted. The Reclamation Program is responsible for regulation of mine reclamation throughout the state.

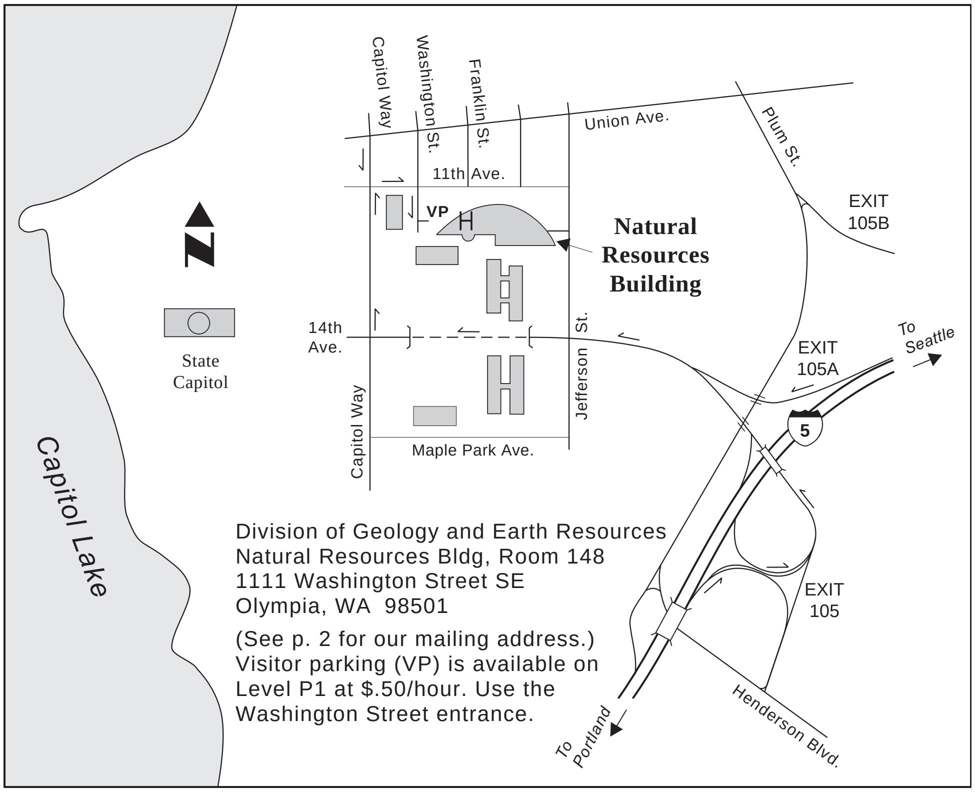
Dave has 23 years experience as a geologist. Prior to working for the state, he worked for Amoco Minerals and Union Geothermal doing exploration throughout the western U.S. and Alaska and for Core Laboratories doing petroleum exploration and development in North America and internationally. He has also worked in the geotechnical field and evaluated slope stability and landslide hazards at mine, building, and forestry sites.

Dave's current research projects include the Inventory of Inactive and Abandoned Mine Lands, the effects of sand and gravel mining on flood plains, and geological mapping in the Puget Sound.

Dave received his bachelor of science degree in geology from Portland State University and his master of science degree in geology from the University of Utah.

Both Ron and Dave are licensed geologists with the State of Washington. ■

HOW TO FIND OUR MAIN OFFICE



Division of Geology and Earth Resources
Natural Resources Bldg, Room 148
1111 Washington Street SE
Olympia, WA 98501

(See p. 2 for our mailing address.) Visitor parking (VP) is available on Level P1 at $.50/hour. Use the Washington Street entrance.

Resources for Earth Science and Geography Instruction

This website offers links organized around the sequence of topics typically taught in an introductory earth science or physical geography class. Links are also available for environmental science, earth science/geography education, career opportunities, and more. The sites selected are based on image quality, ease with which lesson plans can be developed, organization, authenticity, scope, and format. [http://personal.cmich.edu/~Franc1m/homepage.htm]

Free Preparedness and Mitigation Brochures in English and Spanish

We now have copies of "Surviving a Tsunami—Lessons from Chile, Hawaii, and Japan" (U.S. Geological Survey Circular 1187) and "Sobreviviendo a un tsunami: lecciones de Chile, Hawai y Japón" (USGS Circular 1218). We also have a Spanish-language emergency-preparedness brochure, "Plan de preparación familiar para emergencias". For a free copy of any of these brochures, contact us at our main office (see address on p. 2). Supplies are limited, so please request only one copy of each brochure per household.

DIVISION PUBLICATIONS

Print Publications

Reconnaissance Investigation of Sand, Gravel, and Quarried Bedrock Resources in the Mount St. Helens 1:100,000 Quadrangle, Washington, Information Circular 95, by David K. Norman, Andrew B. Dunn, and Cathrine M. Kenner, 52 p., 1 plate, scale 1:100,000. $4.40 + .35 tax (Wash. residents only) = $4.75.

