Major Events Bring in 1997

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Winter weather systems dumph snow on Puget Sound communities. The snow then sees融
subsequent rain, caused numerous landslides. These landslides resulted in fatalities and extensive property damage. Even larger landslides seem possible from the potential for devastating earthquakes and the threat of massive flows from Mount Rainier that has been featured in recent newspapers. These kinds of real and potential events remind us that awareness of a threat from nature is not sufficient by itself. Understanding the geologic conditions, selecting mitigation measures, and implementing emergency preparation plans can reduce future losses.

In this issue of Washington Geology is an article by the staff of the Department of Natural Resources and the Department of Ecology about the late December 1996 rain-on-snow events. The article documents the various combinations of topography, geology, and hydrology that, combined with poor land-management practices, have created situations leading to property loss and fatalities.

In the regulatory arena, the final Environmental Impact Statement (FEIS) was issued for the Crown Jewel mine in Oakesdale County. When permitted, this mine will counter the economic losses in northeast Washington caused by the closure of the Hecla operations at Republic, Ferry County, and of the Canol gas pipeline at Otter Lake, Chelan County. The Notice of Availability was published in the Federal Register on February 7, 1997. In the Record of Decision by the Forest Service and the Bureau of Land Management, Alternative B has been selected. This alternative is for an open-pit mine to operate around the clock to produce 3,000 tons of gold ore per 24-hour period. The ore will be treated in a mill facility using on-site tank cyanidation. Ore reserves have been calculated to be 8.7 million tons with an average grade of 0.166 oz of gold per ton, using a cut-off grade of 0.034 oz per ton. A recent upswing in the price of gold has increased the reserve to 9.1 million tons of ore. The appeal period for the Record of Decision for Forest Service is 45 days from the date of publication. The Appeal is due February 3, 1997 and the Bureau of Land Management 30 days from the date of the notice in the Federal Register (Feb. 7, 1997).

Geologist(s): Michael S. Lingley, Assistant State Geologist

Related Websites:
- Washington State Department of Natural Resources
- Division of Geology and Earth Resources
- PO Box 47007, Olympia, WA 98504-7007

Cover Photo: The front wall of this boating supply store on Harbor Ave SE in Seattle was pushed out by one lobe of a debris flow that initiated on the bluff behind the store and broke through the rear wall. (Alan S. Kelleher, February 1997.)

The other lobe flowed around the north side of the building and came to rest next to the truck (right side of photo).

How to Find Our Main Office

Division of Geology and Earth Resources
Natural Resources Building Room 148
1111 11th Avenue SW
Olympia, WA 98501

Buses (2 for our mailing address)
Visitor parking (VP) is available on Level P1 at 5:00
MI. Use the Washington St. entrance.

Recently Released

Assessing earthquake hazards and reducing risk in the Pacific Northwest, volume 1 of U.S. Geological Survey Professional Paper 1566. The volume editors are A. M. Rogers, T. J. Walsh, W. J. Kockelman, and G. R. Priest. Included are articles about earthquake sources, paleoseismology, evolution of the Cascadia margin, and earthquake focal mechanisms in Washington. Plate 1 is a map showing known or suspected faults with Quaternary displacement in northern Washington, Oregon, and Washington at a scale of 1:2,000,000.


Davidson, J. D., 1997, In the rain’s way: Earth, v. 6, no. 1, pp. 20-21, 60-61.


Green, Colleen, 1997, After the deluge—Strategies to combat the ravages of runoff: Erosion Control, v. 4, no. 1, pp. 30-37.


Saxton, K. E., 1995, Wind erosion and its impact on off-site air quality in the Columbia Plateau—An integrated research plan: American Society of Agricultural Engineers Transactions, v. 38, no. 4, pp. 1031-1036.


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INTRODUCTION

Washington ranked 20th in the nation in total value of nonfuel mineral production in 1995, the last year for which production figures are available. A $382,370,000 increase, or approximately 14 percent over 1994, which occurred for most commodities, had the notable exceptions of coal and sand and gravel. The value of gold production decreased by 42 percent in 1995 (Fig. 1) due to closing of mines at Wanatchee and Republic (Derkey, 1996). It increased slightly in 1996.

This article reviews 1996 activities in the nonfuel mineral industry of Washington. Firm production values are not yet available from the U.S. Geological Survey for 1996. Volunteered information obtained from individual owners of mining companies and individuals provided data for this preliminary update. In addition, several companies and individuals were contacted directly because they were known to be operating in the state. The tables in this article should not be considered a complete listing of mineral industry activities.

Additional details about the geology of the metallic mineral deposits in Washington and other industry activities are available in the reviews of Washington's mineral industry published in the first issue of Washington Geology each year for example, Derkey and Gulick, 1992; Derkey, 1993, 1994, 1995, 1996; Gulick, 1994, and Gulick and Lingley, 1993). Questions about metal mining activities and exploration should be referred to Bob Derkey in the Division's Spokane office. Information about the sand and gravel industry and reclamation can be obtained from Dave Norman in the Olympia office. See p. 2 for addresses and phone numbers.

METALLIC MINERAL INDUSTRY ACTIVITIES

About 32 percent of the total value (nearly $582,500,000) of all nonfuel mineral commodities produced in Washington in 1995 came from metal production. When figures become available, the overall value of metal production will probably be lower in 1996.

In the past, activities in the metallic mineral industry are divided into three categories: major mining and exploration projects, small-scale mining and exploration projects, and property-related activities. The distinction, however, was maintained. Location maps are included for the first two categories, and tables are provided for each of the three categories.

Major Metal Mining and Exploration Projects

The locations of the six major metal mines or exploration projects in Washington in 1996 are shown on Figure 2. Table 1 lists the location and activity in 1996 and briefly describes the geology of the deposits.

All known precious metal production in Washington in 1996 was by Echo Bay Minerals Co. at their Kettle River Pro-

Figure 1. Gold production in Washington, 1985-1996. The decline in gold production reversed in 1996 because of a 24,000-oz increase from Echo Bay Minerals Co., the only known producer in the state. Hacienda Mining Co., deposited 5,282,430 oz, for a total of 5,306,410 oz for 1996. This production was on mines that produced only a small amount in the final stages of operations in 1995. The Lone Jack mine did not produce in 1996 due to subeconomic grade ore.

[Figure 1 is a graph showing gold production in Washington from 1985 to 1996, with a notable increase in 1996.]

Includes:
Driedger, C. L., "What to do with a volcano in your backyard?"—Volcano hazards outreach at Mount Rainier. p. 67-68.

Open-File and Water-Resources Investigations Reports


Includes:


OTHER REPORTS ON WASHINGTON GEOLOGY


November 1996 through February 1997

THESSES


U.S. GEOLOGICAL SURVEY
Published reports

Includes:
Adams, John, Great earthquakes recorded by turbidity flows off the Oregon-Washington coast, p. 147-158.
Goldfinger, Chris; Kulin, L. D.; Yeats, R. S.; Applegate, T. B. Jr.; Mackay, M. E.; Cochrane, G. R., Active strike-slip faulting and folding of the Cascadia subduction zone plate boundary and forearc in central and northern Oregon, p. 223-236.
The author presents the geologic history of the Wenatchee area, with Wenatchee as the geographic center of the discussion. The book describes geologic events more or less chronologically. His presentation is that of an advanced amateur, with college courses and much practical experience, but no great writing in geology. Chapter headings are: In the beginning; The formation of Washington State; The rock cycle; Igneous rock structures; Basalt flows of the Columbia Plateau; Volcanoes and earthquakes; Consolidated and unconsolidated sedimentary deposits; Metamorphic structures; Landslides; Bresl-Missoula floods; Moses Coulee; Erratics, Knapp and Navarre Coulees; Malaga slide; Metalllic, industrial and carboniferous activity in the Wenatchee area; and Conclusion.

The book has a number of strengths. Although the geologic events described center on Wenatchee, many are treated in a regional, statewide, or even larger context, so the book is meaningful to people living outside the Wenatchee area. There is enough informal cross-referencing in the text to tie concepts, localities, and geologic events together adequately. The author displays an obvious wide-ranging interest in geology, has read the geologic literature treating the Wenatchee area, understands the principal concepts and interpretations of geologists who have published on the geology of the area, has observed the geology of the area extensively, and presents the information in an easy-to-read way. His discussion is quite broad-ranging—he has attempted to cover the whole of the geologic history of the Wenatchee area, not just selected geologic events. Basic criteria and methods to understand his discussion are explained, so the book can be read by a layperson without reference to other works.

This book adds to our understanding of geologic events that tie the geology to human activities. He explains the significance of past geologic events such as earthquakes and volcanic eruptions and discusses their impact on future events. Most of the locations are described and located well enough so the reader could find them with the aid of good maps and a knowledge of the section, township, and range location system. Mason does quite a nice job of describing the sedimentary units in the Wenatchee area—the Swauk, Chumstick, and Wenatchee Formations. He covers the various aspects of the Columbia River basin nicely and at considerable length. His treatment, perhaps, is of the events of the last glaciation, especially the glacial Lake Missoula outburst floods and how they and related events shaped the topography and unconsolidated deposits found in the Wenatchee area today.

I think the most impressive feature of the book is the 198 color photographs, all taken by the author and his wife. Most illustrate the chosen feature well and have reproduced well. The book also has a number of weaknesses. These include random capitalization, frequent misspellings, choice of wrong homonyms (roll for role, brakes for breaks, vain for vein, sheer for shear, mixed usage of terrain and terrace), careless and inconsistent use of the names of geologic units, lack of location maps, and use of “strata” and “stratum” without regard to the number of strata being discussed. Mason uses the term “structure” as a catchall term that includes, in different places, folds, faults, outcrops, peperastoliths, hills, and igneous intrusions. This is quite irritating to a geologist who is accustomed to the word having a specific and much narrower meaning.

The author simplifies the plate tectonic history of Washington to only three accretionary packages, which he calls the Okanagan micro-island continent, Cascade micro-island continent, and Crescent terrace. For the non-geologist reader, this simplification is probably acceptable, even desirable. There are a few outright mistakes and garbled definitions, for example, from page 58, “The oldest sedimentary formation within our state may be the Swauk.” From page 18, “An unconsolidated sedimentary material is rather self explanatory. The sediment is loose and ‘unstratified’ ” and, from page 131, “An erratic is defined as a ‘rock’ of indeterminable size, transported by ice from its ‘spin’ [sic] position, to some other indeterminate location.”

Overall, the book is a worthwhile effort and has much to offer both amateur and professional geologists. It would have been an outstanding book if the manuscript had been reviewed by a geologist and if misspellings, wrong homonyms, and English usage had been corrected.

by J. Eric Schuster

Ginkgo Petrified Forest Museum
Ginkgo Petrified Forest Museum in Vantage 1997 hours are 10 am-6 pm, weekends only in April; Saturday-Sunday, May 1-12; and Thursday-Sunday, June 15-16. Labor Day, when the schedule is reduced to Friday-Sunday. Groups tours (for a fee) of the facility are available year-round and can be arranged by calling (509) 856-2769. New events this year:

- The museum will be showing and selling the video “The Great Floods,” depicting the Pleistocene outburst floods from glacial Lake Missoula.
- Ecology class: Wild Plants of the Desert, a 4-hour seminar describing native plants and their uses. By appointment, 12 person minimum, $3 per person. Led by Debbie Hall. Begins in April, weekdays only, schools will get reduced rates. Reserve time by calling the museum.
- Ginkgo seedlings will be sold to raise fund for the museum.
Charles Phillips Purdy, Jr. (1916–1997)

Phil Purdy, geologist with the Washington Division of Mines and Geology for several years, died in Spokane on February 24, 1997, at age 81. During his career as a mining geologist he worked for both federal and state governments and for several corporations in the western United States, Canada, Greenland, and Central America. He retired in 1985, settled in Spokane, and became active with the Mineral Information Institute.

He began working for the Division as a geologist on April 7, 1947, and resigned on October 15, 1948. The 1948-1950 biennial report of the Division of Mines and Geology (Glover, 1951) lists Purdy’s education as S.B. in Geology, Harvard College, and postgraduate in mining geology, Massachusetts Institute of Technology. He was the author of several reports for the Division, listed below.


NORTHWEST PALEONTOLOGICAL SOCIETY

1. May 3 meeting at the Burke Museum: Showcase session for members’ collections

2. June 7 trip being planned to Chuckanut Formation outcrops, Bill Smith, leader

3. August 9 trip to Oquash and Coal Creeks, Cowitz Formation; Bill Smith, leader

For more information about these field trips, contact Bill Smith, 33322 Ridgeland Dr., Silverdale, WA 98383.

The membership fee is $15/year, $25 for families, $10 for student or senior, and $5 junior; send checks to Betty Jarrold, 1780 NE 102nd Ct., Redmond, WA 98073. (Although elections are slated for May, applications will be forwarded to the appropriate officer.)

NORTHWEST GEOLOGICAL SOCIETY

At the April 8 meeting, John Delaney will discuss exploration of the Juan de Fuca Ridge. On May 13, Darrel Cowan will talk about the San Juan Islands, a preview to the members-only field trip he will lead June 6. Next month, June 10, the division will host its annual earth resources plans to bring to each meeting copies of important new publications, new division releases, and papers related to the speaker’s subject. These would be “for inspection only” as an effort to inform members of what is available.

Meetings are held at the University Plaza Hotel, just west of 5th and Cherry, Every Thursday. Anyone interested, please attend these meetings.

Tom Bush is president of the society, David Knoblauch is president-elect, Linda Schiefer is Treasurer, Matt Mero is Director, and Jeff Quigley is the section’s Chairman. For membership information, write to Roni Charney (NWGS Secretary), 19245 11th Ave NW, Seattle, WA 98177-2613. Dues are $20 a year, $5 for students.

Table 2. Operator and a brief description of the activity and geology of small-scale mining and exploration projects in Washington in 1996

<table>
<thead>
<tr>
<th>Property</th>
<th>Company</th>
<th>Activity</th>
<th>Area geology</th>
</tr>
</thead>
<tbody>
<tr>
<td>Black Hawk</td>
<td>Echo Bay Exploration Inc.</td>
<td>Drilled 2 holes</td>
<td>Gold mineralization in massive iron replacement skarn in Permian sedimentary rocks</td>
</tr>
<tr>
<td>Morning Star</td>
<td>Echo Bay Minerals Co.</td>
<td>Drilled 3 holes on license</td>
<td>Volcanoclastic massive sulfide mineralization in Mesoproterozoic Boring Formation</td>
</tr>
<tr>
<td>Gold Mountain</td>
<td>Globex Nevada, Inc.</td>
<td>Geologic mapping, geophysics, drilled 14 holes</td>
<td>Gold-plutonic mineralization in an alkalic dike of the Jurassic Shasket Skilet complex</td>
</tr>
<tr>
<td>Three Crosses</td>
<td>Art Baiden</td>
<td>Drill</td>
<td>Mineralization in diabase and gabbro of the Ingalls Complex</td>
</tr>
<tr>
<td>Williams Creek</td>
<td>Goodwill Exploration Inc.</td>
<td>Seeding new permits</td>
<td>Placement under lease with Williams Creek</td>
</tr>
<tr>
<td>September Moon</td>
<td>Ross Kilmer</td>
<td>Geophysics, geologic mapping, open old adit</td>
<td>Placement under lease with Ross Kilmer</td>
</tr>
<tr>
<td>Palmer Mountain</td>
<td>Willard Wallcer</td>
<td>Property acquisition, reconnaissance, sampling</td>
<td>Place under lease with Willard Wallcer</td>
</tr>
</tbody>
</table>

no. 3) in mid-February 1996. They exercised their option and purchased the property. Santa Fe has, however, put on hold any decision to develop the property pending takeover offers for the company. They continue to hold their earn-in agreement on the remainder of Hecla Mining Co.’s holdings at Republic in Ferry County.

