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GEOLOGIST LICENSING ACT

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In 1989, a major effort was undertaken to introduce legislation for the registration of geologists. In response, the legislature enacted SHB1597 requiring the Department of Licensing (DOL) to conduct a sunrise review of the practice of geology and to document evidence that the public health, safety, and welfare were adversely affected by non-regulation. In 1990, the Association of Engineering Geologists (AEG) published "Suggested Geologists Practice Act" and that same year the American Institute of Professional Geologists also produced "Suggested Geologists Practice Act Texts and Commentaries". In October of 1990, the "Sunrise Review of the Practice of Geology" recommended that "no state licensing of geologists be required at this time" due to insufficient evidence for actual or potential harm to the public by unqualified practitioners.

Despite efforts by AEG and others since 1989, proposed registration or licensing of geologists did not leave legislative committee. In the late 1990s, several things changed—local governments implemented the Growth Management Act and had to consider geologically hazardous areas, and western Washington suffered a disastrous three years during which landslides caused five fatalities and nearly $35 million in residential and property loss. In response, the Legislature during the 2000 Regular Session passed Engrossed Substitute Senate Bill 6455.

The Geologist Licensing Act was signed into law by Governor Locke on March 31, 2000 (Chapter 253, Laws of 2000). Persons who practice geology in the State of Washington will be required to be licensed beginning July 1, 2001. The DOL, under the direction of a seven-member board, will administer the program. The State Geologist is an *ex officio* member of the board. Citizens of Washington will have an opportunity to vote on the establishment of fees at the November 2000 election, per Section 24 of the bill. DOL was not appropriated any funding to administer this program, so they are going to the Legislature next session with a supplemental budget request for funding for the period of July 1, 2000 through June 30, 2001.

A temporary advisory committee will be established in the fall to provide technical assistance to DOL. The committee will begin meeting to draft administrative rules on proposed fees, the application process, eligibility, and the examination process. A permanent board will be appointed by the Director of DOL by July 2001. ■

PUGET SOUND SHORELINES WEBSITE

A new website from the Washington Department of Ecology offers information and ideas for exploring and living on Puget Sound. The site includes descriptions of beaches, bluffs, and spits; tips for building and buying property on the shore; profiles of several shoreline-dependent species (including salmon); information on laws and permits; and much, much more. There is a wealth of information in this site designed to lead to improved shoreline stewardship in the Sound. (http://www.wa.gov/ecology/sea/pugetsound/)

Cover photo: Stacks at Cape Flattery showing cavernous weathering features (tafoni) in the cliff face above the high-tide level and the high-tide bench formed at the level of permanent rock saturation. View to the south.

The Metallic, Nonmetallic, and Industrial Mineral Industry of Washington in 1999

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INTRODUCTION

Production of nonfuel mineral commodities in Washington in 1998 was valued at $609,474,000 (Arnold Tanner, U.S. Geological Survey, oral commun., 2000). This represents a 10 percent increase from 1997. Firm numbers for value of production in 1999 are not yet available. Metallic mineral production accounted for approximately 23 percent, nonmetallic mineral production accounted for 23 percent, and aggregate production accounted for 54 percent of the value of nonfuel mineral production in 1998.

This article summarizes company activities in 1999 based on results of a telephone survey by the Department of Natural Resources in January of 2000. Summary tables and location maps are provided for both metallic and nonmetallic mineral operations. All of the larger, known mining operations were contacted, but because some, especially small operations, were not contacted, this report does not contain a complete listing of mineral industry activities in the state. The known major mining operations contribute the majority of the value of the State's nonfuel mineral production.

Additional details about the geology of the metallic mineral deposits and earlier industry activities in the State are available in prior reviews of Washington mineral industry published in the first issue of *Washington Geology* each year (for example, Derkey, 1995, 1996, 1997, 1998; Gulick, 1995). Questions about metallic and nonmetallic mining activities and exploration should be referred to Bob Derkey in the Division's Spo-

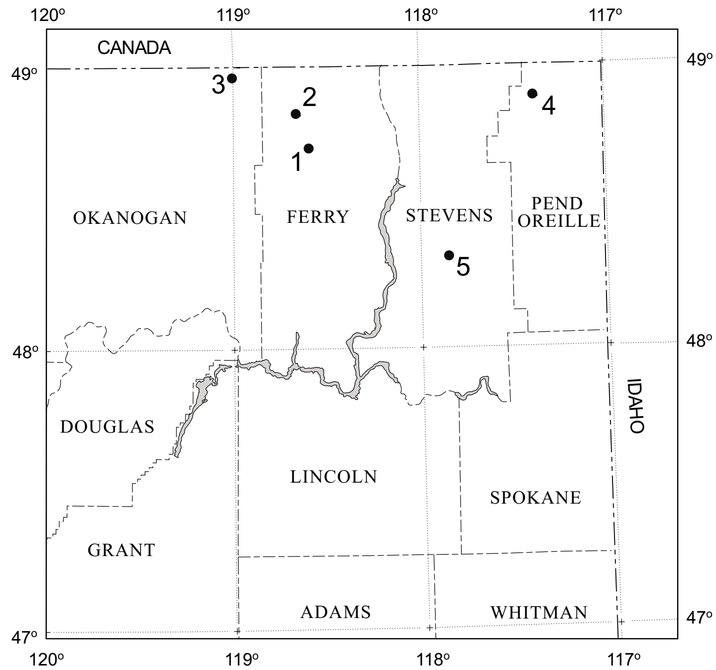

Figure 1. Location of major metal mining and exploration projects in northeastern Washington in 1999. Table 1 below identifies mines numbered on the map.

Table 1. Operator and brief description of the activity and geology at major metal mining and exploration projects in Washington in 1999 *(companion to Fig. 1)*

No.	Property	Location	County	Commodities	Operator	Activity	Area geology
1	Lamefoot	secs. 4, 8, T37N, R33E	Ferry	Au, Ag	Echo Bay Minerals Co.	Milled 381,603 tons of ore from the Lamefoot deposit that contained ~73,700 oz of gold	Gold mineralization in massive iron exhalative/replacement mineralization in Permian sedimentary rocks
2	K-2	sec. 20, T39N, R33E	Ferry	Au, Ag	Echo Bay Minerals Co., Kettle River Project	Milled 257,258 tons of ore from the K-2 deposit that contained ~56,200 oz of gold	Epithermal deposit in Eocene Sanpoil Volcanics
3	Crown Jewel	sec. 24, T40N, R30E	Okanogan	Au, Cu, Ag, Fe	Battle Mountain Gold Co./Crown Resources Corp.	Continuing to work on permitting to put mine into production	Gold skarn mineralization in Permian or Triassic meta-sedimentary rocks adjacent to the Jurassic–Cretaceous(?) Buckhorn Mountain pluton
4	Pend Oreille mine	secs. 10-11, 14-15, T39N, R43E	Pend Oreille	Zn, Pb, Ag, Cd	Cominco American Inc.	Announced an ore reserve of 6.5 million tons containing 8.9% zinc and 1.6% lead; draft EIS expected in 2000; plan to put mine back into production by 2002	Mississippi Valley–type mineralization in Yellowhead zone of Cambrian–Ordovician Metaline Formation
5	Addy Magnesium mine	secs. 13-14, T33N, R39E	Stevens	Mg	Northwest Alloys, Inc.	Mined 700,000 tons of dolomite; 550,000 tons used for smelting to produce magnesium metal; remainder used for road metal	Cambrian–Ordovician Metaline Formation dolomite

Figure 2. Aerial view of the Pend Oreille mine at Metaline Falls from the east. Cominco American, Inc., is working to put this mine back into production. *Photo courtesy of Cominco American and Libby Photography.*

Table 2. Operator and brief description of exploration and small scale mining operations in 1999

Property	County	Operator	Activity
Wenatchee Gold Belt project	Chelan	Palouse Resources	Drilled 2 holes
Golden Eagle	Ferry	Newmont Gold Co.	Maintained property
Three Crosses	Kittitas	Art Baydo	Some drilling
Merry Widow	Kittitas	Dan Sanders	Bulk sample testing
Phoenix	Kittitas	James Forman	Bulk sampling of lode deposit
Bullfrog mill site	Kittitas	Linda Ferderer	Processing about 30 tons of material per year
Gold Nugget	Kittitas	Keith Prukop	Placer operation, 2 acres
Independence	Kittitas	A. J. Barkus	Placer sampling, 5-acre site
South Cle Elum Ridge	Kittitas	Robert Salmon	Bulk sampling proposed
Maverick	Kittitas	Wally Mieras	Small scale mining
Sunset Mountain Daisey	Kittitas	Rob Repin	Submitted plan for processing 500 cubic yards of material annually
Crazy 8 placer	Kittitas	Mike Parish	0.5-acre placer sampling
Deathtrap mining claim	Kittitas	Robert Sawyer	Exploring
Little Jewel	Kittitas	Mark Lytle	Bulk sampling
Wind River	Skamania	DeLano Wind River Mining Co.	Maintained property
Van Stone mine	Stevens	Mano River Resources Inc.	Continued reclamation work
New Gold Hill	Whatcom	Ed Pariseau	Rehabilitating old workings, sampling

kane office. Information about the sand and gravel industry and mine reclamation can be obtained from Dave Norman in the Olympia office. (See p. 2 for addresses and phone numbers.)

METALLIC MINERAL INDUSTRY

Major metal mining operations in Washington in 1999 included gold mining at the Lamefoot and K-2 gold deposits, preparation of a draft environmental impact statement to reestablish mining for zinc and lead at the Pend Oreille mine, waiting for decisions on permit applications required to mine at the Crown Jewel gold deposit, and magnesium metal production from dolomite mined at the Addy dolomite quarry. The only known major mineral exploration projects for metallic minerals in Washington in 1999 were exploration for additional reserves in and adjacent to the Lamefoot and K-2 gold deposits and at the Pend Oreille mine. Activities for metallic commodities in 1999 are summarized in Figure 1 and Table 1 *(see p. 3)*.

The Kettle River Project of Echo Bay Minerals Co. near Republic in Ferry County mined and produced gold containing a small amount of silver from the Lamefoot and K-2 gold deposits. The majority of the silver came from the K-2 deposit. In 1999, the Lamefoot deposit (Fig. 1, no. 1) produced 73,700 oz of gold from 381,603 tons of ore. Reserves at the Lamefoot deposit will be depleted in January of 2001. The K-2 deposit (Fig. 1, no. 2), which will become the major gold mine for the Kettle River Project, produced 56,200 oz of gold from 257,258 tons of ore in 1999. Exploration for reserves to replace those being mined in 1999 was concentrated in and around the K-2 deposit. Combined production from the two deposits, which was processed at Echo Bay's mill near the Overlook deposit, was 129,900 oz of gold from 638,861 tons of ore. The Lamefoot deposit is an exhalative/replacement-type deposit in Permian rocks, and the K-2 deposit is an epithermal vein–type deposit in Eocene volcanic rocks. Both deposits are in the Republic graben.

Cominco American announced an ore reserve of 6.5 million tons at the Pend Oreille mine (Fig. 1, no. 4; Fig. 2), a Mississippi Valley–type zinc-lead deposit in northern Pend Oreille County. The company will ship zinc and lead concentrates to their smelter in Trail, B.C. Startup will be sometime after closure of the parent company's Sullivan mine in nearby British Columbia.

The Crown Jewel gold deposit (Fig. 1, no. 3) near Chesaw in Okanogan County is a skarn-type gold deposit in a sequence of Pennsylvanian to Triassic(?) clastic and carbonate sedimentary rocks. Previously announced reserves for the deposit are 8.7 million tons of ore at a grade of 0.186 oz of gold per ton. These rocks contain more than 1.6 million oz of gold. The operator, Battle Mountain Gold Company, prepared an environmental impact statement that was released in February 1997. The company has since been working to obtain permits to mine the deposit.

Northwest Alloys Inc. mined dolomite near Addy (Fig. 1, no. 5) in Stevens County for magnesium metal production and for road aggregate in 1999. A total of 550,000 tons was sent to the smelter, and approximately 150,000 tons of waste rock was used for road aggregate. Northwest Alloys also used some of the byproducts from smelting for fertilizer and soil conditioners.

A number of small-scale mining operations or exploration projects (predominantly for gold) were active in 1999 (see Table 2 for a summary).

NONMETALLIC MINERAL INDUSTRY

Nonmetallic mineral commodities (carbonates, clays, diatomite, olivine, and silica) accounted for approximately 23 percent of the approximately $609,474,000 value of nonfuel mineral production for Washington in 1998. Activities for nonmetallic commodities in 1999 are summarized in Figure 3 and Table 3. A summary of previous nonmetallic mineral activity can be found in articles by Gulick (1995) and Derkey (1996, 1997, 1998, 1999).

Two companies mined limestone (calcium carbonate) and dolomite (calcium magnesium carbonate) for use as a soil conditioner and (or) as feed lime in 1999. Pacific Calcium, Inc., produced from the Tonasket (Fig. 3, no. 111) and Brown (Fig. 3, no. 112) quarries in Okanogan County, and Allied Minerals, Inc., produced from the Gehrke quarry (Fig. 3, no. 117) in Stevens County. Northwest Alloys sold some byproducts from their magnesium metal production at Addy (Fig. 1, no. 5) in Stevens County. Columbia River Carbonates continued to produce calcium carbonate from the Wauconda quarry (Fig. 3, no. 113). They currently are looking for an alternate source of high-brightness limestone closer to their processing plant in Longview, Cowlitz County. Northport Limestone Co. mined carbonate from the Sherve quarry (Fig. 3, no. 122) in Stevens County and shipped most of it to Trail, B.C., for use as a fluxing agent in smelting. Northwest Marble Products Co. (Fig. 3, no. 119) continued to produce color- and site-specific carbonate products for terrazzo tile and related uses, as it has for a number of years.

Olivine Corp. mined 48,000 tons of refractory-grade olivine from its Swen Larsen quarry (Fig. 3, no. 125) in Whatcom County in 1999. Of that total, Olivine Corp. shipped 47,500 to Unimin, a Belgian company that produces casting sands and other refractory products at Hamilton in Skagit County.

Much of the clay produced in western Washington was mined by or for Lafarge Corp. and Ash Grove Cement Co. for use in cement. Lafarge Corp. mined 30,730 tons of clay from the Twin River quarry (Fig. 3, no. 101), and Ash Grove Cement Co. mined 6,100 tons of clay from its Castle Rock quarry (Fig. 3, no. 102). Pacific Coast Coal Co. mined a clay interbed from the John Henry No. 1 coal mine (Fig. 3, no. 109) and shipped almost 7,000 tons to Ash Grove Cement Co.

Mutual Materials continued to mine clay for the manufacture of bricks and related products. They mined in Spokane County at the Mica pit (Fig. 3, no. 116), in Pend Oreille County at the Usk pit (Fig. 3, no. 115), and in King County at the Elk (Fig. 3, no. 105) and Section 31 (Fig. 3, no. 106) pits. Mutual Materials also shipped stockpiled clay from the Clay City pit (Fig. 3, no. 114) in Pierce County.

Celite Corp. mined and processed 92,039 tons from diatomite pits (Fig. 3, no. 103) in sec. 3, T17N, R23E and sec. 7, T17N, R24E in Grant County. The company shipped 61,357 tons of finished diatomite.

Lane Mountain Silica Co. mined 275,989 tons of Addy Quartzite from the Lane Mountain quarry (Fig. 3, no. 118) in Stevens County. Following processing, the company shipped 217,687 tons of high-purity quartz, most of which was used to manufacture clear glass bottles and jars. Approximately 20 percent of the ore is removed during processing. This waste material, which had accumulated over a number of years, is now being shipped to Richmond, B.C., and is used to manufacture cement. Lane Mountain agglomerates the fine-grained siliceous waste material into small lumps by mixing a small amount of cement with it prior to shipping in order to avoid massive solidification during rail transport.

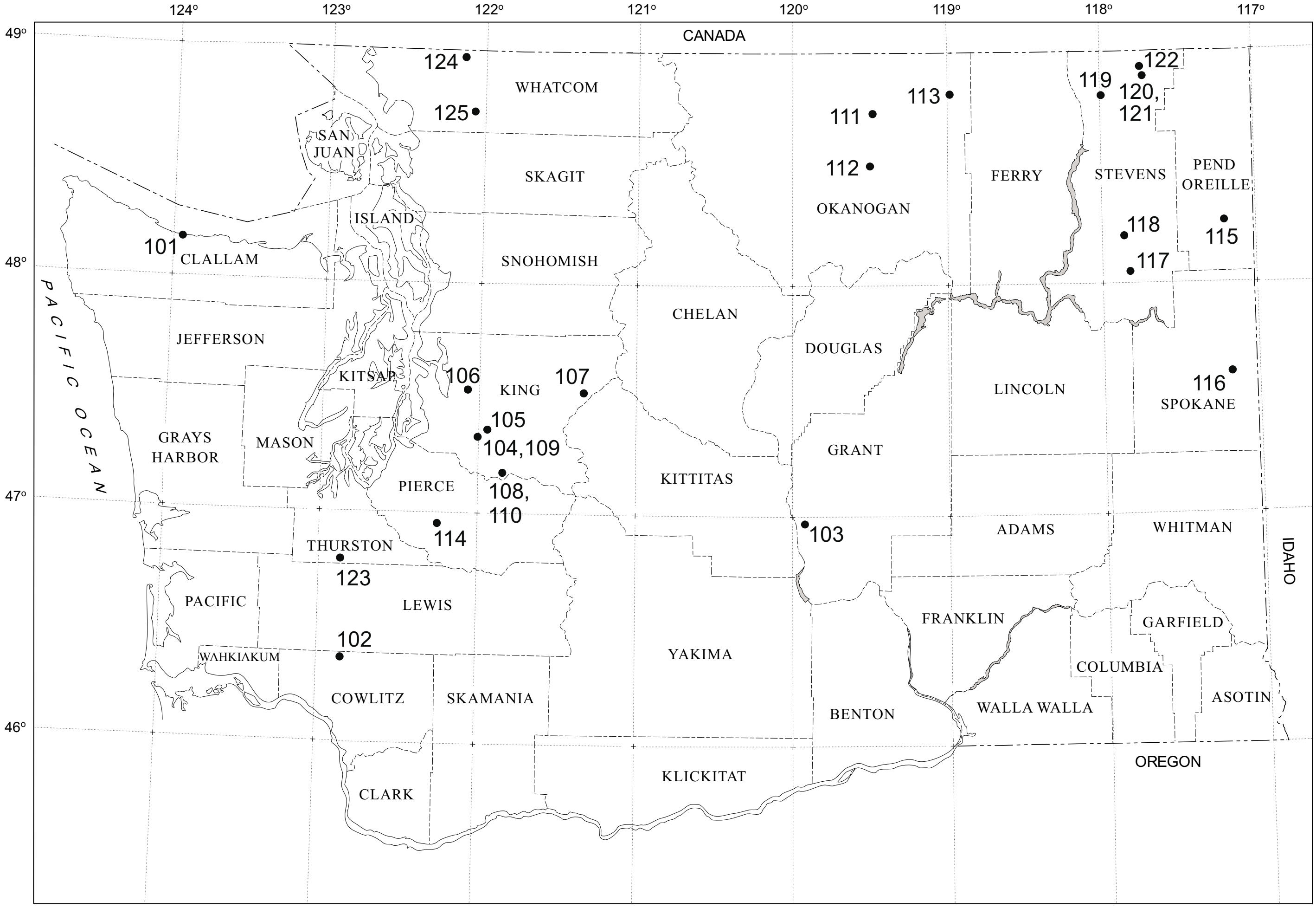

Figure 3. Location of nonmetallic mining operations in Washington in 1999. See Table 3 for additional details about each of these projects.

Reserve Silica Corp. mined 70,000 tons of quartz-rich Puget Group sands from the Ravensdale pit in King County (Fig. 3, no. 104). Most of Reserve's production is used for the manufacture of colored bottle glass.

Ash Grove Cement Co. mined nearly 130,000 tons of silica from its Superior quarry (Fig. 3, no. 108) in King County; the company uses the silica for making cement.

James Hardie Building Products Inc. mined 100,000 tons of silica from their Scatter Creek mine (Fig. 3, no. 110) in King County, which they used for the manufacture of Hardiboard products.

AGGREGATE INDUSTRY

The need for aggregate is longstanding as is illustrated in Figure 4. Aggregate (sand and gravel and crushed stone) produced for the construction industry, in terms of value and amount produced, accounted for approximately 54 percent of the

Table 3. Operator and brief description of the activity and geology of nonmetallic mining operations in Washington in 1999 *(companion to Fig. 3)*

No.	Property	Location	County	Commodities	Operator	Activity	Area geology
101	Twin River quarry	secs. 22-23, T31N, R10W	Clallam	clay	Lafarge Corp.	Mined 30,730 tons for making cement	Mudstone(?) in upper Eocene–lower Miocene Twin River Group
102	Castle Rock quarry	sec. 18, T10N, R1W	Cowlitz	clay	Ash Grove Cement Co.	Mined 6,100 tons of shale/clay used as an additive for cement	Eocene–Oligocene sedimentary rocks
103	Celite diatomite pits	sec. 3, T17N, R23E; sec. 7, T17N, R24E	Grant	diatomite	Celite Corp.	Mined 92,039 tons of ore and produced 61,357 tons of finished diatomite	Miocene 'Quincy diatomite bed', local sedimentary interbed at base of Priest Rapids Member, Columbia River Basalt Group
104	Ravensdale pit	sec. 1, T21N, R6E	King	silica	Reserve Silica Corp.	Added new circuit with magnetic separator to decrease iron content; mined and washed 85,000 tons; shipped 65,000 tons of silica sand to Seattle area for glass manufacture	Sandstone of the Eocene Puget Group
105	Elk pit	sec. 34, T22N, R7E	King	shale	Mutual Materials Co.	Mined 5,000 tons of shale (clay) for bricks; reserves nearly depleted	Illite- and kaolinite-bearing shales of the Eocene Puget Group

Table 3. Operator and brief description of the activity and geology of nonmetallic mining operations in Washington in 1999 *(continued)*

No.	Property	Location	County	Commodities	Operator	Activity	Area geology
106	Sec. 31 pit	sec. 31, T24N, R6E	King	shale	Mutual Materials Co.	Mined 42,000 tons for producing bricks	Shale of the Eocene Puget Group
107	Spruce claim	secs. 29-30, T24N, R11E	King	crystals	Robert Jackson	Extracted mineral and crystal specimens from the Spruce 16 claim	Quartz and pyrite crystals in breccia pipe and open voids along faulted megabreccia in northern phase granodiorite and tonalite (25 Ma) of Snoqualmie batholith
108	Superior quarry	sec. 1, T19N, R7E	King	silica	Ash Grove Cement Co.	Mined 140,000 tons of silica; shipped 106,000 to cement plant in Seattle; expanding quarry	Silica cap in hydrothermally altered Miocene andesites on a caldera margin
109	John Henry No. 1	sec. 12, T21N, R6E	King	clay	Pacific Coast Coal Co.	Mined 7,024 tons of clay; almost all shipped to Ash Grove Cement Co. in Seattle	Upper middle Eocene silty clay near base of Puget Group comprising 30-ft-thick zone above Franklin #9 coal seam
110	Scatter Creek mine	secs. 5-6, T19N, R8E	King	silica	James Hardie Building Products Inc.	Mined 100,000 tons of silica for fiber cement and Hardiboard products	Cap rock material from hydrothermally altered and silicified andesite of an igneous complex
111	Tonasket limestone	sec. 25, T38N, R26E	Okanogan	limestone	Pacific Calcium, Inc.	Mined 13,147 tons of limestone for soil conditioner and feed lime	Metacarbonate rocks in conglomerate-bearing member of Permian Spectacle Formation (Anarchist Group)
112	Brown quarry	sec. 26, T35N, R26E	Okanogan	dolomite	Pacific Calcium, Inc.	Mined 4,903 tons of dolomite used for soil conditioner	Metadolomite member of the Triassic Cave Mountain Formation
113	Wauconda quarry	sec. 13, T38N, R30E	Okanogan	limestone	Columbia River Carbonates	Mined limestone and shipped it to their processing plant near Longview	High-calcium, pre-Tertiary white marble lenses in mica schist, calc-silicate rocks, and hornfels
114	Clay City pit	sec. 30, T17N, R5E	Pierce	clay	Mutual Materials Co.	No activity in 1999; hauled from existing stockpiled clay	Tertiary kaolin-bearing, altered andesite
115	Usk mine	sec. 7, T32N, R44E	Pend Oreille	clay	Mutual Materials Co.	Mined and stockpiled 5,000 tons for making bricks	Holocene lacustrine clay, silt, and sand; light gray clay fires dark
116	Mica mine	sec. 14, T24N, R44E	Spokane	clay	Mutual Materials Co.	Mined 43,000 tons of clay to produce bricks	Lacustrine clay of Miocene Latah Formation overlying saprolitic, pre-Tertiary felsic gneiss
117	Gehrke quarry	sec. 2, T29N, R39E	Stevens	dolomite	Allied Minerals, Inc.	Mined approximately 7,000 tons; marketed as soil conditioner	Isolated pod of Proterozoic Y Stensgar Dolomite(?) (Deer Trail Group)
118	Lane Mountain quarry	secs. 22, 34, T31N, R39E	Stevens	silica	Lane Mountain Silica Co. (divn of Hemphill Brothers, Inc.)	Mined 234,427 tons and shipped 217,687 tons of sand, mostly for glass manufacture; shipped 16,740 tons of byproduct to cement plant in B.C.	Cambrian Addy Quartzite
119	Northwest marble mine; several locations	sec. 19, T38N, R38E	Stevens	dolomite	Northwest Marble Products Co.	Mined and milled 3,800 tons of color/site-specific aggregate materials for building and industrial applications	Dolomite of the Cambrian–Ordovician Metaline Formation; additional colored dolomite products are quarried elsewhere
120	Joe Janni limestone deposit	sec. 13, T39N, R39N	Stevens	limestone	Joeseph A. & Jeanne F. Janni limestone deposits	Leased to Columbia River Carbonates; samples collected and submitted for analysis	Deposit is in Cambrian Maitlen Phyllite, Reeves Limestone Member
121	Janni limestone quarry	sec. 13, T39N, R39E	Stevens	limestone	Peter Janni and Sons	Leased to Columbia River Carbonates; samples collected and submitted for analysis	Deposit is in Cambrian Maitlen Phyllite, Reeves Limestone Member
122	Sherve quarry	sec. 8, T39N, R40E	Stevens	limestone	Northport Limestone Co. (divn of Hemphill Brothers, Inc.)	Mined 50,000 tons of fluxing grade limestone; shipped 55,000 tons to Cominco smelter at Trail, B.C.; also used for road metal	Limestone in the upper unit of Cambrian–Ordovician Metaline Formation
123	Bucoda pit	sec. 14, T15N, R2W	Thurston	clay	Mutual Materials Co.	No activity in 1999	Glacial clay of the Pliocene–Pleistocene Logan Hill Formation overlying silty clay of the Eocene Skookumchuck Formation
124	Maple Falls quarry	secs. 7, 18, T40N, R6E	Whatcom	limestone	Clauson Lime Co.	Mined approximately 125,000 tons used for riprap, crushed rock, and landscape rock	Sheared, jointed Lower Pennsylvanian limestone overlain by sheared argillite and underlain by argillite, graywacke, and volcanic breccia of the Chilliwack Group
125	Swen Larsen quarry	sec. 34, T38N, R6E	Whatcom	olivine	Olivine Corp.	Mined and milled 48,000 tons used for refractory purposes	Dunite from the Twin Sisters Dunite (outcrop area >36 mi^2) in Whatcom and Skagit Counties

Figure 4. Gravel mining and crushing rock for Omak Streets, 1913. Crushing cobbles and small boulders in 1913 was a labor-intensive process compared to present-day gravel mining operations. Rocks too large to be used as aggregate were crushed to a usable fragment size. The process illustrated in the photo began with screening gravel, including large boulders, through a grizzly (upper left of photo), which was made of wood with cracks narrow enough to keep boulders too large to be crushed from going to the crusher. Some of the boulders are piled up behind the road roller (bottom center of photo). The fraction that passed through the grizzly was then transferred by wheelbarrow (center of photo) to a jaw crusher (center right of photo). The road roller was used to drive the crusher and to power a bucket-line conveyor. The conveyor transferred the newly crushed material to a storage bin. Horse-drawn wagons then transferred the aggregate to the streets of Omak. An empty wagon is crossing in front of the grizzly in the center of the photo and another wagon is loading from the storage bin. *Photo courtesy of Cheney Cowles Museum, Spokane, Wash.*

$609,474,000 total value in 1998. The construction and paving industries are the principal consumers of aggregate. Large sand and gravel operations are common near heavily populated areas where the need for aggregate is greatest. High ground transportation costs generally preclude large aggregate operations any great distance from where the aggregate is to be used. Small seasonal or project-dependent operations can be found throughout the state. The small pits are operated by city, county, and state road departments and small companies for smaller-scale needs.