Late Pleistocene Stratigraphy in the South-Central Puget Lowland, Pierce County, Washington, Report of Investigations 33, by Richard K. Borden and Kathy Goetz Troost, 33 p., color front and back cover. $2.78 + .22 tax (Wash. residents only) = $3.00.

Inactive and Abandoned Mine Lands Inventory—Roy and Barnum-McDonnell Mines, Morton Cinnabar Mining District, Lewis County, Washington, Open File Report 2001-1, by Fritz E. Wolff, Donald T. McKay, Jr., and David K. Norman, 7 p. $.93 + .07 tax (Wash. residents only) = $1.00.

Electronic Publications

Late Pleistocene Stratigraphy in the South-Central Puget Lowland, Pierce County, Washington (*see above)* is at http://www.wa.gov/dnr/htdocs/ger/pubs_ol.htm.

Inactive and Abandoned Mine Lands Inventory—Roy and Barnum-McDonnell Mines, Morton Cinnabar Mining District, Lewis County, Washington (*see above)* is at http://www.wa.gov/dnr/htdocs/ger/pubs_ol.htm.

The Digital Bibliography of the Geology and Mineral Resources of Washington State is now available on our website at http://www.wa.gov/dnr/htdocs/ger/washbib.htm. We've been maintaining this index since 1935, but we could only publish it in incremental printed volumes until 1998. We then issued the full searchable database on CD-ROM, but now—We're on the Net!

The searchable database includes the citations and indexing for all of the items we've found about the geology, geologic hazards, and mineral resources of Washington back to 1798—more than 31,000 items as of December 2001. The database also includes more than 5,700 other items in our library. We add about 1,000 items about Washington geology to the system annually and the database is updated monthly.

The digital bibliography is getting more use as the word gets out. In the ranking of DNR's most used websites, it was 101st in August, 46th in September, and 24th in October.

The Index to Geologic and Geophysical Mapping is available on our website as a PDF file at http://www.wa.gov/dnr/htdocs/ger/mapindex.htm.

STAFF NEWS

■ **Chris Johnson**, former reclamation geologist at Southwest Region, has been promoted to chief reclamation geologist (Geologist 4), filling the position left vacant when Dave Norman was promoted to Assistant State Geologist. He will oversee the Surface Mine Reclamation Program statewide. Chris has 20 years of experience as an exploration and on-site mine geologist. In addition to his strong background in geology and mining, Chris has experience in slope stability, reclamation, and hydrology. He has a B.S. and M.S. in geology from Brigham Young University.

■ **Hoa Le** has joined the staff as an Office Assistant Senior. Hoa has worked seven years for DNR and was previously in the SEPA Center. She came from Viet Nam in 1991. Hoa has an A.T.A. degree in office administration, legal secretary, and accounting. She is currently attending The Evergreen State College to pursue a B.A. degree.

■ **Matt Brookshier** has been hired as a Geologist 3 with the Mine Reclamation Program. He was previously employed by the U.S. Army Corps of Engineers to plan and perform investigations to implement site restoration. He received his B.S. in geology through the engineering geology option at the University of Kansas in 1995.

■ **Pat Pringle**'s photo of 'the big stump' in Orting was used in the Nov. 24, 2001, *Science News* cover story on Mount Rainier, "Take a look at Mount Rainier, America's most dangerous volcano", by Sid Perkins. The construction of homes and sewers in Orting has exposed more than 100 huge stumps, the remains of old-growth forests that were smothered by mudflows from Mount Rainier. Read the whole article online at http://www.sciencenews.org/20011124/bob18.asp.

■ **Pat Pringle** and Kevin Scott's paper on the "Postglacial influence of volcanism on the landscape and environmental history of the Puget Lowland, Washington..." is now online at http://www.wa.gov/puget_sound/Publications/01_proceedings/sessions/sess_4d.htm. The paper was presented at the fifth Puget Sound Research Conference, Feb. 12–14, in Bellevue. **Tim Walsh**, **Wendy Gerstel**, Bill Graeber, and Hugh Shipman's abstract—Influence of intercepted landslides on nearshore habitat—is at the same address.

■ **Pat Pringle** gave presentations at the Spokane Geological Society, Olympia Rotary Club, and Port Townsend Marine Science Center during the past month. The title of the Spokane talk was "Volcanoes, earthquakes, and landslides—How buried and submerged trees are revealing secrets of our geologic and environmental history—A virtual field trip".

■ **Fritz Wolff** wrote an article for the 2000 Mining History Journal, v. 7, titled "Driving the Kellogg Tunnel—Two miles to glory or ruination?" The Kellogg Tunnel was driven during the period 1897 to 1902 at the Bunker Hill lead-silver mine in Idaho. It is still in use 100 years later.

WASHINGTON STATE DEPARTMENT OF
Natural Resources

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