Small-Scale Mining and Exploration Projects

A number of smaller scale mining and exploration projects were ongoing in 1996. Figure 7 shows the locations of these projects. Table 2 lists the projects and their activities and includes a brief comment about the geology of the deposit. The majority of those companies and individuals were looking for gold. As in 1995, the Lone Jack mine (Fig. 7, no. 22) in Whatcom County, was in operation in 1996. However, the vein that the company had intercepted at depth in 1995 proved to be of lower than expected grade, and the company did not ship any ore in 1996. Delano-Wind River Mining Co. mined and stockpiled approximately 2,000 tons of ore at the Wind River gold deposit (Fig. 7, no. 19) in Skamania County. The company intends to continue to work at the site to establish a milling facility. Globex Nevada Inc. conducted geophysical and geological studies before it drilled 14 deep holes on the Gold Mountain deposit (Fig. 7, no. 13) in rocks of the Shasket Skilet alkaline complex at the north end of the Republic Graben in northern Ferry County. Echo Bay Minerals Co. explored the Black Hawk property (Fig. 7, no. 11), seeking mineralization similar to the last year’s discovery by Ferron Copper Co. of the Three Crosses property near Cle Elum in Kittitas County. The company completed some exploratory drilling in 1996. Owners of placer properties on Williams Creek (Fig. 7, nos. 15, 16) near Liberty in Kittitas County were seeking permits to operate.

The most active 1996 exploration target for base metals was deposits that have potential volcanic massive sulfide (VMS) mineralization. Echo Bay Exploration drilled three holes on the Morning Star (Fig. 7, no. 12) deposit in northern Ferry County. Aerial for sources conducted a geologic study on possible VMS mineralization at the Trout Creek property (Fig. 7, no. 20) in Shoosmith County. Northwest Mineral Ltd. explored Toulou Mountain (Fig. 7, no. 21) in Stevens County to establish a property with potential for VMS and contact metamorphic mineralization. Jim Creek (Fig. 7, no. 18) in Pend Oreille County has potential for base metal mineralization. Consolidated Viscrrent Resources, Ltd. was investigating methods of recovering nickel and scandium from the South Pass laterite deposit (Fig. 7, no. 23) in Whatcom County.

Maintained Property

A number of companies and individuals maintained their properties in 1996, either through the filing of claims, leases, or completion of assessment work on unpatented claims. Table 3 lists those properties.

NONMETALLIC MINERAL INDUSTRY ACTIVITIES

The combined production of nonmetallic mineral commodities (carbonates, clays, diatomite, olivine, and silica) accounted for about $163 million, or approximately 28 percent of the approximately $582 million of nonfuel mineral production for Washington in 1995, the last year for which figures are available. Figure 8 and Table 4 summarize activities for nonmetallic commodities in 1996. Information covering previous years’ activities for nonmetallic commodities can be found in articles by Gulick (1994, 1995), Gulick and Lingley (1993), and Derkev (1996).
Table 3. Properties known to be maintained or undergoing reclamatory activities but where no active mining or exploration was associated with the activity.

<table>
<thead>
<tr>
<th>Property</th>
<th>Location</th>
<th>Company</th>
<th>Commodities</th>
<th>Arca geology</th>
<th>County</th>
</tr>
</thead>
<tbody>
<tr>
<td>Waconichi Gold</td>
<td>sec. 35, 22N, 30E</td>
<td>Quest International</td>
<td>Au, Ag</td>
<td>Mineralization in altered (commonly silicified) breccias in Eocene arkose sandstone.</td>
<td>Chelan</td>
</tr>
<tr>
<td>Belt project</td>
<td>sec. 3-2, 22N, 17E</td>
<td>Gold Bond Mining Co.</td>
<td>Gold Bond Resources</td>
<td>Vein mineralization in rocks of the Biggs-ophiolite complex</td>
<td>Chelan</td>
</tr>
<tr>
<td>Liver</td>
<td>sec. 15, 40N, 34E</td>
<td>Johnson Explosives</td>
<td></td>
<td>Gold mineralization in silicified rocks of the Jurassic Shastak Creek complex</td>
<td>Ferry</td>
</tr>
<tr>
<td>Apex &amp; Damen</td>
<td>sec. 34, 28N, 10E</td>
<td>CSS Management Corp.</td>
<td></td>
<td>Quartz vein in granodiorite of the Mesozoic Sneequetah batholith</td>
<td>King</td>
</tr>
<tr>
<td>Weayancha properties</td>
<td>sec. 12, 17N, 2E</td>
<td>Weayancha Co.</td>
<td>Au, Ag, Cu, Mo, Pb, Zn, city, silica</td>
<td>Gold-quartz veins in Eocene volcanic rocks of the Weayancha Volcanics</td>
<td>King, Pierce, Thurston, Oglala</td>
</tr>
<tr>
<td>Maverick</td>
<td>sec. 16, 37N, 28E</td>
<td>Wallace Cottely</td>
<td>Au, Ag</td>
<td>Gold-quartz veins in Eocene volcanics</td>
<td>Kittitas</td>
</tr>
<tr>
<td>Sierr Molydock</td>
<td>sec. 16, 37N, 28E</td>
<td>Wilbur Hallauer</td>
<td>Mo, Ca, W</td>
<td>Pyrophyllite-type mineralization in Cretaceous Aenas Creek quartz monzonite and granodiorite; gold in secondary enriched zone</td>
<td>Okanagan</td>
</tr>
<tr>
<td>Aeorn Valley property</td>
<td>sec. 8, 35N, 31E</td>
<td>Sunshine Valley Minerals, Inc.</td>
<td>Au, Ag, Cu, silica</td>
<td>Possible gold mineralization associated with large quartz (high-grade quartz) bodies in probable Premier rocks</td>
<td>Okanagan</td>
</tr>
<tr>
<td>Silver Belle</td>
<td>sec. 25, 38N, 31E</td>
<td>Lovejoy Mining</td>
<td>Au, Ag</td>
<td>Epithermal mineralization in Eocene-Devonian volcanic rocks of the Silver Belle Volcanics</td>
<td>Oglala</td>
</tr>
<tr>
<td>Ida</td>
<td>sec. 16, 31N, 39E</td>
<td>Crown Resources Corp.</td>
<td>Au, Ag, Cu</td>
<td>Epithermal veins in Eocene epithermal volcanics</td>
<td>Okanagan</td>
</tr>
<tr>
<td>Crystal Butte</td>
<td>sec. 55, 30N, 30E</td>
<td>Keystone Gold, Inc.</td>
<td>Au, Ag, Pb, Zn, Sb</td>
<td>Skarn-type mineralization in Persman Spectacle Formation intruded by Mesozoic rocks</td>
<td>Okanagan</td>
</tr>
<tr>
<td>Lucky Knock</td>
<td>sec. 19, 38N, 27E</td>
<td>Magui &amp; Associates</td>
<td>Au, Ag</td>
<td>Skarn-type veins in sedimentary rocks</td>
<td>Oglala</td>
</tr>
<tr>
<td>Billy Goat</td>
<td>sec. 15, 38N, 20E</td>
<td>Sunshine Valley Minerals, Inc.</td>
<td>Au, Ag, Cu</td>
<td>Stockwork in Cretaceous dundrean tuff and breccia</td>
<td>Oglala</td>
</tr>
<tr>
<td>Kelsey</td>
<td>sec. 5-40N, 25E</td>
<td>Wilbur Hallauer</td>
<td>Au, Ag</td>
<td>Opal in joint cracks in basalt at Pullman, Washingtom</td>
<td>Okanagan</td>
</tr>
<tr>
<td>Silver Star</td>
<td>sec. 3-5, 3-5N, 30E</td>
<td>Kinross Gold USA, Inc.</td>
<td>Au, Ag, Mo, Au, Cu</td>
<td>Opal in joint cracks in basalt at Pullman, Washingtom</td>
<td>Okanagan</td>
</tr>
<tr>
<td>Lockwood</td>
<td>sec. 30-32N, 29N, 9E</td>
<td>Island Arc Resources Corp.</td>
<td>Au, Ag, Zn</td>
<td>Ore in veins within the Lockwood-Gonzales Formation</td>
<td>Oglala</td>
</tr>
<tr>
<td>Van Stone mine</td>
<td>sec. 32, 50N, 30E</td>
<td>Zier's Mining Inc.</td>
<td>Au, Ag</td>
<td>Vein-type mineralization in Jurassic-Mesozoic sedimentary rocks</td>
<td>Stevens</td>
</tr>
<tr>
<td>Uranium 1-4 &amp; New Indian</td>
<td>sec. 13, 40N, 39E</td>
<td>Louden &amp; Sunstein &amp; Associates</td>
<td>Au, Ag, Cu, Pb, Zn</td>
<td>Vein-type mineralization in Jurassic-Mesozoic sedimentary rocks</td>
<td>Stevens</td>
</tr>
<tr>
<td>Henry claims</td>
<td>sec. 13, 40N, 39E</td>
<td>Louden &amp; Sunstein &amp; Associates</td>
<td>Au, Ag, Cu, Pb, Zn</td>
<td>Vein-type mineralization in Jurassic-Mesozoic sedimentary rocks</td>
<td>Stevens</td>
</tr>
<tr>
<td>Cleat Group</td>
<td>sec. 27-28N, 45E</td>
<td>David Roberts &amp; Associates</td>
<td>Au, Ag</td>
<td>Vein mineralization in altered (commonly silicified) breccias in Eocene arkose sandstone.</td>
<td>Stevens</td>
</tr>
<tr>
<td>Igneous</td>
<td>sec. 1-20N, 30-40N, 42E</td>
<td>Mines Management, Inc.</td>
<td>Au, Ag, Pb, Zn</td>
<td>Quartz veins in altered (commonly silicified) breccias in Eocene arkose sandstone.</td>
<td>Stevens</td>
</tr>
<tr>
<td>New Light</td>
<td>sec. 28, 39N, 18E</td>
<td>Lion Mines Ltd.</td>
<td>Au, Ag</td>
<td>Quartz veins in altered (commonly silicified) breccias in Eocene arkose sandstone.</td>
<td>Stevens</td>
</tr>
<tr>
<td>Minnesota</td>
<td>sec. 37N, 36E</td>
<td>Seattle-St Louis Mining Co.</td>
<td>Au, Ag</td>
<td>Quartz veins in altered (commonly silicified) breccias in Eocene arkose sandstone.</td>
<td>Stevens</td>
</tr>
<tr>
<td>Acreit</td>
<td>sec. 30, 37N, 17E</td>
<td>Double Eagle Exploration Inc.</td>
<td>Au, Ag, Cu, Pb</td>
<td>Vein-type mineralization in Jurassic-Mesozoic sedimentary rocks</td>
<td>Stevens</td>
</tr>
<tr>
<td>Morse Creek</td>
<td>sec. 31, 17N, 11E</td>
<td>Arco Exploration &amp; Development, Ltd.</td>
<td>Au, Ag</td>
<td>Vein-type mineralization in Jurassic-Mesozoic sedimentary rocks</td>
<td>Stevens</td>
</tr>
</tbody>
</table>

Marshall was always ready to share his time and talent with others. He was interested in a great variety of natural resource-related issues and was always ready to talk about geology. Because Marshall was at his best when working with other people, Figures 1 and 2 picture him with colleagues rather than alone. Those who worked with him will remember and miss him.

by Eric Schuster

Sources
Centriculth Chronicle, December 23, 1996, article entitled "Longtime forestry leader dies in crash."

Works by Marshall Tower Hunting
Hunting, M. T., 1942, Preliminary report of geology along part of Tucuman River, Northwest Society, v. 16, no. 4, p. 103-104.

Figure 2. Staff of the Division of Mines and Geology sometime between 1958 and 1968. Standing, left to right, Bill Rechter, Ted Livingston, Jerry Thores. Seated, left to right, W. A. G. (Bill) Bennett, Gloria DeRosset, Dorothy Rinkenberg, Mark Haun, Marshall T. Hunting, and Joan Preston (f). Not pictured: Wayne Munn. The photograph was taken in the Division library, third floor, General Administration Building. On the table is a large pamphlet that was used to change the scales of source maps for the 1961 state geologic map.
Marshall Tower Huntington (1918 – 1996)

Former State Geologist and Supervisor of the Division of Mines and Geology (now Division of Geology and Earth Resources) Marshall T. Huntington died in a traffic accident near Morton, Washington, on December 21, 1996.

Marshall was born on October 3, 1918, in Silver Creek, Washington, where his family owned a farm. He graduated from Mosyouy High School in 1936. In the summer of 1936, he worked in the placer gold fields of Alaska and attended the University of Alaska, Fairbanks, during the 1936-1937 school year. He then attended Washington State College (WSC, now Washington State University) in Pullman and received a B.S. degree in Geology in 1941. He stayed at WSC for graduate work and received his M.S. degree in Geology in 1942.

At that time, the Division of Geology (the predecessor of the Division of Mines and Geology and the Division of Geology and Earth Resources) was headquartered at WSC, and the Geology Department Chairman, H. E. Culver, was also State Geologist and Division Supervisor. During his college years, Marshall served in the U.S. Army in the Philippines from 1943 to 1945. He began full-time work for the Division of Geology, still headquartered in Pullman, in May 1942. In 1945, the Division of Geology was reorganized with the Department of Mines and Mining and moved to Olympia, where Mines and Mining was already located. The combined division was called the Division of Mines and Geology.

Marshall served as a geologist with the Division under Supervisor and State Geologist Sheldon L. Glover and became Assistant Division Supervisor in 1950. When Glover retired in February 1957, Marshall was named Supervisor and State Geologist. During the early part of Marshall's tenure in Olympia, the Division's offices were on the top floor of the Transportation Building (now the John L. O'Brien Building) near the Legislative Building. In about 1956, the Division moved to the new General Administration Building and occupied a suite of offices, known as Room 335, on the west side of the building near the northwest corner, adjacent to the Division of Water Resources. Part II—Metals, the minerals publication of 1956, and 1,500,000-scale geologic map of Washington published in 1961. The Inventory of Washington minerals has served the mineral industry well and still guides mineral exploration in this state.

Marshall was a member and officer of the Pacific Section of the American Institute of Mining, Metallurgical, and Petroleum Engineers and the Northwest Geological Society. He was certified as a registered mining engineer in 1948. Following his retirement in June 1971, Marshall and Martha moved to their farm near Silver Creek in Lewis County. The effect of retirement on Marshall was wonderful. He retired partly because of increasing regulatory responsibilities, and his duties sometimes left him rather harried. He visited the office a few months after his retirement, and the change was marvelous. He was tanned, smiling, and physically fit. He remained that way. He also remained very, very active, so much so that it is not really accurate to say he retired. He just changed jobs, from geologist to rancher, farmer, forester, and civic leader.