Activities at most large aggregate mining operations in Washington continued at a rate similar to that in previous years. A major issue on the horizon for the aggregate industry in the Pacific Northwest is locating an adequate aggregate source for the city of Portland, Ore. The present source for the city is nearly depleted. The city is looking at glacial flood gravels in Klickitat County as a possible new source of aggregate. Despite its distance from Portland, available transport by barge on the Columbia River makes Klickitat County aggregate less costly than that from other sources.

REFERENCES CITED

Derkey, R. E., 1995, The metal mining industry of Washington in 1994: Washington Geology, v. 23, no. 1, p. 3-17.

Derkey, R. E., 1996, The metallic, nonmetallic, and industrial mining industry of Washington in 1995: Washington Geology, v. 24, no. 1, p. 3-19.

Derkey, R. E., 1997, The metallic, nonmetallic, and industrial mineral industry of Washington in 1996: Washington Geology, v. 25, no. 1, p. 3-11.

Derkey, R. E., 1998, The metallic, nonmetallic, and industrial mineral industry of Washington in 1997: Washington Geology, v. 26, no. 1, p. 3-10.

Derkey, R. E., 1999, The metallic, nonmetallic, and industrial mineral industry of Washington in 1998: Washington Geology, v. 27, no. 1, p. 3-8.

Gulick, C. W., 1995, The industrial mineral industry of Washington in 1994: Washington Geology, v. 23, no. 1, p. 18-20. ■

Wildflowers of the Columbia Basin

U.S. Bureau of Land Management (BLM) staff have produced a very attractive full-color publication, "Watchable Wildflowers: A Columbia Basin Guide", with access directions and species lists for ten scenic areas. It is available for $4 at BLM offices in Spokane (509-536-1200; 1103 N. Fancher; Spokane, WA 99212), Wenatchee, and Portland. It is also available at some bookstores.

Washington's Coal Industry—1999

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In 1999, Washington's two coal mines posted their lowest production since 1984. The Centralia mine in north-central Lewis County and the John Henry No. 1 mine in south-central King County produced a total of 4,077,599 short clean tons of coal. Total production was down by 560,959 tons from the previous year.

The state's largest coal mine, the Centralia Coal Mine, is operated by the Centralia Mining Company, a division of PacifiCorp, which is a subsidiary of Scottish Power. The mine is located 5 miles northeast of Centralia (Fig. 1). The mine is totally dedicated to supplying coal to the Centralia Steam Plant, located a mile from the coal mine.

The Centralia mine completed its 29th year of production in 1999, producing 4,074,400 short tons of subbituminous coal, 547,915 tons less than it produced in 1998. The mine's average annual production over the last 5 years has been 4.4 million tons per year; average annual production over the life of the mine is 4.3 million tons per year.

Coal production in 1999 came from three open pits. Coalbeds mined were the upper and lower Thompson, two splits of the Big Dirty, the Little Dirty, and two splits of the Smith. These coalbeds are part of the Skookumchuck Formation, which is comprised of nearshore marine and nonmarine sedimentary rocks. The Skookumchuck is the upper member of the Eocene Puget Group.

Washington's other producing coal mine, the John Henry No. 1, is located 2 miles northeast of the town of Black Diamond (Fig. 1). The mine is operated by the Pacific Coast Coal Company (PCCC), which completed its 13th full year of production in 1999. Only 3,199 short tons of bituminous coal were produced at the mine in 1999, a reduction of 13,044 tons from its 1998 production. PCCC continues to suffer from losing most of its customers in January of 1997 when a large landslide in the mine significantly reduced its ability to meet the current demand.

Nearly all the coal sold by PCCC in 1999 (90% of sales) went to supplying a new market, which is coal used as a filter media for large industrial and municipal water filtration systems. Although currently small, PCCC is hopeful that the new market will continue to grow. The remaining production consisted of coal sold for electrical generation (8.7%) and to private institutions and residential customers for space heating.

All coal mined in 1999 came from the Franklin No. 9 coalbed, from the mine's Pit No. 1. The Franklin coalbeds are stratigraphically near the base of the undivided Eocene Puget Group in nonmarine deltaic sedimentary rocks.

PCCC continues to mine a 30-foot-thick clay bed that lies stratigraphically below the Franklin No. 9 coalbed (between the Franklin No. 9 and No. 10). In 1999, the company mined 8,000 short tons of clay. The clay is blended with high-alumina clay from another source for the manufacture of portland cement. ■

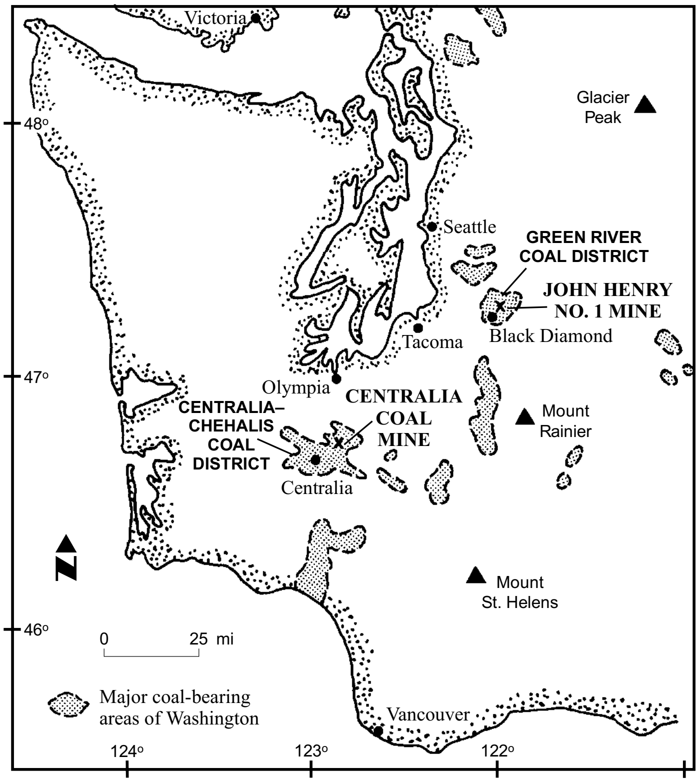

Figure 1. Coal-producing areas and districts of western Washington.

NORTHWEST PALEONTOLOGIC ASSOCIATION

The NPA meets at the Burke Museum on the University of Washington campus at 1:00 p.m. on the second Saturday of January, March, May, July, September, and November.

University activities may result in changes to this schedule. Check the *Aturian* (the association's newsletter) or the website at http://www.cnw.com/~mstern/npa/npa.html for the latest schedule information.

In addition to regular NPA business, each meeting provides a guest speaker on topics relevant to the geological and paleontological history of the Pacific Northwest. Members also bring in materials to share with the group. And refreshments are always provided!

TOPOGRAPHIC MAPS WEBSITE

TopoZone has worked with the USGS to make topographic coverage for the United States available on the Web. The interactive website has every USGS 1:100,000, 1:25,000, and 1:24,000 scale topo map for the entire United States, with more map scales available for some areas. Users can find maps by place name or by latitude and longitude, and can view the maps at three display sizes. Adjacent maps are tiled together on the display, resulting in seamless coverage. TopoZone can be found at http://www.topozone.com.

Shore Platforms at Cape Flattery, Washington

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INTRODUCTION

Shore platforms are found on many cliffed coasts and show a variety of forms. Some are *intertidal shore platforms* that slope gently seaward; others are more or less horizontal *high-tide benches*, some with a steep drop at the seaward edge; and others are much dissected, with many grooves and interruptions. Some shores are boulder-strewn, the boulders resting on a smooth or irregular nearshore sea floor. Where there are no shore platforms, cliffs that pass below low-tide level with deep nearshore water are termed *plunging cliffs*.

The Pacific coast of the U.S. has many cliffed sections, but shore platforms are not as extensive as they are on the Australian, New Zealand, and Japanese coastlines (Sunamura, 1992). In Washington State, they occur on the Cape Flattery peninsula in the northwest corner of the Olympic Peninsula (Fig. 1). In this paper, we will examine the local variations and compare them to shore platforms in other parts of the world.

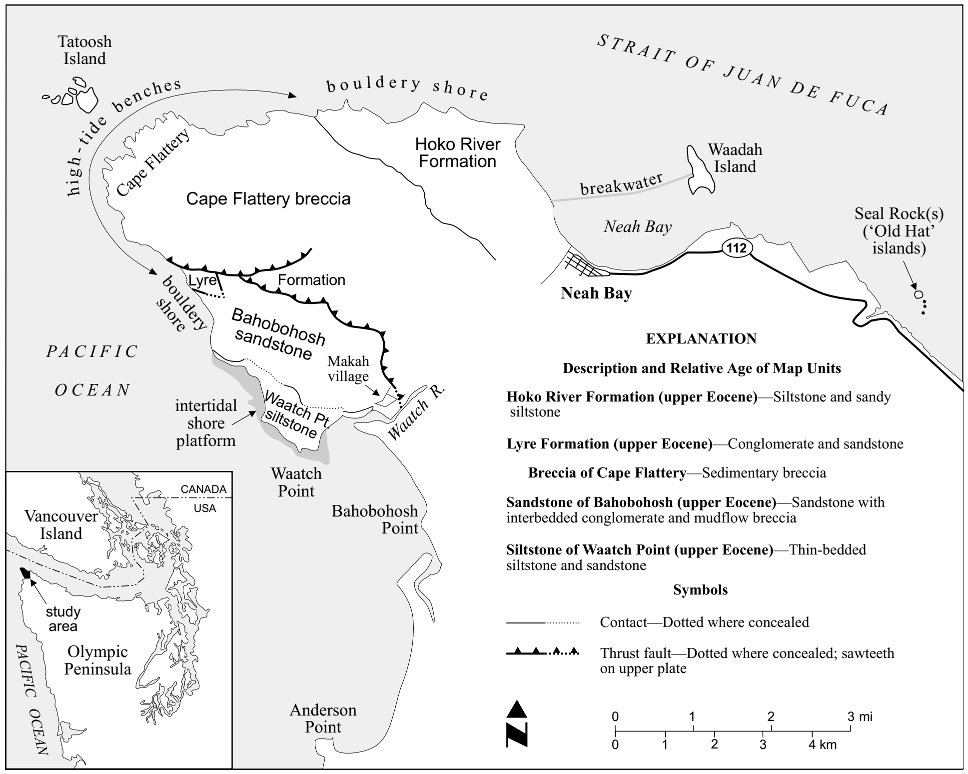

Figure 1. The Cape Flattery peninsula showing the sectors in which various rock formations crop out on the coast (after Snavely and others, 1993). The geology of the Cape Flattery peninsula is much more complex than is shown here. We have simplified things to focus mainly on the coast. Although they are all generally upper Eocene in age, map units are listed from youngest to oldest.

CAPE FLATTERY PENINSULA

Environmental Setting

Cape Flattery is in the West Olympic–Coastal climatic region (Scott, 1989) and has a temperate climate with an average rainfall of 200 cm/yr (79 in./yr), most of the precipitation occurring between October and April. Coastal temperatures average a high in July of 21°C (70°F) and a low in January of 0 to -3°C (32–26°F).

Densely forested, the region's principal trees are Douglas fir (*Pseudotsuga menziesii*), Western hemlock (*Tsuga heterophylla*), Sitka spruce (*Picea sitchensis*), lodgepole pine (*Pinus contorta*), and western arborvitae (*Thuja plicata*) (Schwartz and Terich, 1985).

Prevailing winds at the entrance to the Strait of Juan de Fuca are easterly in winter and southerly to southwesterly in summer (Phillips, 1966). Predominant waves are southwesterly and west-by-southwesterly, though regional cyclones may develop northwesterly waves (Schwartz and others, 1985) Wave data for this region reported by Tillotson and Komar (1997) indicate that summer deep-water significant wave heights range from 1.25 to 1.75 m (4–6 ft) with periods of 5 to 10 seconds, while winter deep-water significant wave heights average 2 to 3 m (6–10 ft) and have periods of 10 to 20 seconds. Winter storms with deep-water significant wave heights of 6 to somewhat over 7 m (20–23 ft) are calculated to generate wave breaker heights reaching 9 to 10 m (30–33 ft) locally.

Tides in the Cape Flattery region are mixed with unequal levels of the two highs and two lows. The tide range is 2.0 m (6.6 ft) for neap tides and 4.0 m (13.2 ft) for spring tides. Tidal currents attain velocities of 3.7 to 7.4 km/hr (2.3–4.6 mi/hr) off the coast of the cape.

Geologic Setting

Much of the Cape Flattery peninsula is cliffed, especially on the western side, which is exposed to Pacific swell and storm waves. There are sectors, particularly on the more sheltered northern (Strait of Juan de Fuca) coast, where weathered colluvium and forest vegetation extend down a coastal slope that

mixed tides – two highs of different elevation and two lows of different elevation in one tidal day (24.84 hours).

neap tides – the tide, midway between spring tides, that reaches the least height.

spring tide – the large rise and fall of the tide at or just after the new or the full moon.

ends in a cliff, an association called *slope-over-wall* or *beveled cliff* (Wood, 1982). Small valleys descend steeply to the coast, opening into coves and little bays. Beaches are rare, except in a few coves and along the shore between Waatch Point and the Makah village. There a beach of sandstone and siltstone pebbles with scattered well-rounded boulders, derived from glacial drift, lies at the foot of slumping forested bluffs (Fig. 2).

The Cape Flattery peninsula consists of an upland underlain by lower Tertiary rocks (Arnold, 1906; Schwartz and Terich, 1985; Snavely and others, 1993) (Fig. 1). In the southern part are the steeply dipping (typically 50–80°NE, but with much variation) thin-bedded siltstones and sandstones of the upper Eocene Waatch Point siltstone, which is well exposed in the cliffs on either side of Waatch Point. Northward these pass stratigraphically beneath the upper Eocene Bahobohosh sandstone, consisting of generally more massive, steeply dipping (typically 50–60°NNE) arkosic and quartz sandstones, breccias, and conglomerates, and the Lyre Formation, upper Eocene conglomeratic sandstones that dip less steeply (~30°NE). The northwestern part of the cape consists of more gently dipping (≤20°N and NW) massive sandstones, breccias, and conglomerates of the Cape Flattery breccia, exposed along the cliffs on either side of Cape Flattery and out on Tatoosh Island. The eastern part of the cape consists mainly of the eastward-dipping (20–40°) Hoko River Formation, upper Eocene siltstones and sandstones with zones of conglomeratic and bouldery channel deposits trending northwestward.

Figure 2. Gravelly beach and shore platform near Waatch Point. View to the northwest.

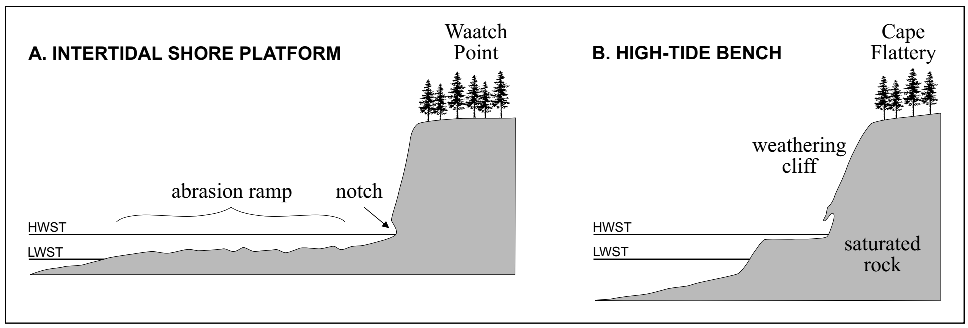

Figure 3. A diagrammatic sketch of **A**, a wide intertidal shore platform cut by wave abrasion, as on the coast at Waatch Point; and **B**, a high-tide bench formed by the weathering and removal of rock down to the level of permanent saturation, as on the coast at Cape Flattery. HWST, high water, spring tide; LWST, low water, spring tide.

Though the geology of the cape is quite complex, the Cape Flattery breccia and Lyre Formation are thought to consist of sediments derived from a source near present-day Vancouver Island and deposited in a submarine fan (Shilhanek, 1992).

Vertical Displacement and Relative Sea-Level Change

The coasts of Oregon, Washington, and British Columbia have been subject to changes in land and sea level, most recently during late Pleistocene and Holocene times. There is evidence that the land was depressed during the Fraser Glaciation, the last phase of glaciation in this region, 17,000 to 10,000 years ago (Armstrong and others, 1965; Easterbrook, 1992; Porter and Swanson, 1998), and that isostatic rebound followed deglaciation (Shipman, 1989, 1993).

In addition, there have been upward and downward movements of the coast due to tectonic uplift or depression along tectonic plate margins as the Juan de Fuca plate passed beneath the North America plate (Atwater, 1987). There have also been changes in sea level, notably the major late Quaternary marine transgression that accompanied global warming and deglaciation in a phase that began about 18,000 years ago. At present, a slow global sea-level rise is in progress (Bird, 1993a). Along some parts of the Washington coast, relative sea level has been falling because land uplift, whether isostatic or tectonic, has exceeded the rate of sea-level rise (Dragert and others, 1994; Savage and others, 1991; Thackray, 1998).

Post-glacial rebound can be discounted at Cape Flattery because, as reported by Savage and others (1991), Neah Bay is located near a nodal rebound line on plottings of such vertical displacement. That is to say, while the region to the southwest is subsiding and the region to the southeast is rebounding upward, Neah Bay is at the fulcrum or hinge point where there is no vertical movement up or down.

In contrast, tectonic uplift as the coastal margin overrides the subducting Juan de Fuca plate has had a significant effect upon relative sea level in this area (Holdahl and others, 1989; Savage and others, 1991). Mitchell and others (1994) and Savage and others (1991) have estimated present-day uplift rates along the coast of the Pacific Northwest using tide gauge records and repeated geodetic leveling surveys (highly accurate vertical-control surveying). They have concluded that with a present-day crustal uplift rate at Neah Bay of 3.4 mm/yr (0.134 in./yr) superimposed on a sea-level rise of 1.8 mm/yr (0.07

in./yr), there is a net uplift of the land relative to sea level of 1.6 mm/yr (0.06 in./yr) at that site. This can be simply restated as a relative sea-level fall of 1.6 mm/yr (0.06 in./yr) in the region around Cape Flattery.

SHORE PLATFORMS

Shore platforms are defined as flat or gently seaward-sloping smooth, or fairly smooth, rock surfaces formed in the zone between high and low tide (Trenhaile, 1987; Sunamura, 1992). They occur on cliffed and rocky coasts in various parts of the world, generally where the coastal rock outcrops are moderately resistant (Emery and Kuhn, 1982; Griggs and Trenhaile, 1994). Most have been formed by abrasion, notably where breaking waves move sand and gravel to and fro across the shore, cutting a surface ramp that slopes seaward from the base of a cliff to below the low-tide line (see intertidal shore platform, Fig. 3A). Such intertidal shore platforms are well known on the chalk coasts of England and France, where shore platforms cut layers of coherent limestone (Wright, 1967) at low angles. Other shore platforms show the influence of structure, and ledges or ridges are formed on the more resistant outcrops. Parts of the intertidal platform surface coincide with bedding planes exhumed by wave hydraulic plucking and abrasion, particularly where the rock formations are horizontal or gently dipping.

Elsewhere, shore weathering processes have played an important part in the shaping of platforms, which may be subhorizontal with a steep drop at the seaward edge (see high-tide bench, Fig. 3B). Disintegration of rock surfaces by repeated wetting (by rainfall, dew, and sea spray) and drying (in intervening fine weather periods) has resulted in the formation of subhorizontal shore platforms at about high-tide level on outcrops of sandstone, siltstone, and basalt on the Australian coast. The level of such a platform is determined by the upper limit to which the rock is permanently saturated. Above it, disintegrated rock material is swept away by wave action, and below it, this kind of weathering ceases (Hills, 1949, 1971; Bird and Dent, 1966). These features have been described from New Zealand (Kirk, 1977; Stephenson and Kirk, 1998).

On some coasts, particularly in arid to semiarid regions, wetting and drying is accompanied by salt crystallization, which also exerts pressure on rock surfaces and fissures, leading to further disintegration (Yaalon, 1982). Solution by rain water, sea spray, and sea water rich in dissolved carbon dioxide has formed similar subhorizontal shore platforms at about mid-tide level on coastal limestones, including dune calcarenites and emerged coral rock, in Australia and elsewhere, notably on oceanic islands (Bird, 1993b).

Biological erosion by shore plants and animals has in many places contributed to the shaping of subhorizontal shore platforms, especially on limestone coasts (Healy, 1968).

Figure 4. Intertidal shore platform cut in Waatch Point sandstones and siltstones, showing dissection along the strike of the outcrop. View to the north.

Figure 5. Cliff-base notch and abrasion ramp littered with fallen boulders at Waatch Point. View to the south.

SHORE PLATFORMS ON CAPE FLATTERY

On the south coast of the Cape Flattery peninsula, forested bluffs and actively receding cliffs stand behind a broad (400 m or 1300 ft wide), gently seaward-sloping (~1°) rocky shore platform cut into the steeply dipping sandstones and siltstones of the Waatch Point siltstone (Fig. 4). In the vicinity of Waatch Point, the cliff base and upper shore form a smooth-sloping abraded ramp (Fig. 5) where beach gravel has been moved to and fro by waves at high tide. Within the broad intertidal zone, steeply dipping strata have been truncated to form an irregular shore platform dissected by furrows cut along joints and bedding planes between ridges of harder sandstone. The rocks are draped with sea wrack (*Fucus* spp.) and other marine vegetation that impedes abrasion and weathering (Fig. 6). Similar features are seen on the north coast of Cape Flattery, where wide, rocky, irregular shore platforms have been cut into the siltstones, sandstones, and conglomerates of the Hoko River Formation and stand in front of forested bluffs and low cliffs.

From Waatch Point, the irregular shore platform, with features following the strike of the rocks, continues northward along the coast, then fades out where the Waatch Point formation passes beneath the more massive Bahobohosh sandstone. Farther north, the upper Eocene Lyre Formation, a conglomeratic sandstone, is exposed in a fault block where the cliffs are fringed by a bouldery shore rather than a shore platform. Still farther north, across another fault, is the Cape Flattery breccia, in which massive breccias and conglomerates form steep cliffs, much dissected by inlets and caves cut out along joint planes. These joints trend southeast–northwest between promontories, islets, and stacks. A narrow subhorizontal shore platform, termed a *high-tide bench*, has been cut at about high-tide level in the Cape Flattery breccia (Figs. 3B and 7) and is similar to shore benches seen in New Zealand and Australia, notably on the sandstones of the Sydney region.

Figure 6. Intertidal shore platform near Waatch Point showing the smooth inner part, actively abraded when waves move sand and gravel to and fro, and the outer part covered with wrack and seaweed. View to the north.

Figure 7. Segments of high-tide benches below cliffs and around stacks at Cape Flattery. View to the south.

The shore benches in New Zealand and Australia were formerly attributed to occasional storm-wave activity (Cotton, 1963), but are now considered to be due to weathering processes and removal of disintegrated material (rather than erosion of solid rock) by strong wave action with the sea at its present level.

The Cape Flattery coast is certainly exposed to frequent strong storm waves, but it is unlikely that storm wave energy is concentrated at any specific tidal level. As in Australia and New Zealand, the bench appears to have been formed by weathering, which has disintegrated the rock at and above the high-tide line. There is evidence that the rock is also disintegrating in the cliff face, notably on the landward side of sea stacks, where developing tafoni (cavernous weathering) coalesce to form notches and caves with overhangs and flat floors at the bench level (Fig. 8). The disintegrated material in the zone of wetting and drying is swept away by storm waves to expose a bench at the level of permanently saturated rock, close to mean high-tide level. Frost shattering may also play a minor role here, in the manner evidenced on the chalk shore platforms of southeast England (Robinson and Jerwood, 1987). A noteworthy feature is the presence of patches of yellow and green marine vegetation on the benches, occupying the niche of permanently saturated rock. It is possible that these plants are now contributing to rock weathering by root penetration and the exudation of corrosive fluids, but it is evident that the bench was formed by physical weathering and wave wash before this vegetation colonized it.

Similar subhorizontal high-tide benches are seen around islands and rock stacks on outcrops of the Cape Flattery breccia off Anderson Point (Fig. 1) to the south of the Waatch River estuary and on Seal Rocks east of Neah Bay, where rocky islands of Oligocene sandstones and siltstones are surrounded by shore benches (Fig. 9). Islands of this kind have been termed *Old Hat islands* in New Zealand (Bartrum, 1938) and attributed to weathering of shore rock outcrops and removal of weathered material by storm waves down to the level of unweathered rock. Although this is a slowly emerging coast, there are no similar platforms at higher levels, and we infer that the platforms have been weathered and worn down at a sufficient rate to maintain their relationship with present sea level. There are some cliff-face rock ledges, which are structural features formed where storm waves, with the sea at its present level, have washed away soft rock to expose the upper surface of a resistant stratum.

It should be noted that the statement made by Arnold (1906) that "a wave-cut platform skirts nearly the whole shoreline from the vicinity of Freshwater Bay to Cape Flattery and thence down the coast to Point Greenville" is inaccurate in terms of present-day knowledge of shore platform processes and geomorphology. The term *wave-cut platform* is now generally avoided, because waves alone can cut platforms only on very soft rock formations, the presence of sand and gravel being needed to achieve abrasion, and because other processes such as weathering and abrasion shape shore platforms. Moreover, there are sectors on the Cape Flattery peninsula where there are no shore platforms, possibly because there has been insufficient time for them to form on rocks of this hardness.

Figure 8. Stacks at Cape Flattery showing cavernous weathering features (tafoni) in the cliff face above the high-tide level and the high-tide bench formed at the level of permanent rock saturation. View to the south.

Figure 9. Islands of the 'Old Hat' type at Seal Rock(s) east of Neah Bay. View to the northeast.

DISCUSSION AND CONCLUSIONS

There is a correlation between shore platforms formed by wave abrasion and the availability of gravelly debris derived from thinly bedded rock formations, especially where they are steeply dipping and exposed in receding cliffs. On the Cape Flattery peninsula, sand and gravel are also derived from glacial drift deposits capping the cliffs. Wave abrasion is more effective where the waves move this gravelly material to and fro on the shore. The cutting of an abrasion ramp at the cliff base demonstrates that this process is active, undermining the cliffs and promoting their recession. Where the rocks are more massive, gravelly material is sparse and weathering processes become more important. Disintegration of rock surfaces by repeated wetting and drying results in the removal of material down to the level of permanent saturation, where a narrow shore platform or rock bench is formed.

Two kinds of shore platforms occur on Cape Flattery: (1) broad intertidal platforms cut by wave abrasion across steeply dipping strata of the Waatch Point siltstone and Hoko River Formation and dissected along joints and bedding planes (Fig. 3A) and (2) narrower subhorizontal high-tide shore benches on the more massive, less steeply dipping rocks of the Cape Flattery breccia (Fig. 3B). On intervening rock formations, shore platforms are poorly developed, but there are some boulder-strewn shores and scattered rocky outcrops in front of cliffs. All of these features are now in equilibrium with present-day sea level and ongoing coastal geomorphic processes.

Furthermore, dissection along joints and bedding planes of the shore platform at Waatch Point may be interpreted as continual lowering in response to a relative sea-level fall, much like dissection of late Pleistocene (interglacial) emergent shore platforms seen on the coasts of Cornwall in southwest England (Bird, 1998)

From the observations presented here, we conclude that if land uplift has exceeded sea-level rise and the coast of the Cape Flattery peninsula has been emerging during the past few thousand years, the intertidal shore platforms near Waatch Point and the high-tide benches on the cliffs at Cape Flattery must have been wasting downward at a rate similar to that of the relative sea-level fall (1.6 mm/yr or 0.06 in./yr). This is supported by the fact that they now stand at levels of wave abrasion and shore weathering consistent with the sea at its present level.

REFERENCES

Armstrong, J. E.; Crandell, D. R.; Easterbrook, D. J.; Noble, J. B., 1965, Late Pleistocene stratigraphy and chronology in southwestern British Columbia and northwestern Washington: Geological Society of America Bulletin, v. 76, no. 3, p. 321-330.