Marshall continued to do occasional geological consulting jobs, and he stayed in touch with the Division, but part of his energy went into public service and raising cattle, berries, fruit trees, and beans. At various times he was board member for Lewis County Conservation District, member of Lewis County Farm Bureau Association, American Farm Bureau Advisory Committee on forestry, Lewis County Planning Commission, Lewis County Farm Forestry Association, and Lewis County Search and Rescue. In 1992, his was the Lewis County Farm Bureau of the Year, and in 1995, the Wildlife Federation of the Year. He served 14 years as secretary/treasurer of the Mosyouy Viking Scholarship Fund.


Figure 2. Location of nonmetallic mining operations in Washington in 1966. Table below identifies mines from numbers on the map. See Table 4 (next page) for additional details on each of these projects.

**Carbonates**

Northwest Alloys continued to market agricultural soil conditioners, mainly carbonate byproducts; they obtain production of magnesium metal and Alkali (Fig. 2, no. 6) in Stevens County. Other companies producing calcium or magnesium carbonate from limestone or dolomite, respectively, include Columbia River Carbonates from the Wauconda quarry (Fig. 8, no. 111) and Pacific Calcium Products, from the Totonago quarry (Fig. 8, no. 111) and Brown (Fig. 8, no. 112) quarries in Okanogan County. The Gehrke (Fig. 8, no. 117), Northwest Marble Products (Figs. 8, no. 119), Joe Jann (Fig. 8, no. 120), and Janni Lime (Fig. 8, no. 121) quarries in Stevens County were also in operation in 1996. The only known carbonate deposit operation in western Washington was the Maple Falls quarry (Fig. 8, no. 123) in Whatcom County.

<table>
<thead>
<tr>
<th>No.</th>
<th>Property</th>
<th>Commodity</th>
<th>Location</th>
<th>County</th>
</tr>
</thead>
<tbody>
<tr>
<td>101</td>
<td>Twin River quarry</td>
<td>clay</td>
<td>sec. 22, T23N, 10W</td>
<td>Chelan</td>
</tr>
<tr>
<td>102</td>
<td>Cañada Rock quarry</td>
<td>clay</td>
<td>sec. 18, T20N, 1W</td>
<td>Chelan</td>
</tr>
<tr>
<td>103</td>
<td>Volcanic and Rock Top deposits</td>
<td>clay</td>
<td>sec. 13, T23N, 25E</td>
<td>Douglas/Grant</td>
</tr>
<tr>
<td>104</td>
<td>Cielo Corp. diatomite pits</td>
<td>diatomite</td>
<td>sec. 3, T21N, 23E</td>
<td>Okanogan</td>
</tr>
<tr>
<td>105</td>
<td>Ravensdale pit</td>
<td>silica</td>
<td>sec. 34, T22N, 7E</td>
<td>Okanogan</td>
</tr>
<tr>
<td>106</td>
<td>Ekl pit</td>
<td>silica</td>
<td>sec. 31, T22N, 4E</td>
<td>Okanogan</td>
</tr>
<tr>
<td>107</td>
<td>Sec. 31 pit</td>
<td>silica</td>
<td>sec. 19, T21N, 4E</td>
<td>Okanogan</td>
</tr>
<tr>
<td>108</td>
<td>Prairie claim</td>
<td>crystals</td>
<td>sec. 5, T21N, 23E</td>
<td>Omak</td>
</tr>
<tr>
<td>109</td>
<td>Superior quarry</td>
<td>silica</td>
<td>sec. 1, T19N, 21E</td>
<td>Omak</td>
</tr>
<tr>
<td>110</td>
<td>John Henry #1</td>
<td>clay</td>
<td>sec. 12, T21N, 6E</td>
<td>Okanogan</td>
</tr>
<tr>
<td>111</td>
<td>Tomasket limestone quarry</td>
<td>limestone</td>
<td>sec. 25, T21N, 24E</td>
<td>Okanogan</td>
</tr>
<tr>
<td>112</td>
<td>Brown quarry</td>
<td>dolomite</td>
<td>sec. 26, T25N, 26E</td>
<td>Okanogan</td>
</tr>
<tr>
<td>113</td>
<td>Wauconda quarry</td>
<td>limestone</td>
<td>sec. 13, T23N, 30E</td>
<td>Omak</td>
</tr>
<tr>
<td>114</td>
<td>Clay City pit</td>
<td>clay</td>
<td>sec. 35, T22N, 41E</td>
<td>Spokane</td>
</tr>
<tr>
<td>115</td>
<td>Somers clay pit</td>
<td>clay</td>
<td>sec. 14, T22N, 41E</td>
<td>Spokane</td>
</tr>
<tr>
<td>116</td>
<td>Mica mine</td>
<td></td>
<td>sec. 15, T22N, 39E</td>
<td>Whatcom</td>
</tr>
<tr>
<td>117</td>
<td>Gehrke quarry</td>
<td></td>
<td>sec. 24, T23N, 39E</td>
<td>Whatcom</td>
</tr>
<tr>
<td>118</td>
<td>Lane Mountain quarry</td>
<td></td>
<td>sec. 19, T23N, 39E</td>
<td>Whatcom</td>
</tr>
<tr>
<td>119</td>
<td>Northwest marble mine</td>
<td></td>
<td>sec. 19, T22N, 38E</td>
<td>Whatcom</td>
</tr>
<tr>
<td>120</td>
<td>Joe Jann limestone deposit</td>
<td>limestone</td>
<td>sec. 13, T23N, 39E</td>
<td>Whatcom</td>
</tr>
<tr>
<td>121</td>
<td>Janni limestone quarry</td>
<td></td>
<td>sec. 13, T23N, 39E</td>
<td>Whatcom</td>
</tr>
<tr>
<td>122</td>
<td>North Alaska marble mine</td>
<td>limestone</td>
<td>sec. 8, T22N, 40E</td>
<td>Whatcom</td>
</tr>
<tr>
<td>123</td>
<td>maple Falls quarry</td>
<td></td>
<td>sec. 34, T23N, 38E</td>
<td>Whatcom</td>
</tr>
</tbody>
</table>

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Table 4. Operator and a brief description of the activity and geology of nonmetallic mining operations in Washington in 1996.

<table>
<thead>
<tr>
<th>Property</th>
<th>Company</th>
<th>Activity</th>
<th>Area geology</th>
</tr>
</thead>
<tbody>
<tr>
<td>Twin River quarry</td>
<td>Holman Inc.</td>
<td>Mixed 60,000 tons, development</td>
<td>Murdercrater (in) people of the upper Eocene to lower Miocene Twin Rivers Formation (Eocene–Oligocene sequence)</td>
</tr>
<tr>
<td>Castle Rock quarry</td>
<td>Ash Grove Cement Co.</td>
<td>Mixed 40-490 tons</td>
<td>Eocene–Oligocene sequence sedimentary rocks</td>
</tr>
<tr>
<td>Volcanic and Rock Top deposits</td>
<td>Basic Resources Co.</td>
<td>Permitted is nearly completed, target is for 60,000 tons production in the first year</td>
<td>Calcium bentonite (clay) interbed in Miocene Columbia River Basalt Group near Moses Coulee</td>
</tr>
<tr>
<td>Celite Diatomite pits</td>
<td>Celite Corp.</td>
<td>Mixed over 100,000 tons of ore and approximately 200,000 tons of finished diatomite</td>
<td>Miocene “Quinault diatomite” located in the Asotin County, Washington, United States.</td>
</tr>
<tr>
<td>Rascoula pit</td>
<td>Reserve Silica Co.</td>
<td>Mixed and washed 70,000 tons</td>
<td>Sandstone of the Eocene Puget Group</td>
</tr>
<tr>
<td>Elk pit</td>
<td>Mutual Materials Co.</td>
<td>Mixed 13,000 tons to produce bricks</td>
<td>Elko- and kashekar-bearing shales of the Eocene Puget Group</td>
</tr>
<tr>
<td>Sec. 31 pit</td>
<td>Mutual Materials Co.</td>
<td>Mixed 65,000 tons to produce bricks</td>
<td>Shale of the Eocene Puget Group</td>
</tr>
<tr>
<td>Spruce claim</td>
<td>Robert Jackson</td>
<td>Extracting mineral and crystal specimens</td>
<td>Quartz and pyrite crystals in large, open veins along faulted geologic features in the northern phase of the Lewis and Clark fault-parallel shear zone.</td>
</tr>
<tr>
<td>Superior quarry</td>
<td>Ash Grove Cement Co.</td>
<td>Exploration drilling and development, no production</td>
<td>Exploration drilling and development, no production</td>
</tr>
<tr>
<td>John Henry #1</td>
<td>Pacific Coal Co.</td>
<td>Mixed 16,000 tons of limestone for soil conditioner and feed limestone</td>
<td>Metal-bearing rock in the conglomerate-bearing member of the Permian Spectacle Formation (Permian Group)</td>
</tr>
<tr>
<td>Tonasket limestone quarry</td>
<td>Pacific Calcimine, Inc.</td>
<td>Mixed 6,000 tons of limestone for soil conditioner and feed limestone</td>
<td>Groundwater (in) Lower Miocene Columbia River Basalt Group</td>
</tr>
<tr>
<td>Brown quarry</td>
<td>Pacific Calcimine, Inc.</td>
<td>Mixed 4,000 tons of soil conditioner and feed limestone</td>
<td>Groundwater (in) Lower Miocene Columbia River Basalt Group</td>
</tr>
<tr>
<td>Wascoula quarry</td>
<td>Columbia River Carbonates</td>
<td>Mixed 105,000 tons of workers to produce 75,000 tons</td>
<td>High-calcium, pre-Tertiary white marble lenses in mica schist, calcrete rocks, and horizons</td>
</tr>
<tr>
<td>Clay City pit</td>
<td>Mutual Materials Co.</td>
<td>Mixed 6,300 tons to produce bricks</td>
<td>Tertiary kaolinite-bearing, altered argillite</td>
</tr>
<tr>
<td>Sonora clay pit</td>
<td>Quarry Tille Co.</td>
<td>Mixed 4,000 tons of soil conditioner and feed limestone</td>
<td>Laminar clay of the Miocene Latah Formation overlying silty clay of the Pleistocene Puyallup Formation</td>
</tr>
<tr>
<td>Mica mine</td>
<td>Mutual Materials Co.</td>
<td>Mixed 42,000 tons, stockpiled to produce bricks</td>
<td>Laminar clay of Miocene Latah Formation overlying sapropelite, pre-Tertiary felsic gneiss</td>
</tr>
<tr>
<td>Galerie quarry</td>
<td>Allied Minerals, Inc.</td>
<td>Mixed about 3,000 tons</td>
<td>Ilmenite pods of Potomac Y Strange Dolomite (?) (Devonian Group)</td>
</tr>
<tr>
<td>Lake Mountain quarry</td>
<td>Lake Mountain Silica Co. (division of Hemphill Brothers, Inc.)</td>
<td>Mixed 300,000 tons, planted at near the plant at Valley</td>
<td>Dolomite of the Cambrian–Ordovician Formation (division of Hemphill Brothers, Inc.)</td>
</tr>
<tr>
<td>Northwest marble mine; other quarries</td>
<td>Northwest Marble Co. (division of Hemphill Brothers, Inc.)</td>
<td>Mining, milling, calcite specific aggregating materials for building and industrial applications</td>
<td>Dolomite of the Cambrian–Ordovician Formation (division of Hemphill Brothers, Inc.)</td>
</tr>
<tr>
<td>Joss Limestone deposit</td>
<td>Joseph A. &amp; Jeanne F. Limestone deposit</td>
<td>Leased to Columbia River Carbonates</td>
<td>Dolomite of the Cambrian–Ordovician Formation (division of Hemphill Brothers, Inc.)</td>
</tr>
<tr>
<td>Joss Limestone deposit</td>
<td>Peter Janss and Sons</td>
<td>Columbia River Carbonates shipped some 200,000 tons of limestone to their plant in Woodland, WA</td>
<td>Dolomite of the Cambrian–Ordovician Formation (division of Hemphill Brothers, Inc.)</td>
</tr>
<tr>
<td>Stovall quarry</td>
<td>Northwest Limestone Co. (division of Hemphill Brothers, Inc.)</td>
<td>Mixed 40,000 tons, processed on site</td>
<td>Limestone in the upper unit of Cambrian–Ordovician Metamorphic Formation</td>
</tr>
<tr>
<td>Maple Falls quarry</td>
<td>Claustral Lime Co.</td>
<td>Mixed about 60,000 tons, used for rip rap and some aggregate and landscape rock</td>
<td>Shoared, jointed Lower Pennsylvanian limestone overlain by shered arfie and andesite by andesite, graywacke, and volcanic breccia of the Shilhawick Group</td>
</tr>
<tr>
<td>Sven Earnet quarry</td>
<td>Oliveau Corp.</td>
<td>Mixed and milled 41,000 tons for refractory/inclined uses; majority of production used by UNIMIN Corp.</td>
<td>Shoared, jointed Lower Pennsylvanian limestone overlain by shered arfie and andesite by andesite, graywacke, and volcanic breccia of the Shilhawick Group</td>
</tr>
</tbody>
</table>


(See also: URL: www.engineers.org/52.htm)


Washington Division of Geology and Earth Resources Bulletin 78, 2 v.


Photo Credits

Wendy Gerstel – 3-5, 9B, 23-29
Leonard Palmer – 19B
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George W. Thornton – 14-19A
Tim Walsh – 8A, 8B, 9A

Note added in proof: As this issue was going to press, another rainstorm hit the Puget Sound area and caused at least 30 more landslides.

Errata

The price for Open File Report 96-4, Preliminary bibliog-raphy and index of the geology and mineral resources of Washington, 1991–1995, (announced in the previous issue) should increase $1.03 each.

The caption and the photos on p. 22 in the previous issue were taken by Tim Walsh of our staff.

In the previous issue, the article “A Field Guide to Washington State Acaiology” contains the end of the last sentence “and will briefly discuss Ringside Formation correlates throughout the region, setting the stage for future regional sedimentologic inter-pretations.” This phrase wandered in from somewhere else and does not actually belong with the field guide.
as continuous raveling and sloughing. The larger landslides tend to be more episodic. When heavy winter precipitation is added to bluffed sediments, unstable parts of the slope tend to fail. (See, for example, Thorsen, 1983.) The frequency over time and space of these failures increases during and after particularly heavy precipitation. In some places, human activities (such as poor construction practices) have exacerbated the rate of bluff retreat by landsliding.

By learning to recognize old landslides and studying the effects of construction and landsliding near and on slide-prone areas, we may be able to plan for the slides to come.

In 1990, the legislature passed the Growth Management Act (amended 1994; Washington Geology, v. 21, no. 3, p. 1-37) to create local ordinances that govern the development of unstable coastal bluff areas, RCW 36.70A.170 requires that "on or before September 1, 1991, each county, and each city, shall designate where appropriate....critical areas". These include "geologically hazard-
From Clay to Bricks

Robert E. Darkey
Washington Division of Geology and Earth Resources
904 W. Riverside, Room 209, Spokane, WA 99201-1011

Clay is a term applied to both a group of minerals and a rock made up of clay-size particles (generally less than 1/256 of a millimeter). Of the several definitions for clay in the American Geological Institute’s Dictionary of Geology (Bates and Jackson, 1987, p. 122), the following best fits clay for making bricks. It is (1) “a loose, earthy, extremely fine-grained sediment or soft rock”; (2) it commonly contains “subordinate amounts of finely divided quartz, decomposed feldspar, and other non-clay minerals; and (3) it “forms a plastic, moldable mass when mixed with water, retains its shape on drying, and is firm, rocklike, and permanently hard on heating and firing.”

Mutual Materials operates several brick plants in eastern and western Washington. (See the industrial minerals section of the preceding article, p. 11.) The Mica plant, located 15 miles southeast of Spokane, uses a deposit of the Latea Formation to make bricks and related materials. This Miocene formation contains a high proportion of clay. The company makes a wide variety of shapes, sizes, and colors of face bricks, that is bricks used to face a building. They also make fire bricks, mainly for wood stoves, and tile for chimney liners.

The following figures illustrate some of the steps of making bricks from clay.

Reference Cited

Figure 1. Highwall of clay pit. This is one of several pits where Mutual Materials Co. mines clay for making bricks at its plant in Mica, southeast of Spokane. The deposit contains about 65 percent clay, the remainder being quartz, feldspar, and mica. The non-clay fraction is about 65 percent quartz, 20–30 percent feldspar, and 5–10 percent mica. The pit highwall shown displays considerable color variation; the darker parts are stained by iron oxide, an iron mineral. By carefully controlling the size of clay from this and several other pits, the Mica plant can produce a wide spectrum of brick colors.

Figure 2. When the desired blend of source clay is reached, an appropriate amount of water is added. The clay is squeezed or forced into a mold from which it is extruded, in much the same way as toothpaste is squeezed out of its tube. The clay is extruded in a continuous stream onto a slowly moving conveyor belt. Different orifices are used to obtain the different sizes and shapes of bricks. If the design calls for holes in the brick, they are created at the orifice.

- Gullies and surface erosion – Dissection of the bluff edge by natural drainage or discharge from pipes, culverts, and ditches.

- Springs – Mid-slope ground-water seepage from the bluff face, particularly noteworthy are increases in flow.

Safeguarding Against Landslide Hazards

The following are some measures that can be taken to mitigate or avoid landslide hazards:

- Use setbacks – Expect natural slope processes to continue, and provide adequate construction setback for structures in landslide hazard areas.

- Reduce surface erosion – Keep drains and culverts clear. Avoid discharge onto the slope—direct surface water runoff (especially from impermeable surfaces) to the base of the slope in nonperforated pipe. This is called tufflining.

- Reduce ponding and infiltration – Limit opportunities for water to pond on the surface by draining or regrading. Consider connecting to city sewers instead of installing or replacing septic systems.

- Maintain and improve vegetation – Trees and shrubs provide root strength to hold the soil in place and help dewater the slope. If they are removed, root strength will be gone within 2 to 12 years and will not be easily restored.

- Protect bluff from surface erosion – Apply erosion mats, plastic sheeting, or other erosion-control material where vegetation will not take hold.

DISCUSSION

The Paget Lowland bluffs have experienced landslides for thousands of years. Bluff retreat is a normal process. Some of the small-scale, but still potentially destructive, retreat occurs
Figure 25. This closeup of the sand slurry deposit (Fig. 24) shows that sand flowed onto the bench from left to right in the photo (now uphill). Partial drying of the sand and subsequent rotation of the bench resulted in the formation of these tension cracks parallel to the back edge of the bench (upper left of photo). Note footprints for scale.

Figure 26. In this view to the north, the large tension crack near the outer edge of the bench indicates active movement. The geologist in the foreground is standing in the crack; the other is at the north end of the crack. The railroad tracks are about 60 ft below and to the left.

WHAT CAN BE DONE TO IDENTIFY AND AVER POTENTIAL LANDSLIDES?

As the Growth Management Act and its enabling regulations state, avoidance is the safest approach when it comes to land-use practices in areas of unstable slopes. However, in many places urban growth has already encroached on these slopes. If you live at the edge of a bluff or in an area that has experienced landslides in the past, there are some things you can do to reduce the rate of bluff retreat and improve the stability of the slope with respect to shallow failures and surface erosion. Deep-seated failures are more difficult to control, but it is clearly beneficial to reduce infiltration and surface runoff from roofs and driveways and to fix clogged or leaking storm drains.

Listed at the end of this article are several publications that provide useful information on amelioration of unstable bluff slopes. Figures 27 through 29 show examples of stabilization efforts in the Seattle area, not all of which were successful. The following lists offer landslide identification criteria and prevention and mitigation techniques.

Identification of Landslide Hazard Areas

These are some characteristics that may be indicative of a landslide hazard area:

1. Active bluff retreat – Continuing sloughing or calving of bluff sediments, resulting in a vertical or steep bluff face with little to no vegetation.
2. Pre-existing landslide – Landslide debris within an eroded head scarp.
3. Tension cracks – Ground fractures along and/or near the edge of a bluff or ravine.
4. Structural damage – Settling and cracking of building foundations near edge of a bluff or ravine; also separation of steps or porch from the main structure.
5. Toppling, bowed, or jackstrawed trees – Disruption of the ground surface by active movement causes trees to lean and/or fall in different directions or to grow in a curve instead of straight.

Figure 3. Cutting bricks. The conveyor belt carries the stream of clay through this cylinder-like apparatus, which periodically rotates one-third of a turn. The apparatus contains three sets of "piano" wires, and when it is turned by the dogs on the two wheels of the cylinder, the wires cut the clay into a brick shape. Because the extruded clay is moving at a steady pace, the cylinder also moves during the cut to ensure it is straight.

Figure 4. Moving right along... The freshly cut clay blocks now pass onto a belt that is moving slightly faster than the one that fed the clay to the cutter; this increases the space between the blocks. The bricks shown here are soft, but of the typical size and have three holes.

Figure 5. Stacking clay blocks to be sent to the dryer and kiln. The soft bricks move to where they are manually stacked on cars. This is the most labor-intensive part of the process. Once stacked on the cars, the clay blocks are moved along rails through the dryer and the kiln. The Mira plant can produce an unusual near-white brick from the LaTah deposit. Because of this characteristic of the clay, the company can also make bricks in a number of light or pastel colors by adding colorant or small amounts of clay of another color.
DANTE'S PEAK, FACT OR FICTION?

Dante's Peak, a disaster thriller from Universal Studios, dramatizes the hazards faced by communities near active volcanoes. Set in the North Cascades of Washington, the movie portrays the roles of U.S. Geological Survey (USGS) scientists and local public officials during the reawakening and eruption of a fictional volcano—one that resembles dozens of real volcanoes from northern California to Alaska. To separate fact from fiction, the USGS issued a release titled "Dante's Peak FAQ's (frequently asked questions)." Examples include:

- Hot springs may heat up before an eruption, but probably not in a matter of seconds as shown in the movie.
- If a town's water supply originates directly from a volcano's ground-water system, it could become contaminated, but probably not as quickly as shown in the movie.
- Earthquakes associated with eruptions rarely exceed magnitude 5, which are large enough to sway trees and damage buildings, but not to destroy them as shown in the movie.
- It's uncommon for a volcano to erupt different types of magma at the same time, that is, the furnaces and flows characteristic of fluid magma and the explosive ash and pyroclastic flows characteristic of more viscous magma.
- Trying to drive over a hot lava flow (1,700°F) would result in melting tires and an exploding gas tank.
- Lakes near volcanoes can become acidic and cause burns to human skin but are unlikely to dissolve an aluminum boat in a matter of minutes as shown in the movie.
- Hardly any vehicle can outrun a pyroclastic flow moving at speeds of up to 100 mph.

For more information, contact C. Dan Miller, U.S. Geological Survey Cascades Volcano Observatory, 5400 MacArthur Blvd., Vancouver, WA 98661; (360) 696-7885 (office), (360) 696-7866 (fax), cmiller@mail.wrl.usgs.gov (e-mail), or visit the USGS website discussion about the movie at http://vulcan.wr.usgs.gov/News/DantesPeak.

EARTH GODDESSES OF THE PACIFIC NORTHWEST

Abqishanakhu (Tlingit) - Chthonic goddess who protects the pillar-support of the earth.
Dah-ko-beed (Dawanalish) - "Tacoma." Earth goddess of the Cascade mountains.
Haynakana (Tlingit) - "The Old Woman Underneath." She supports the earth either by holding it or by tending the boulder that holds it. She causes earthquakes, which her people believe means she is hungry. To appease her they throw grease on the fire so it will melt and run down to her. Alternate form: Haynakana.
Klah Klahnee (Yakima, Klickitat) - Goddess of the "Three Sister" mountain in Oregon.
Loo-wit (Wtoothim, Klickitat) - Fire goddess of Mount St. Helens.
Nemastina (Tahltan) - Earth mother. She supports the earth, and when she shifts she causes earthquakes.
Pahto (Yakima, Klickitat) - Goddess of Mount Adams.
Plash-plash (Yakima, Klickitat) - "White Spots." Goddess of Goat Rocks near White Pass. One of the five mountain wives of the sun. The others are the goddesses Walkashum (Simcoe Mountains), Pahto (Mount Adams), Loo-wit (Mount St. Helens), and Tacoma (Mount Rainier).
Tacoma (Salish, Nisqually, Payaollah, Yakima) - Earth goddess of Mount Rainier. Alternate forms: Dah-ko-beed, Ta-cobud, Takobah, Takobah, Tehoma.
Walkashum (Yakima, Klickitat) - Goddess of Simcoe Mountain in southwestern Washington.
Waches (Yakima) - Goddess of Mount Hood in Oregon. Alternate form: Wyesast.

Reference

At the beginning of an idealized cycle, the bluff has a uniform slope. Water infiltrates the surface soils and perches above the relatively impermeable materials at the base of this sandy sequence. Saturation creates pore-water pressures that reduce the effective strength of these materials.

Runoff and precipitation introduced by the sources shown in A have infiltrated and weakened the sediments, causing failure of the unconsolidated upper sand unit. Once mobilized, the sand moves (sometimes episodically, sometimes continuously) along the contact with the underlying less permeable unit on the mid-slope bench, often cascading as a secondary landslide off the bluff formed by the lower unit. This migration of material across the bench decreases the buttressing of the upper bluff. Failure surfaces can be deep (those that project into the lower, less permeable materials) as well as shallow.

Mentioned mines were the Tono, Thompson, Big Dirty, Little Dirty, and Smith. These coals occur in the Skookumchuck Formation, composed of nearshore marine and nonmarine sedimentary rocks. The Skookumchuck is the upper formation of the Eocene Puget Group.

In 1996, the mine produced coal from four open pits. Coal beds mined were the Tono, Thompson, Big Dirty, Little Dirty, and Smith. These coals occur in the Skookumchuck Formation, composed of nearshore marine and nonmarine sedimentary rocks. The Skookumchuck is the upper formation of the Eocene Puget Group.

Figure 1. Coal-producing areas and districts, western Washington.

Figure 2. John Henry No. 1 Mine, Pit No. 1, in January 1997. In this view to the southeast is the northwest limb of the anticlinal structure. Light-colored bare rock to the left of the pond forms the floor of the Franklin No. 7 coalbed. The Franklin Nos. 7, 8, and 9 coalbeds merge in this part of the mine. The excavator is alongside these three coalbeds (dark-colored material).

Structure in the mine. Production comes from four coalbeds, the Franklin Nos. 7, 8, and 9. These coal beds occur stratigraphically near the base of the undivided Eocene Puget Group in nonmarine deltaic sedimentary rocks. In late January 1997,
PCCS was mining the Franklin Ns. 7, 8, and 9 coalbeds along the right side of the ridge, where the three coalbeds stratiographically merge (Fig. 2). PCCS also mines a clay bed between the Franklin Ns. 7 and 9 coalbeds. This clay bed is blende with high alumina clay for manufacturing Portland cement.

Figure 3. John Henry No. 1 Mine, Pit No. 1, January 1977. In this view (to the southwest) the face of the Franklin No. 7 coalbed forms the steeply dipping plane of bare rock to the left of the eroded portion. Here the southwest limb of the double plunging anticlinal structure is exposed. The Franklin Ns. 7, 8, and 9 coalbeds are exposed in the distance at road level (behind the mine truck), where they merge stratiographically and occur near the crest of the plunging anticline where the dip has not flattened.

Clarification of Information in “Geohyrdologic Review of the Cedar River Ground-water Basin”

The following letter was sent January 23, 1997, to Kathleen Cotttingham, Supervisor, DNR.

Dear Ms. Cotttingham:

The December 1996 issue of the DNR publication “Washington Geology” contained an article entitled “Geohydrologic Review of the Cedar River Ground-water Basin” [v. 24, no. 4]. The article was written by Stephen H. Evans and Roy E. Jensen. A statement was made in the article with respect to the Department of Ecology and water rights that was not accurate, and I want to express some concern and provide you with some accurate information regarding water right decisions.

In the introduction section of the article, the statement was made that “the current Washington Department of Ecology moratorium on allocating and developing ground water demands stratastratigraphic lows it is to acquire comprehensive ground water information.” My concern with this statement is two-fold:

1. DOE has instituted a moratorium on the allocation of water rights. It is true that the decision-making process for water right applications was drastically impaired in 1994 when the budget passed by the legislature resulted in massive cuts in the agency, and specifically the Shorelands and Water Resources Program, which handles water right applications.

2. Additionally, the recent Watershed Assessment done in the Cedar River Basin utilized existing information to show that water is in short supply in the critical summer months. The fact that the Cedar River does not meet required instream flows on the average of 81 days out of the year indicates that we cannot continue to issue water rights without adversely affecting existing water rights, instream uses, and our natural resources and habitat. This does not translate into a moratorium on the issuance of water rights. Rather it means that applicants need to look for alternatives to new water for their water supply. DOE is working with applicants who are proposing such alternatives. What these assessments point out is that the era of inexpensive, easy water supply is over.

The “development of ground water” is not something that is within the mission of DOE. It is the responsibility of the department to make a careful evaluation of water right applications, but that it must act in the interests of the public as a whole. This may mean that denial of water right applications is necessary, as in the Cedar River Watershed. Again, [this does not translate into a moratorium on the issuance of water rights. It is wrong to make the assumption that denial of water right applications in one area means denial in another area. Conditions and proposals are different in other areas, and we must address the issues specific to those areas.

I’m sure you can appreciate the need to have accurate information regarding agency policies and mandates, in this era of “distrust of government. I know you must face some of these same issues working with a state agency. Thank you for your consideration of these issues. Please feel free to contact me with any questions or concerns at (206) 649-7096.

Sincerely,

Raymond Heilig
Shorelands and Water Resources Program

National Natural Landmarks

The 1995 “Section 8” annual report regarding the status of the landmarks indicates that the Drumheller Channels site in Washington is now considered threatened or damaged. For a copy of this report or a brochure about the 34 sites in the cascades area, contact the National Park Service, Columbia Cascades System Office, 700 First Ave., Seattle, WA 98104-0160. See also their web page at http://www.nps.gov/cenw/ml.htm.

occurred in these areas. We also discuss what area residents can do to avoid such serious consequences and prepare for the effects of future rains and snows. At the end of the article is a list of helpful books and articles.

Geology by Examples

Seattle Area Stratigraphy

Several different mechanisms contribute to the instability of coastal bluffs in the Puget Sound region. The resulting landslides can range in size from small, shallow soil slips to large, deep-seated rotational slump-earthflows. Most of those resulting from the February 1996 and 1996-1997 storms were some variation of the ones shown earlier in this article and described in the following text accompanying sketches.