Arnold, Ralph, 1906, Geological reconnaissance of the coast of the Olympic Peninsula, Washington: Geological Society of America Bulletin, v. 17, p. 451-468.

Atwater, B. F., 1987, Evidence for great Holocene earthquakes along the outer coast of Washington State: Science, v. 236, no. 4804, p. 942-944.

Bartrum, J. A., 1938, Shore platforms: Journal of Geomorphology, v. I, p. 451-468.

Bird, E. C. F., 1993a, Submerging coasts: Wiley [Chichester, England], 184 p.

Bird, E. C. F., 1993b, The coast of Victoria: Melbourne University Press [Melbourne, Australia], 324 p. + xv.

Bird, E. C. F., 1998, The coasts of Cornwall: Alexander [Fowey, England], 237 p.

Bird, E. C. F.; Dent, O. F., 1966, Shore platforms on the south coast of New South Wales: Australian Geographer, v. 10, no. 2, p. 71-80.

Cotton, C. A., 1963, Levels of planation of marine benches: Zeitschrift für Geomorphologie, v. 7, no. 2, p, 97-111.

Dragert, Herb; Hyndman, R. D.; Rogers, G. C.; Wang, Kelin, 1994, Current deformation and the width of the seismogenic zone of the northern Cascadia subduction thrust: Journal of Geophysical Research, v. 99, no. B1, p. 653-668.

Easterbrook, D. J., 1992, Advance and retreat of Cordilleran ice sheets in Washington, U.S.A.: Géographie physique et quaternaire, v. 46, no. 1, p. 51-68.

Emery, K. O.; Kuhn, G. G., 1982, Sea cliffs—Their processes, profiles and classification: Geological Society of America Bulletin, v. 93, p. 644-654.

Griggs, G. B.; Trenhaile, A. S., 1994, Coastal cliffs and platforms. *In* Carter, R. W. G.; Woodroffe, C. D., editors, Coastal evolution—Late Quaternary shoreline morphodynamics: Cambridge University Press [Cambridge, England], p. 425-450.

Healy, T. R., 1968, Bioerosion on shore platforms in the Waitemata Formation, Auckland: Earth Sciences Journal, v. 2, no. 1, p. 26-37.

Hills, E. S., 1949, Shore platforms: Geological Magazine, v. 86, no. 3, p. 137-152.

Hills, E. S., 1971, A study of cliffy coastal profiles based on examples in Victoria, Australia: Zeitschrift für Geomorphologie, v. 15, no. 2, p.137-180.

Holdahl, S. R.; Faucher, Francois; Dragert, Herb, 1989, Contemporary vertical crustal motion in the Pacific Northwest. *In* Cohen, S. C.; Vanicek, Petr, editors, Slow deformation and transmission of stress in the Earth: American Geophysical Union Geophysical Monograph 49, v. 4, p. 17-29.

Kirk, R. M., 1977, Rates and forms of erosion on intertidal platforms at Kaikoura Peninsula, South Island, New Zealand: New Zealand Journal of Geology and Geophysics, v. 20, no. 3, p. 571-613.

Mitchell, C. E.; Vincent, Paul; Weldon, R. J., II; Richards, M. A., 1994, Present-day vertical deformation of the Cascadia margin, Pacific Northwest, United States: Journal of Geophysical Research, v. 99, no. B6, p. 12,257-12,277.

Phillips, E. L., 1966, Washington climate for these counties: Clallam, Jefferson, Island, San Juan, Skagit, Snohomish, Whatcom: Washington State Cooperative University Extension Service EM 2626, 63 p.

Porter, S. C.; Swanson, T. W.; 1998, Radiocarbon age constraints on rates of advance and retreat of the Puget lobe of the Cordilleran ice sheet during the last glaciation: Quaternary Research, v. 50, no. 3, p. 205-213.

Robinson, D. A.; Jerwood, L. C., 1987, Sub-aerial weathering of chalk shore platforms during harsh winters in southeast England: Marine Geology, v. 77, no. 1/2, p. 1-14.

Savage, J. C.; Lisowski, Michael; Prescott, W. H., 1991, Strain accumulation in western Washington: Journal of Geophysical Research, v. 96, no. B9, p. 14,493-14,507.

Schwartz, M. L.; Mahala, James; Bronson, H. S., III, 1985, Net shore-drift along the Pacific coast of Washington State: Shore and Beach, v. 53, no. 3, p. 21-25.

Schwartz, M. L.; Terich, T. A., 1985, Washington. *In* Bird, E. C. F.; Schwartz, M. L., editors, The world's coastline: Van Nostrand Reinhold Co., Inc., p. 17-22.

Scott, J. W., 1989, Washington, a centennial atlas: Western Washington University [Bellingham, Wash.], 155 p.

Shilhanek, A. B., 1992, The sedimentology, petrology, and tectonic significance of the middle Eocene Flattery breccia, Lyre Formation, northwestern Olympic Peninsula, Washington: Western Washington University Master of Science thesis, 138 p.

Shipman, Hugh, 1989, Vertical land movements in coastal Washington—Implications for relative sea level changes: Washington Department of Ecology, 37 p.

Shipman, Hugh, 1993, Vertical land movements in coastal Washington—Implications for coastal erosion and sea level rise. *In* Wise, W. M., editor, Our coastal experience—Assessing the past, confronting the future: Coastal Society, International Conference, 12th, Proceedings, p. 681-689.

Snavely, P. D.; MacLeod, N. S.; Niem, A. R.; and others, 1993, Geologic map of Cape Flattery, Clallam Bay, Ozette Lake, and Lake Pleasant quadrangles, Washington: U.S. Geological Survey Miscellaneous Investigations Series Map I-1946, 1 sheet, scale 1:48:000.

Stephenson, W. J.; Kirk, R. M., 1998, Rates and patterns of erosion on intertidal shore platforms, Kaikoura Peninsula, South Island, New Zealand: Earth Surface Processes and Landforms, v. 23, no. 12, p. 1071-1085.

Sunamura, T., 1992, Geomorphology of rocky coasts: Wiley [Chichester, England], 302 p.

Thackray, G. D., 1998, Convergent-margin deformation of Pleistocene strata on the Olympic coast of Washington, USA. *In* Stewart, I. S.; Vita-Finze, Claudio, editors, Coastal tectonics: Geological Society [London] Special Publication 146, p. 199-211.

Tillotson, Kevin; Komar, P. D., 1997, The wave climate of the Pacific Northwest (Oregon and Washington)—A comparison of data sources: Journal of Coastal Research, v. 13, no. 2, p. 440-452.

Trenhaile, A. S., 1987, The geomorphology of rock coasts: Clarendon Press [Oxford, England], 394 p.

Wood, Alan, 1982, Slope-over-wall cliffs. *In* Schwartz, M. L., editor, Encyclopedia of beaches and coastal environments: Hutchinson Ross [Stroudsburg, Penn.], p. 759.

Wright, L. W., 1967, Some characteristics of the shore platforms of the English Channel and the northern part of North Island, New Zealand: Zeitschrift für Geomorphologie, v. 11, no. 1, p. 36-46.

Yaalon, D. H., 1982, Salt weathering. *In* Schwartz, M. L., editor, Encyclopedia of beaches and coastal environments: Hutchinson Ross [Stroudsburg, Penn.], p. 708-709. ■

Washington's Inactive and Abandoned Metal Mine Inventory and Database

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INTRODUCTION

Presently in Washington State there is no systematic database of inactive and abandoned metal mines and their associated environmental problems. The Washington Department of Natural Resources (DNR) has the most complete historic information in archives, publications, and a database of economic attributes (Derkey and others, 1990). The U.S. Bureau of Mines/U.S. Geological Survey's Minerals Availability System/Mineral Industry Location System (MAS/MIL) database is considered inadequate because of errors in the data set and incomplete environmental information. The creation of a state-managed environmental database is a cooperative effort between DNR, the U.S. Forest Service (USFS), the U.S. Bureau of Land Management (BLM), the U.S. Environmental Protection Agency (EPA), and the Washington Department of Ecology (DOE), with DNR as the lead agency. A state-managed database has advantages because the state has access to many of the records needed (for example, land ownership) and can easily update and maintain the database. The goal is to build a single database and geographic information system (GIS) coverage of mines in the state. This database is critical to a systematic survey and prioritization of environmental hazards, site remediation, and reclamation of wildlife habitat at these mines. To date the EPA, USFS, and DNR have contributed funding for the project.

HISTORY OF MINING AND ITS EFFECT ON THE ENVIRONMENT IN WASHINGTON

Washington State had a very active metal mining industry in its early history. The dominant metals mined have been gold, silver, copper, lead, zinc, and magnesium. The earliest record of lode mining in the state was about 1871 when Hiram F. Smith, a future member of the Washington State legislature, discovered gold near the base of Chopaka Mountain in Okanogan County

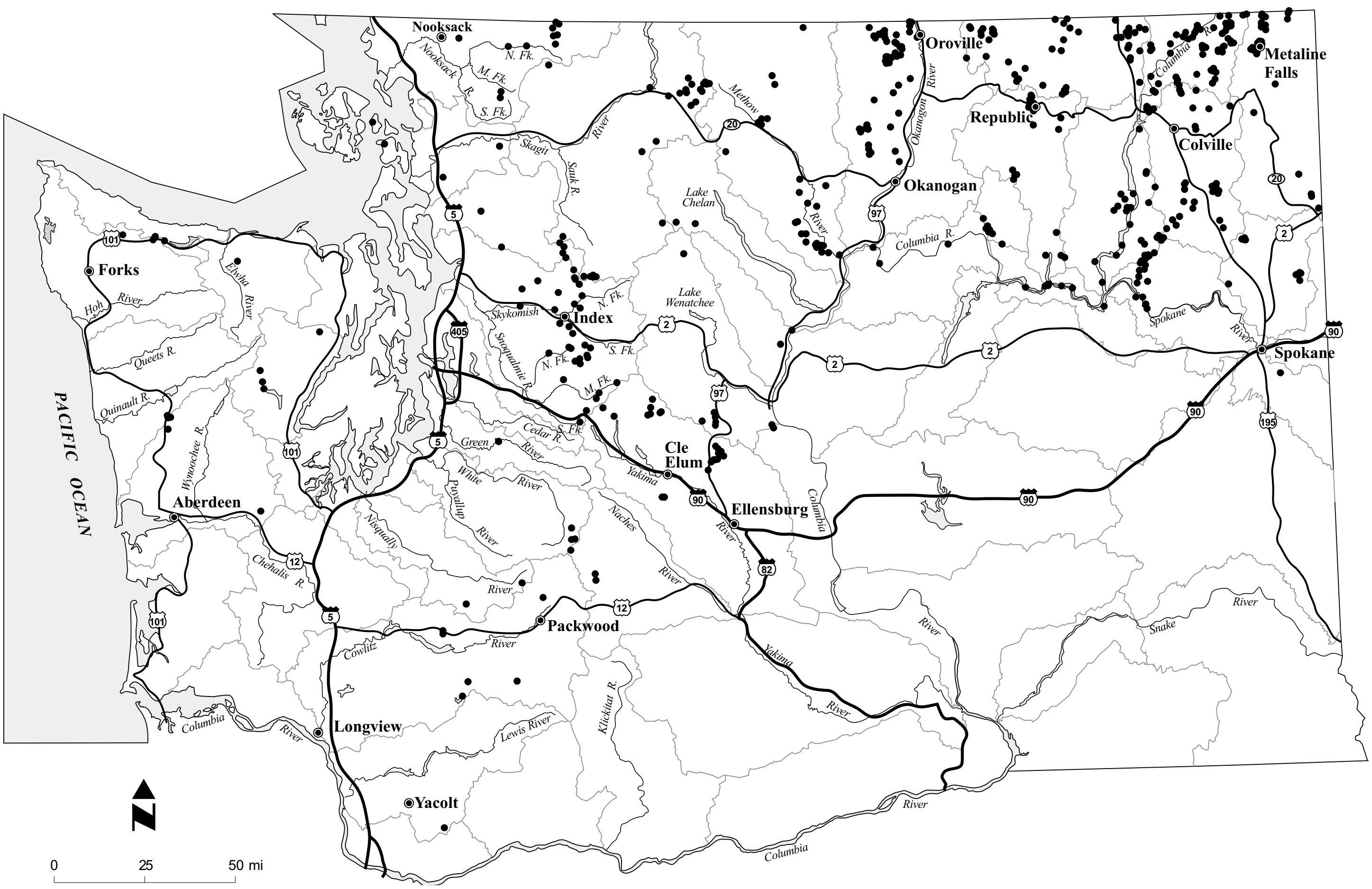

Figure 1. Locations of some major abandoned metal mines and their watersheds in Washington, based on data from Derkey and others (1990). Most metal mining has occurred in the northern Cascades and northeastern Washington. Copper, lead, zinc, magnesium, gold, and silver have been the main elements sought.

(Moen, 1982). Since then, there have been thousands of mines and prospects. These mines are primarily in the Cascade Range and the Okanogan Highlands of northeastern Washington (Fig. 1). Most of the mines were small and completely unregulated. Virtually all of the pre-1971 mines (before the beginning of environmental regulation in the state) have become inactive or have been abandoned. Old mine sites typically contain unreclaimed tailings, waste-rock piles, and openings that do not meet present-day standards. They can pose local environmental hazards and impact water quality because of acid mine drainage (AMD). There are often open shafts and adits, which are dangerous "attractive nuisances" and may need closure (Fig. 2). On the other hand, some of the mines have become critical wildlife habitat and need preservation or enhancement.

Figure 2. Mine portals and adits such as this one at the Holden Mine can be dangerous physical hazards and sources of water pollution when acid mine drainage is generated and metals are transported to surface or ground water.

CONSTRUCTING THE DATABASE

A literature and record search will be conducted for documented abandoned mines in Washington. Based on the results of the search, a subgroup of sites will be selected for on-site investigation. As information becomes available it will be incorporated into the database. The major categories of information to be entered into the database are listed below.

General Information

General information will include the name of the mine, the owner/operator, dates of operation, landowner, location (latitude and longitude), type of mine, minerals mined, production information, ore processing, and access to the site. DNR, as well as most other agencies, uses mine names to track the history of a mine. Land ownership is important because it will allow for easier designation of responsibility for site cleanup. One of the most important tasks will be to assign an accurate location to the mines. To date, many mines locations in our records are inaccurate. Locations will be determined from USGS maps and site visits using the global positioning system (GPS). Whether the mine is underground or an open pit will be included. The production and processing history at the site can be an indicator of the extent of mining and potential water problems. For example, it can tell us whether or not cyanide or mercury was used in ore processing and may be contaminating the site or nearby streams.

Physical Elements

Physical elements such as elevation and topography, geology of the area, and deposit type can have an effect on environmental risks at a mine site. High-elevation mines or mines on steep slopes can be more difficult to reclaim. The local geology can also influence water quality and mine hazards. For example, mines located in carbonate formations or rocks that have a high buffering capacity have a lower potential for AMD. Location of faults and other geologic structures is critical to understanding potential pathways to ground water.

Physical Hazards and Components of the Mine

Mine shafts, old buildings, underground workings, waste rock, and tailings are present at many old mine sites and can be dangerous. Mine shafts are vertical mine openings that may be the most dangerous aspect of many mines (U.S. Bureau of Mines, 1994) (Fig. 3). All physical features such as adits, shafts, pits, ponds, tailings and waste rock dumps, open drill holes, structures, and hazardous materials will be noted on site visits and included in the database. Ease of public access will be noted, as this may bear on the priority for hazard abatement.

Vegetation

Visual evaluation of the types of vegetation near a mine and their state of health can provide clues to the health of the area. Plants can be affected by a high metal content in soils and may be an indicator of the need for reclamation. Bare slopes with no vegetation are more likely to erode and fail and to deliver sediment to surface water. Evidence of healthy natural revegetation suggests that a site is on the road to recovery and a natural succession of species will follow.

Wildlife

Some abandoned mines have become important resources for wildlife. Rattlesnakes, bats, bears, or mountain lions can den or escape the heat in the dark recesses of a mine. Underground mines can be critical habitat for such species. Perhaps most important is the use of abandoned mines by bats (Tuttle and Taylor, 1994). Mines are key sites for bats for rearing young in summer, for hibernating in winter, and for use as temporary havens. The microclimate of the mine, especially the temperature, determines whether or not bats can use a mine. Abandoned mines will not be closed without proper biological assessment by qualified personnel.

Water Quality

Mineral deposits and (or) their development are potential sources of surface- and ground-water pollution that may require reclamation and remediation (Fig. 4). Few data exist to document the extent of this problem in Washington (Raforth and others, 2000). Acid generation is dependent upon mineralogy, surface- and ground-water hydrology, and oxygen availability. Metallic deposits, particularly those rich in base metal sulfides, may generate natural acid drainage, which may be accelerated by mine development. Discharges may occur from underground mines, open pits, waste-rock piles, tailings, haul roads, and mill sites. Reactions of sulfides often produce brilliantly colored metal precipitates and bacteria communities in surface waters down-gradient.

The low-pH conditions of AMD at metal mines may pose significant health risks to floral and faunal species, including humans. Heavy metals mobilized as a result of the acid generation pose the greatest threat, particularly to aquatic species. If there are multiple mines or natural sources of acid drainage in a watershed being considered for reclamation and remediation, it is important to know the location of the various sources and their relative contribution of metals. Environmental conditions leading to AMD and water and sediment sampling data collected during site visits will be critical information included in the database.

Figure 3. Unnamed open mine shaft approximately 50 feet deep on Palmer Mountain in Okanogan County. Open shafts such as this can be extremely hazardous because of loose material around the collar, rotting timbers, and vertical depths that could be fatal in a fall.

Figure 4. Tailings deposited along the banks of the Similkameen River from the Kaaba Texas mine were removed and the banks revegetated in 1999 and 2000. The revegetation was the result of an interagency cooperation between BLM, EPA, DOE, and DNR. The metal-bearing tailings were loaded onto trucks and hauled to an upland repository where metals would not be released to the environment. Approximately 80,000 cubic yards of tailings were removed. *(Photo courtesy of EPA Region X.)*

Reclamation

Specific site observations regarding actions needed to abate hazards and reclaim the site will also be entered into the database. Examples of such observations include slope instability, shafts to be plugged, soil amendments needed, erosion control, and water quality. A digital photo log will be included for mines that receive visits.

CONCLUSIONS

The proposed database will be used to gather information to aid reclamation and remediation at abandoned mines that are damaging the environment. A watershed approach using the information in the database will result in more efficient reclamation and remediation and wiser use of state dollars, as a watershed can be treated as a whole and sites can be ranked in priority of need.

REFERENCES

Derkey, R. E.; Joseph, N. L.; Lasmanis, Raymond, 1990, Metal mines of Washington—Preliminary report: Washington Division of Geology and Earth Resources Open File Report 90-18, 577 p.

Moen, W. S., 1982, The mineral industry of Washington—Highlights of its development, 1853–1980: Washington Division of Geology and Earth Resources Information Circular 74, 26 p.

Raforth, R. L.; Johnson, Art; Norman, D. K., 2000, Screening level investigation of water and sediment quality of creeks in ten eastern Washington mining districts, with emphasis on metals: Washington Department of Ecology Publication No. 00-03-004, 96 p.

Tuttle, M. D.; Taylor, D. A. R., 1994, Bats and mines: Bat Conservation International Resource Publication No. 3, 41 p.

U.S. Bureau of Mines, 1994, Abandoned mine land inventory and hazard evaluation handbook; Draft: U.S. Bureau of Mines, 162 p. ■

Holocene Glacier Peak Lahar Deposits in the Lower Skagit River Valley, Washington

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Introduction

Catastrophic deposition of volcanic sediment and lahars from Glacier Peak (Fig. 1) accompanied post-glacial fluvial, estuarine, and deltaic in-filling of the Skagit River valley east of Mount Vernon (Fig. 2, map B). Lahars are one of the greatest hazards associated with composite volcanoes such as Glacier Peak. They can travel great distances, placing people living in valleys draining the volcano at risk.

Lahars and Lahar Runouts

Lahars are debris or mudflows that originate on the slopes of a volcano. The driving force of a lahar is gravity. In a normal river flood, water carries individual rock particles along. In a lahar, particles are so concentrated that they flow downslope en masse, carrying the water. Lahars are generally restricted to stream valleys, although large-volume lahars have been known to pass over topographic barriers under rare circumstances. Noncohesive lahars have a low clay content (<3%) and typically begin as a flood surge that incorporates enough sediment to become a debris flow. They can transform downstream to more diluted flow types such as a lahar runout flow.

Evidence for Lahar Runout Deposits in the Lower Skagit River Valley

Lahar runout deposits are preserved in the lower Skagit River valley in 10 to 50 ft (3–15 m) high terraces adjacent to the flood plain (Fig. 2). These terraces abut the glaciated uplands and underlie the cities of Burlington, Sedro-Woolley, Lyman, and Hamilton and much of the nearby agricultural area. Farther downvalley, the lahar runout deposits are overlain by estuarine or deltaic sediments.

By analyzing well and boring logs and isolated outcrops, we were able to trace the lahar deposits as a 10 to 60 ft (3–18 m) thick semicontinuous stratum 84 mi (135 km) downvalley from Glacier Peak to near La Conner and Puget Sound (Fig. 3) (Dragovich and others, 2000, in press). That this stratum is made up of lahar runout deposits is indicated by (1) the overall stratigraphic relations, (2) the abundance and composition of dacite clasts in the deposits, and (3) the similar ages of the lower Skagit Valley stratum and lahars emanating from Glacier Peak. The lahar runout deposits appear to originate from a single eruptive event on the basis of the upward fining of sandy gravel to sand. Samples from 18 lahar deposit sites (from near Glacier Peak to La Conner) have remarkably similar rare earth, trace, and major element geochemistries, which also suggest a single eruptive event.

The lahar runout deposits in the lower Skagit Valley are most likely the downstream equivalent of the Kennedy Creek assemblage (KCA) of Beget (1981, 1982), a volcanic complex

Glacier Peak, unlike other Cascade volcanoes in Washington, does not stand as a prominent backdrop to metropolitan centers. Glacier Peak's attractions, as well as its hazards, thus tend to be overlooked. Yet like most other Cascade volcanoes, Glacier Peak has erupted several times since the Ice Age glaciers retreated 15,000 years ago, most recently around the eighteenth century. Since glacial times, Glacier Peak has had larger and more explosive eruptions than any Washington volcano except Mount St. Helens. If similar eruptions took place today, they could place nearby communities at serious risk. *From Waitt, R. B.; Mastin, L. G.; Beget, J. E., 1995, Volcanic-hazard zonation for Glacier Peak volcano, Washington: U.S. Geological Survey Open-File Report 95-499, 9 p., 2 pl.*

Downloaded from USGS/Cascades Volcano Observatory, Vancouver, Washington, website on August 18, 2000. http://vulcan.wr.usgs.gov/Volcanoes/GlacierPeak/framework.html

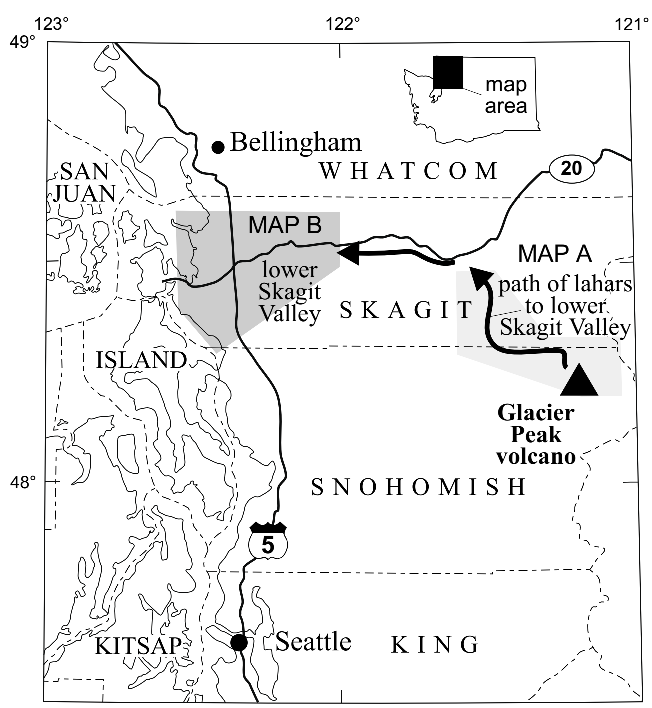
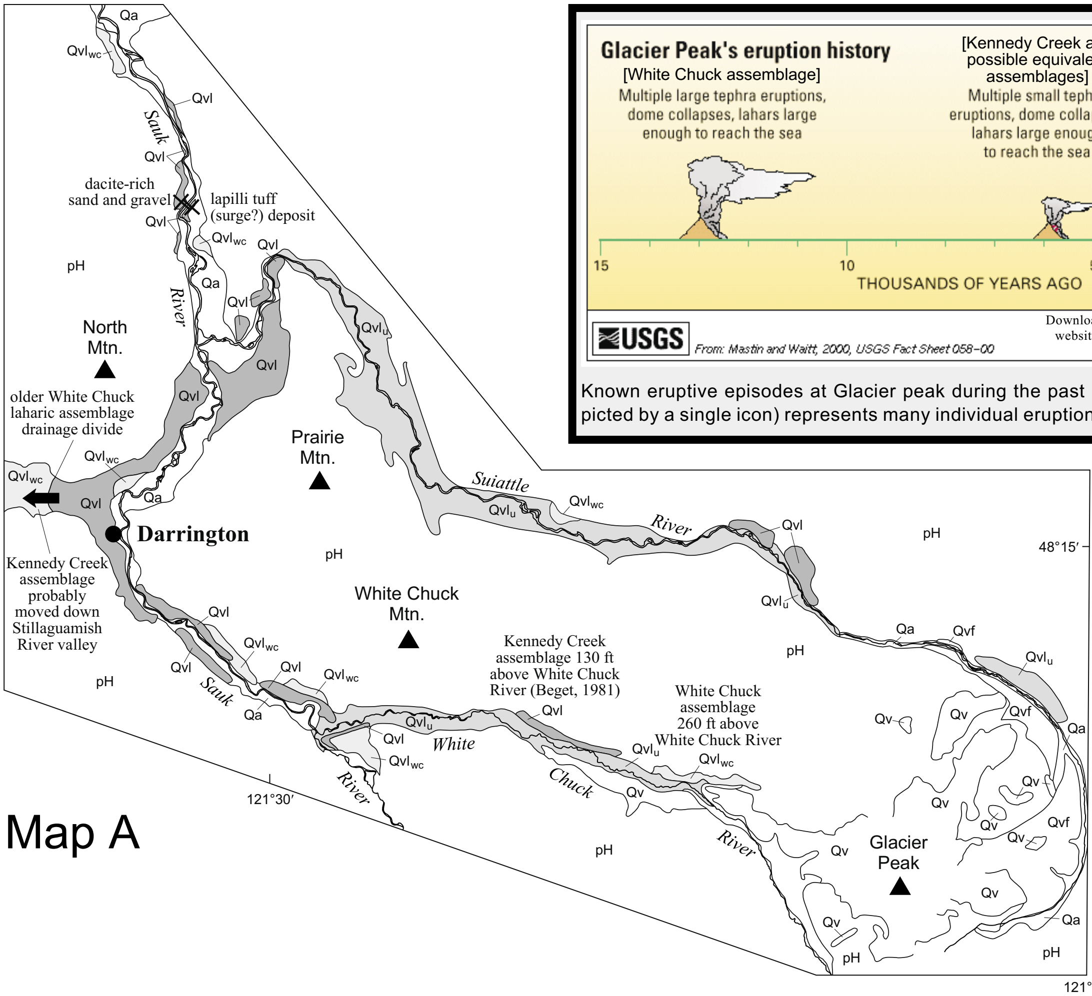


Figure 1. Map showing the path of the Glacier Peak lahars and the location of maps A and B in Figure 2. Dashed lines are county borders.