The typical undisturbed stratigraphy in the central Puget Sound area consists from the top down of a thin soil layer overlying relatively impermeable till (hard pan), permeable sands, and/or near impermeable clays and silts (Fig. 20). However, in many areas, the stratigraphy can be more complicated (Figs. 15, 17).

Throughout much of the Seattle area, till of Vashon age (approximately 13,000 years old), approaching thicknesses of up to 30 ft, forms a relatively strong and resistant cap that covers much of the highlands and protects softer underlying layers from erosion. Although till is in many places impermeable to ground water, fractures and gullies in the till surface allow percolation into the lower, sedimentary layers. Till commonly overlies advance outwash deposits locally known as the Espenscheid Sand.

The Espenscheid Sand was deposited by streams issuing from the ice sheet while it was located some distance to the north. It is highly permeable (well-drained) and poorly consolidated. In typical Espenscheid deposits, the upper part may be dry, even in winter, whereas ground water flows rapidly through its basal zone, where the water is perched on underlying clays and silts. Water saturation builds pore pressure, which in turn reduces soil strength and allows the sand to mobilize and slide along the surface of the clay (Fig. 21). In some places, the sand is so poorly consolidated that it collapses on itself. Permeability within the Espen-Scheid Sand varies laterally and vertically, and ground water piping can occur along weak zones. Gullies form where piping intersects the surface.

The compact clays and silts underlying the Espenscheid Sand were deposited in a proglacial lake that existed before the ice advance into the Puget Sound area. The name "Lawton Clay" is applied to this thinly and parallel-bedded clay and silt unit. The Lawton Clay perches ground water, forming the slopping surface on which the Espenscheid Sand can slide (Fig. 21a, c). The clay unit, generally more competent, remains in place, with only minimal seasonal retreat. Each passing winter, the sand portion of the bluff retreats at a faster rate than the clay and the resulting landform is the characteristic stepped or bench-bluff (Fig. 21c). Deep-seated failures can occur where a failure surface extends into the clay unit. (For discussions of these and other relations between ground water and landslides, see Tubbs, 1974; Dunne and Leopold, 1978; Freeze and Cherry, 1977; Thorsen, 1987; and Evans, 1994.)

Any of these Pleistocene units may overlie knobs and fault blocks of impermeable Tertiary bedrock. The upper surfaces of these bedrock protrusions may also percolate water and act as glide planes for landslides (Fig. 18).

Processes along the Burlington Northern-Santa Fe (BNSF) Railroad North of Carkeek Park

The landslides that occurred along the BNSF Railroad tracks (Figs. 12-26) provide excellent examples of the different types of failures and the different slope retreat rates discussed above and seen throughout the storm-damaged areas (Fig. 22). It is important to understand and anticipate these landslides, as they have been and will continue to be responsible for damage along the Puget Sound shoreline.
Puget Sound Bluffs: The Where, Why, and When of Landslides Following the Holiday 1996/97 Storms

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From late December 1996 to early January 1997, a series of winter storms delivered snow, freezing rain, warm rain, and wind to the west coast, producing landslides with ice damage, and landslides from Washington to central California. Individual weather systems like these arrive almost annually; the consequences of their combination are somewhat more remarkable, but nonetheless occur every few years somewhere in the region. The region's long history of slope failure following heavy precipitation events is discussed in Tubbs (1974), Thorsen (1987), Miller (1991), and Evans (1994).

In the Pacific Northwest, the autumn months had above-normal precipitation, building high soil moisture and heavy snowpacks. In late December, a cold continental air mass moved over northwest Washington, while a series of warm wet storms began moving in from the Pacific Ocean. The incoming moisture first fell as snow north of the cold front and freezing rain south of it. In the southern Puget Sound region and the Columbia Gorge-Portland area, ice storms brought down trees and power lines, while snow accumulated from about Olympia northward, reaching depths of up to 3 ft in north King County. Then on January 1 and 2, warm air, combined with locally heavy rains, quickly melted much of the low-elevation snow. This caused flooding in most streams in the Puget Lowland and in many of the rivers draining the Olympics and the Cascades.

The combination of pre-existing soil moisture, heavy rain, and rapid snowmelt brought soils to or near saturation. This had different effects, depending on the terrain. On the gentler flood plains, perching of water on tills and emergence of ground water from shallow aquifers caused lingering flooding of low-lying areas. But in the steep bluffs and ravines that border Puget Sound, Lake Washington, and the larger river valleys, lateral movement of ground water toward the free faces caused elevated pore-water pressures that triggered hundreds of landslides. A selection of these landslides is presented in this report.

Following a disaster declaration by President Clinton for most counties in Washington, the Federal Emergency Management Agency (FEMA) made funds available for identification, investigation, and remediation of the landslides, among other emergency needs. Division of Geology and Earth Resources geologists were asked by the Washington State Emergency Management Division to help the City of Seattle with damage assessment. Helicopter flights and several days of on-the-ground visits provided an overview of storm effects. The Division submitted oral and written reports to the City of Seattle and worked with other local geologists and landslide experts to examine new slides and slide-prone areas that threatened structures and transportation corridors. At the same time, private consultants assisted homeowners in repairing the damage and provided advice on slope stabilization techniques.
Figure 3. This building supply store on Harbor Avenue SW stands in a line of commercial and residential structures at the base of the bluff on the west side of Duvall Hill. Many buildings here were ruptured along the upper portions of the bluff as a result of the December storms.

At this site, a fairly small debris flow (approx. 200 yd²) hit the back of the building and splinter into two lobes, one flowing north around the outsides of the building, the other pushing through and out the front of the building. (See also the cover photo.) The area of vegetation on the bluff behind the store is a layer of sand that failed when it became saturated by ground water seeping on the underlying clay. An explanation of this common geologic situation is given in Figures 20 and 21.

Figure 4. The "Anderson house" (known by the name of its designer) is cantilevered over the slope above Ferry Avenue SW, north of the bluff shown in Figure 3. Below it, and about 15 feet above the street, a small debris flow initiated in saturated material (here claysium) covering clay deposits. Clay layers can be seen in the lower part of the photo. Slides like this commonly increase in size through headward erosion.

Figure 15. Slide activity such as this in the Voiceless Bay area of Whidbey Island can result in periodic retreat of the bluff edge by as much as 20 feet or so in seconds. During this recent slide, a portion of the side in front of the large house was lost. Such episodes commonly are preceded and followed by decades of little erosion, making estimates of average bluff retreat rates potentially meaningless. In this location there are multiple impermeable silts layers that channel water, in contrast to conditions like those at Snellhead (Fig. 3), where water is concentrated above one impermeable "perching" layer. Slides here can be triggered by an abundance of water (as in the December/January storms) or by wave erosion at the base of the bluff. Rainfall may simply be the "last straw." In many locations around the sound, water from winter rains is accumulated in drainages and may cause landslides to occur months later as it slowly migrates toward the bluff. In the mid-1970s in the Golden Gardens area of Seattle, slides occurred well into summer after a series of exceptionally wet winters.

Figure 16. Several beach homes in the east side of southern Whidbey Island had close calls from debris avalanches. Debris avalanche tracks and deposits here will soon be colonized by alders. Stumps or patches of alder trees that are all of the same age can indicate areas where slide activity occurred in the past; the age of the trees indicates approximately when the slides occurred. In the 1900s and 1990s, many beach level developments like these were constructed on fill behind bulwarks. Material for the fill was commonly hosed off the slopes or bulldozed from the bluffs. This may have contributed to continued slope instability by destabilizing the toe of the slide.

Figure 17. Fortunately, homes here were built with adequate setbacks—no more for these failures. The depth of a failure surface can influence the rate of retreat of the edge of the upland surface. In this case, west of Port Townsend, shallow debris avalanching (far left) has occurred in a significant edge retreat yet. The west bluff on the right indicates a relatively deep-seated slide of upper-bluff sediments, only. (See Fig. 21.) The surface of failure for the middle slope is even deeper, "daylighting" at (or below?) bench level (Fig. 21B, C), and has caused the most retreat. At many sites along the coastal bluffs, sedimentary units are not laterally continuous, and conditions can be quite different over a distance of 100 feet or less.
Figure 12. This slide, one of many that occurred along a stretch of railroad tracks north of Carkeek Park, lies within an older, larger slide scar. Past slides along these tracks have temporarily halted train traffic many times. Such slides have knocked railroad cars into Puget Sound, at times resulting in injuries or hazardous spills. Trip wires are strung just above the waiting rail along the tracks. An interrupted circuit signals when (but not precisely where) landslides occur. Figures 21 through 26 illustrate the different mechanisms responsible for landsliding along this stretch of bluff. Development at the top of the bluff can contribute to and is affected by the slides. Coastal modifications such as the bulkhead (built in the 1890s to support the railroad bed) also affect slope and near-shore processes. The bulkhead does not prevent landslides, but does control the rate and nature of redistribution of slope debris in the near-shore zone. Material dumped into the Sound by railroad crews cleaning the tracks is rapidly redistributed out of the narrow and steep intertidal zone and offshore by wave energy reflected off the bulkhead.

Figure 13. Locations of landslide damage shown in Figures 14 through 19.

Figure 14. At Salchett Head at the southern end of Whidbey Island, mudflows temporarily block access to these beach-level homes during wet winters. The upper bluff is porous glacial outwash sand that dries out in summer. The silt that forms the lower bluff (below dashed line) and perches ground water to damp and green year-round. The top of the silt is approximately at the position of the dashed line. The scarp in the background and the partially brecciated bench are characteristic of such slide areas where percolating ground water is perched above the less permeable silts. The sands are weaker than the silts and slide readily when saturated. Similar situations are present north of Carkeek Park and in the Golden Gardens area of Seattle, among other places. (See Figs. 20, 21.)

Figure 5. This view to the east shows three homes along Aki Avenue SW in West Seattle that were affected by a growing deep-seated landslide. The largest displacement occurred west (toward the viewer) of the low house on the left. A line of trees (dashed) standing on the down-dropped portion of the slide in front of the headscarp. Also visible is the displacement of the deck of the large house in the center. The tension crack delineating the headscarp continues through the deck area in the center house and into the back of the house to the right (south). The dark line extending from the house on the left is a drainage ditch (see p. 29). Another segment of the headscarp is visible to the left of the lining.

Figure 6. This photo shows one of the larger Seattle landslides along Perkins Lane on the southwest side of the Magnolia neighborhood. This is an area of continuing large-scale instability. Immediately following the February 1996 storm, a 1,000-yd² landslide (Figs. 21, 25) slid from the upper portion of the bluff into the back yard of the home on the right. Seattle engineers attempted to mitigate the problem by regrading and revetting the upper slope. However, the February landslide was a shallow manifestation of a deep-seated rotational failure that formed, or might have already existed, in the sand, gravel, and silt deposits of the bluff at this site. This deep-seated slide was reactivated in December 1996, damaging at least five houses. These three are now uninhabitable. The white plastic sheeting on the slope was probably placed there in an attempt to prevent water from infiltrating the soil. This site is representative of the geologic conditions shown in Figures 20 and 21.

Figure 7. This house in West Seattle (lower right), and a portion of the road that runs behind it, was built on fill, commonly failure-prone when saturated. Note the down-dropped (and previously patched) section of the road between the white lights. Tension cracks start to the left of the area that extends to the right, under the house. Fill material at the lower right corner of the house appears to be displaced. Also note the reactivated rills in the drainage below the road (lower left corner of this photo). These may have been caused by excessive runoff onto colluvium and till.
Figures 5A & 6. This landslide at the intersection of Ferry Avenue SW and California Way SW, just to the north of the "Anderson house" (Fig. 4), illustrates geologic conditions that contribute to many Seattle landslides. Sand exposed in the upper bluff (barely visible in the upper left corner of B) has been sliding onto the bench (visible in the upper portion of both photos) and then sliding along that bench to the lower bluff's edge (see Figs. 20, 21). These photos were taken several days after the initial landslide. Sand was still slowly rolling out over the clay toward the face of the slope. Despite the large amount of recent precipitation, much of the upper part of the sand unit remained well drained and dry. Route exposed above the parson (circled in B) are being stretched and torn because they are at the contact (dashed line) between the sand and the impermeable clay, from which ground water is seeping (more visible in A). The clay layers just above the fallen tree in A remain intact. This landslide blocked the intersection and forced its closure for more than a week.

Figures 9A & 6. This shallow landslide, just north of the intersection of Ferry Avenue and California Way SW (Fig. 8), occurred following the storm of February 1996. Subsequent grading and covering with plastic sheeting stabilized this portion of the slope enough to prevent shallow failure during the December 1996 storms. However, disruption of the pavement and sidewalk at the base of the slide (B) suggests that the slope may be moving along a deeper failure surface and may still (or again) be active. Notice the tilted street lamp. Although the plastic serves to prevent shallow failures, it does little to prevent a deep-seated failure, such as that shown in Figure 6. Just below California Way are several homes and businesses; at the time of the inspection, a sign indicated that more building is proposed. In A, snow, more than a week old, is still lying at the base of the plastic.

Figure 10. This view to the west over the Magnolia Bridge, a major artery into downtown Seattle, shows the landslide that forced the closure of the bridge and the "red-tagging" (condemning or declaring uninhabitable) of at least five homes along the headscarp of the slide. This slide occurred after the rains had ceased. Notice the displaced bridge trusses, the debris on the house at the base of the slope, and the broken water main just below the fallen truss and above the house.

Figure 11. The owners of the house under construction in the center of this photo recognized the potential for instability at the site. The "shorthead" (concrete sprayed on the slope) on the face of the slope was intended to protect the sandy upper part of the slope from surface erosion, but failed, probably due to excessive hydraulic pressure. The shorthead seems to hang like a curtain over the bluff face, with the last portion hanging tautly.
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Figure 10. This view to the west over the Magnolia Bridge, a major artery into downtown Seattle, shows the landslide that forced the closure of the bridge and the "shutterline" (concrete sprayed on the slope) on the face of the slope was intended to protect the sandy upper part of the slope from surface erosion, but failed, probably due to excessive hydrostatic pressure. The shutterline seems to hang like a curtain over the bluff face, with the left portion having fallen away.

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Figure 12. This slide, one of many that occurred along a stretch of railroad tracks north of Carkeek Park, lies within an older, larger slide scar. Past slides along these tracks have temporarily halted train traffic many times. Such slides have knocked railroad cars into Puget Sound, at times resulting in injuries or hazardous spills. Trip wires are strung just above the retaining wall along the tracks. An interrupted circuit signals, when (but not precisely when) landslides occur. Figures 21 through 26 illustrate the different mechanisms responsible for landwashing along this stretch of bluff. Development at the top of the bluff can contribute to and is affected by the slides. Coastal modifications such as the bulkhead built in the 1890s to support the railroad bed also affect slope and near-shore processes. The bulkhead does not prevent landwashing, but does control the rate and nature of redistribution of slide debris in the near-shore zone. Material dumped into the Sound by railroad crews cleaning the tracks is rapidly redistributed out of the narrow and steep intertidal zone and offshore by wave energy reflected off the bulkhead.

Figure 13. Locations of landslide damage shown in Figures 14 through 19.