Known eruptive episodes at Glacier peak during the past 15,000 years. Each episode (depicted by a single icon) represents many individual eruptions. The ages of these episodes, in calendar years before present, are corrected from dates based on a radiocarbon time scale. The uncorrected radiocarbon ages for these episodes, which appear in some publications, are 11,200, 5,100, 2,800, 1,800, 1,100, and 300 yr B.P. *From Mastin, L. G.; Waitt, R. B., 2000, Glacier Peak—History and hazards of a Cascade volcano: U.S. Geological Survey Fact Sheet 058-00 [unpaginated].*

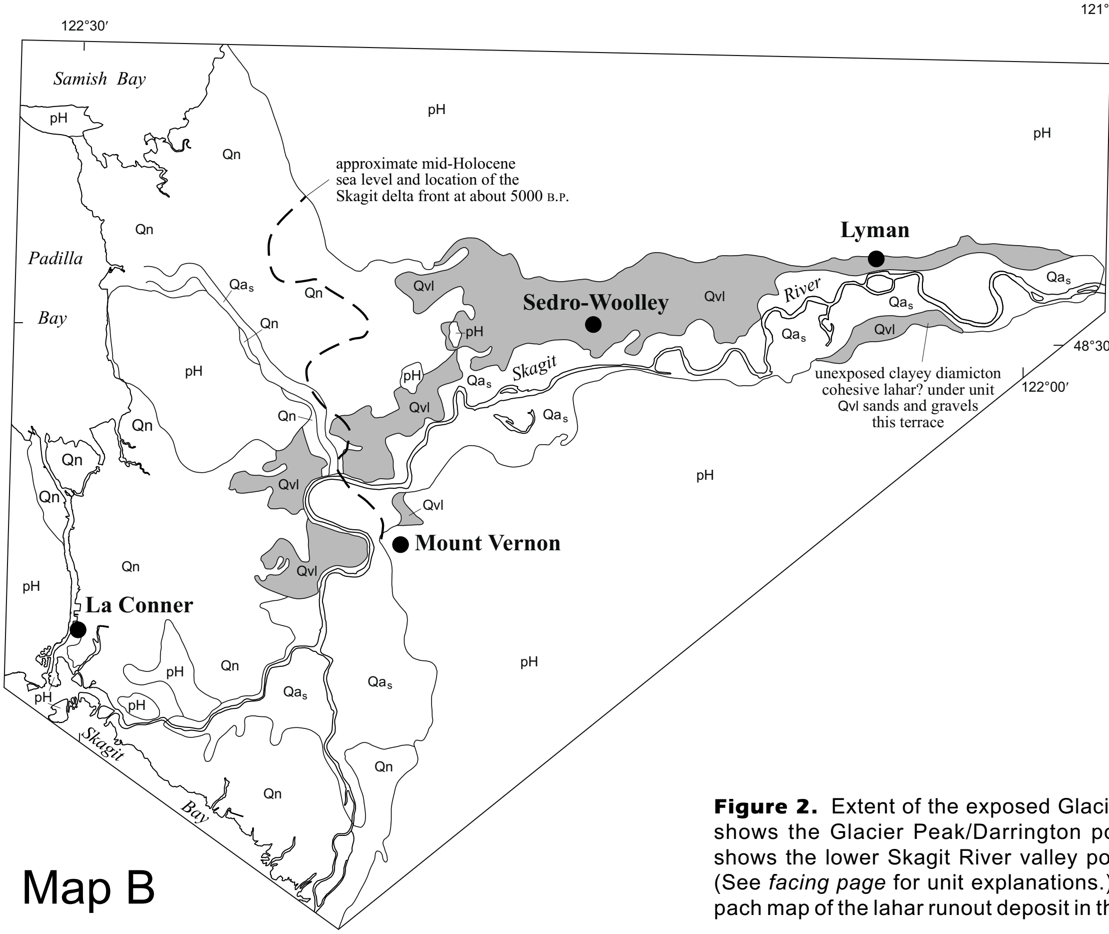


Figure 2. Extent of the exposed Glacier Peak lahar deposits. Map A shows the Glacier Peak/Darrington portion of the deposits. Map B shows the lower Skagit River valley portion. Lahar units are shaded. (See *facing page* for unit explanations.) Compare map B with the isopach map of the lahar runout deposit in the lower Skagit Valley (Fig. 3).

that originated from Glacier Peak. The assemblage consists of lacustrine deposits, alluvium, pyroclastic flow deposits, and noncohesive and cohesive lahar deposits and was probably produced by several eruptive events over a period of about 400 years. The KCA forms terraces in the White Chuck, Sauk, and Skagit River valleys. These deposits are several hundred feet thick near Glacier Peak and thin downvalley.

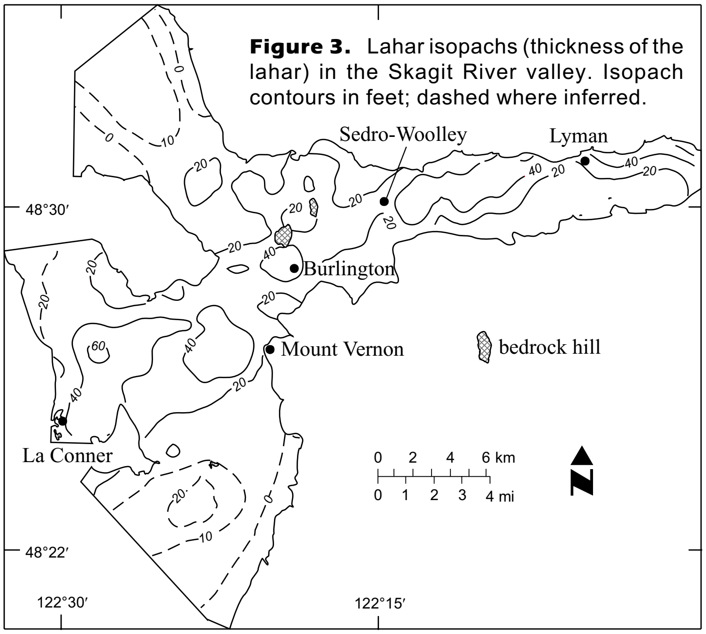


Figure 3. Lahar isopachs (thickness of the lahar) in the Skagit River valley. Isopach contours in feet; dashed where inferred.

EXPLANATION

HOLOCENE SURFICIAL DEPOSITS (younger than unit Qvl)

Qa, Qa_s — **Alluvium (Holocene)**—Gravel, sand, silt, and clay deposits with minor peat.

Qn — **Estuarine and deltaic deposits of the lower Skagit Valley (Holocene)**—Mostly composed of organic-rich silt, silty clay, and fine sand with lesser peats; locally includes sand and gravel of beach and fluvial origin.

HOLOCENE TO PLEISTOCENE SEDIMENTARY AND VOLCANIC DEPOSITS

Qvl — **Kennedy Creek assemblage of Beget (1981) (mid-Holocene)**—Distal, noncohesive gravelly sand and sand lahar and lahar-runout deposits with proximal, typically thickly bedded pyroclastic flow, dome collapse, lahar, and tephra deposits; proximal deposits locally contain interbedded lacustrine deposits. Probably includes correlative Baekos Creek and Dusty Creek assemblages of Beget (1981). (We correlate this volcanic assemblage and eruptive period with the lahar-runout deposits of the lower Skagit Valley.)

Qvf — **Volcaniclastic and volcanic fill of the White Chuck and Suiattle River valleys (Holocene and latest Pleistocene?)**—Suiattle fill consists of a thickly bedded assemblage of lahars, pyroclastic flows, air-fall ash, alluvium, and rare lava flows that grades downvalley into lahars; White Chuck fill consists of a thickly bedded assemblage of lahars, pyroclastic flows, alluvium, and reworked ash and silt that partly grades downvalley into Kennedy Creek and White Chuck assemblage lahars (Tabor and others, 1988); Beget (1982) correlated much of the debris in these volcanic aprons with the mid-Holocene eruptive episode of unit Qvl.

Qv — **Undivided volcanic rocks and deposits of Glacier Peak (Holocene to Pleistocene)**—Includes valley-bottom, valley-side, ridge-capping, and undivided flows and flow breccias of Tabor and Crowder (1969) and Tabor and others (1988); locally includes pyroclastic deposits (for example, White Chuck valley vitric tuff); available geochemical analyses suggest that some of the dacite flows on Glacier Peak are associated with the mid-Holocene unit Qvl pyroclastic and laharic event(s).

Qvl_{wc} — **White Chuck assemblage of Beget (1982) (late Pleistocene)**—Intermittent tephra eruptions of large-volume pyroclastic flows, lahars, dome collapse eruptions.

Qvl_u — **Undivided lahars from Glacier Peak (Holocene to Pleistocene)**—Boulder diamicton to well-sorted sand and gravel; includes poorly mapped lahars probably correlative with units Qvl and Qvl_{wc} as well as other volcanic assemblages of Beget (1981); contacts from Tabor and others (1988).

PRE-HOLOCENE GLACIAL DEPOSITS AND BEDROCK

pH — **Glacial deposits and bedrock (pre-Holocene)**

Charcoal in volcanic sand from the uppermost part of the lower Skagit Valley deposits yielded an age of 4,780 ±80 yr B.P., suggesting that some or all are mid-Holocene in age. This is somewhat younger than, but similar to, the 5,020 to 5,500 yr B.P. age of the KCA (Beget, 1982). Beget's ages are from charred logs in the KCA near Glacier Peak. Sources of error associated with ^{14}C ages make the temporal correlation between the lower Skagit Valley deposits and the KCA possible. Data suggest massive lahar runout deposition in the lower Skagit Valley at about 5 ka. The Baekos Creek and Dusty Creek assemblages of Beget (1982), which are loosely dated between 3,400 and 6,700 yr B.P., may also have been deposited during the eruptive episode that formed the KCA.

Beget (1982) estimated a total original volume of 0.5 to 0.7 mi^3 (2–3 km^3) for the KCA on the flanks of Glacier Peak. The Dusty Creek and Baekos Creek assemblages have an estimated total original volume of more than 2.5 mi^3 (10 km^3) (Beget, 1982). We estimate the volume of the lower Skagit Valley lahar deposits as 0.5 to 0.7 mi^3 (2–3 km^3) (Fig. 3). If our correlations are correct and these were all part of the KCA, the preserved KCA may have a volume of more than 3.6 mi^3 (15 km^3), which means that it inundated most of the major Glacier Peak drainages and probably reached all the way to Puget Sound.

Conclusion

Surface and subsurface mapping of the Kennedy Creek assemblage and its equivalents contributes important geologic information relevant to regional and local growth management planning and emergency preparedness in the lower Skagit Valley. The lahar deposits are noncohesive (contain little clay or silt), quite permeable, and locally occur between less permeable silt and (or) clay deposits. This, together with the thickness of the KCA and its stratigraphic position at or near the surface, makes these deposits an important shallow aquifer.

From an earthquake hazards standpoint, the lahar deposits are uncompacted or poorly consolidated and locally saturated. Therefore, areas underlain by these deposits likely have an increased susceptiblity to liquefaction during strong earthquakes (Palmer and others, 1994). Finally, these distal *volcanic* deposits remind us that while Glacier Peak can generally not be seen from urban areas, it is an active volcano that periodically erupts in an explosive catastrophic manner. Lahar runouts that inundate the lower Skagit Valley are one result of these eruptions. We will continue to test and refine our hypothesis that these dacite-rich lahar runout deposits are the result of one large eruptive event at about 5000 yr B.P.

Further Information

For further discussion and a presentation of supportive geochemical, sedimentologic, stratigraphic and other data for massive laharic inundation of the lower Skagit River valley, see Dragovich and Grisamer (1998) and particularly Dragovich and others (1999, 2000a, b, and in press).

Acknowledgments

Several geologists have been involved in DGER's geologic mapping effort in the lower Skagit River valley and have contributed to the ideas presented here. They include Dave Norman, Minda Troost, Garth Anderson, Jason Cass, Tom Lapen, Carly Grisamer. We also thank Pat Pringle for his review and

Continued on p. 59

Quake Forecast Shifts to Land

Scientists say data show the heart of a huge disaster under the Coast Range and the western Willamette Valley

Tuesday May 4, 1999
By Richard L. Hill of *The Oregonian* staff

SEATTLE — New research indicates that a massive earthquake could occur directly underneath the Oregon Coast Range and the western portion of the Willamette Valley.

For nearly 15 years, scientists have warned that a magnitude 8 or 9 earthquake could strike about 30 miles offshore and rock the coast, causing severe shaking and huge tsunamis. However, recent data gathered from satellites by scientists at Oregon State University and three other institutions show that the colossal quake could hit much farther inland and cause more severe damage to a larger area —including the more populated cities of the Willamette Valley such as Portland, Salem and Eugene.

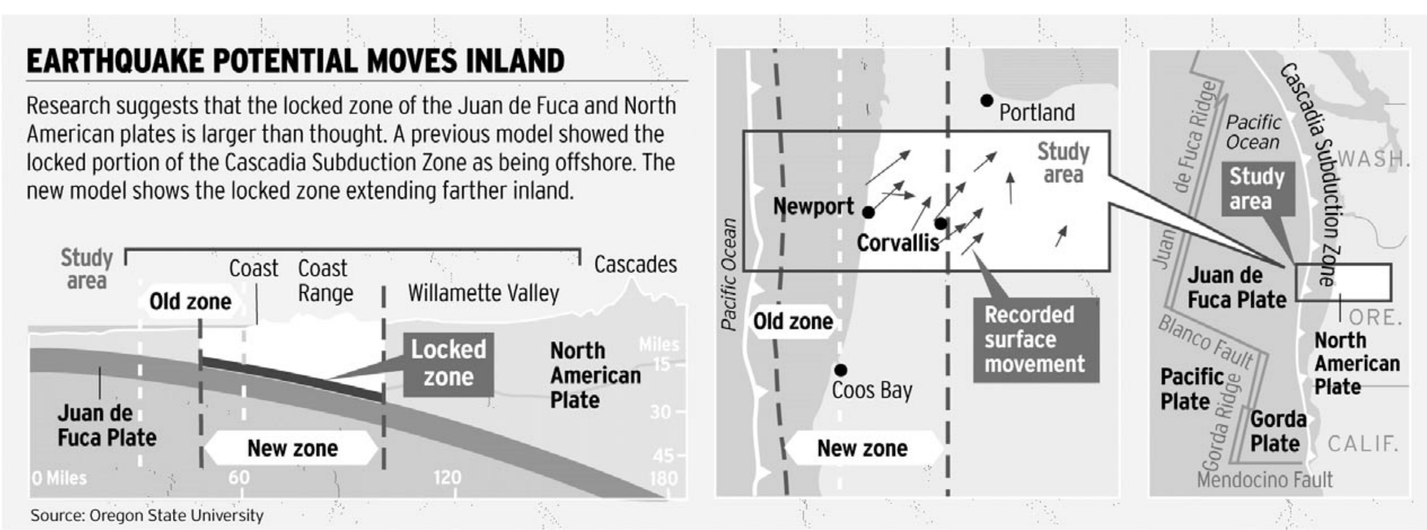
No one knows when such an earthquake might strike the Northwest, but the geologic evidence suggests that such quakes occur about every 400 years, plus or minus 200 years. The last major earthquake on the Oregon coast—believed to be a magnitude 9—occurred 300 years ago, previous studies showed.

Chris Goldfinger, a marine geologist at OSU, and his colleagues will present their findings today in Seattle at the annual meeting of the Seismological Society of America. They also reported the results recently to the Oregon Seismic Safety Advisory Committee.

The research team found that the locked portion of the Cascadia Subduction Zone—where the eastward-moving Juan de Fuca Plate plunges under the western-moving North American Plate—extends beneath the Coast Range and as far as the western side of the Willamette Valley. The locked zone probably is wider than previously thought, although the new data give less information about the width.

To come to this new conclusion, the scientists used the satellites of the Global Positioning System to detect extremely small movements of the Earth's surface in an area from the central Oregon coast into the central Willamette Valley. Two permanent GPS receivers in Newport and Corvallis monitor movement full time, while other receivers were taken to several sites to measure yearly movement.

The researchers expected to find little movement because of the lack of earthquakes and previous data that showed little uplift in central-western Oregon, something commonly associated with a locked subduction fault.



MICHAEL MODE/THE OREGONIAN

NORTHWEST SCIENCE REPORTER WINS AGU PRIZE

Richard L. Hill, science reporter for *The Oregonian*, has won an American Geophysical Union 2000 award for science journalism.

Hill is the first winner of AGU's new David Perlman Award for Excellence in Science Writing—News for his story, "Quake Forecast Shifts to Land", published May 4, 1999. The Perlman Award is named for the science editor of *The San Francisco Chronicle*, who was the 1997 winner of AGU's Sustained Achievement Award in Science Writing. Hill's story, which was published at the top of page one in *The Oregonian*, reported new research that concluded that western Oregon could be the epicenter of a "colossal" earthquake of magnitude 8 or 9. Previous estimates had suggested that such a quake could occur some 30 miles offshore, causing much less potential damage. The story is available at http://www.oregonlive.com/news/99/05/st050408.html.

The Perlman Award consists of a plaque and $2,000. An independent committee of scientists and journalists recommends the winner to the AGU Council, whose Executive Committee makes the final decision. The Perlman Award is for stories written under deadline pressure of one week or less. Work prepared for any medium except books is eligible. Hill will receive his award at the AGU Fall Meeting in San Francisco, California, in December.

Instead, they found that the ground is moving nearly half an inch a year toward the northeast. The rapid velocity worries earthquake researchers and indicates that the underlying plates are locking up rather than sliding by each other, resulting in incredible strain.

As the Juan de Fuca Plate presses forward to the northeast in the locked zone, it causes the piggybacking North American Plate to bulge upward and inland toward the northeast. The pressure continues to build for years until an earthquake unleashes the stress in one powerful jerk, causing the bulge to collapse and forcing the area to drop instantly.

"We were very surprised by the results we got," said Goldfinger, an OSU assistant professor of oceanography. "It was quite different from what we expected. We thought this would be an area that would show little, if any, movement."

The half-inch of movement each year is imperceptible, but the accumulated pressure that has been stored since the last major earthquake in 1700 can only be unleashed in an earthquake.

"That means there's been 300 years of strain that will be released," said John L. Nabelek, a seismologist and OSU associate professor of oceanography who participated in the study. "And it's not just the proximity of the strain to larger cities that is a concern, but we've found that the surface area of the entire locked zone is much larger than previously thought. That means a larger quake."

Goldfinger said the data suggest that the two plates are "essentially bolted together—they're 100 percent coupled.

"In addition, the Coast Range is an extremely strong, rigid block of rock that is more than capable of accumulating the sort of energy you need for a large earthquake."

Other scientists involved in the study included Robert McCaffrey, an associate professor of earth and environmental science at Rensselaer Polytechnic Institute in Troy, N.Y., and Mark Murray of Stanford University. The work was conducted in cooperation with Curtis L. Smith of the National Geodetic Survey in Salem. Will Prescott of the U.S. Geological Survey supplied previous GPS measurements that improved the results.

The new findings have made Goldfinger, who in previous years argued that the largest subduction-zone quake was more likely to be a magnitude 8 than a 9, rethink his theory. "This changes my views 180 degrees," he said. "The whole argument for an 8 rather than a 9 disappears."

Although quakes of either size would be devastating, shaking from a magnitude 9 event would last two to three minutes—about twice as long as the shaking a magnitude 8 quake would produce.

Researchers elsewhere in the Northwest have come up with similar results using the satellite-based Global Positioning System. The locked zone between the plates extends farther landward beneath Washington and Southern Oregon as well, and a little farther under Vancouver Island than previously thought.

A larger research effort, planned next year, will examine an area from Northern California to Canada, including Portland.

The Cascadia Subduction Zone is a 750-mile long fault that runs 60 to 150 miles offshore from British Columbia to Northern California. Similar subduction zones have produced the two largest recorded earthquakes in the world—a magnitude 9.5 quake on the coast of Chile in 1960 and a magnitude 9.2 quake in southern Alaska in 1964.

No quakes of that size have been measured in Oregon's brief recorded history, but evidence from buried marshes along the coast indicate that such events occurred at least seven times in the past 3,000 years. The last one hit the coast in January 1700, and large quakes appear to have struck about 1,100 years ago, 1,300 years ago and 1,700 years ago.

Curt D. Peterson, a professor of geology at Portland State University who has uncovered many of the buried marshes along the Northwest coast, said the new research supported his decade-old theory that the locked zone might be twice as wide as thought and capable of generating a huge quake.

"I hope this new evidence is going to help planners and government agencies get back on track about the seriousness of the hazard. The metro areas such as Seattle and Portland need to examine what a magnitude 9 means in terms of the whole region going all at once," Peterson said.

Mark Darienzo, earthquake and tsunami program coordinator for the Oregon Office of Emergency Management, said the study supported concerns that a huge subduction-zone earthquake "is not just a coastal problem, but could be an inland problem as well."

"More research is needed," Darienzo said, "but these new findings show that the potential for such a quake can't be overlooked—it shouldn't be just tossed aside."

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This story was briefly updated in a longer story summarizing all kinds of other research about the Cascadia Subduction Zone, including archaeological studies. It ran on Jan. 26, 2000, the 300th anniversary of the last great quake. The following is the pertinent excerpt from the Jan. 26 story:

McCaffrey, Goldfinger and the other researchers are analyzing more extensive GPS data they collected last summer. "The new data might change the picture about the locked zone somewhat," Goldfinger said. "It's a very complicated problem, and it's going to take a while to sort this out." ■

MOUNT BAKER/GLACIER PEAK COORDINATION PLAN

Mount Baker and Glacier Peak volcanoes in northwest Washington have each erupted within the last three centuries. Although neither mountain shows signs of unrest that might lead to renewed eruptive activity, Glacier Peak did produce one of the largest explosive eruptions of any Cascade volcano in the past fifteen thousand years and future eruptions at either volcano could cause significant disruption in nearby drainages and downwind areas.

To prepare for future unrest, emergency managers from Snohomish, Skagit, and Whatcom Counties, representatives of the State of Washington (Departments of Emergency Management and Natural Resources) and the Province of British Columbia, as well as personnel from the U.S. Forest Service and U.S. Geological Survey are working together to produce a Mount Baker/Glacier Peak coordination plan.

The purpose of the plan is to coordinate the actions that various agencies must take to minimize loss of life and damage to property before, during, and after a hazardous geologic event at either volcano. The plan strives to assure timely and accurate dissemination of warnings and public information and also includes the necessary authorities as well as statements of responsibilities of county, state, and federal agencies in the U.S. and Canada. A similar response plan has been produced by the Mount Rainier Volcanic Hazards Work Group for Mount Rainier volcano.

Abstracts on the Geology of Mount Rainier

These abstracts were presented at the combined Northwest Scientific Association 1999 Annual Meeting and Mount Rainier National Park 100th Anniversary Geology Symposium. The abstracts are reprinted from the unpublished symposium proceedings. Several of the abstracts have minor updates or corrections from the original version, and contact information has been revised to reflect new addresses for several authors. (The e-mail address for lead author is in parentheses.)

SURFACE ELEVATION MEASUREMENTS ON NISQUALLY GLACIER, MOUNT RAINIER, WA, 1931–1998

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Barbara A. Samora, Mount Rainier National Park

Between the mid-1800s and the 1920s, Nisqually Glacier (Fig. 1) receded about 1 km. This retreat fueled concern among water managers that future glacier runoff would be insufficient to fill the reservoir at the newly completed hydroelectric facility at La Grande. In 1931, Tacoma City Light began a series of transverse surface elevation measurements in an effort to measure the extent of thinning. These annual to semiannual measurements have been continued by the U.S. Geological Survey and by private contractors for the National Park Service and are the longest continuous series of glacier measurements in North America. Measurements indicate that increased snowpack produces zones of locally thickened ice near the head of the glacier that propagate downvalley as kinematic waves over a period of years. The greatest thickening during the period of measurement occurred between 1931 and 1945 when the glacier thickened by about 50 percent near 2,800 m of altitude. This and subsequent thickenings during the mid- 1970s to mid-1980s produced waves that advanced its terminus. Glacier thinning occurred during intervening periods. Between 1994 and 1997, the glacier thickened by 17 m at 2,800 m altitude, indicating probable glacier advance during the first decade of the 21st century.

Figure 1. Department of Natural Resources geologist Venice Goetz stands on the left lateral 'Little Ice Age' moraine of Nisqually Glacier and looks at its rubble-covered surface. View to the north. Photo by Pat Pringle, 1991.

HYDROTHERMAL INDICATORS IN STREAMS AND SPRINGS AT MOUNT RAINIER

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A surface water survey during 1993–98 sought evidence of the effects of hydrothermal processes and materials. The choice of indicator parameters was guided by a conceptual model of transport of hydrothermal fluids from the upper part of the cone outward toward areas of leakage on the lower flanks. This model considered hot acid sulfate-chloride water to be neutralized by reaction with andesite and cooled by dilution with cold ground water prior to discharge into surface waters. An alternative model considered dissolution of hydrothermally mineralized rock by cold water. Easily measured indicators that accommodate both models include temperature, pH, electrical conductivity, sulfate, and chloride. The geochemical characteristics of four sites stand out from among over 50 that were sampled within or proximal to the outcrop area of Mount Rainier andesite. Two sets of thermal springs with elevated sulfate and chloride occur near Paradise and Winthrop Glaciers. Cold neutral water with elevated sulfate and chloride discharges from Winthrop Glacier. Cold acid sulfate water drains from hydrothermally altered debris covering the snout of Tahoma Glacier.

MOWICH LAKE SILL COMPLEX IN NORTHWEST PART OF MOUNT RAINIER NATIONAL PARK, WASHINGTON

Paul E. Hammond (pehammon@teleport.com) and Keith A. Brunstad, Portland State University, Portland, OR; Peter R. Hooper, Washington State University, Pullman, WA; Robert A. Duncan, Oregon State University, Corvallis, OR; Bruce K. Nelson, University of Washington, Seattle, WA

To compare various lava-flow sequences designated as Fifes Peak Formation in the central Cascade Range, We examined strata so named in Mount Rainier National Park. Mapping in the Mowich Lake area reveals not lava flows but a prominent sill complex about 60 km^2 in area with an exposed thickness of 1 km. Sills are 0.5 to 200 m in thickness and traceable for up to 2 km distance. Dikes, 5 to 50 m thick, striking chiefly northwesterly, and plugs, 100 m wide, intrude the sills, have similar composition, and were feeders to the complex. A pluton at least 2 km^2 in area underlies the complex. All rocks of the complex are porphyritic augite-hypersthene andesite and microdiorite. They are calc-alkaline in composition and well-evolved magmatically. Pertinent compositions are: 56–67% SiO, 0.7–1.4% TiO_2, 1.6–5.2% MgO, 0.3–3.3% K_2O, 320–970 ppm Ba, 260–710 ppm Sr, 135–270 ppm Zr, and 8–15 ppm Nb. Host rocks are mainly lithic tuff-breccia, silicic tuff, and one 90-m sequence of basaltic lava flows. ^{40}Ar-^{39}Ar dating indicates the age of the complex to be 17 to 23 Ma. Petrologically similar lava flows along the White River valley to the north are possibly co-magmatic in origin and erupted during formation of the sill complex. Lava flows of the type Fifes Peak Formation lying 40 km to the east are petrologically distinctive and older at 24–25 Ma.

GLACIER ADVANCES NEAR MOUNT RAINIER AT THE LAST GLACIAL/INTERGLACIAL TRANSITION

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The most recent example of global and rapid climatic change occurred at the transition from the last glaciation to the current interglaciation (ca. 15,400–11,600 cal yr B.P.). One key element to our understanding of rapid climate change is the geographic distribution of short-term climatic oscillations. A comparison of climate and glacier behavior in the Pacific Northwest with the relatively well-established sequences from northwestern Europe allows us to test whether climatic events occurred throughout the northern hemisphere or not. Glaciers in the vicinity of Mount Rainier advanced twice during this time. Radiocarbon dates obtained from lake sediments adjacent to the corresponding moraines show that the first advance occurred before 13,200 cal yr B.P. During the North Atlantic Younger Dryas event, between 12,900 and 11,600 cal yr B.P., glaciers retreated near Mount Rainier, probably due to a lack of available moisture, but conditions may have remained cold. The onset of warmer conditions occurred at about 11,600 cal yr B.P. Organic sedimentation lasted for at least 700 years before glaciers re-advanced between 10,900 and 9,950 cal yr B.P. Glaciers in the vicinity of Mount Rainier seem to have advanced in response to regional or local shifts in late-glacial climate. The evidence does not support the view that glacier behavior in the Pacific Northwest paralleled that in the regions surrounding the North Atlantic.

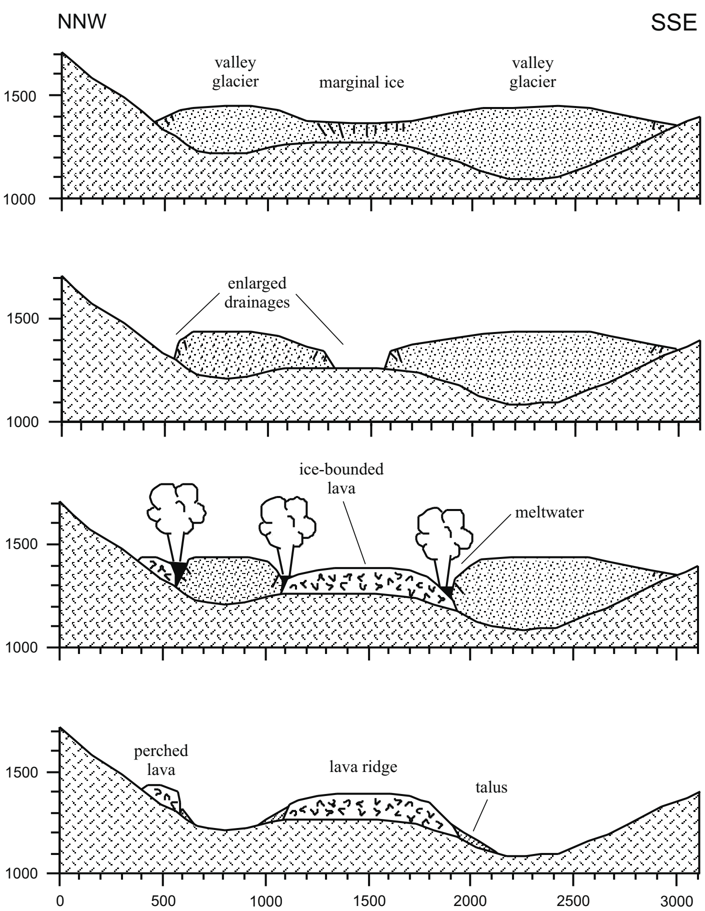

Figure 2. Sequential cross-sectional views (top to bottom) of proposed ice-marginal formation of ridge-forming and perched lava flows. Elevations and horizontal distances in meters. *Modified from Lescinsky and Sisson (1998).*

MOUNT RAINIER SUMMIT CAVES VOLCANIC ACTIVITY

François Le Guern (Francois.Le-Guern@lsce.cnrs-gif.fr), E Ponzevera, LSCE-CNRS, Yvette, France; William M. Lokey, Federal Emergency Management Agency, Region X, Bothell, WA; and Richard D. Schroedel, Pierce County Department of Emergency Management, Tacoma, WA

In 1997–1998, we explored the caves and took samples of the volcanic gases on the summit of Mount Rainier. In the eastern crater, we mapped 700 m of caves. The main fumaroles in this crater are located at the eastern entrance ('airplane' cave). Air circulated downwards in the eastern branch and upwards in the northern and southern branches. Very few fumaroles were observed deep within the cave, and the air circulation kept the atmosphere safe to breathe. The CO_2 content measured in the fumaroles was around 1 percent and the CO_2 concentration in the cave atmosphere was close to 300 ppm. No sulfur was detected in the gases. In the western crater, 155 m of caves were mapped. Fumaroles with sulfur crystal formation at a temperature of 86°C were located and sampled in the cave lake. The atmosphere in this cave contained 0.3 percent CO_2 and 2 to 5 ppm H_2S, giving it a rotten egg odor. These concentrations are below the toxic admitted concentrations. Samples of soil minerals resulting from rock alteration by the volcanic gases were taken in both caves. Thanks to the cooperation of the National Park Service staff, the Mountain Climbing Rangers, the Tacoma Mountain Rescue Unit, and Pierce County Emergency Management, we have been able to work a week on the summit.

LAVA AND ICE INTERACTION AT MOUNT RAINIER, WASHINGTON

David T. Lescinsky (dlescins@julian.uwo.ca), Department of Earth Sciences, University of Western Ontario, London, ON; Tom W. Sisson, U.S. Geological Survey, Menlo Park, CA; and Jonathan H. Fink, Arizona State University, Tempe, AZ

Numerous lava flows on Mount Rainier show evidence supporting interaction with glacial ice. The most notable of these are the thick ridge-forming flows that extend radially onto the lower flanks of the volcano. The great thicknesses (≤400 m) and steep margins of these flows are the result of lava flowing into ice canyons within glaciers and ice sheets (Figs. 2 and 3). Water and steam associated with melting of the ice rapidly quenched the sides of these flows producing glass and narrow (5–10 cm diameter) columnar fractures. Some lavas have columnar fractures on their upper surfaces indicating that they traveled some distance subglacially. Such indicators of lava–ice interaction can be used to determine the presence and

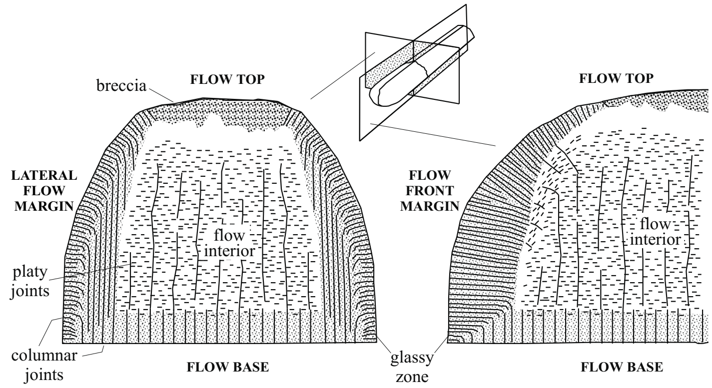

Figure 3. Idealized cross sections of ice-marginal lava flows. Vertical exaggeration ~5x. Note that in the case of perched flows, only one side of the flow shows ice-contact features. *Modified from Lescinsky and Sisson (1998).*

approximate thicknesses of glaciers during past eruptions. Future lava flows at Mount Rainier will likely interact with ice and snow. Eruption observations at glaciated volcanoes suggest that lava flows are less hazardous than explosive eruptions. Lava melts ice, causing increased runoff, but since melting is relatively slow, few floods occur. However, when lava flow fronts collapse they produce hot avalanches and pyroclastic flows that can rapidly scour and melt snow and ice, generating dangerous debris flows.

Reference: Lescinsky, D. T.; Sisson, T. W., 1998, Ridge-forming, ice-bounded lava flows at Mount Rainier, Washington: Geology, v. 26, no. 4, p. 351-354.

SULFATE ANOMALIES AND LOADS OF SELECTED STREAMS DRAINING MOUNT RAINIER

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One way to determine which parts of Mount Rainier have been weakened by volcanic fluid/rock interaction is to look at the alteration products being transported by streams draining the mountain. Oxidation of fumarolic gases produces acid-sulfate waters that alter and bleach rock. The highest SO_4 concentrations occur in Tahoma Creek, South Puyallup River, South Mowich River, and West Fork White River. With some time lag, sulfate concentration varies inversely with discharge rate in Tahoma, South Mowich, and West Fork White, but is almost constant and independent of discharge in the South Puyallup. Quantifying the sulfate load in these predominately glacial streams is difficult because of the large diurnal change in discharge and the generally poor gaging conditions. Measurements of sulfate loads at low-flow (fall) conditions in 1997 and 1998 are consistent for Tahoma Creek (~5,000 kg/day), South Puyallup River (~900 kg/day), and West Fork White River (~3,000 kg/day). The anomalous sulfate concentrations and high sulfate loads of the aforementioned streams show that the west and north sides of Mount Rainier have been weakened by hydrothermal alteration.

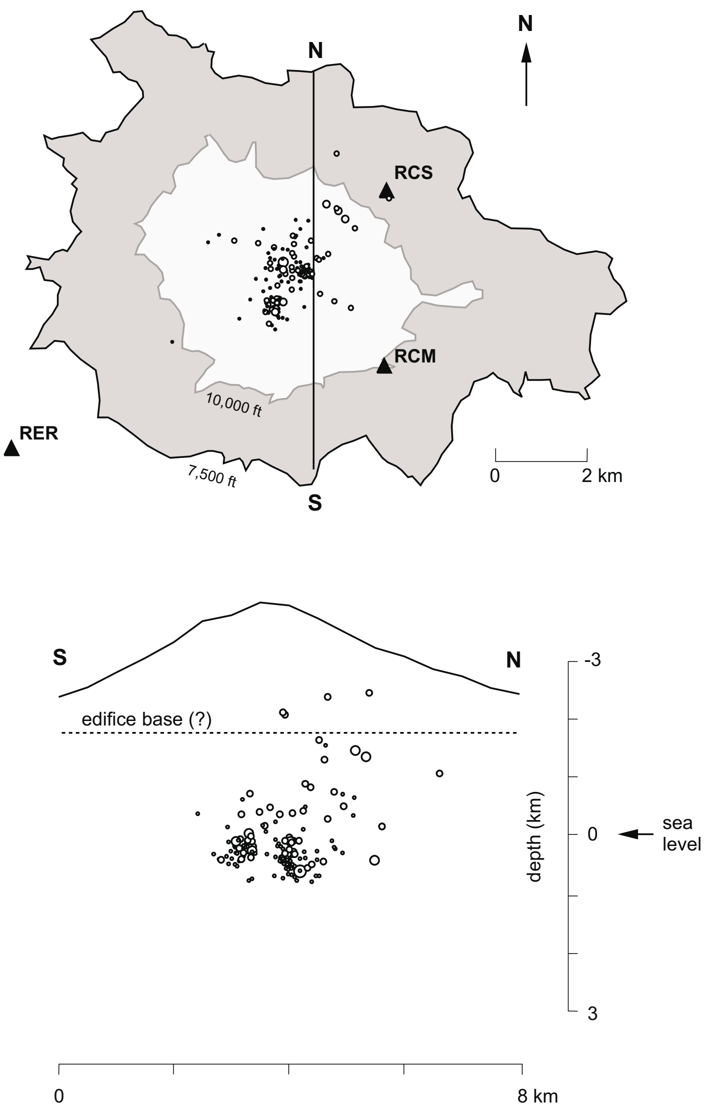

Figure 4. Map and cross section of high-frequency volcano-tectonic earthquake hypocenters at Mount Rainier. Symbols explained in Figure 5. *Modified from Moran and others (2000).*

SEISMICITY STUDIES AT MOUNT RAINIER

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The Pacific Northwest Seismograph Network (PNSN) installed two seismometers on the flanks of Mount Rainier in 1989 and another at Camp Muir in 1993. Data recorded by these and other nearby seismometers over the last decade were used to investigate the nature of seismicity directly beneath Mount Rainier, as well as the nature of the "plumbing system" beneath the volcano (Figs. 4, 5, and 6). An average of 1–2 high-frequency "volcano-tectonic" (VT) earthquakes occur directly beneath the summit in a given month. VT earthquakes occur in several clusters located from 2 km above to 1 km below sea level, well below the inferred base of the volcanic edifice. Many of the computed focal mechanisms are normal, with most stress axes deviating significantly from the regional stress field. These characteristics are most consistent with

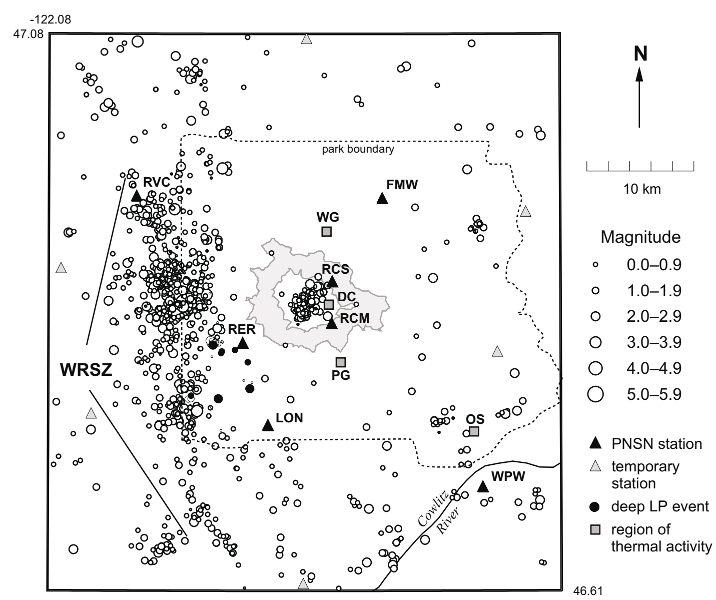

Figure 5. Seismicity in the area surrounding Mount Rainier. Dark triangles are permanent PNSN stations; gray triangles are temporary stations run during 1995–1996. Hollow circles are earthquakes; solid black circles show locations of deep, long-period events; gray squares correspond to off-summit geothermal fields. DC, Disappointment Cleaver; WG, Winthrop Glacier; PG, Paradise Glacier; OS, Ohanapecosh Hot Springs; LON, Longmire; WRSZ, Western Rainier seismic zone. *Modified from Moran and others (2000).*

earthquake occurrence in association with hydrothermal circulation within and below the base of the edifice, which serves to weaken rock and/or reduce effective stress to the point that gravity-induced slip can occur. These and other events were also used to invert for P-wave velocity structure beneath Mount Rainier. The resulting images show a broad region of slightly reduced velocities at depths of 4–14 km, possibly indicating the presence of a volume of hot rock with small amounts of magma and/or magmatic fluids. This volume could be the source for heat and magmatic fluids that feed existing surface fumarole fields.

Reference: Moran, S. C.; Zimbelman, D. R.; Malone, S. D., 2000, A model for the magmatic–hydrothermal system at Mount Rainier, Washington, from seismic and geochemical observations: Bulletin of Volcanology, v. 61, p. 425-436.

AN AUTOMATED LAHAR-DETECTION SYSTEM FOR THE CARBON AND PUYALLUP RIVERS, WA

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To reduce the risk from lahars in the Carbon and Puyallup River valleys from a catastrophic flank collapse at Mount Rainier, the U.S. Geological Survey and the Pierce County Department of Emergency Management have begun a 2-year pilot project to install and operate an automated lahar detection system. With the cooperation of the City of Orting, Plum Creek Logging, and Champion Pacific, a set of five lahar sensors was placed in each drainage in 1998. As a lahar front passes the sensors, the ground vibration from the flow will trigger each sensor sequentially. Additionally, two of the sensors in each set act as “dead-men”. They will be destroyed by any sizeable lahar and the system will note the cessation of their transmissions. Data from the sensors are telemetered to computers at the Washington Department of Emergency Management at Camp Murray and the Tacoma–Pierce County Law Enforcement Support Agency in Tacoma. The computers monitor the data and will sound an alarm when the proper sequence of events indicates that a lahar is en route. It is estimated that a lahar could reach the present confluence of the Puyallup and Carbon River valleys in as little as 30 minutes after detection.

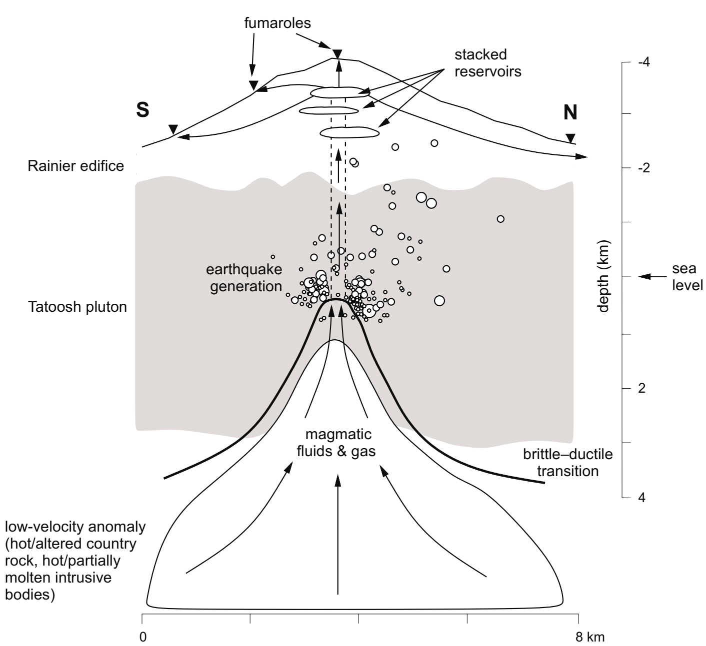

Figure 6. Diagram showing rising fluids in a conceptual model of the magmatic-hydrothermal system beneath Mount Rainier, derived from geochemical and seismic constraints. *Modified from Moran and others (2000).*

PROBABILITIES OF MOUNT RAINIER TEPHRA ERUPTIONS

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Most analyses of eruption probabilities assume that the probability of a volcanic eruption may be treated as a Poisson process. Time histories for some volcanoes match this assumption well. In some cases, however, the time history contains disparate time intervals between eruptions, with some being short and others being much longer. Mullineaux’s (1974) data for ages of tephra layers at Mount Rainier have three intervals >2000 years punctuated by seven that are <600 years. The exponential distribution for a Poisson process for the probability that an eruption will occur within some time period does not represent clumped data well. An alternate distribution is the double exponential. The basic notion is that there are two states, one involving short intervals and a second involving long intervals. The probability of an eruption occurring in each of these states is governed by an exponential distribution. This double-exponential distribution matches the available data well and resolves a conceptual problem for volcanoes with clumped eruption time intervals. Probability for a 30-year time period calculated using the double exponential of tephra eruptions for Mount Rainier is twice that for the single exponential.

Reference: Mullineaux, D. R., 1974, Pumice and other pyroclastic deposits in Mount Rainier National Park, Washington: U.S. Geological Survey Bulletin 1326, 83 p.

TEMPORAL AND SPATIAL VARIATION OF GLACIERS ON MOUNT RAINIER

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Analyses of the database of glacial cover on Mount Rainier indicate a decrease in the total area of 18.5 percent (112.4–91.6 km^2) on the maps of Mount Rainier surveyed dating 1913 and 1962. This is a decrease in area of about 0.36 km^2 per year. From 1971 to 1994, the rate of shrinkage of glaciers significantly slowed. The total area measured on the 1994 USGS Digital Line Graphs is 90.4 km^2, which represents a rate of loss of 0.05 km^2/yr since 1971. Comparing the changes around the mountain between 1913 and 1994, the southeastern and southwestern glaciers have decreased the most (31.5% and 28.2% of their total area), while the northwestern and the northeastern glaciers have decreased by 21.1 and 19.6 percent of their total area. Measured and estimated volumes for all the glaciers of Mount Rainier also decreased. From 1913 to 1971, the volume decreased 22.7 percent from 5.62 to 4.34 km^3 and from 1971 to 1994, decreased 3.1 percent to 4.21 km^3. About a third of the total loss of volume between 1913 and 1994 occurred in the northeastern glaciers, while the southwestern, southeastern and northwestern glaciers decreased by 22.2 percent, 23.7 percent, and 21.5 percent, respectively, of the total volume. This is opposite to the change in area, except for the northwestern glaciers. There are three plausible explanations for the spatial and temporal variation of the glaciers: differences in response time to small changes in mass balance, percentage of debris cover, and variations in solar radiation due to differences in cloud cover.

BURIED FORESTS OF MOUNT RAINIER VOLCANO—EVIDENCE FOR EXTENSIVE HOLOCENE INUNDATION BY LAHARS IN THE WHITE, PUYALLUP, NISQUALLY, AND COWLITZ RIVER VALLEYS

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Buried trees exist in every major river valley that drains Mount Rainier. Lahars and episodic sedimentation via laharic flooding have buried forests as far downstream as Puget Sound and Toledo. This subfossil wood can be dated with ^{14}C and/or dendrochronology and can also provide valuable paleoclimate data. Previous reports document buried forests about 5000, 2600, 2300, and 600 radiocarbon years old. Ages of recently exhumed forests in the Duwamish River valley indicate that lahars inundated significant areas of that valley and possibly parts of the Puyallup River valley about 1600? and 1100 years ago (^{14}C) (Fig. 7). Trees in the lower Cowlitz River valley were buried about 2900 and 200 years ago, but it is not clear if the sedimentation was triggered by a volcanic eruption at Mount Rainier. These buried forests provide more evidence that eruptions from Mount Rainier have been more frequent, and resultant laharic flooding and aggradation more extensive, than previously thought and demonstrate the long-term trend of significant and, at times, catastrophic aggradation in river valleys downstream of stratovolcanoes.

Figure 7. View to the east of a tree stump (lower right center) that was buried in a pumiceous volcanic sand deposit (lahar runout) in Auburn, Wash. The sand, which extends as far as the Port of Seattle, was deposited by a lahar that was triggered by an eruption at Mount Rainier. Radiocarbon dating of rings from the outer wood yielded an age of about 1100 years before present.

3-D EDIFICE STABILITY OF MOUNT RAINIER, WA

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Massive slope failures have affected the edifice and surrounding valleys of Mount Rainier, and the consequences of future failures may be severe. We use a 3-D slope stability model to examine edifice instability resulting from the interplay between topography, potential failure surfaces, and the 3-D distribution of rock strength. We evaluate the potential for large ($> 0.1\ km^3$) gravitationally induced landslides using three scenarios. Our initial scenario, using homogeneous rock properties, examines instability induced by topography alone. In this case, the least stable portion of the edifice is predicted in the steep, north-facing Willis Wall, an area where few large landslides have originated. Our second scenario incorporates variations in strength caused by the hydrothermal alteration of volcanic rocks. Using geologic mapping, we divide the edifice into four units: strong basement rocks; relatively strong, fresh volcanic flows and breccias; slightly weaker, lightly altered rocks; and weak, highly altered rocks. In this scenario, the west-facing Sunset Amphitheater is predicted as the least stable; many past failures have originated from this area. In our third scenario we build on the second scenario by adding the 3-D geologic complexity of the large subsurface Osceola failure scar, where newer volcanic rocks overlie older altered rocks. This model predicts some reduced stability of the eastern flank, although the overall least stable region is still the Sunset Amphitheater area.

THE GEOLOGIC HISTORY OF MOUNT RAINIER VOLCANO, WASHINGTON

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Mount Rainier (MR) volcano is composed of andesite and dacite lava flows with subordinate pyroclastic flow deposits. Unlike nearby Mount St. Helens, lava domes and pumice falls are of negligible volume. Average MR lava and pumice are 61.8 weight percent SiO (andesite) and 64.2 weight percent SiO (dacite), respectively. Pyroclastic flows are not distinct in composition from lavas. Modern MR began to form close to 500 ka atop the extensively eroded remains of an ancestral volcano that shed the lahars and pyroclastic flows of the voluminous Lily Creek Formation, dated at 1.2 and 1.3 Ma. Eruptive activity moderated after about 1 Ma, but did not cease entirely, and then increased substantially subsequent to 500 ka, leaving a voluminous and nearly continuous volcanic record through the Holocene. Two episodes of heightened eruptive activity, 500 to 420 ka and 280 to 190 ka, marked the emplacement of an approximately east–west radial dike system, the eruption from flank vents of the most voluminous individual lavas, and (probably) the formation of most flank hydrothermal alteration. Lavas erupted between 40 and 6 ka are confined to the upper south flank of MR and may fill a south-facing collapse crater. Volume estimates indicated an integrated eruptive rate of 0.4 km^3/ka (±0.1) for the south-flank lavas. The altered and faulted ENE flank of MR collapsed at 5.6 ka, forming the Osceola mudflow. Subsequent eruptions nearly filled that crater and volume estimates for it indicate a similar integrated eruption rate of 0.35 km^3/ka (±0.1).

THE BURROUGHS MOUNTAIN LAVA FLOW, MOUNT RAINIER, WA

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The andesite of Burroughs Mountain is representative of large volume andesite-dacite lavas erupted from flank vents on

Mount Rainier. The 3.4 km^3 lava conformably overlies andesitic block and ash-flow tuffs. The aims of our study are to understand the processes that create voluminous andesitic magmas and that lead to their explosive or effusive eruption. Samples of the lava and juvenile block and ash-flow clasts are chemically similar, despite differing eruptive styles, and range from 56.4 to 64.3 weight percent SiO and from 2.4 to 4.9 weight percent MgO. Absence of geographic compositional zoning in the lava and similarity with the pyroclastic deposits suggest that ascent and degassing processes, rather than a zoned magma reservoir, led to the differing eruptive styles. Our working model is that the pyroclastic flows erupted from a summit vent, and the lava then erupted from a radial dike, having vented its gas complement through the previously opened summit conduit system. The major element compositions of lava and tuff samples vary systematically, consistent with fractional crystallization, but incompatible trace element contents vary widely at constant apparent degrees of differentiation. This scattered variation of incompatible trace elements indicates that the magma reservoir was assembled from multiple parent magmas, perhaps from differing sources or involving differing degrees of assimilation, and that there was insufficient time for the magma to become homogenized or develop systematic compositional zoning before it erupted.

HOLOCENE ERUPTIVE HISTORY OF MOUNT RAINIER

James W. Vallance (james@fuego.civil.mcgill.ca), McGill University, Montreal, PQ; Susan Donoghue, University of Hong Kong

In Holocene time, Mount Rainier erupted 11 vesicular tephras and 20 to 25 nonvesicular tephras. The vesicular tephras contain pumice, scoria, or both and range in volume from 1 to 100 million m^3. The sand- and silt-sized tephras comprise a mixture of juvenile black vitric pyroclasts, dark gray lithic (juvenile and accessory) fragments, and subordinate amounts of pumice. Analysis of glass in vitric pyroclasts shows an unusually wide range of pyroclast compositions within eruptives and between eruptives. These fine-grained tephras are widespread and represent a significant part of the Holocene eruptive history of Mount Rainier. The silt-sized tephras are glass rich and up to four appear to be associated with pyroclastic flows. Many of the sand-sized tephras correspond with periods of effusive cone building. Some of the nonvesicular tephras are part of eruption sequences that include vesicular tephras, and others represent discrete eruptions. Mount Rainier has erupted about 20 times beginning about 9,700 yr B.P. Multiple eruptions occurred from 6,800 to 5,000 yr B.P. About 5,000 yr B.P., phreatomagmatic eruptions culminated in the formation of the Osceola mudflow. Cone building ensued between 5,000 and 4,500 yr B.P. More recent notable eruptions include four to five between 2,600 and 2,200 yr B.P., two at about 1,000 yr B.P., one at about 500 yr B.P., and one at about A.D. 1850.

SIGNIFICANCE OF ROCK STRENGTH RESULTS AND SLOPE STABILITY CALCULATIONS TO EDIFICE AND FLANK INSTABILITY AT MOUNT RAINIER

Robert J. Watters (watters@mines.unr.edu) and Steve D. Bowman, University of Nevada, Reno, NV; David R. Zimbelman, G.O.Logic, White Salmon, WA; James K. Crowley, U.S. Geological Survey, Reston, VA

Rock strength results from field and laboratory studies permit using the strength of surface rocks to determine the confined rock mass strength for potential failure surfaces and the corresponding slope factor of safety (FOS). The strength results indicate that nonuniform rock mass strengths, consisting of relatively stronger and weaker rock masses, are normal on the volcano. Slope stability calculations from two areas where historical instability has occurred and one from one relatively stable area provide examples: 1) The Sunset Amphitheater area, where instability is common within altered and faulted rock; 2) Little Tahoma Peak, where major discontinuities and altered rock exist and the site of a large rock avalanche in 1963; and 3) The Willis Wall, an approximately 1000 m headwall where slope angles exceed 50 degrees. Preliminary stability calculations indicate that the lowest FOS values, between 1.0 and 1.3, occur at Little Tahoma Peak and Sunset Amphitheater, and the highest FOS values, 1.2 to 1.6, occur in the Willis Wall region. These results indicate that Sunset Amphitheater and Little Tahoma Peak are marginally stable and at high risk for future instability.

NON-UNIFORM DISTRIBUTION OF VOLCANIC HAZARDS, MOUNT RAINIER

David R. Zimbelman (hazard@gorge.net), G.O.Logic, White Salmon, WA; Robert J. Watters, University of Nevada, Reno, NV; James K. Crowley and Robert O. Rye, U.S. Geological Survey, Reston, VA

All of the geologic features necessary for large edifice-collapse events are in place at Mount Rainier volcano. However, results from geologic mapping, remote sensing, geotechnical, and geochemical studies show that geologic features controlling the most potentially destructive volcanic hazard types occur non-uniformly. In a general sense, the east and west sectors of the volcano are more deeply dissected by glaciers, have hosted numerous historic debris avalanches and flows, and contain active fumaroles, large areas of hydrothermally altered rock, near-vertical fracture systems, and radial dikes. In contrast, the north and south sectors generally lack these features and have hosted fewer collapse events. Rainier's young summit cone contains two overlapping, east–west-aligned craters and active fumaroles with magmatic components, suggesting that the geologic controls on the active hydrothermal system generally mimic controls on past events. Risk mitigation efforts will be most effective when they reflect the non-uniform distribution of the geologic controls on volcanic hazards, a consideration that increases in importance closer to the volcano.