Figure 14. At Scallat Head at the southern end of Whidbey Island, mudflows temporarily block access to these beach-level homes during wet winters. The upper bluff is porous glacial outwash sand that dries out in summer. This unit forms the lower bluff (below dashed line) and perches ground water to damp and green year round. The top of the sill is approximately at the position of the dashed line. The scarp in the background and the partially eroded bench are characteristic of such slide areas where percolating ground water is perched above the less permeable silts. The sands are weaker than the silts and slide readily when saturated. Similar situations are present north of Carkeek Park and in the Golden Gardens area of Seattle, among other places. (See Figs. 20, 21.)

Figure 5. This view to the east shows three homes along Aki Avenue SW in West Seattle that were affected by a growing deep-seated landslide. The largest displacement occurred west (toward the viewer) of the low house on the left. Note the person (circled) standing on the down-dropped portion of the slide in front of the headscarp. Also visible is the displacement of the deck of the large house in the center. The tension crack delineating the headscarp continues through the deck area in the center house and into the backyard of the house to the right (south). The dark line extending from the house on the left is a tine for drainage (see p. 29). Another segment of the headscarp is visible to the left of the tine.

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Puget Sound Bluffs: The Where, Why, and When of Landslides Following the Holiday 1996/97 Storms

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From late December 1996 to early January 1997, a series of winter storms delivered snow, freezing rain, warm rain, and wind to the west coast, producing floods, snow and ice damage, and landslides from Washington to central California. Individual weather systems like these arrive almost annually; the consequences of their combination are somewhat more remarkable, but nonetheless occur every few years somewhere in the region. The region's long history of slope failure following heavy precipitation events is discussed in Tubbs (1974), Thorsen (1987), Miller (1991), and Evans (1994). In the Pacific Northwest, the autumn months had abovenormal precipitation, building high soil moisture and heavy snowpacks. In late December, a cold continental air mass sat over northwest Washington, while a series of warm wet storms began moving in from the Pacific Ocean. The incoming moisture first fell as snow north of the cold front and freezing rain south of it. In the southern Puget Sound region and the Columbia Gorge-Portland area, ice storms brought down trees and power lines, while snow accumulated from about Olympia northward, reaching depths of up to 3 ft in north King County. Then on January 1 and 2, warm air, combined with locally heavy rains, quickly melted much of the low-elevation snow. This caused flooding in most streams in the Puget Lowland and in many of the rivers draining the Olympics and the Cascades.

The combination of pre-existing soil moisture, heavy rain, and rapid snowmelt brought soils to or near saturation. This had different effects, depending on the terrain. On the gentler drift planes, perching of water on till and emergence of ground water from shallow aquifers caused lingering flooding of low-lying areas. But in the steep bluffs and ravines that border Puget Sound, Lake Washington, and the larger river valleys, lateral movement of ground water toward the free faces caused elevated pore-water pressures that triggered hundreds of landslides. A selection of these landslides is presented in this report.

Following a disaster declaration by President Clinton for most counties in Washington, the Federal Emergency Management Agency (FEMA) made funds available for identification, investigation, and remediation of the landslides, among other emergency needs. Division of Geology and Earth Resources geologists were asked by the Washington State Emergency Management Division to help the City of Seattle with damage assessment. Helicopter flights and several days of on-ground visits provided an overview of storm effects. The Division submitted oral and written reports to the City of Seattle and worked with other local geologists and landslide experts to examine new slides and slide-prone areas that threatened structures and transportation corridors. At the same time, private consultants assisted homeowners in repairing the damage and provided advice on slope stabilization techniques.

This article is a photographic essay that provides a geologic explanation for these landslides. In Seattle and to the north, the areas of Magnolia, West Seattle, and Whitehorse Island were particularly hard hit (Figs. 1, 13). Captions for Figures 2-12 and 14-21 describe the setting of the landslides that...
PCCC was mining the Franklin Nos. 7, 8, and 9 coalbeds along the western limit of the basin, where the three coalbeds are stratigraphically merge (Fig. 2). PCCC also mines a clay bed between the Franklin Nos. 6 and 8 coalbeds. This clay is blown with high alumina clay for manufacturing Portland cement.

Figure 3. John Henry No. 1 Mine, Pit No. 1, January 1997. In this view (to the southwest) the floor of the Franklin No. 7 coalbed forms the steeply dipping plane of bare rock to the left of the eroded ridge. Here the southeast limb of the doublly plunging anticline structure is exposed. The Franklin Nos. 7, 8, and 9 coalbeds are exposed in the distance at road level (behind the mine truck), where they merge structurally and occur near the crest of the plunging anticline where the dip has flattened.

Clarification of Information in "Geohydrologic Review of the Cedar River Ground-water Basin" The following letter was sent January 23, 1997, to Kileen Cortinghaun, Supervisor, DNR. Dear Ms. Cortinghaun: The December 1996 issue of the DNR publication "Washington Geology," containing an article entitled "Geohydrologic Review of the Cedar River Ground-water Basin" [v. 24, no. 4], the article was written by Stephen H. Evans and Roy E. Jensen. A statement was made in the article with respect to the Department of Ecology and water rights that was not accurate, and I want to express some concern and provide you with some accurate information regarding water right decisions. In the introduction section of the article, the statement is made that "the current Washington Department of Ecology moratorium on allocating and developing ground water dem- onstrates how critical it is to acquire comprehensive ground water information." My concern with this statement is two-fold:

1. DOE has instituted no moratorium on the allocation of water rights. It is true that the decision-making process for water right applications was drastically impaired in 1994 when the budget passed by the legislature resulted in massive cuts in the agency, and specifically the Shoreslands and Water Resources Program, and this has hindered water right applications.

Additionally, the recent Watershed Assessment done in the Cedar River Basin utilized existing information to show that water is in short supply in the critical summer months. The fact that the Cedar River does not meet required instream flows on the average of 81 days out of the year indicates that we cannot continue to issue water rights without adversely affecting existing water rights, instream uses, and our natural resources and habitat. This does not translate into a moratorium on the issuance of water rights. Rather it means that applicants need to look for alternatives to new water for their water supply. DOE is working with applicants who are proposing such alternatives. What these assessments point out is that the era of inexpensive, easy water supply is over.

2. The "development of ground water" is not something that is within the mission of DOE. It is the responsibility of the department to make a careful evaluation of water right applications, but that it must act in the interests of the public as a whole. This may mean that denial of water right applications is necessary, as in the Cedar River Watershed. Again, [this] does not translate into a moratorium on the issuance of water rights. It is wrong to make the assumption that denial of water right applications in one area means denial in another area. Conditions and proposals are different in other areas, and we must address the issues specific to those areas.

I'm sure you can appreciate the need to have accurate information regarding agency policies and mandates, in this era of "distrust" of government. I know you must face some of these same issues working with a state agency. Thank you for your consideration of these issues. Please feel free to contact me with any questions or concerns at (206) 649-7096.

Sincerely,

Raymond Hellwig
Shoreslands and Water Resources Program

National Natural Landmarks

The 1995 "Section 8" annual report regarding the status of the landmarks indicates that the Drumheller Channels site in Washington is now considered threatened or damaged. For a copy of this report or a brochure about the 34 sites in the Cascades area, contact the National Park Service, Columbia Cascade System Support Office, 909 First Ave., Seattle, WA 98104-1060. See also their web page at http://www.nps.gov/ccso/ml.htm.
At the beginning of an idealized cycle, the bluff has a uniform slope. Water seeps through the surface soil and perches above the relatively impermeable materials at the base of this sandy sequence. Saturation creates pore-water pressures that reduce the effective strength of these materials.

Runoff and precipitation introduced by the sources shown in A have infiltrated and weakened the sediments, causing failure of the unconsolidated upper sand unit. Once mobilized, the sand moves (sometimes episodically, sometimes continuously) along the contact with the underlying less permeable unit on the mid-slope bench, often cascading as a secondary landslide off the bluff formed by the lower unit. This migration of material across the bench decreases the buttressing of the upper bluff. Failure surfaces can be deep (those that project into the lower, less permeable materials) as well as shallow.

Movement of slide debris toward the lower bluff further destabilizes the upper bluff, causing continued sloughing onto the bench. Either failure of the upper bluff onto the bench or failure of the side debris off the lower bluff can trigger a cycle of movement. Movement along a deep-seated surface can result in this sequence of events.

PCCCC increased its sales share for the industrial sector to about 75 percent of its total sales in 1996 (up from 54 percent in 1995). The coal is used largely in the manufacture of cement and lime in the Puget Sound area. Actual sales increased by about 3,000 tons in 1996 for that sector. The greatest change accounting for the drop in total sales for this year was its sales share for the export market; the coal is sent to South Korea for steam generation. Export sales dropped by about 68,000 tons and accounted for about 24 percent of total sales in 1996 (down from 46 percent in 1995). The remaining sales (less than 1 percent) went to supply public and private institutions and residential customers for space heating.

In 1996, PCCCC mined coal at its Pit No. 1 (Figs. 2, 3), extending its mining deeper along the flanks of the anticlinal structure in the mine. Production comes from four coalbeds, the Franklin Nos. 7, 8, 9, and 10. These coal beds occur stratigraphically near the base of the undivided Eocene Puget Group in nonmarine deltaic sedimentary rocks. In late January 1997,
DAIITE'S PEAK, FACT OR FICTION?

Dante's Peak, a disaster thriller from Universal Studios, dramatizes the hazards faced by communities near active volcanoes. Set in the North Cascades of Washington, the movie portrays the roles of U.S. Geological Survey (USGS) scientists and local public officials during the re-awakening and eruption of a fictitious volcano—one that resembles dozens of real volcanoes from northern California to Alaska. To separate fact from fiction, the USGS issued a release titled "Dante's Peak FAQ's (frequently asked questions)." Examples include:

- Hot springs may heat up before an eruption, but probably not in a matter of seconds as shown in the movie.
- If a town's water supply originates directly from a volcano's ground-water system, it could become contaminated, but probably not as quickly as shown in the movie.
- Earthquakes associated with eruptions rarely exceed magnitude 5, which are large enough to sway trees and damage buildings, but not to destroy them as shown in the movie.
- It's uncommon for a volcano to erupt different types of magma at the same time, that is, the fountains and flows characteristic of fluid magma and the explosive ash and pyroclastic flows characteristic of more viscous magma.
- Trying to drive over a hot lava flow (1,700°F) would result in melting tires and an exploding gas tank.
- Lakes near volcanoes can become acidic and cause burns to human skin but are unlikely to dissolve an aluminum boat in a matter of minutes as shown in the movie.

EARTH GODDESS OF THE PACIFIC NORTHWEST

Abgishanakhou (Tlingit) — Chthonic goddess who protects the pillar-support of the earth.

Dab-ko-beed (Dawinamish) — "Tasoma", Earth goddess of the Cascade Range.

Hawicano (Tlingit) — "The Old Woman Underneath". She supports the earth either by holding it or by tending the beaver lodge that holds it. She causes earthquakes, which her people believe means she is hungry. To appease her they throw grease on the fire so it will melt and run down her. Alternate form: Hawicano.

Klah Klaknee (Yakima, Klickitat) — Goddess of the "Three Sister" mountain in Oregon.

Loo-wit (Mucknomah, Klickitat) — Fire goddess of Mount St. Helens.

Nez perce (Tahltan) — Earth mother. She supports the earth, and when she shifts she causes earthquakes.

Pahto (Yakima, Klickitat) — Goddess of Mount Adams.

Plash-plash (Yakima, Klickitat) — "White Spots," Goddess of Goat Rocks (near White Pass). One of the five mountain wives of the sun. The others are the goddesses Wawkskum (Simcoe Mountain), Pahto (Mount Adams), Loo-wit (Mount St. Helens), and Tacom (Mount Rainier).

Tacoma (Salish, Nezqually, Payaulpt, Yakima) — Earth goddess of Mount Rainier. Alternate forms: Dab-ko-beed, Tacobud, Takobud, Takobud, Tehoma.

Wahkskum (Yakima, Klickitat) — Goddess of Simcoe Mountain in southwestern Washington.

Wacness (Yakima) — Goddess of Mount Hood in Oregon. Alternate form: Wyecst.

Reference:

WHAT CAN BE DONE TO IDENTIFY AND AVERT POTENTIAL LANDSLIDES?

As the Growth Management Act and its enabling regulations state, avoidance is the safest approach when it comes to land-use practices in areas of unstable slopes. However, in many places urban growth has already encroached on these slopes. If you live at the edge of a bluff or in an area that has experienced landslides in the past, there are some things you can do to reduce the rate of bluff retreat and improve the stability of the slope with respect to shallow failures and surface erosion. Deep-seated failures are more difficult to control, but it is clearly beneficial to reduce infiltration and surface runoff from roofs and driveways and to fix clogged or leaking storm drains.

Listed at the end of this article are several publications that provide useful information on amelioration of unstable bluff slopes. Figures 27 through 29 show examples of stabilization efforts in the Seattle area, not all of which were successful. The following lists offer landslide identification criteria and prevention and mitigation techniques.

Identification of Landslide Hazard Areas

These are some characteristics that may be indicative of a landslide hazard area:

1. Active bluff retreat – Continuing sloughing or calving of bluff sediments, resulting in a vertical or steep bluff face with little to no vegetation.
2. Pre-existing landslide – Landslide debris within an arcuate head scarp.
3. Tension cracks – Ground fractures along and/or near the edge of the top of a bluff or ravine.
4. Structural damage – Settling and cracking of buildings foundations near edge of a bluff or ravine; also separation of steps or porch from the main structure.
5. Topping, bowed, or jackstrawed trees – Disruption of the ground surface by active movement causes trees to lean and/or fall in different directions or to grow in a curve instead of straight.

Figure 3. Cutting bricks. The conveyor belt carries the stream of clay through this cylinder-like apparatus, which periodically rotates one-third of a turn. The apparatus contains three sets of “piano” wires, and when it is turned by the cogs on the two wheels of the cylinder, the wires cut the clay into a brick shape. Because the extruded clay is moving at a steady pace, the cylinder also moves during the cut to ensure it is straight.

Figure 4. Moving right along... The freshly cut clay blocks now pass onto a belt that is moving slightly faster than the one that fed the clay to the cutter; this increases the space between the blocks. The bricks shown here are still soft, but of the typical size and have three holes.

Figure 5. Stacking clay blocks to be sent to the dryer and kiln. The soft bricks move to where they are manually stacked on cars. This is the most labor-intensive part of the process. Once stacked on the cars, the clay blocks are moved along rails through the dryer and the kiln. The Miss plant can produce an unusual near-white brick from the Latah deposit. Because of this characteristic of the clay, the company can also make bricks in a number of light or pastel colors by adding colorants or small amounts of clay of another color.
Clay is a term applied to both a group of minerals and a rock made up of clay-size particles (generally less than 0.002 mm of a millimeter). Of the several definitions for clay in the American Geological Institute’s Dictionary of Geology (Bates and Jackson, 1987, p. 122), the following best fits clay for making bricks. It is (1) “a loose, earthy, extremely fine-grained sediment or soft rock”; (2) it commonly contains “subordinate amounts of finely divided quartz, decomposed feldspar,” and other non-clay minerals; and (3) it “forms a plastic, moldable mass when mixed with water, retains its shape on drying, and is firm, rocklike, and permanently hard on heating and firing.” Mutual Materials operates several brick plants in eastern and western Washington. (See the industrial minerals section of the preceding article, p. 11). The Mica plant, located 15 miles southwest of Spokane, uses a deposit of the Latekip Forma
tion to make bricks and related materials. This Miocene formation contains a high proportion of clay. The company makes a wide variety of shapes, sizes, and colors of face bricks, that is bricks used to face a building. They also make fire bricks, mainly for wood stoves, and tile for chimney liners. The following figures illustrate some of the steps of making bricks from clay. Reference Cited Bates, R. L.; Jackson, J. A., 1987, Glossary of geology (3d ed.): American Geological Institute, 788 p.