Related Websites

USGS/Cascades Volcano Observatory
http://vulcan.wr.usgs.gov/Volcanoes/Rainier/framework.html

Mount Rainier National Park home page
http://www.nps.gov/mora/ ■

Great Cascadia Earthquake Tricentennial

The proceedings and abstract volume "Penrose Conference 2000, Great Cascadia Earthquake Tricentennial, Program Summary and Abstracts", Oregon Department of Geology and Mineral Industries, Special Paper 33, is now available for $15 from the Nature of the Northwest Information Center, 800 NE Oregon St., #5, Portland, OR 97232, (503) 872-2750, and the DOGAMI field offices in Baker City and Grants Pass. See http://sarvis.dogami.state.or.us/store/press/38-PenroseConf.htm. The volume will be released in Canada next month as Geological Survey of Canada Open-File Report 3938. See http://www.nrcan.gc.ca/gsc/.

EARTH CONNECTIONS

Resources For Teaching Earth Science

HILLS, SCALES, AND HIKING TRAILS

BACKGROUND AND PURPOSE:

Contour lines connect a series of points of equal elevation measured from mean sea level. Lines that are closely spaced indicate steep slopes, lines that are farther apart indicate gentler slopes. Geology and geomorphic processes control the formation of different natural features. Every map needs a north arrow (usually pointing toward the top of the map) for orientation and a scale for estimation of distances. This lesson will teach you to recognize topographic features and human-made structures. The accompanying map sections were both taken from the U.S. Geological Survey Snoqualmie Pass 7½-minute (1:24,000-scale) quadrangle.

QUESTIONS

(Use both map sections. Grades 1–5 should answer questions A–D; grades 6–12 should answer A–I.)

A. Name three human-made features represented by symbols on the map. Circle the symbols. (For example, highway, ski lift, house, hiking trail, logging road, footbridge.)

B. Find and name one peak, two lakes, and three creeks or rivers.

C. Using the scale bar, estimate how far you would travel to get from Ski Acres to Snoqualmie Ski Area. In which direction will you be traveling? Which way do both ski areas face?

D. In what direction is Lodge Lake from Ski Acres?

E. Find the ridge immediately west of the ski areas. What is the elevation of the highest point of this ridge? Why is this important?

F. Describe some differences between the east and west slopes of the ridge at this location.

G. Cliffs usually form in rock. Do you see any cliffs along the ridge? Which way do they face?

H. Look at the top map section of the Middle Fork of the Snoqualmie River. What can you say about the shape of the valley (across the valley)? (Hint: consider the difference between closely spaced and widely spaced contour lines.) Try drawing a profile of the valley shape. What might have caused this valley shape?

I. Using the scale, estimate how far it is along the hiking trail from Goldmyer Hot Springs to the wilderness boundary just east of Rock Creek. If your hiking speed averages 2 miles per hour (faster downhill, slower uphill), how long will it take you to get there? Which direction would take you less time?

DISCUSSION

1. How do landforms control land uses?

2. Where is it easier to build roads, and what are some of the effects of how and where we build roads?

3. What areas of the map would be safer for home sites and why? What areas are unsafe and why?

4. Note how some valleys have U-shaped bottoms and some have V-shaped bottoms. What geologic or geomorphic processes might cause these differences?

5. Why is it important to have the radio tower located on the ridge?

6. Use maps to estimate travel times and discuss types of terrain encountered.

ESSENTIAL SCIENCE LEARNING BENCHMARKS

1.1 Students will use properties to identify, describe and categorize landforms.
1.2 Students will recognize the components, structure, and interconnections of patterns among major landforms.

GRADE LEVELS

1st–12th grades

SUBJECTS

Geography
Earth science

CONCEPTS

Identifying geologic and human features on topographic maps.

SKILLS

Identifying patterns and relationships and interpreting maps.

OBJECTIVES

Students will become familiar with map use and orientation.

TIME NEEDED

45 minutes

THERE IS NOTHING WHICH CAN BETTER DESERVE OUR PATRONAGE THAN THE PROMOTION OF SCIENCE AND LITERATURE. KNOWLEDGE IS IN EVERY COUNTRY THE SUREST BASIS OF PUBLIC HAPPINESS.

George Washington, address to Congress, January 8, 1790

Lesson created by:
Wendy Gerstel
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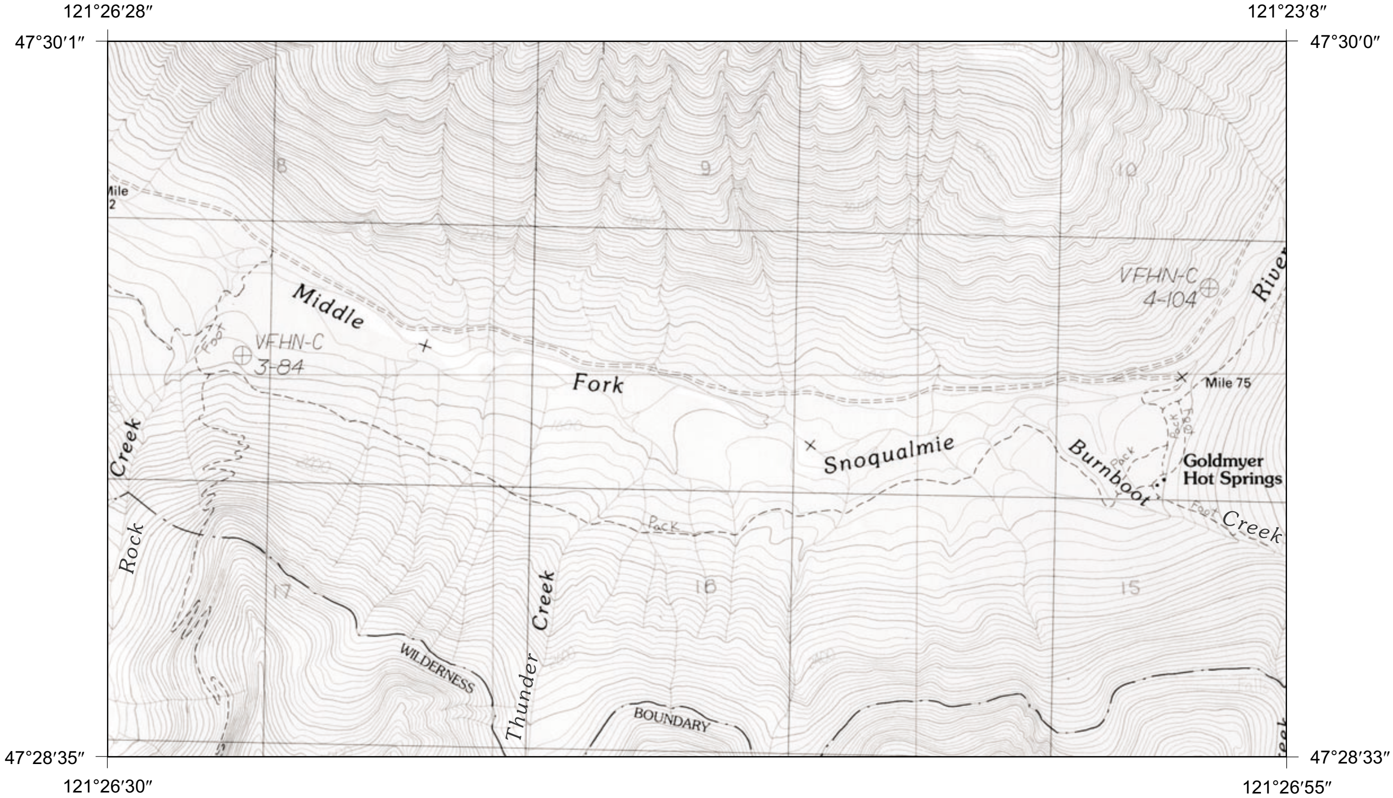
PO Box 47007
Olympia, WA 98405-7007
e-mail: geology@wadnr.gov

Earth Connections No. 3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47°30′1″
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Middle
Fork
Snoqualmie
River
VFHN-C
3-84
VFHN-C
4-104
Mile 75
Goldmyer
Hot Springs
Burnboot
Creek
Rock
Creek
Thunder Creek
WILDERNESS
BOUNDARY
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9
10
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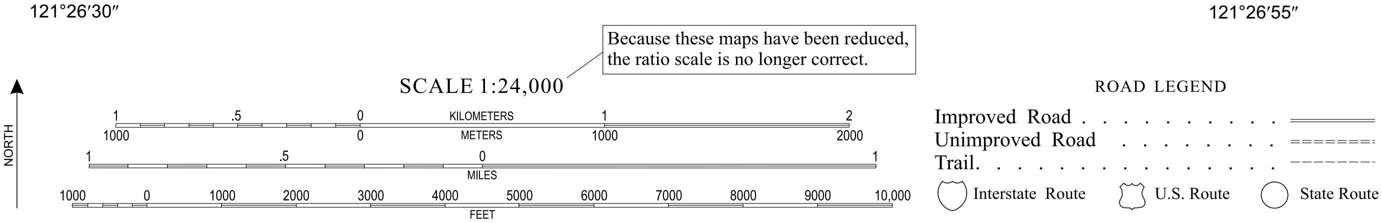
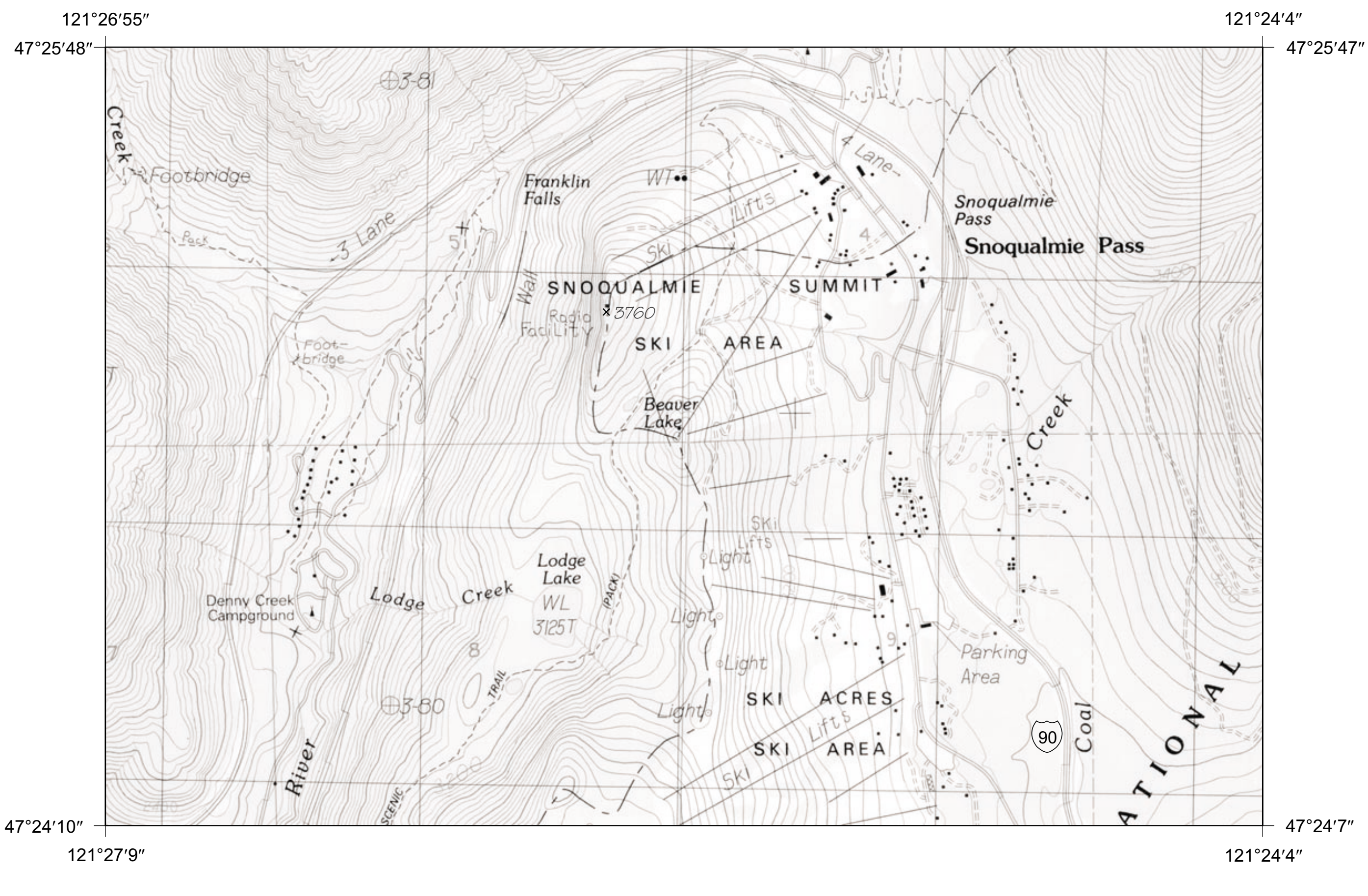

Because these maps have been reduced, the ratio scale is no longer correct.
SCALE 1:24,000
NORTH
KILOMETERS
METERS
MILES
FEET
ROAD LEGEND
Improved Road
Unimproved Road
Trail
Interstate Route
U.S. Route
State Route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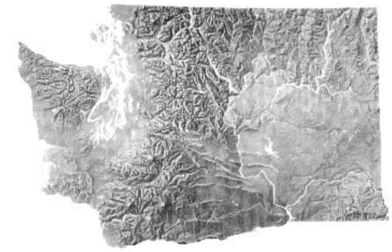
47°24′7″
121°27′9″
121°24′4″
Franklin
Falls
Snoqualmie
Pass
Snoqualmie Pass
4 Lane
3 Lane
SNOQUALMIE SUMMIT
SKI AREA
Radio
Facility
3760
Beaver
Lake
Footbridge
Foot-
bridge
Lodge
Lake
WL
3125T
Denny Creek
Campground
Lodge Creek
SKI ACRES
SKI AREA
Parking
Area
90
Coal
Creek
River
ATIONAL

EARTH CONNECTIONS

Resources For Teaching Earth Science



VIRTUAL VACATION

BACKGROUND:

If you were unable to go very far for your summer vacation, a short geologic interlude is awaiting you on the Internet (your local library may have access). Visit the national parks and explore their geologic wonders on a 'virtual' vacation!

Complete the following data sheet and give it to your teacher to let him or her know you are having fun exploring the geology of your national parks. You may photocopy the data sheet for each park visited on the Internet.

And send a copy to *Washington Geology*; PO Box 47007; Olympia, WA 98504-7007, or e-mail it to geology@wadnr.gov. The best geologic exploration(s) submitted before the end of November 2000 may be published in a future edition of *Earth Connections*.

PROCEDURE:

Begin your journey at the Internet website for national parks—http://www.nps.gov/

Select *Nature Net: Natural Resources in the Park*; then select *Geology* for a list of park programs; then select *Park Geology Tour* for a variety of geologic topics. Select the one that interests you most (like volcanoes, glaciers, fossils, etc.).You will be shown a lists of parks that have the geologic topic selected. Many national parks are listed under more than one of the geologic topics, for example, Mount Rainier, Washington, can be accessed through glaciers or volcanoes. Select the park you are interested in learning more about. Complete the data sheet and submit it as mentioned above.

DATA SHEET

Student name ______________________ Grade ______ Age ______

School ______________________ City ______________ State ______

Park name ______________________________ State ______________

Geologic features present (glaciers, volcanoes, fossils, etc.) ______________________

____

____

Draw (*and attach to this data sheet)* a picture of your favorite geologic feature or a map of the location of your park within a state.

What is the age of the feature(s)? ______________________________
(For example, the date of the last eruption of a volcano or the age of fossils)

What are some interesting connections between the biologic communities and the geology of this park that you learned from this vacation? (For example, how long it took plants to start to grow around Mount St. Helens after the 1980 eruption.)

____

____

____

If you were planning this for a family vacation, what modes of transportation would be necessary for you to get to the park gate?

____

____

ESSENTIAL SCIENCE LEARNING BENCHMARKS

1.1 Students will use properties to identify, describe and categorize landforms.

1.3 The student understands that science and technology are human endeavors, interrelated to each other, to society and to the workplace.

GRADE LEVELS

4th–8th grades

SUBJECTS

Earth science
Biological science

CONCEPTS

Earth science landforms may vary from park to park. National Parks hold many different landforms. The biotic and abiotic communities have different connections between them in various parks.

SKILLS

Using technology to acquire information; categorizing landforms.

OBJECTIVE

Students will use the Internet to research a particular national park and write about the geologic features present.

TIME NEEDED

20 minutes of Internet time

IT'S MORE IMPORTANT TO PAVE THE WAY FOR THE CHILD TO WANT TO KNOW, THAN TO PUT HIM OR HER ON A DIET OF FACTS.

Rachel Carson

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and Earth Resources
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Earth Connections No. 3

Resources For Educators

Washington State Science Teachers Association Conference, October 12–14, 2000, Vancouver, WA. Topics include teaching elementary science using kits and technology, assessing student learning, how children learn, and how technology shapes our world. Field trips include nearby natural areas, testing labs, research and development facilities, and model schools. (http://www.wsta.net)

Science Olympiad is an international nonprofit organization devoted to improving the quality of science education, increasing student interest in science, and providing recognition for outstanding achievement in science education by both students and teachers. Goals are accomplished through classroom activities, research training workshops, and the encouragement of intramural, district, and regional, state, and national tournaments. (http://www.macomb.k12.mi.us/ims/cr/science/so/nsoly/index2.htm)

Washington Science Olympiad will be conducting the 16th annual competitions for middle and high schools in 2001. Non-competitive Science Olympiad activities are available for the elementary level. There were over 150 teams from all parts of the state involved in the 1999 competitions.

The middle and upper divisions of the Science Olympiad are academic, interscholastic competitions designed to increase student interest in science and improve on the quality of science education. The emphasis on active involvement, relevance, problem-solving, and process skills. The Science Olympiad tournament consists of 32 events encompassing the entire spectrum of science disciplines. Included are biology, earth science, chemistry, physics, technology, and engineering. Some events require knowledge of facts and concepts, while others rely on processes, skills, or applications. Creativity, team work, and cooperative problem-solving are part of every event.

Teams begin preparing in the fall for the competition. Six regional tournaments are held throughout the state during March. Team placement at these tournaments determines advancement to the state level of competition held in April. State winners move on to compete at the National Tournament in Colorado Springs, CO, May 18–19, 2001. (http://www.members.home.com/wascioly/)

Water Ways is a dynamic intra-disciplinary curriculum that gives middle school students an opportunity to explore the Spokane–Coeur d'Alene watershed. The teacher tool kit includes a 30″ x 40″ satellite map of the Spokane–Coeur d'Alene watershed and a teacher's guide designed and written by local teachers. Contact Debbie Boswell at The Lands Council; 517 S. Division; Spokane, WA 99202; (509) 838-4912, (509) 838-5155 fax, or DBoswell@landscouncil.org to obtain the *free* Water Ways curriculum materials. (http://www.landscouncil.org/alerts/wways.htm and http://www.lsw.org/scd)

Gateway to Educational Materials allows teachers to type a topic, grade level, and other information to search for and retrieve lessons, instructional units and other *free* educational materials specific to grade level and topic from more than 140 websites. (http://www.thegateway.org)

Federal Resources for Educational Excellence (FREE) offers free learning resources from the federal government. It has links to information on the arts, educational technology, foreign languages, health and safety, language arts, mathematics, physical education, science, social studies, and vocational education. Kids Corner has information on threatened and endangered species. In addition to providing fact sheets, activities, and suggestions about what kids can do to help, the site links to the Endangered Species Program website, where you'll find descriptions and images of threatened and endangered species, announcements of additions to the lists of threatened and endangered species, and information on programs and activities. (http://www.ed.gov/free/)

The Learning Space is an online learning community of teachers in Washington State with over 570 participants and is a collaboration of US West, NEA Teacher Network, NEA, University of Washington, Washington State University, OSPI, and Kent School District. (http://www.learningspace.org)

Well Connected Educator is the online publishing center and forum for the K–12 community to read, write, and talk about education technology. (http://www.techlearning.com)

Olympic National Park has education links and classroom mini-lessons about geology, plants, animals, tribes, and more. Contact Olympic National Park, 600 E. Park Ave., Port Angeles, WA 98362-6798, (360) 452-4501. (http://www.nps.gov/olym/home.htm)

Washington State Department of Natural Resources has presentations and speakers available on request. For more information, contact (360) 902-2100 or http://www.wa.gov/dnr/.

"Trees to Seas: Journey of the Wild Salmon" board game is available as a downloadable PDF file at http://www.wa.gov/dnr/htdocs/rp/urban/game/index.htm.

Fire Prevention curriculum for K–3 students uses Smokey the Bear to introduce skills necessary for more advanced fire-related science, language, and mathematics, and the life skills necessary to be fire safe adults. Activities and assessments are tied to learnings and lesson plans for grades 4–12. To receive a free copy, call 1-800-527-3305, ext. 0, or e-mail Fire_prevention@wadnr.gov. (http://www.wa.gov/dnr/base/rec-edu.html)

The Burke Museum offers kits for teachers on topics ranging from Pacific Northwest cultures to life sciences, with six kits devoted to earth science. The kits are portable boxes of specimens, background information, and a description of the items in the box. Some kits have additional resources. Kits rent for $20 a week or $25 for two weeks, tax included. Payment may be cash, check, or money order. Reserve kits by calling (206) 543-5591. Pick up kits from 9:00 am to 5:00 pm, Monday through Friday, or on weekends by arrangement. If the kit is to be mailed, there are additional fees and the renter pays return postage. (http://www.washington.edu/burkemuseum/education.html)

Ice Age Floods Institute Field Trips

September 21, 2000; 8:00 am to 5:00 pm
CREHST, 95 Lee Blvd; Richland, Washington

Trip is planned to cover Wallula Gap and Palouse Falls, plus many of the features in between, such as Washtucna Coulee, Devils Canyon and Snake River gravel bars.

September 28, 2000; 8:00 am to 5:00 pm
Edgewater Resort, 56 Bridge St.; Sandpoint, Idaho

Trip will feature the site of the Ice Dam and the immediate effects of the outburst from Glacial Lake Missoula, what lies beneath Lake Pend Oreille, the features left by the outburst over Farragut State Park and on across Rathdrum Prairie, and the formation of many of the smaller lakes in the area. Preregister by Sept. 21.

A fee of $20 for each of the tours covers bus transportation, box lunch, refreshments, and guidebook. A number of seats will be reserved for K–12 teachers. Teachers need not be Institute members, but must preregister and pay the tour fee.

The Mineral Information Institute's mission is to increase mineral literacy among school-age youth. They will mail Teacher Helper packets to teachers on request. (http://www.mii.org)

Resource-World.Net is an educational site designed to give viewers a greater appreciation for where the materials we depend upon for every day life come from and the processes involved in making them. You may select an element from the periodic table and learn about its properties, history, uses, and sources. You may select from a number of common consumer items and learn about the raw materials that go into them. In the future, you will be able to select a mineral commodity and learn where it comes from, how it is formed, and where it is used. (http://www.resource-world.net) ■

BOOK REVIEW: Geology of the North Cascades—A Mountain Mosaic

by Rowland Tabor and Ralph Haugerud
Published by The Mountaineers
1001 SW Klickitat Way, Suite 201
Seattle, WA 98134
mbooks@mountaineers.org
www.mountaineersbooks.org
ISBN 0-89886-623-5 $19.95 U.S.

Imagine being led to magnificent vistas where you can see ancient seas team with life, volcanoes erupt, continents collide, and glaciers grow and shrink with time-lapse speed! In *Geology of the North Cascades—A Mountain Mosaic*, geologists Rowland Tabor and Ralph Haugerud escort us to those viewpoints via some first-class descriptive geology. These two geologists have spent decades exploring the canyons and peaks of the region and unraveling its obscure, tortured, and dynamic geologic history. The resulting interpretations weave a rich tapestry of mountains, rocks, and the geologic forces that have created and are still modifying the North Cascades. Their entertaining and readable field guide is filled with memorable metaphors and is effectively illustrated with numerous sketches and maps that make the geologic story accessible to anyone with a basic interest in geology. It is a great tool for teachers and students alike.

Tabor and Haugerud begin their personalized field trip with a geologic primer, a straightforward overview of basic geology, geologic time, plate tectonics, volcanism, and erosional processes—all of which have acted in concert to create the spectacular and complicated North Cascades. After reviewing the history of thought about the geologic forces that created the Cascade Range, including the pioneering work of Peter Misch, the authors lay out the geologic evidence discovered by numerous researchers, including themselves, piece by piece as if they were assembling a quilt with contributions from many different weavers.

More than 110 diagrams, such as a north–south transect through the Cascade Range (fig. 6), give the reader insight into the scenery as well as a glimpse of the underlying geologic structure. Figure 19, for example, is a beautifully simple portrayal of the three major birthplaces of rocks—the continental, oceanic, and volcanic-arc environments. Anne Crowder and Ed Hanson drew many of the fine sketches, and many more are by the authors or from other sources.

Tabor and Haugerud are adept at moving us smoothly from the simple to the complex. On pages 16 and 17, we amble through a discussion of the structure of the Earth, and by page 21, we are ascending comfortably through the mixed-up rocks of the Bell Pass mélange. We learn to think "big" about the forces that have created these mountains, this "stack of odd bedfellows". The Easton terrane is a "geologic baked Alaska" whose rocks were quickly buried to great depths and then uplifted in the blink of a geologic eye before being warmed too much. We are reminded that the Earth's crust is in constant motion—*Buchia* clams found at more than 6,300 ft elevation at Excelsior Ridge (p. 94), for example, provide dramatic evidence of great dislocations of rock.

Along our journey, Tabor and Haugerud employ a variety of vivid and enjoyable metaphors to simplify the complicated geology and help the reader to visualize and remember the geological processes. Large bodies of molten rock that bind fault zones are "...stitching plutons. The younger ones embroider the already stitched-together terrane mosaic". In an orthogneiss, "...the dark minerals are somewhat aligned, like fish in the current of a stream." Rocks are foliated "like pages in a book" or lineated "like pasta in a package of uncooked spaghetti". Deforming an igneous rock full of flat and elongate crystals is like "mushing out a mixture of pennies...and nails...in taffy". And the authors don't pull any punches or miss a chance to pull our leg—if a trail "lacks rock excitement", we hear about it!

Rock masses sliding and deforming through geologic time aren't the only processes that fascinate the authors. They are also awed by ice-age glaciation and its deposits, as well as by the compelling evidence of more recent geologic events, such as the "Great Fill" of the Suiattle River caused by a large eruption of Glacier Peak volcano some 5,000 years ago and the large, probably earthquake-triggered Church Mountain rockslide–debris avalanche. It is clear to the reader that the North Cascades landscape is still in motion!

To provide details about the geology of specific sites or areas, the authors have included more than 100 "geologic notes" that are conveniently organized by major rivers, beginning with the Skagit and ending at the Methow. All of the major sites are keyed to a shaded relief "points of interest" map generated from digital information at a very usable scale of 1:180,000. This map is contained in an insert that also features color photographs and a color geologic map of the area (~1:575,000 scale). Informative sidebars are scattered throughout the book and include such titles as "Making sense of metamorphic rocks and terranes in general", "Paleomagnetism: Finding a rock's place of birth", and "Making granite and its relatives". An index and six-page glossary help the reader navigate through the book's challenging verbal terrain, and six pages of references point to additional trails of information for the curious and adventurous. Overall, the compartmentalization and resources of this book make it a good reference volume, because you can read it bit by bit.

If I have waxed poetic about *Geology of the North Cascades—A Mountain Mosaic*, it's because the book is *that* good. Where else could we gather such insights about the trails we hike than this virtual guided tour by two geologists whose passion has led them to ponder these ancient Earth environments preserved in rock and sediment!? The numerous sketches, diagrams, and maps make mountains, metamorphic rocks, and plate tectonics come to life. Tabor and Haugerud not only share their favorite trails and viewpoints, but also teach us to read the rocks and understand the scenery in terms of its underlying form. Along the way, they conquer one of the most formidable peaks in Northwest writing—unveiling the secrets of the very complicated geology of the North Cascades for the hiker and geologic civilian in an entertaining, readable, and well-organized guidebook.

Patrick T. Pringle
Washington Division of Geology and Earth Resources

FOSSILS ON FEDERAL AND INDIAN LANDS

The U.S. Department of the Interior has delivered a report on "Fossils on Federal and Indian Lands" to Congress. The entire report can be seen at www.doi.gov/fossil/fossilreport.htm.

Geologist Registration Bill Passes

The 2000 legislature has enacted a geologist registration bill after several decades of failing to pass similar legislation. The bill creates a geologist registration board within the Department of Licensing. Administrator for the program will be Margaret Epting. Inquiries should be directed to her at:

Margaret Epting, Administrator
Geologist Licensing Board
Washington Department of Licensing
PO Box 9045, Olympia, WA 98507-9045
phone: 360-664-1386; *fax:* 360-664-2551
e-mail: mepting@dol.wa.gov
website: www.wa.gov/dol/bpd/geofront. htm

Before the registration program can go into effect, however, the Department of Licensing must have authority to levy a registration fee. Initiative 695, which was passed by voters in November, requires a public vote on new fees or taxes. State election officials are preparing a referendum for the November ballot that would ask voters to give the Department of Licensing that authority.

In March, however, I-695 was ruled unconstitutional in King County Superior Court. That decision was appealed to the Washington Supreme Court, which heard oral arguments on June 29. If the Superior Court decision is upheld, or if the court grants an exemption, geologists will be required to be registered to practice geology in Washington beginning July 1, 2001. Otherwise, geologist registration will be subject to a statewide vote on November 7, 2000.

The text of the bill follows. The official text may be found at the website http://www.leg.wa.gov/pub/billinfo/1999-00/senate/6450-6474/6455-s_sl_04032000.txt.

Signing ceremony for the Washington Geologists Licensure Act (ESSB 6455), which establishes licensure for geologists, engineering geologists, and hydrologists in Washington. Left to right: Mike Ryherd (lobbyist), Art Coulters (retired geologist), Senator Georgia Gardner (prime sponsor), Ken Neal, Gary Locke (Governor), Glen Strachan, Tim Walsh (geologist), Nick Federici (lobbyist), and Glenn Wyatt. *Photo courtesy of the Washington State Senate.*

ENGROSSED SUBSTITUTE SENATE BILL 6455

AS AMENDED BY THE HOUSE

Passed Legislature - 2000 Regular Session

State of Washington 56th Legislature 2000 Regular Session

By Senate Committee on Commerce, Trade, Housing & Financial Institutions (originally sponsored by Senators Gardner, Winsley, Fraser, Shin, Kohl-Welles, Brown, Costa, Fairley, and Jacobsen)

Read first time 02/04/2000

AN ACT Relating to the regulation of geologists; adding a new chapter to Title 18 RCW; prescribing penalties; providing an effective date; and providing for submission of a certain section of this act to a vote of the people.

BE IT ENACTED BY THE LEGISLATURE OF THE STATE OF WASHINGTON:

NEW SECTION. **Sec. 1.** The legislature finds it is in the public interest to regulate the practice of geology to safeguard life, health, and property and to promote the public welfare.

NEW SECTION. **Sec. 2.** (1) It is unlawful for any person to practice, or offer to practice, geology for others in this state, or to use in connection with his or her name or otherwise assume or advertise any title or description tending to convey the impression that he or she is a licensed geologist, or other licensed specialty geologist title, unless the person has been licensed under the provisions of this chapter.

(2) A person shall be construed to practice or offer to practice geology, within the meaning and intent of this chapter, if the person:

(a) Practices any branch of the profession of geology;

(b) By verbal claim, sign, advertisement, letterhead, card, or in any other way represents himself or herself to be a geologist;

(c) Through the use of some other title implies that he or she is a geologist or that he or she is licensed under this chapter; or

(d) Holds himself or herself out as able to perform or does perform any geological services or work recognized by the board as the practice of geology for others.

NEW SECTION. **Sec. 3.** The definitions in this section apply throughout this chapter unless the context clearly requires otherwise.

(1) "Board" means the geologist licensing board.

(2) "Department" means the department of licensing.

(3) "Director" means the director of the department of licensing.

(4) "Engineering geologist" means a geologist who, by reason of his or her knowledge of engineering geology, acquired by education and practical experience, is qualified to engage in the practice of engineering geology, has met the qualifications in engineering geology established under this chapter, and has been issued a license in engineering geology by the board.

(5) "Engineering geology" means a specialty of geology affecting the planning, design, operation, and maintenance of en-

gineering works and other human activities where geological factors and conditions impact the public welfare or the safeguarding of life, health, property, and the environment.

(6) "Geologist" means a person who, by reason of his or her knowledge of geology, mathematics, the environment, and the supporting physical and life sciences, acquired by education and practical experience, has met the qualifications established under this chapter, and has been issued a certificate of licensing as a geologist by the board.

(7) "Geology" means the science that includes: Treatment of the earth and its origin and history, in general; the investigation of the earth's constituent rocks, minerals, solids, fluids, including surface and underground waters, gases, and other materials; and the study of the natural agents, forces, and processes that cause changes in the earth.

(8) "Hydrogeology" means a science that involves the study of the waters of the earth, including the study of the occurrence, circulation, distribution, chemistry, remediation, or quality of water or its role as a natural agent that causes changes in the earth, and the investigation and collection of data concerning waters in the atmosphere or on the surface or in the interior of the earth, including data regarding the interaction of water with other gases, solids, or fluids.

(9) "Licensed specialty geologist" means a licensed geologist who has met the qualifications in a specialty of geology established under this chapter and has been issued a license in that specialty by the board.

(10) "Practice of engineering geology" means performance of geological service or work including but not limited to consultation, investigation, evaluation, planning, geological mapping, and inspection of geological work, and the responsible supervision thereof, the performance of which is related to public welfare or the safeguarding of life, health, property, and the environment, except as otherwise specifically provided by this chapter, and includes but is not limited to the commonly recognized geological practices of construction geology, environmental geology, and urban geology.

(11) "Practice of geology" means performance of geological service or work including but not limited to collection of geological data, consultation, investigation, evaluation, interpreting, planning, geological mapping, or inspection relating to a service or work that applies to geology, and the responsible supervision thereof, the performance of which is related to public welfare or the safeguarding of life, health, property, and the environment, except as otherwise specifically provided by this chapter.

(12) "Practice of geology for others" includes, but is not limited to:

(a) The preparation of geologic reports, documents, or exhibits by any commission, board, department, district, or division of the state or any political subdivision thereof or of any county, city, or other public body, or by the employees or staff members of the commission, board, department, district, or division of the state or any political subdivision thereof or of any county, city, or other public body when the reports, documents, or exhibits are disseminated or made available to the public in such a manner that the public may reasonably be expected to rely thereon or be affected thereby; and

(b) The performance of geological services by any individual, firm, partnership, corporation, or other association or by the employees or staff members thereof, whether or not the principal business of the organization is the practice of geology, which the geological reports, documents, or exhibits constituting the practice of geology are disseminated or made available to the public or any individual or organization in such a manner that the public or individual or combination of individuals may reasonably be expected to rely thereon or be affected thereby. However, geological reports, documents, or exhibits that are prepared by the employees or staff members of any individual, firm, partnership, corporation, or other association or commission, board, department, district, or division of the state or any political subdivision thereof or any county, city, or other public body that are for use solely within such organizations are considered in-house reports, documents, or exhibits and are not the practice of geology for others unless or until the reports are disseminated or made available as set forth in (a) or (b) of this subsection.

(13) "Practice of hydrogeology" means the performance of or offer to perform any hydrogeologic service or work in which the public welfare or the safeguarding of life, health, environment, or property is concerned or involved. This includes the collection of geological data, and consultation, investigation, evaluation, interpretation, planning, or inspection relating to a service or work that applies hydrogeology.

(14) "Responsible charge" means the exercise of fully independent control and direction of geological work or the supervision of such work, and being fully responsible, answerable, accountable, or liable for the results.

(15) "Specialty" means a branch of geology that has been recognized under this chapter for the purposes of licensure. Engineering geology is considered to be a specialty of geology.

(16) "Subordinate" means any person who assists in the practice of geology by a licensed geologist or an exempt person, without assuming the responsible charge of the work.

NEW SECTION. Sec. 4. The state geologist licensing board is created. The board consists of seven members, six of whom shall be appointed by the director, who shall advise the director concerning the administration of this chapter. Of the initial appointments to the board, five shall be actively engaged in the practice of geology for at least ten years, five of which shall have been immediately prior to their appointment to the board. Subsequent to the initial appointments, five members of the board must be geologists licensed under this chapter, two of whom shall be licensed in a specialty of geology recognized under this chapter. Insofar as possible, the composition of the appointed geologists serving on the board shall be generally representative of the occupational distribution of geologists licensed under this chapter. One member of the board must be a member of the general public with no family or business connection with the practice of geology. The supervisor of geology of the department of natural resources is an ex officio member of the board. Members of the board shall be appointed for terms of four years. Terms shall be staggered so that not more than two appointments are scheduled to be made in any calendar year. Members shall hold office until the expiration of the terms for which they were appointed and until their successors have been appointed and have qualified. A board member may be removed for just cause. The director may appoint a new member to fill a vacancy on the board for the remainder of the unexpired term. Each board member shall be entitled to compensation for each day spent conducting official business and to reimbursement for travel expenses in accordance with RCW 43.03.240, 43.03.050, and 43.03.060.

NEW SECTION. Sec. 5. The director has the following authority in administering this chapter:

(1) To adopt, amend, and rescind rules approved by the board as deemed necessary to carry out this chapter;

(2) To adopt fees as provided in RCW 43.24.086;

(3) To administer licensing examinations approved by the board and to adopt or recognize examinations prepared by other organizations as approved by the board;

(4) To issue subpoenas and administer oaths in connection with an investigation, hearing, or proceeding held under this chapter;

(5) To take or cause depositions to be taken and use other discovery procedures as needed in an investigation, hearing, or proceeding held under this chapter;

(6) To compel attendance of witnesses at hearings;

(7) In the course of investigating a complaint or report of unprofessional conduct, to direct the board to conduct practice reviews and disciplinary hearings;

(8) To take emergency action ordering summary suspension of a license, or restrict or limit a licensee's practice pending further proceedings by the director;

(9) To use the board or, at the request of the board, the office of administrative hearings, as authorized in chapter 34.12 RCW, to conduct hearings. However, the director or the director's designee shall make the final decision as to disposition of the charges;

(10) To enter into contracts for professional services determined to be necessary for adequate enforcement of this chapter;

(11) To adopt standards of professional conduct and practice as approved by the board;

(12) In the event of a finding of unprofessional conduct by an applicant or license holder, to impose sanctions against a license applicant or license holder as provided by this chapter;

(13) To enter into an assurance of discontinuance in lieu of issuing a statement of charges or conducting a hearing. The assurance shall consist of a statement of the law in question and an agreement to not violate the stated provision. Violation of an assurance under this subsection is grounds for disciplinary action;

(14) To designate individuals authorized to sign subpoenas and statement of charges; and

(15) To employ investigative, administrative, and clerical staff as necessary for the enforcement of this chapter.

NEW SECTION. Sec. 6. The board has the following authority in administering this chapter:

(1) To establish rules, including board organization and assignment of terms, and meeting frequency and timing, for adoption by the director;

(2) To establish the minimum qualifications for applicants for licensure as provided by this chapter;

(3) To approve the method of administration for examinations required by this chapter or by rule as established by the director. To approve the adoption or recognition of examinations prepared by other organizations for adoption by the director. To set the time and place of examinations with the approval of the director;

(4) To establish and review standards of professional conduct and practice for adoption by the director. Rules of professional conduct will be consistent with those outlined for engineers and land surveyors;

(5) To designate specialties of geology to be licensed under this chapter;

(6) To conduct disciplinary hearings; and

(7) To conduct practice reviews.

NEW SECTION. Sec. 7. In order to become a licensed geologist, an applicant must meet the following requirements:

(1) The applicant shall be of good moral and ethical character as attested to by letters of reference submitted by the applicant or as otherwise determined by the board;

(2) The applicant shall have graduated from a course of study in geology satisfactory to the board or satisfy educational equivalents determined by the board;

(3) The applicant shall have a documented record of a minimum of five years of experience in geology or a specialty of geology, obtained subsequent to completion of the academic requirements specified in this section, in geological work of a character satisfactory to the board, demonstrating that the applicant is qualified to assume responsible charge of such work upon licensing as a geologist. The board shall require that three years of the experience be gained under the supervision of a geologist licensed in this or any other state, or under the supervision of others who, in the opinion of the board, are qualified to have responsible charge of geological work;

(4) The applicant shall have passed an examination covering the fundamentals and practice of geology prescribed or accepted by the board;

(5) The applicant shall meet other general or individual requirements established by the board pursuant to its authority under this chapter;

(6) For licensing in any geological specialty recognized under this chapter, an applicant must first be a licensed geologist under this chapter, and then meet the following requirements:

(a) In addition to the educational requirements for licensing as a geologist defined in subsection

(2) of this section, an applicant for licensing in any specialty of geology established by the board shall have successfully completed advanced study pertinent to their specialty, or equivalent seminars or on-the-job training acceptable to the board;

(b) The applicant's experience shall include a documented record of five years of experience, after completion of the academic requirements specified in this subsection, in geological work in the applicable specialty of a character satisfactory to the board, and demonstrating that the applicant is qualified to assume responsible charge of the specialty work upon licensing in that specialty of geology. The board shall require that three years of the experience be gained under the supervision of a geologist licensed in the specialty in this or any other state, or under the supervision of others who, in the opinion of the board, are qualified to have responsible charge of geological work in the specialty; and

(c) The applicant must pass an examination in the applicable specialty prescribed or accepted by the board;

(7) The following standards are applicable to experience in the practice of geology or a specialty required under subsections (3) and (6) of this section:

(a) Each year of professional practice of a character acceptable to the board, carried out under the direct supervision of a geologist who (i) is licensed in this state or is licensed in another state with licensing standards substantially similar to those under this chapter; or (ii) meets the educational and experience requirements for licensing, but who is not required to be licensed under the limitations of this chapter, qualifies as one year of professional experience in geology;

(b) Each year of professional specialty practice of a character acceptable to the board, carried out under the direct supervision of a

(i) geologist who is licensed in a specialty under this chapter, or who is licensed as a specialty geologist in another state that has licensing requirements that are substantially similar to this chapter;

or (ii) specialty geologist who meets the educational and experience requirements for licensing, but who is not required to be licensed under the limitations of this chapter, qualifies as one year of practice in the applicable specialty of geology; and

(c) Experience in professional practice, of a character acceptable to the board and acquired prior to one year after the effective date of this section, qualifies if the experience (i) was acquired under the direct supervision of a geologist who meets the educational and experience requirements for licensing under this chapter, or who is licensed in another state that has licensing requirements that are substantially similar to this chapter; or (ii) would constitute responsible charge of professional geological work, as determined by the board;

(8) Each year of full-time graduate study in the geological sciences or in a specialty of geology shall qualify as one year of professional experience in geology or the applicable specialty of geology, up to a maximum of two years. The board may accept geological research, teaching of geology, or a geological specialty at the college or university level as qualifying experience, provided that such research or teaching, in the judgment of the board, is comparable to experience obtained in the practice of geology or a specialty thereof;

(9) An applicant who applies for licensing within one year after this section becomes effective shall be considered to be qualified for licensing, without further written examination, if the applicant possesses the following qualifications:

(a)(i) A specific record of graduation with a bachelor of science or bachelor of arts or higher degree, with a major in geology granted by an approved institution of higher education acceptable to the board; or

(ii) Graduation from an approved institution of higher education in a four-year academic degree program other than geology, but with the required number of course hours as defined by the board to qualify as a geologist or engineering geologist; and

(b) Experience consisting of a minimum of five years of professional practice in geology or a specialty thereof as required under subsections (3) and (7) of this section, of a character acceptable to the board;

(10) An applicant who applies for licensing in a specialty within one year after recognition of the specialty under this chapter shall be considered qualified for licensing in that specialty, without further written examination, if the applicant:

(a) Is qualified for licensing as a geologist in this state; and

(b) Has experience consisting of a minimum five years of professional practice in the applicable specialty of geology as required under subsections (3) and (7) of this section, of a character acceptable to the board; and

(11) The geologists initially appointed to the board under section 4 of this act shall be qualified for licensing under subsections (7) and (8) of this section.

NEW SECTION. Sec. 8. An application for licensing shall be filed with the director on a form provided by the director and must contain statements made under oath demonstrating the applicant's education and practical experience. The director may require any information and documentation that reasonably relates to the need to determine whether the applicant meets the criteria for licensing. The application fee for initial licensing shall be determined by the director as provided in RCW 43.24.086. The application, together with the fee, must be submitted to the department prior to the application deadline established by the director. Fees for initial licensing shall include the examination and issuance of a certificate. If the director finds an applicant ineligible for licensing, the fee shall be retained as an application fee.

NEW SECTION. Sec. 9. Examinations of applicants for licensing, when required, shall be held at such times and places as determined by the board with the director's approval. The scope of the examination shall be directed to an applicant's ability to practice geology or any approved specialty of geology in a manner to ensure the safety of life, health, and property. A candidate failing an examination may apply for reexamination. Subsequent examinations will be granted upon payment of a fee to be determined by the director as provided in RCW 43.24.086.

NEW SECTION. Sec. 10. The director shall issue a certificate of licensing to any applicant who has satisfactorily met all of the requirements of this chapter for licensing as a geologist or an approved specialty geologist. The certificate shall show the full name of the license holder, shall have a certificate number, and shall be signed by the director and an officer of the board. The issuance by the director of a certificate of licensing to an individual shall be prima facie evidence that the person is entitled to all the rights and privileges of a licensed geologist or specialty geologist while the certificate remains unrevoked or unexpired. Each license holder shall obtain a seal of the design authorized by the director, bearing the licensee's name, certificate number, and the legend "licensed geologist" together with any specialty in which the individual may be authorized. Geological reports, plans, and other technical documents prepared by or under the responsible charge of the license holder shall be signed, dated, and stamped with the seal or facsimile thereof. Each signature and stamping constitutes a certification by the license holder that the document was prepared by or under his or her responsible charge and that to his or her knowledge and belief the document was prepared in accordance with the requirements of this chapter.

NEW SECTION. Sec. 11. The director may, upon application and payment of a fee determined by the director as provided in RCW 43.24.086, issue a license and certificate without further examination as a geologist or specialty geologist to any person who holds a license or certificate of qualification issued by proper authority of any state, territory, or possession of the United States, District of Columbia, or any foreign country, if the applicant's qualifications, as evaluated by the board, meet the requirements of this chapter and the rules adopted by the director.

NEW SECTION. Sec. 12. Licenses issued in conformance with this chapter shall be renewed periodically on a date to be set by the director in conformance with RCW 43.24.140. A license holder who fails to pay the prescribed fee within ninety days following the date of expiration shall pay a renewal fee equal to the current fee plus an amount equal to one year's renewal fee. Any license that has been expired for five years or more may be reinstated in conformance with rules adopted by the director. Reinstatement conditions may include demonstration of continued practice or competency in the practice of geology or an approved specialty of geology.

NEW SECTION. Sec. 13. (1) All fees and fines collected under the provisions of this chapter shall be paid into the geologists' account, created in subsection (2) of this section.

(2) The geologists' account is created in the custody of the state treasurer. All receipts from fines and fees collected under this chapter must be deposited into the account. Expenditures from the account may be used only to carry out the duties re-

quired for the operation and enforcement of this chapter. Only the director of licensing or the director's designee may authorize expenditures from the account. The account is subject to allotment procedures under chapter 43.88 RCW, but an appropriation is not required for expenditures.

NEW SECTION. **Sec. 14.** The following acts are prohibited and constitute grounds for disciplinary action or denial, suspension, or revocation of any license under this chapter:

(1) Knowingly violating any of the provisions of this chapter or the rules adopted under this chapter;

(2) Knowingly making a material misstatement or omission in the application for or renewal of a license;

(3) Not meeting the qualifications for licensing set forth by this chapter;

(4) Incompetency, misconduct, fraud, gross negligence, or repeated incidents of negligence in or related to the practice of geology;

(5) Conviction of a gross misdemeanor or felony or the commission of any act involving moral turpitude, dishonesty, or corruption whether or not the act constitutes a crime. If the act constitutes a crime, conviction in a criminal proceeding is not a condition precedent to disciplinary action. Upon such conviction, however, the judgment and sentence is conclusive evidence at the ensuing disciplinary hearing of the guilt of the license holder or applicant of the crime described in the indictment or information, and of the person's violation of the statute on which it was based. For the purposes of this section, conviction includes all instances in which a plea of guilty or nolo contendere is the basis for the conviction and all proceedings in which the sentence has been deferred or suspended. Nothing in this section abrogates rights guaranteed under chapter 9.96A RCW;

(6) Advertising that is false, fraudulent, or misleading;

(7) Suspension, revocation, or restriction of the individual's license to practice the profession by competent authority in any state, federal, or foreign jurisdiction, a certified copy of the order, stipulation, or agreement being conclusive evidence of the revocation, suspension, or restriction;

(8) Aiding or abetting an unlicensed person to practice if a license is required;

(9) Failure to adequately supervise subordinates to the extent that the public health or safety is at risk;

(10) Failure to cooperate with the director by: (a) Not furnishing any necessary papers or documents requested by the director for purposes of conducting an investigation for disciplinary action, denial, suspension, or revocation of a license under this chapter;

(b) Not furnishing in writing a full and complete explanation covering the matter contained in a complaint filed with the department; or

(c) Not responding to subpoenas issued by the director, whether or not the recipient of the subpoena is the accused in the proceeding;

(11) Failure to comply with an order issued by the director or an assurance of discontinuance entered into with the director;

(12) Interference with an investigation or disciplinary proceeding by willful misrepresentation of facts before the director or the director's authorized representative, or by use of threats or harassment against any client or witness to prevent them from providing evidence in a disciplinary proceeding or any other legal action; or

(13) Committing any other act, or failing to act, which act or failure are customarily regarded as being contrary to the accepted professional conduct or standard generally expected of those practicing geology.

NEW SECTION. **Sec. 15.** The procedures governing adjudicative proceedings before agencies under chapter 34.05 RCW govern all hearings before the director or his or her designee. Upon a finding that a license holder or applicant has committed unprofessional conduct, the director may issue an order providing for one or any combination of the following:

(1) Revocation of the license;

(2) Suspension of the license for a fixed or indefinite term;

(3) Restriction or limitation of the practice;

(4) Issuance of a civil fine not to exceed five thousand dollars for each violation;

(5) Requiring satisfactory completion of a specific program of remedial education or treatment;

(6) Monitoring of the practice by a peer approved by the director;

(7) Reprimand or censure;

(8) Compliance with conditions of probation for a designated period of time;

(9) Withholding of a license request;

(10) Refund of fees billed to and collected from the consumer; or

(11) Other corrective action.

Any of the actions under this section may be totally or partly stayed by the director. All costs associated with compliance with orders issued under this section are the obligation of the license holder or applicant.

NEW SECTION. **Sec. 16.** A person, including but not limited to consumers, licensees, corporations, organizations, and state and local governments or agencies, may submit a written complaint to the department charging a license holder or applicant with unprofessional conduct and specifying the grounds for the charge. If the director determines that the complaint merits investigation, or if the director has reason to believe, without a formal complaint, that a license holder or applicant may have engaged in unprofessional conduct, the director shall investigate to determine if there has been unprofessional conduct. A person who files a complaint under this section in good faith is immune from suit in any civil action related to the filing or contents of the complaint. The director, individuals acting on the director's behalf, and members of the board are immune from suit in any action, civil or criminal, based on disciplinary proceedings or other official acts performed in the course of their duties in the administration and enforcement of this chapter.

NEW SECTION. **Sec. 17.** The board shall immediately suspend the license or practice permit of a person who has been certified pursuant to RCW 74.20A.320 by the department of social and health services as a person who is not in compliance with a child support order. If the person has continued to meet all other requirements for a license under this chapter during the suspension, reissuance of the license shall be automatic upon the board's receipt of a release issued by the department of social and health services stating that the licensee is in compliance with the child support order. The procedure in RCW 74.20A.320 is the exclusive administrative remedy for contesting the establishment of noncompliance with a child support order, and suspension of a license under this subsection, and satisfies the requirements of RCW 34.05.422.

NEW SECTION. Sec. 18. The following acts are prohibited and any person committing any of the following acts is guilty of a class 1 civil infraction under chapter 7.80 RCW:

(1) The practice or offer to practice geology or geological specialty without being licensed in accordance with the provisions of this chapter;

(2) Presenting or attempting to use as his or her own the certificate of licensing or seal of another;

(3) Giving any false or forged evidence of any kind to the director or his or her authorized representative in obtaining a license;

(4) Falsely impersonating any other licensee; or

(5) Attempting to use the expired or revoked certificate of licensing. All fees, fines, and penalties collected or assessed by a court because of a violation of this section shall be remitted to the department to be deposited into the geologists' account created in section 13 of this act.

NEW SECTION. Sec. 19. The director is authorized to apply for relief by injunction without bond, to restrain a person from the commission of any act that is prohibited under this chapter. In such proceedings, it is not necessary to allege or prove either that an adequate remedy at law does not exist, or that substantial or irreparable damage would result from continued violation. The director, individuals acting on the director's behalf and members of the board are immune from suit in any action, civil or criminal, based on disciplinary proceedings or other official acts performed in the course of their duties in the administration and enforcement of this chapter.

NEW SECTION. Sec. 20. The following activities do not require a certificate of licensing under this chapter:

(1) Geological work performed by an employee or a subordinate of a geologist or specialty geologist licensed under this chapter, provided that the work does not include responsible charge of geological work as covered by this section, and is performed under the direct supervision of a geologist licensed under this chapter, who shall be and remains responsible for such work;

(2) Geological work performed by officers and employees of the United States practicing solely as such officers and employees;

(3) Geological work performed exclusively in the exploration for energy and mineral resources, insofar as such work has no substantial impact upon the public health, safety, and welfare as determined by regulations issued by the director;

(4) Geological research conducted through academic institutions, agencies of the federal or state governments, nonprofit research institutions, or for-profit organizations, including submission of reports of research to public agencies;

(5) Teaching geology or related physical or natural sciences;

(6) The practice of engineering or other licensed professions: (a) The acquisition of engineering data involving soil, rock, ground water, and other earth materials; evaluation of the physical and chemical properties of soil, rock, ground water, and other earth materials; and the utilization of these data in analysis, design, and construction by professional engineers appropriately registered or licensed in this state; and (b) similar work performed by persons or organizations licensed or registered in any other profession or occupation related to geology, provided that such work is permitted under the applicable licensing or registration law, and is incidental to the practice or the profession or occupation for which licensing or registration is required. Nothing in this section shall be construed to permit the use of the title geologist or engineering geologist, or any other specialty as defined by the director, by an engineer or other licensed professional except as licensed under this chapter;

(7) General scientific work customarily performed by such physical or natural scientists as chemists, archaeologists, geographers, hydrologists, oceanographers, pedologists, and soil scientists, providing such work does not include the design and execution of geological investigations, being in responsible charge of geological or specialty geological work, or the drawing of geological conclusions and recommendations in a way that affects the public health, safety, or welfare; or

(8) The giving of testimony, or preparation and presentation of exhibits or documents for the sole purpose of being placed in evidence before any administrative or judicial tribunal or hearing, providing such testimony, exhibits, or documents do not imply that the person is registered under the provisions of this chapter.

NEW SECTION. Sec. 21. If any provision of this act or its application to any person or circumstance is held invalid, the remainder of the act or the application of the provision to other persons or circumstances is not affected.

NEW SECTION. Sec. 22. Sections 1 through 21 of this act constitute a new chapter in Title 18 RCW.

NEW SECTION. Sec. 23. Sections 1 through 21 of this act take effect July 1, 2001.

NEW SECTION. Sec. 24. The secretary of state shall submit section 5 of this act to the people for their adoption and ratification, or rejection, at the next general election to be held in this state, in accordance with RCW 43.135.090 (section 2, chapter 1, Laws of 2000, Initiative Measure No. 695). The suggested ballot title for this act is: "Shall the state department of licensing be authorized to levy fees on geologists sufficient to pay for their licensure?"

Passed the Senate March 7, 2000.
Passed the House March 3, 2000.
Approved by the Governor March 31, 2000.
Filed in Office of Secretary of State March 31, 2000.

"SUNRISE TO PARADISE" HONORED BY AAAS

The American Association for the Advancement of Science has chosen "Sunrise to Paradise: The Story of Mount Rainier National Park" by Ruth Kirk as one of the Best Books of 1999. This wonderful book makes the science and natural history of Mount Rainier National Park exciting and accessible. Published in 1999 by University of Washington Press, the book has 152 p., 280 photos (most in color), and numerous first-person accounts. Its suggested retail price (soft cover) is $24.95.