Figure 1. Highwall of clay pit. This is one of several pits where Mutual Materials Co. mines clay for making bricks at its plant in Mica, southeast of Spokane. The deposit contains about 65 percent clay, the remainder being quartz, feldspar, and mica. The non-clay fraction is about 65 percent quartz, 24–20 percent feldspar, and 5–10 percent mica. The pit highwall shown displays considerable color variation; the darker parts are stained by limonite, an iron mineral. By carefully controlling the size of clays from this and several other pits, the Mica plant can produce a wide spectrum of brick colors.

Figure 2. When the desired blend of source clay is reached, an appropriate amount of water is added. The clay is squeezed or forced into a mold from which it is extruded, in much the same way as toothpaste is squeezed out of its tube. The clay is extruded in a continuous stream onto a slowly moving conveyor belt. Different orifices are used to obtain the different sizes and shapes of bricks. If the design calls for holes in the brick, they are created at the orifice.

- Gullying and surface erosion – Dissection of the bluff edge by natural drainage or discharge from pipes, culverts, and ditches.
- Springs – Mid-slope ground-water seepage from the bluff face; particularly noteworthy are increases in flow.

Safeguarding Against Landslide Hazards

The following are some measures that can be taken to mitigate or avoid landslide hazards:

- Use setbacks – Expect natural slope processes to continue, and provide adequate construction setback for structures in landslide hazard areas.
- Reduce surface erosion – Keep drains and culverts clear. Avoid discharge onto the slope—direct surface water runoff (especially from impermeable surfaces) to the base of the slope in nonperforated pipe. This is called tightfitting.
- Reduce ponding and infiltration – Limit opportunities for water to pond on the surface by draining or regrading. Consider connecting to city sewers instead of installing or replacing septic systems.
- Maintain and improve vegetation – Trees and shrubs provide root strength to hold the soil in place and help dewater the slope. If they are removed, root strength will be gone within 2 to 12 years and will not be easily restored.
- Protect bluff from surface erosion – Apply erosion mats, plastic sheeting, or other erosion-control material where vegetation will not take hold.

DISCUSSION

The Paget Lowland bluffs have experienced landslides for thousands of years. Bluff retreat is a normal process. Some of the small-scale, but still potentially destructive, retreat occurs
arduous areas", which are areas that "because of their susceptibility to erosion, sliding, earthquake, or other geological events, are not suited to the siting of commercial, residential, or industrial development consistent with public health or safety concerns" (RCW 36.70A.030).

The regulations (365-150-080 WAC) state that:

"geologically hazardous areas... pose a threat to the health and safety of citizens when incompatible commercial, residential or industrial development is sited in areas of significant hazard. Some geological hazards can be reduced or mitigated by engineering, design, or modified construction techniques so that risks to health and safety are acceptably reduced. When technology cannot reduce risks to acceptable levels, building in geologically hazardous areas is best avoided. This distinction should be considered by counties and cities who do not classify geological hazards as they develop their classification scheme.

(b) Counties and cities shall classify geologically hazardous areas as either:

(i) known or suspected risk.

(ii) no risk.

(iii) risk unknown - data are not available to determine the presence or absence of a geological hazard."

Identification of geologically hazardous areas is now in place in most cities and counties of Washington. Of the recent slides in Seattle, not a single one occurred at a site developed solely under the new ordinances, suggesting that they may be providing a safeguard against slide hazards. Nevertheless, Seattle declared a 90-day moratorium on development in landslide hazard areas to assess the adequacy of the steep slope ordnance. For information on designated steep-slope hazard areas in your community, contact your local planning agency or building department.

If you are uncertain about the conditions surrounding or underlying your home or property, consult the listed references or any of the many other available at your library or local jurisdictional offices. If you are still unsure, seek geological advice from a professional geologist or geotechnical engineer.

ACKNOWLEDGMENTS

We acknowledge funding support for this project through Linda Burton-Ramsay from the Washington State Emergency Management Division. Assistance in the office and in the field was generously offered by Gerald W. Thorsen, consulting geologist; John Perrier and T. J. McDonald of the City of Seattle; Newell Lee, Jr., (helicopter pilot) of the Washington Department of Transportation; Tom Badger, local geologist; and Steve Palmer, Washington Division of Geology and Earth Resources. Sketches of slope profiles in Figure 21 were drawn by Leonard Palmer, Jari Roloff and Keith Likert provided graphic support.

REFERENCES AND FURTHER READING


(Descriptions of damage assessments conducted from Jan. 7-17, mentions forthcoming reports and meetings.)

New Director for Northwest Mining Association

Late last fall, the Northwest Mining Association named Laura E. Skar its new director. Ms. Skar was vice president and general counsel for a mining company in Reno, Nevada. She also served as Director, 14 years of management, operations, and legal experience in the oil and gas industry, with a focus on land use, reclamation, development, and tax issues. She was chief of the Colorado Department of Natural Resources, Minerals, Energy, and Geology Policy Advisory Board, as Regional Vice President of the Independent Petroleum Association of America, and as president of the Independent Petroleum Association of Mountain States. She has authored legislation dealing with oil, gas, and mining tax reform, economic development, and deregulation of natural resource industries. She has long been involved in larger, state, and local levels. Ms. Skar has graduate degrees in Business Administration and law and has won several awards. She replaces the former director, Tim Olsen.

INDUSTRIAL MINERAL INDUSTRY ACTIVITIES

Industrial mineral commodities, construction sand and gravel, and construction stone accounted for approximately 42 percent of the $582 million total value of nonfuel mineral production for Washington in 1995, the last year for which figures are available. The overall production volume and value of construction sand and gravel, the single most valuable nonfuel mineral commodity in Washington, was $154 million, a $10 million decrease from value of 1994 production.

Sand and gravel operations consist of many small and several large pits throughout the state. Most large operations are concentrated around population centers. The most encouraging news is that pits that were in the advanced permitting stage at the beginning of the 1996 are or will soon be permitted to mine. The Dupont deposit operated by Lone Star Northwest went into production, and permitting for a deposit near Shelton owned by Manke Family Resources Ltd. is nearly completed. Both deposits are accessible from the water, which allows hauling the aggregate; this lowers transportation costs to markets in nearby communities and the greater Seattle area. Other deposits near Monroe in Snohomish County are in the permitting stage.

REFERENCES CITED


AGGREGATE FACTS

Washington construction projects consume nearly 77 million tons of aggregates each year.

Washingtonians consume about 12-14 tons of aggregate and use 1.3 yd³ of concrete and 1.25 tons of asphalt each year.

A typical county road uses about 4,600 tons of aggregates for each mile.

The average 2,000-ft² house in western Washington uses about 210 tons of aggregate in its foundation, driveway, and walkways.

Because transportation is nearly 40 percent of the cost to produce aggregates, aggregate products are most commonly used within about 30 miles of their origin.

(Provided by Meridian Aggregate Co.)

Washington Geology, vol. 25, no. 1, March 1997
Table 4. Operator and a brief description of the activity and geology of nonmetallic mining operations in Washington in 1996

<table>
<thead>
<tr>
<th>Property</th>
<th>Company</th>
<th>Activity</th>
<th>Area geology</th>
</tr>
</thead>
<tbody>
<tr>
<td>Twin River quarry</td>
<td>Holtman Inc.</td>
<td>Mined 60,000 tons, development</td>
<td>Mudrock(?) in three members of the upper Eocene to lower Miocene Twin Rivers Formation</td>
</tr>
<tr>
<td>Castle Rock</td>
<td>Ash Grove Cement Co.</td>
<td>Mined 40,400 tons</td>
<td>Exocene-Oligocene marine sands</td>
</tr>
<tr>
<td>Volcanic and</td>
<td>Basic Resources Co.</td>
<td>Permitted quarry is nearly completed, target in 60,000 tons production</td>
<td>Calcium bentonite (clay) interbeds in Miocene Columbia Basin Group near Moses Coulee</td>
</tr>
<tr>
<td>Ash Rock Top</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>diatomite pits</td>
<td>Cellic Corp.</td>
<td>Mined over 100,000 tons of ore and produced about 60,000 tons of finished diatomite</td>
<td>Micaceous “Quinon diatomite bed”, a locally occurring sedimentary interbed at the base of the Pliocene Peabody Member, Columbia River Basalt Group</td>
</tr>
<tr>
<td>Rattlesnake pit</td>
<td>Reserve Silica Co.</td>
<td>Mined and washed 70,000 tons</td>
<td>Sandstone of the Eocene Puget Group</td>
</tr>
<tr>
<td>Elk pit</td>
<td>Mutual Materials Co.</td>
<td>Mined 13,000 tons to produce bricks</td>
<td>Elite- and kaolinite-bearing shales of the Eocene Puget Group</td>
</tr>
<tr>
<td>Sec. 31 pit</td>
<td>Mutual Materials Co.</td>
<td>Mined 65,000 tons to produce bricks</td>
<td>Sand of the Eocene Puget Group</td>
</tr>
<tr>
<td>Spray claim</td>
<td>Robert Jackson</td>
<td>Extracting mineral and crystal specimens</td>
<td></td>
</tr>
<tr>
<td>Superior quarry</td>
<td>Ash Grove Cement Co.</td>
<td>Exploration drilling and development, no production</td>
<td></td>
</tr>
<tr>
<td>John Henry #1</td>
<td>Pacific Coast Coal Co.</td>
<td>Mined 16,000 tons of limestone for soil condition and feed line</td>
<td></td>
</tr>
<tr>
<td>Tonasket limestone quarry</td>
<td>Pacific Calcium, Inc.</td>
<td>Mined 60,000 tons of clay that was shipped to Ash Grove Cement Co.</td>
<td></td>
</tr>
<tr>
<td>Brown quarry</td>
<td>Pacific Calcium, Inc.</td>
<td>Mined 4,000 tons for soil conditioner</td>
<td></td>
</tr>
<tr>
<td>Wenas Run quarry</td>
<td>Columbia River Carbonates</td>
<td>Mined 105,000 tons of coal with net production of 78,000 tons</td>
<td>Mica-bearing rocks in the conglomerate-bearing member of the Pliocene Puget Group comprising a 30-ft thick zone above the Frackline #4 coal seam</td>
</tr>
<tr>
<td>Clay City pit</td>
<td>Mutual Materials Co.</td>
<td>Mined 6,300 tons to produce bricks</td>
<td></td>
</tr>
<tr>
<td>Sonsen clay pit</td>
<td>Quarry Tile Co.</td>
<td>Produced ceramic tile from 1,545 tons of stockpile</td>
<td></td>
</tr>
<tr>
<td>Mica mine</td>
<td>Mutual Materials Co.</td>
<td>Mined 42,000 tons, stockpiled to produce bricks</td>
<td></td>
</tr>
<tr>
<td>Galilee quarry</td>
<td>Allied Minerals, Inc.</td>
<td>Mined about 3,000 tons</td>
<td></td>
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<tr>
<td>Lake Mountain</td>
<td></td>
<td>Mined 300,000 tons, milled at plant near Valley</td>
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</tr>
<tr>
<td>Northwest marble mine; other quarries</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Jami limestone deposit</td>
<td>Joseph A. &amp; Jeanine F. Peabody Brothers, Inc.</td>
<td>Mine limestone deposits</td>
<td></td>
</tr>
<tr>
<td>Jami limestone quarry</td>
<td>Peter Jami Sons</td>
<td>Columbia River Carbonates shipped some limestone to their plant in Woodland, WA</td>
<td></td>
</tr>
<tr>
<td>Stine quarry</td>
<td>Northup limestone Co. (division of Hemphill Brothers, Inc.)</td>
<td>Mined 40,000 tons, processed on site</td>
<td></td>
</tr>
<tr>
<td>Maple Falls quarry</td>
<td></td>
<td>Mined about 60,000 tons, used for rip rap and some aggregate and landscape rock</td>
<td></td>
</tr>
<tr>
<td>Sven Larson quarry</td>
<td>Oliven Corp.</td>
<td>Mined and milled 41,000 tons for refractory/linerate uses; majority of production used by UNIMIN Corp.</td>
<td></td>
</tr>
</tbody>
</table>


(Describes nonstructural landslide mitigation; written mostly for local governments.)


(Although found on Orange County, Calif., this book contains much information relevant to the Pacific Northwest. It is available from the International Conference of Building Officials, 5580 Workman Mill Rd., Whittier, CA 90601-2208.)


Burke Museum Closes to Prepare New Exhibits

The Burke Museum will close its doors April 28 to reno va and install exhibits. It will reopen this coming November. "Life and times of Washington State—A trek through geologic time" and "Pacific voices—Worlds within our community" are two long-term exhibits being prepared for November.

Errata

The price for Open File Report 96-3, Preliminary bibliography and index of the geology and mineral resources of Washington, 1991-1995, (announced in the previous issue) should be $1.03 each.

The price for the book and the photos on p. 22 in the previous issue were taken by Tim Walsh of our staff.

In the previous issue, the article "A Field Guide to Washington State Acheology" contains at the end of the last sentence: “and the caption ‘Rines’ Formation correlates throughout the region, setting the stage for future regional sedimentologic interpretations.” This phrase wandered in from somewhere else and does not actually belong with the field guide.

Photo Credits

Wendy Gerstel—3-5, 9B, 23-29
Leonard Palmer—19B
Hugh Shipman—2, 6, 7, 10-12, 22
Carl Weltman—14-19A
Tim Walsh—8A, 8B, 9A

Note added in proof: As this issue was going to press, another rainstorm hit the Puget Sound area and caused at least 30 more landslides.
Marshall Tower Huntington (1918 - 1996)

Marshall served as a geologist with the Division under Supervisor and State Geologist Sheldon L. Glover and became Assistant Division Supervisor in 1956. When Glover retired in February 1957, Marshall was named Supervisor and State Geologist. During the earlier part of Marshall's tenure in Olympia, the Division's offices were on the second floor of the Transportation Building (now the John L. O'Brien Building) near the Legislative Building. In about 1956, the Division moved to the new General Administration Building and occupied a suite of offices, known as Room 335, on the west side of the building near the northwest corner, adjacent to the Division of Water Resources. Prior to 1967, the Division had been part of the Department of Conservation and Development. On July 1, 1967, that department was disbanded, and the Division was transferred to the administration of Natural Resources.

During his career with the Division, Marshall's major emphases were on development and conservation of mineral resources, geologic mapping, regulation of oil and gas drilling, and, later, surface mining reclamation. Marshall's most important and lasting contributions were his Inventory of Washington mining maps, Part II—Metals, published in 1956, and 1,000,000-scale geologic map of Washington published in 1961. The Inventory of Washington minerals has served the mineral industry well and still guides mineral exploration in this state.

Marshall was a member and officer of the North Pacific Section of the American Institute of Mining, Metallurgical, and Petroleum Engineers and the Northwest Geological Society. He was certified as a registered mining engineer in 1948. Following retirement from the Division, Marshall moved from Olympia to Silver Creek in Lewis County. The effect of retirement on Marshall was wonderful. He had retired partly because of increasing regulatory responsibilities, and his duties sometimes left him rather harried. He visited the office a few months after his retirement, and the change was marvelous. He was tanned, smiling, and physically fit. He remained that way. He also remained very, very active, so much so that it is not really accurate to say he retired. He just changed jobs, from geologist to farmer, rancher, forester, and civic leader.

Marshall continued to do occasional geological consulting jobs, and he stayed in touch with the Division, but most of his energy went into public service and raising cattle, berries, and cherries. At various times he was board member for Lewis County Conservation District, member of Lewis County Farm Bureau Association, American Farm Bureau advisory committee on forestry, Lewis County Planning Commission, Lewis County Farm Forestry Association, and Lewis County Search and Rescue. In 1992, he was the Lewis County Farm Bureau. And in 1995, the Wildlife Federation. He served the year. He served 14 years as secretary/treasurer of the Mossyrock Viking Scholarship Fund.

Figure 1. The Washington State College field camp in Horsehair Basin at the headwaters of the Methow River, Chelan County. Front row, left to right, Charles W. P. Schumaker, Donald R. Marino, Marshall T. Huntington, and William J. Tarr. Photograph courtesy of Mrs. H. E. Culver. Some identifications courtesy of Grant Valentine.

Figures 8. Location of nonmetallic mining operations in Washington in 1966. Table below identifies mines from numbers on the map. See Table 4 for details of each of these projects.

Phil Puppy, geologist with the Washington Division of Mines and Geology for several years, died in Spokane on February 24, 1997, at age 81. During his career as a mining geologist he worked for both federal and state governments and for several corporations in the western United States, Canada, Greenland, and Central America. He retired in 1985, settled in Spokane, and became active with the Mineral Information Institute. He began working for the Division as a geologist on April 7, 1947, and resigned on October 15, 1948. The 1948–1950 biennial report of the Division of Mines and Geology (Glover, 1951) lists Puppy’s education as S.B. in Geology, Harvard College, and postgraduate in mining geology, Massachusetts Institute of Technology. He was the author of several reports for the Division, listed below.

Division Publications

NORTHWEST PALEONTOLOGICAL SOCIETY
1. May 3 meeting at the Burke Museum: Showcase session for members’ collections.
2. June 4 trip being planned to Chuckanut Formation outcrops; Bill Smith, leader.
3. August 8: Trip to Ochlostra and Coal Creeks, Cowitz Formation; Bill Smith, leader.

For more information about these field trips, contact Bill Smith, 3332 Ridgeland Dr., Silverdale, WA 98383.

Membership fees are $15/year for families, $10 for student or senior, and $5 junior; send checks to Bettey Jarvis, 1787 NE 102nd Ct, Redmond, WA 98073. (Although elections are held for members only, all applications will be forwarded to the appropriate officers.)


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The author presents the geologic history of the Wenatchee area, with Wenatchee as the geographic center of the discussion. This describes geologic processes in a more or less chronologically. His presentation is that of an advanced amateur, with college courses and much practical experience, but no formal training in geology. Chapter headings are: In the beginning; The formation of Washington State; The rock cycle; Igneous rock structures; Basalt flows of the Columbia Plateau; Volcanoes and earthquakes; Consolidated and unconsolidated sedimentary deposits; Metamorphic structures; Landslides; Bretz-Missoula floods; Moses Coulee; Erratics, Knapp and Navarre Coulees; Malaga slide; Metalliferous, industrial and carbonaceous activity in the Wenatchee area; and Conclusion.

The book has a number of strengths. Although the geologic events described center on Wenatchee, many are treated in a regional, statewide, or even larger context, so the book is meaningful to people living outside the Wenatchee area. There is enough informal cross-referencing in the text to tie concepts, localities, and geologic events together adequately. The author displays an obvious wide-ranging interest in geology, has read the geologic literature treating the Wenatchee area, understands the geologic concepts and interpretations of geologists who have published on the geology of the area, has observed the geology of the area extensively, and presents the information in an easy-to-read way. His discussion is quite broad-ranging—he has attempted to cover the whole of the geologic history of the Wenatchee area, not just selected geologic events. Basic chapters on rock types, metamorphic rocks, and sedimentary rocks are well illustrated, and the discussion is explained, so the book can be read by a layperson without reference to other works.

The author adds several features that tie the geology to human activities. He explains the significance of past geologic events such as earthquakes and volcanic eruptions and discusses the implications reflected in future events. Most of the topics are described and located well enough so the reader could find them with the aid of good maps and a knowledge of the section, township, and range location system.

Mason does quite a nice job of describing the sedimentary units in the Wenatchee area—the Swauk, Chumstick, and Wenatchee Formations. He covers various aspects of the Columbia River basalt unit and considers differences in the river's stratigraphy and consideration. This is a good introduction to the book and a number of weaknesses. These include random stratification, major misjudgments, choice of wrong homonyms (roll for role, brakes for breaks, vain for vein, sheer for shear, mixed usage of terrain and terrain), careless and inconsistent use of the names of geologic units, lack of location maps, and use of "strata" and "stratum" without regard to the number of strata being discussed. Mason uses the term "structure" in a catchall term that includes, in different places, folds, faults, outcrops, peperast, haloclastite, lithic, and igneous intrusions. This is quite irritating to a geologist who is accustomed to the word having a specific and much narrower meaning.

The author simplifies the plate tectonic history of Washington by only three section packages, which he calls the Okanogan micro-island continent, Cascade micro-island continent, and Crescent Terrace. For the non-geologist reader, this simplification is probably acceptable, even desirable. There are a few outright mistakes and garbled definitions, for example, from page 58, "The oldest sedimentary formation within our state may be the Swauk.", from page 18, "An unconsolidated sedimentary material is rather self explanatory. The sediment is loose and un stratified.", and, from page 131, "An erratic is defined as a 'rock of indeterminate size, transported by ice from its 'in situ' position, to other position in different igneous location.'" Otherwise, the book is an worthwhile effort and has much to offer both amateur and professional geologists. It would have been an outstanding book if the manuscript had been reviewed by a geologist and if misspellings, wrong homonyms, and English usage had been corrected.

by J. Eric Scharer

New Book on the Paleontology of British Columbia

"Life in Stone," a book about the paleontology, fossils, and fossil collectors of British Columbia has just been printed by the University of British Columbia Press. Rolf Ludvigsen has compiled and edited the contributions of numerous scientists and produced a comprehensive introduction to ancient life in our neighboring province. If not available locally, it can be ordered from Dathe Books, 919 Robson St., Vancouver, BC V6Z 1A5 (604) 684-4496. The price is about $65.00 Canadian or $45.50 U.S.

Ginkgo Petrified Forest Museum

Ginkgo Petrified Forest Museum in Vantage hours are 10 am-6 pm, weekdays only in April; Friday-Sunday, May 1-12; and The schedule for the fall and winter is the same as last year. Groups are reduced to Friday-Sunday. Tours groups (for a fee) of the facility are available year-round and can be arranged by calling (509) 856-2700. New events this year include:

- The museum will be showing and selling the video "The Great Floods," depicting the Pleistocene outburst floods from glaciated Lake Missoula.
- Ecology class: Wild Plants of the Desert, a 4-hr seminar describing native plants and their uses. By appointment, 12 person minimum, $3 per person. Led by Debbie Hall. Begins in April, weekdays only; schools will get reduced rates. Reserve time by calling the museum.
- Ginkgo seedlings will be sold to raise fund for the museum.

Figure 7. (above) Location of small-scale metal mining and exploration projects in Washington in 1996. The table at right is a customized list of figures on the map. See Table 2 (next page) for additional details for each of the projects.

Cominco American Incorporated, through its parent company Cominco Limited, acquired the Pend Oreille Mine (Fig. 2, no. 5) in the northeast corner of the state. The company assisted in an extensive, ongoing surface and underground exploration program (Fig. 6) at the mine with hopes of identifying additional reserves of zinc and lead ore on which to base a production decision.

Santa Fe Pacific Gold Corp. completed their exploration drilling program to evaluate the Golden Eagle deposit (Fig. 2, no. 3).
November 1996 through February 1997

THESES

U.S. GEOLOGICAL SURVEY
Published reports

Includes:
Adams, John, Great earthquakes recorded by turbidity currents of the Oregon—Washington coast, p. 147-158.

Ma, Li; Crosson, R. S.; Ludwin, R. S., Western Washington earthquake focal mechanisms and their relationship to regional tectonic stress, p. 257-283.
Rogers, A. M., Walsh, T. J.; Priest, G. R., Map showing known or suspected faults with Quaternary displacement in the Pacific Northwest, Plate 1, scale 1:2,000,000.
Rogers, A. M., Walsh, T. J.; Kockelman, W. J.; Priest, G. R., Map showing known or suspected faults with Quaternary displacement in the Pacific Northwest, Plate 1, scale 1:2,000,000.

Figure 3. (top right) Almost 90 percent of the 2,000 tons of gold ore processed daily at Echo Bay Mineral Company's Kettle River Operations is from the Lamefoot deposit, an underground gold mine northeast of Republic in Ferry County. The portal to the mine is shown here. Miners remove alternate blocks of ore; the remaining blocks support the overlying rock. Cement is mixed with waste materials to backfill the mined-out area. After the cement sets, it provides the essential support to allow mining of the remaining block of ore. The truck on the right is unloading cement into the large vertical tank. The vehicle at the center is headed into the mine; it will haul 26 to 25 tons of ore to the surface. At the left is a scale where each load of ore is weighed. Because owners of this deposit receive royalties for the gold produced from their portion of the deposit, the company must record the tons of ore extracted.

Figure 4. (right) Portal of the new K-2 gold deposit of Echo Bay Minerals Co. The mine operated as a development/exploration project in 1995. In 1996, development continued with development ore being shipped to the company's mill northeast of Republic.

Figure 5. (bottom left) One of the few drills operating for mineral exploration in Washington in 1996. This one, adjacent to the K-2 deposit of Echo Bay Mineral Company, was drilling to extend reserves at the mine.

Figure 6. (bottom right) Portal of the Pend Oreille mine near Riceville Falls. This mine has been the focus of an extensive program to identify zinc and lead resources. The big change in 1996 was the announcement that Cominco American Incorporate had acquired the property. If sufficient resources can be identified, the company will reopen the Pend Oreille mine when their giant lead-zinc-Sultan deposit in British Columbia is mined out in about 4 years.
Figure 2. Location of major metal mining and exploration projects in Washington in 1996. Table at right identifies mines from numbers on the map.

Table 2. Location of major metal mining and exploration projects in Washington in 1996

<table>
<thead>
<tr>
<th>Property</th>
<th>Company</th>
<th>Activity</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lamefoot mine</td>
<td>Echo Bay Minerals Co.</td>
<td>Kettle River Project</td>
<td>OVERLOOK mine site</td>
</tr>
<tr>
<td>K-2 mine</td>
<td>Echo Bay Minerals Co.</td>
<td>Kettle River Project</td>
<td>Underground development, shipped about 62,500 tons of ore to the mill near the Overlook mine site. Exploration around mine site included 20,000 feet of drilling.</td>
</tr>
<tr>
<td>Golden Eagle mine</td>
<td>Santa Fe Pacific Gold Corp.</td>
<td>Bould-Nickels Mines Co.</td>
<td>Underground exploration drilling and drilling from underground workings</td>
</tr>
<tr>
<td>Pend Oreille mine</td>
<td>Cominco American Inc.</td>
<td></td>
<td>Conducted exploration drilling from the surface and underground exploration drilling and drilling from underground workings</td>
</tr>
<tr>
<td>Addy Mine</td>
<td>Northwest Alloys Inc.</td>
<td></td>
<td>Mining dolomite, smelting to produce magnesium metal</td>
</tr>
</tbody>
</table>


Includes:

Dredge, C. L., "What to do with a volcano in your backyard?—Volcano hazards outreach at Mount Rainier," p. 67-68.


Open-File and Water-Resource Investigations Reports


Includes:

Gannett, M. W., Geology overview, p. 10-11.


OTHER REPORTS AND PAPERS ON MINING AND GEOLOGY IN WASHINGTON


Cascadia Region Earthquake Workgroup, 1996, "Cascadia storms—A dress rehearsal?" Proceedings from the 1st annual meeting: Cascadia Region Earthquake Workgroup, 72 p.


Robert E. Derkey
Washington Division of Geology and Earth Resources
304 W. Riverside, Room 209, Spokane, WA 99201-1011

INTRODUCTION
Washington ranked 20th in the nation in total value of nonfuel mineral production in 1995, the last year for which production figures were available. However, nearly a 10 percent increase over 1994, which occurred for most commodities with the notable exceptions of gold and sand and gravel. The value of gold production decreased by 42 percent in 1995 (Fig. 1) due to closing of mines at Wanapum and Republic (Derkey, 1996). It increased slightly in 1996.

This article reviews 1996 activities in the nonfuel mineral industry of Washington. Farm production values are not yet available from the U.S. Geological Survey for 1996. Volunteered information obtained from an interview survey of mining companies and individuals provided data for this preliminary update. In addition, several companies and individuals were contacted directly because they were known to be operating in the state. The tables in this article should not be considered a complete listing of mineral industry activities.

Additional details about the geology of the metallic mineral industry and other industry activities are available in the reviews of Washington's mineral industry published in the first issue of Washington Geology each year (for example, Derkey and Gulick, 1992; Derkey, 1993, 1994, 1995, 1996; Gulick, 1994, and Gulick and Lingley, 1995). Questions about metal mining activities and exploration should be referred to Bob Derkey in the Division's Spokane office. Information about the sand and gravel industry and reclamation can be obtained from Dave Norman in the Olympia office. See p. 2 for addresses and phone numbers.

METALLIC MINERAL INDUSTRY ACTIVITIES
About 32 percent of the total value (nearly $825,500,000) of all nonfuel mineral commodities produced in Washington in 1995 came from metal production. When figures become available, the overall value of metal production will probably be lower in 1996.

In 1996, activities in the metallic mineral industry are divided into three categories: major mining and exploration projects, small-scale mining and exploration projects, and production. The category "production" includes the value of minerals that were mined in 1996. Location maps are included for the first two categories, and tables are prepared for each of the three categories.

Major Metal Mining and Exploration Projects
The locations of the six major metal mines or exploration projects in Washington in 1996 are shown on Figure 2. Table 1 lists the key characteristics for each in 1996 and briefly describes the geology of the deposits.

All known precious metal production in Washington in 1996 was by Echo Bay Minerals Co. at their Kettle River Pro...


OTHER REPORTS OF INTEREST


Washington Department of Natural Resources, 1996, Final environmental impact statement—Habitat conservation plan: Washington Department of Natural Resources, 1 v.


We Now Have a Web Page
URL: http://www.wa.gov/dnr/html/docs/ger/ger.html

Division Release
Geologic Map of the Pomeroy Area, Southeastern Washington, Open File Report 96-5, compiled by Peter R. Hooper and Beth A. Gillespie, A 26 p. text accompanies this map, scale 1:38,520. $1.84 + $0.16 tax (WA residents only) = $2.00.

INSIDE THIS ISSUE
I The metallic, nonmetallic, and industrial mineral industry of Washington in 1996, p. 3
I From clay to bricks, p. 12
I Washington's coal industry—1996, p. 15
I Puget Sound cliffs and the where, why, and when of landslides following rain-on-snow events, p. 17