"Sunrise to Paradise" was listed in an annual catalog "Science Books & Films" (http://www.sbfonline.com/) in which AAAS reviews their selections. The book was an Editor's Choice, along with 3 films, 3 software titles, and 33 other books. Titles honored range from "Cosmic Phenomena" to "The Very First Things to Know About Frogs" to "Isaac Newton" and "Dance of the Continents". They are selected for a general audience, including young adults. "Sunrise to Paradise" was reviewed under the 970 heading, General History of North America.

Oil and Gas Lease Auction

Oil and Gas Potential in Washington State

Much of Washington State is underlain by folded and faulted Tertiary siliciclastic rocks varying in thickness from about 10,000 to 30,000 feet. This section includes sandstones that range from thick low-porosity sections similar to those associated with deep basin-centered gas accumulations to the "Ocean City sand", which is 700 feet thick, has 30 percent porosity, and permeability in excess of a darcy. Fewer than 200 wells deeper than 4,000 feet have penetrated the prospective area, which is about half the size of Louisiana. While no wells currently produce, a stripper oil field and two low-volume gas fields have been developed. Geochemical studies demonstrate widespread gas-generative source rocks and underplated oil-prone strata near the coast. The structure of the area is complex, but includes untested regional anticlinoriums such as Horse Heaven Hills, which is 120 miles in length.

About the Auction

The Washington State Department of Natural Resources oil and gas lease auction is scheduled for January 11, 2001, in Olympia, Washington. The type of auction will be announced later. The successful bidder will be determined by the highest bonus bid offered for each parcel. The starting bonus bid will be $2.00/acre.

For more information, contact:

Ellis Vonheeder, Business Systems Support Division
Washington State Department of Natural Resources
PO Box 47014; Olympia, WA 98504-7014
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e-mail: ellis.vonheeder@wadnr.gov

For additional geological and geophysical data, contact the Washington Division of Geology and Earth Resources at (360) 902-1450.

Selected References

Oil and Gas Potential in Washington—General

Lingley, W. S., Jr.; von der Dick, Hans, 1991, Petroleum geochemistry of Washington—A summary: Washington Geology, v.19, no. 4, p. 23-27.

McFarland, C. R., 1983, Oil and gas exploration in Washington, 1900–1982: Washington Division of Geology and Earth Resources Information Circular 75, 119 p.

Oil and Gas Potential in Siliciclastic Rocks in Western Washington

Walsh, T. J.; Lingley, W. S., Jr., 1991, Coal maturation and the natural gas potential of western and central Washington: Washington Division of Geology and Earth Resources Open File Report 91-2, 26 p.

Oil and Gas Potential in Siliciclastic Rocks in Eastern Washington

Campbell, N. P.; Reidel, S. P., 1994, Further exploration for gas warranted in Columbia Basin: Oil and Gas Journal, v. 92, no. 18, p. 127-132.

Lingley, W. S., Jr.; Walsh, T. J., 1986, Issues relating to petroleum drilling near the proposed high-level nuclear waste repository at Hanford: Washington Geologic Newsletter, v. 14, no. 3, p. 10-19.

Potential in Underplated Oil-Prone Strata near the Washington Coast

Palmer, S. P.; Lingley, W. S., Jr., 1989, An assessment of the oil and gas potential of the Washington outer continental shelf: University of Washington, Washington Sea Grant Program, Washington State and Offshore Oil and Gas, 83 p., 12 plates.

Snavely, P. D., Jr.; Kvenvolden, K. A.; and others, 1989, Preliminary evaluation of the petroleum potential of the Tertiary accretionary terrane, west side of the Olympic Peninsula, Washington: U.S. Geological Survey Bulletin 1892, 45 p., 1 plate. ■

BOOK REVIEW: The Amber Forest—A Reconstruction of a Vanished World

by George Poinar, Jr., and Roberta Poinar
Princeton University Press, 1999, 239 p., $29.95

Remember the DNA 'source' for all those Jurassic Park dinosaurs? Remember how we wondered how DNA that old came from the implied source area—the Dominican Republic? Well, this book doesn't contain anything about dinosaurs, and that should take care of that. But it will introduce you to an amazing array of insects—and other treasures—trapped in resin that has become the world-famous amber of Hispaniola.

The amber is from 15 million to 45 million years old (nowhere near Jurassic), and most of the resin was generated by the algarrobo tree. In this amber are the hints the Poinars use to tell us what the forest looked like. The modern life styles of many of the insects and plants are the clues to the past. We find animals that lived in the canopy and on the forest floor and all levels in between—even some aquatic forms that may have lived in 'tank' bromeliads.

The insects range from large termites to tiny mites, some of which are still riding on their host. Plant remains are leaves, flowers, pollen, and fruits. There are feathers and a lizard. All are perfectly preserved. Interestingly, there are life forms in amber here that no longer live in this hemisphere.

The text is very readable. The authors introduce insects by habitat and by habits. Terminology is technical but will not overwhelm a nonscientist. There is a list that gives the frequency of occurrences of the various insects (by order or family) and plants (by class and parts), a list of taxa that have been found (by genus or higher level), and a nice index. The text closes with a chapter about caring for amber, the fakes out there, and the business of DNA extraction.

The book is amply illustrated by 171 very sharp black and white photos and 171 color photos of the black and white subjects (all of which, sadly, lack scales). There are numerous sketches as well.

Readers who are interested in amber are probably acquainted with the senior author's technical and more popular works, such as "Life in Amber", which he also wrote with Roberta Poinar, an electron microscopist. This book has to be the perfect introduction to Western Hemisphere amber. Paleobotanists and paleoentomologists ought to acquire this one. The price is right for such a well-illustrated guide. Now we need someone to do the same kind of book for the Baltic amber.

Kitty Reed

In Memoriam: Carl R. McFarland

Former Division of Geology and Earth Resources geologist, Carl R. McFarland, died on February 21, 2000, at Olympia, Washington. Carl was born on October 1, 1922, at Ft. Bayard, New Mexico. He attended school in Duncan, Arizona, but left high school in 1937 after his sophomore year to work at the Phelps Dodge Copper Company to help support his family.

He served in the U.S. Army in the 24th Infantry Division in the Pacific Theater in World War II and was honorably discharged as a Sergeant Major. He completed his GED and went on to complete B.S. and M.S. degrees in Geology at Brigham Young University between 1949 and 1955. He and Margaret Zinck were married in Olympia on July 5, 1949.

From 1955 to 1960, Carl worked for the Atlantic Refining Company in the oil fields of the southwest. Between 1960 and 1967, he was a general contractor, building 120 homes in Roswell, New Mexico, where he also served on the city council. Then the McFarlands moved to Olympia, where Carl worked as a building inspector for the City of Olympia.

In 1968, he began working for the Washington State Department of Natural Resources, Lands Division, as a Geologist 2. In 1971, he was promoted to Geologist 3. His duties with the Lands Division included mineral and oil and gas leasing and sales of minerals from state-managed lands.

In 1978, he transferred to the Division of Geology and Earth Resources, where he compiled publications on oil and gas exploration and mining operations, maintained the Division's oil and gas drilling records, and participated in field studies to assess oil and gas potential in western Washington. In 1983, Carl was promoted to Geologist 4 and assumed responsibility for managing the Division's surface mining reclamation, oil and gas drilling, and geothermal drilling regulatory programs. He retired on May 31, 1985.

Carl loved construction, and in his off hours, he built four houses in the Olympia area and remodeled several others for family and friends. After retirement, he and Margaret enjoyed traveling, and they visited many states and countries.

We, the staff of the Division of Geology and Earth Resources, regarded Carl highly. His sense of humor, kindness, thoughtfulness, and willingness to help in any situation, whether it was to give advice on a reclamation or drilling project or an analysis and suggestions on someone's remodeling plans, were his hallmarks. These qualities endeared Carl to everyone who knew him, and they made us much the richer, both professionally and personally. Carl is survived by his wife, Margaret, a son, Carl, Jr., daughters, Kathleen Lee, Patti Thorn, and Jody Boudia, and seven grandchildren. A daughter, Geraldine, preceded him in death.

Publications

McFarland, C. R., 1979, History of oil and gas exploration in the State of Washington: Washington Geologic Newsletter, v. 7, no. 3, p. 1-6.

McFarland, C. R., 1979, Oil and gas exploration in Washington, 1900–1978: Washington Division of Geology and Earth Resources Information Circular 67, 119 p.

McFarland, C. R.; McLucas, G. B.; Ribgy, J. G.; Stoffel, K. L., 1979, Directory of Washington mining operations, 1979: Washington Division of Geology and Earth Resources Information Circular 69, 100 p.

McFarland, C. R., 1980, Metallic and nonmetallic mineral exploration wrap-up, 1979: Washington Geologic Newsletter, v. 8, no. 1, p. 1-6.

McFarland, C. R., 1981, Oil and gas exploration in Washington, 1900–1981: Washington Division of Geology and Earth Resources Information Circular 67R, 119 p.

McFarland, C. R., 1981, Oil and gas potential of the northwest [abstract]: Northwest Mining Association, 87th Annual Convention, Abstracts, 1 p.

McFarland, C. R., 1982, Oil and gas potential of the northwest and 1981 drilling activities: Washington Geologic Newsletter, v. 10, no. 2, p. 1-4.

McFarland, C. R., 1983, Oil and gas exploration in Washington, 1900–1982: Washington Division of Geology and Earth Resources Information Circular 75, 119 p.

McFarland, C. R., 1984, Washington: Oil and Gas Compact Bulletin, v. 43, no. 1, p. 40.

McFarland, C. R., 1985, Oil and gas activity in Washington, 1984: Washington Geologic Newsletter, v. 13, no. 1, p. 15.

Rau, W. W.; McFarland, C. R., 1982, Coastal wells of Washington: Washington Division of Geology and Earth Resources Report of Investigations 26, 4 sheets.

Sources

Manson, C. J., compiler and editor, 2000, Digital bibliography of the geology and mineral resources of Washington, 1798–1999: Washington Division of Geology and Earth Resources Digital Report 1, 2000 Edition, 1 compact disc.

The Olympian, 2000, Carl R. McFarland obituary: The Olympian, Olympia, WA, February 24, 2000, p. B4.

Washington Geologic Newsletter, 1985, Carl McFarland retires: Washington Geologic Newsletter, v. 13, nos. 3 and 4, p. 6. ■

EARTH SCIENCE WEEK VIDEOFEST

In honor of Earth Science Week, October 9–13, the Division of Geology and Earth Resources in Olympia will show free screening some of the latest earth science videos at noon at the Natural Resources Building, 1111 Washington St. SE, or the General Administration Building, 210 11th Ave SW*.

October 9, GA Room 207*
DOWN TO EARTH; MINERALS, THE MATERIALS OF EARTH

October 10, NRB Room 175b
GEOLOGIC TIME; EARTH'S STRUCTURES

October 11, NRB Room 175a
BIRTH OF A THEORY; PLATE DYNAMICS

October 12, GA Room G3*
THE SEA FLOOR; A NATION'S EDGE

October 13, NRB Room 175b
CAREERS FOR GEOSCIENTISTS;
WOMEN WHO WALK THROUGH TIME

Friday the 13th is also the Second Annual Department of Natural Resources Career Day.

Bring your lunch and a friend! Programs run 60 minutes, except the one on Oct. 13, which runs 75 minutes. Parking is 50¢/hour at the NRB and GAB (see p. 59). For more information, call (360) 902-1473 or e-mail lee.walkling@ wadnr.gov.

Selected Internet Resources in the Geosciences and Related Fields, with an Emphasis on Washington State

compiled by Lee Walkling (lee.walkling@wadnr.gov)
Washington Division of Geology and Earth Resources
PO Box 47007; Olympia, WA 98504-7007

COMPREHENSIVE GEOSCIENCE RESOURCES

Consortium for International Earth Science Information Network
http://www.ciesin.org

Geologic Information About Washington
http://geology.wr.usgs.gov/docs/stateinfo/WA.html

Geological Surveys and Natural Resources Departments (worldwide)
http://craton.geol.brocku.ca/guest/jurgen/surveys.htm

Internet Resources in the Earth Sciences
http://www.lib.berkeley.edu/EART/EarthLinks.html

Online Resources for Earth Scientists
http://www.gisnet.com/gis/ores/

Virtual Library Earth Sciences
http://www.geo.ucalgary.ca/VL-EarthSciences.html

West's Geology Directory
http://www.soton.ac.uk/~imw/links.htm

PACIFIC NORTHWEST GOVERNMENT AGENCIES

State of Washington homepages
http://access.wa.gov

Washington State Department of Natural Resources
http://www.wa.gov/dnr/

Washington Division of Geology and Earth Resources
http://www.wadnr.gov/dnr/htdocs/ger/ger.html

Washington State Department of Ecology
http://www.wa.gov/ecology/

Washington State Department of Transportation
http://www.wsdot.wa.gov

Washington State Department of Transportation Research Page
http://www.wsdot.wa.gov/ppsc/research/rpage.htm

Oregon State homepage
http://www.state.or.us

Oregon Department of Geology and Mineral Industries
http://sarvis.dogami.state.or.us/homepage/

California Department of Conservation
http://www.consrv.ca.gov

Idaho Geological Survey
http://www.idahogeology.org/

British Columbia Ministry of Energy, Mines and Petroleum Resources
http://www.gov.bc.ca/em/

Pacific Northwest National Laboratory
http://www.pnl.gov

U.S. Army Corps of Engineers, Seattle District
http://www.nws.usace.army.mil/

U.S. (FEDERAL) GOVERNMENT AGENCIES

U.S. Forest Service
http://www.fs.fed.us/recreation/states/wa.shtml

U.S. Geological Survey (USGS) homepage
http://www.usgs.gov

U.S. Geological Survey (USGS) – Geology
http://geology.usgs.gov/index.shtml

National Oceanic and Atmospheric Administration (NOAA)
http://www.noaa.gov/

National Geophysical Data Center
http://www.ngdc.noaa.gov/ngdc.html

National Geodetic Survey
http://www.ngs.noaa.gov/

U.S. Bureau of Land Management (BLM)
http://www.blm.gov/nhp/index.htm

U.S. Environmental Protection Agency (EPA)
http://www.epa.gov

U.S. Federal Emergency Management Agency (FEMA)
http://www.fema.gov/

U.S. Fish and Wildlife Service
http://www.fws.gov/

U.S. National Park Service
http://www.nps.gov/
http://www.us-national-parks.net/
http://www2.nature.nps.gov/grd/tour/index.htm (National Parks geology tours)

WASHINGTON UNIVERSITIES, DEPARTMENTS OF GEOLOGY

Central Washington University
http://www.geology.cwu.edu/

Eastern Washington University
http://www.csmt.ewu.edu/csmt/geol/geoldept.HTM

University of Washington Department of Geological Sciences
http://www.geology.washington.edu/

University of Washington Geophysics Program
http://www.geophys.washington.edu/

University of Washington Quaternary Research Center
http://depts.washington.edu/qrc/index.cgi

University of Washington School of Oceanography
http://www.ocean.washington.edu/

Washington State University
http://www.wsu.edu:8080/~geology/

Western Washington University
http://www.ac.wwu.edu/~geology/

CARTOGRAPHY/GIS

Cartography, GIS, and Remote Sensing Resources
http://www.uwsp.edu/geo/internet/cartography.html

Geographic Information Systems (GIS)
http://dir.yahoo.com/Science/Geography/Geographic_Information_Systems__GIS_/

AGI GIS dictionary
http://www.geo.ed.ac.uk/agidict/welcome.html

EARTHQUAKES, SEISMOLOGY AND TECTONICS

Seismosurfing the Internet for Earthquake Data
http://www.geophys.washington.edu/seismosurfing.html

USGS Earthquake Information
http://quake.wr.usgs.gov/

National Earthquake Information Center
http://wwwneic.cr.usgs.gov/

University of Washington Geophysics Program
http://www.geophys.washington.edu/

Pacific Northwest Seismograph Network
http://www.geophys.washington.edu/SEIS/PNSN/

Where do Washington earthquakes occur
http://www.geophys.washington.edu/SEIS/PNSN/INFO_GENERAL/NQT/where_do.html

Pacific Northwest earthquake hazards
http://www.geophys.washington.edu/CREW/Other/hazmap.html

GEMS AND MINERALS AND ROCKHOUNDING

Gems and minerals of Washington
http://www.jewelrymall.com/states/WA.html

Gem and mineral and rockhounding clubs of Washington
http://www.wa.gov/dnr/htdocs/ger/clubs.htm

Stonerose Interpretive Center (fossils)
http://www.ferryco.com/stonerose/visiting.htm

Washington State Mineral Council
http://members.aol.com/washminrl/wsmc.htm

Geology Adventures
http://www.geologyadventures.com/

GEOGRAPHIC/GEOLOGIC NAMES

Geographic Names Information System
http://mapping.usgs.gov/www/gnis/

Geologic Names Lexicon
http://ngmsvr.wr.usgs.gov/Geolex/

U.S. and territories geographic names
http://mapping.usgs.gov/www/gnis/gnisform.html

Washington Place Names Database
http://www.tpl.lib.wa.us/v2/nwroom/WaNames.htm

HYDROLOGY, OCEANOGRAPHY, COASTAL STUDIES

Water Resources of Washington State
http://wwwdwatcm.wr.usgs.gov/wrd-home.html

Water Resources of the United States
http://water.usgs.gov/

State of Washington Water Research Center
http://www.wsu.edu/swwrc/

Washington Sea Grant
http://www.wsg.washington.edu/

Universities Water Information Network
http://www.uwin.siu.edu/#

Puget Sound Shorelines
http://www.wa.gov/ecology/sea/pugetsound/

LIBRARY CATALOGS

USGS Library
http://www.usgs.gov/library/

Washington State Library/
The Evergreen State College Library/
St. Martin's College Library
http://cals.evergreen.edu/search~b01i01a01

University of Washington
http://www.lib.washington.edu/

University of Washington
Natural Sciences Library
http://www.lib.washington.edu/Natsci/

Earth Sciences Information Centre (Canada)
http://www.nrcan.gc.ca/ess/esic/libcat_e.html

NOAA Seattle Regional Library
http://www.wrclib.noaa.gov/

Mining Environment Database
(J. M. Desmarais Library)
http://www.laurentian.ca/www/library/jnd.html

Washington Division of Geology and Earth Resources Library
http://www.wa.gov/dnr/htdocs/ger/lib2.htm
catalog (soon to be online; now available on CD-ROM, call 360-902-1450)

MAPS

Washington State Maps
http://www.wamaps.com/

USGS Topographic Maps
(select Washington in list of states)
http://mapping.usgs.gov/mac/maplists/selectstatelist.html

Lewis County Map Atlas
http://www.co.lewis.wa.us/PublicWorks/mapatlas.htm

Thurston GeoData Center
http://www.geodata.org/

MINERALS

Mineralogy Database
http://web.wt.net/~daba/Mineral/

The Mineral and Gemstone Kingdom
http://www.minerals.net/

MINING/MINE RECLAMATION

INFOMINE, Mining Industry Information
http://www.infomine.com/

Northwest Mining Association
http://www.nwma.org/

Mining History Association
http://www.lib.mtu.edu/mha/mha.htm

Mining History Network
http://www.ex.ac.uk/~RBurt/MinHistNet/

Mining Technology
http://www.mining-technology.com/

OTHER GEOLOGICAL HAZARDS OF WASHINGTON STATE

Tsunami!
http://www.geophys.washington.edu/tsunami/intro.html

Tsunami! (Scientific American article)
http://www.sciam.com/1999/0599issue/0599gonzalez.html

Tsunami hazard mitigation
http://www.pmel.noaa.gov/~bernard/senatec.html

West Coast and Alaska
Tsunami Warning Center
http://wcatwc.gov/

Tsunami links
http://www.pmel.noaa.gov/tsunami-hazard/links.html

Land subsidence
http://www.wrcc.osmre.gov/fedAML.html

Land subsidence for homeowners
http://www.mines.edu/fs_home/tboyd/Coal/homeowner/

Landslides from February 1996 storms
http://landslides.usgs.gov/html_files/nlic/Wash_hrp/wash1.htm

Landslides from winter 1998/97 storms
http://www.wa.gov/dnr/htdocs/ger/landslid.htm

Flooding in Washington State
http://www.mrsc.org/pubsafe/emergency/flooding.htm

EPA Map of Radon Zones–Washington
http://www.epa.gov/iaq/radon/zonemap/zmapp47.htm

Citizen's Guide to Radon
http://www.epa.gov/iaq/radon/pubs/citguide.html

PROFESSIONAL ORGANIZATIONS

American Association of Petroleum Geologists
http://www.aapg.org/indexns.shtml

American Geological Institute
http://www.agiweb.org/

American Geophysical Union
http://www.agu.org/

Association for Women Geoscientists
http://www.awg.org/

Association of Earth Science Editors
http://www.aese.org/

Association of Engineering Geologists
http://aegweb.org/

Columbia Basin Geological Society
http://www.ior.com/~davery/cbgs.htm

Computer Oriented Geological Society
http://www.csn.net/~tbrez/cogs/

Geological Society of America
http://www.geosociety.org/

Geoscience Information Society
http://www.geoinfo.org/

National Association of
Geoscience Teachers
http://www.nagt.org/

Northwest Geological Society
http://www.scn.org/tech/nwgs/

Northwest Paleontologic Association
http://www.cnw.com/~mstern/npa/npa.html

Society of Exploration Geophysicists
http://seg.org/

Soil and Water Conservation Society
http://www.swcs.org/

Washington Science Teachers Association
http://www.pnl.gov/education/wsta.html

PROSPECTING

Gold and Fish pamphlet
(rules and regulations for mineral prospecting and placer mining in Washington State)
http://www.wa.gov:80/wdfw/hab/goldfish/goldfish.htm

Washington Prospectors Mining Association
http://www.washingtonprospectors.org/

SOILS

Natural Resources Conservation Service
(formerly Soil Conservation Service)
http://www.nrcs.usda.gov/

VOLCANOES/VOLCANISM

Cascade Volcano Observatory
http://vulcan.wr.usgs.gov/

University of Washington Volcano Systems Center
http://www.vsc.washington.edu/

VENTS Program
(Juan de Fuca submarine volcanics)
http://www.pmel.noaa.gov/vents/ ■

BLAST FROM THE PAST. This photo was taken on April 23, 1983, almost 3 years after the May 18, 1980, eruption of Mount St. Helens. View is to the south across Spirit Lake, about 8 miles north-northeast of the crater. Note the dusting of ash on the snow on the east flank of the mountain. Photo courtesy of Gary Ott, Twisp, Wash.

New National Natural Landmarks Regulations

Final revised regulations on the National Natural Landmarks (NNL) Program were published in the Federal Register on May 12, 1999, ending a 10-year moratorium on the designation of these landmarks. The revised regulations are tailored to be more responsive to concerns of land rights groups, improve the operation of the NNL program, and strengthen landowner involvement in landmark designations. "Natural landmarks are among the best examples of our Nation's geological and ecological features," said Mike Soukup, National Park Service Associate Director for Natural Resource Stewardship and Science. "Owners of designated landmarks can be proud of the significant voluntary contribution they are making to our country by protecting these sites."

Key revisions and clarifications in the regulations are:

- Owners of sites under consideration for possible NNL designation are to be fully notified in advance of such consideration and be given the opportunity to comment on the proposals.
- Entry onto private lands for purposes of new NNL evaluation is *not* allowed without written permission. (This was always the general operating protocol but it is now more explicit and requires written permission.)
- Property will not be designated as part of an NNL if the owner objects to such designation within a specified time period. (Areas under consideration often encompass multiple properties owned by different government agencies or private citizens. Some may desire designation, while others may not.)
- The National Park System Advisory Board will review all future designations.
- The overall effects of NNL designation are clearly addressed.

The new regulations also clear up various misconceptions about NNLs that have perpetuated over the last ten years. For example, designation does not change the ownership or management of a site and does not dictate activity by the Federal government. Designated sites do not have to be open to the public. It is a voluntary partnership between citizens and the government. Many citizens and their congressional representatives have been waiting for the moratorium to end so certain sites can be considered for possible designation. ■

National Park Service Ice Age Floods Study

The Ice Age Floods Alternatives Study is the first step toward development of a coordinated interpretive and educational approach to telling the story of the Missoula floods throughout a four-state area—Washington, Oregon, Idaho, and Montana. The study will focus on three major topics:

1. An inventory of significant flood features within the four-state area;
2. Coordinated interpretation and education programs about the floods, ranging from geologic history and how the floods shaped the land to human settlement and use patterns today; and
3. Alternative frameworks for cooperation among agencies from all levels of government, along with various opportunities to involve the private sector.

Planning and coordinating work for the study began in March 1999. Field work in the summer of 1999 lead to a draft study published and distributed in April 2000. A series of public workshops were held in June throughout the region to review the draft.

To provide for wide public involvement in the development of the study, the area affected by the floods was divided into four zones: 1) Glacial Lake Missoula—Montana; 2) Idaho Panhandle and East Central Washington—Washington/Idaho; 3) Mid-Columbia—Washington/Oregon; and 4) Gorge, Lower Columbia, and Willamette—Washington/Oregon. In each of the zones, a locally based group was organized to present the project to the community and to provide essential input to the study.

Funded by the National Park Service under their Special Resource Study Program, coordinating the study and completing the reports was contracted to Jones & Jones, a Seattle firm noted for its planning and design expertise. Jones & Jones worked with a study team to develop workshops in communities across the floods route. The study team consisted of agency representatives from all levels of government and members of the Ice Age Floods Institute, a nonprofit group dedicated to bringing the floods story to a broader audience.

Local study groups inventoried and prioritized their area's flood features and recommended those suitable for interpretive distinction. With this information, the study team, with input from the consultant, developed concepts for coordination, interpretation, and educational programs and will examine alternative frameworks for cooperation among agencies.

By the end of August, a fully developed version of the study report, reflecting suggestions and comments gathered in June, will be distributed for public review. Copies of the executive summary will also be available at that time. The drafts of the report and the summary are intended for wide circulation and discussion.

Principal opportunities for public comment will be at public review meetings in each of the study zones and Seattle:

Portland, Ore., Tues., Sept. 19, 7–9 pm, Miller Hall, World Forestry Center, 4033 SW Canyon Rd (Washington Park, near zoo, off US 26).

Richland, Wash., Wed., Sept. 20, 7–9 pm, CREHST auditorium, 95 Lee Blvd.

Missoula, Mont, Mon., Sept 25, 7–9 pm, Ruby's Inn, 4825 N Reserve St, just south of I-90, exit 101.

Sandpoint, Idaho, Wed., Sept. 27, 2–4 pm, Edgewater Room, Edgewater Resort, 56 Bridge St.

Seattle, Wash., Tue., Oct. 3, 7–9 pm, Burke Museum meeting room, UW campus near NE 45th St & 17th Ave NE entrance.

After the meetings and receipt of other comments, required modifications will be made in the report, and the final version will be submitted to the Director of the National Park Service, who will review it and make his recommendations. He will forward the report to the Secretary of the Interior, who will make his recommendations and then, early in 2001, submit the report to the new Congress for its consideration. Copies of the final study report will be made available to the general public when the report is transmitted to Congress.

Anyone interested in reviewing the report should contact Arlene Yamada (National Park Service, 909 First Ave, Seattle WA 98104, 206-220-4109, arlene_yamada@nps.gov). In addition to the input from the meetings, written comments on the report are encouraged and should be sent by Nov. 1 to William Walters, Deputy Regional Director, Pacific West Region, National Park Service, 909 First Ave, Seattle, WA 98104.

For more information, visit the NPS Ice Age Floods Alternatives Study website at http://www.nps.gov/iceagefloods/. ■

FREEBIES

Free, extra copies of following publications from the Geology Library are being made available on a first-come, first-served basis to our readers. To obtain copies, contact Lee Walkling at (360) 902-1473 or lee.walkling@wadnr.gov.

Bortleson, G. C.; Dion, N. P., 1979, Preferred and observed conditions for sockeye salmon in Ozette Lake and its tributaries, Clallam County, Washington: U.S. Geological Survey Water-Resources Investigations 78-64, 61 p. (2 copies)

Drost, B. W., 1986, Water resources of Clallam County, Washington—Phase 1 report: U.S. Geological Survey Water-Resources Investigations Report 83-4227, 263 p., 5 plates. (1 copy)

Fuste, L. A.; Packard, F. A.; Fretwell, M. O.; Garland, D. P., 1983, Data supplement to, Quality of coal mine drainage in Washington, 1975–1977: U.S. Geological Survey Open-File Report 83-205, 61 p. (6 copies)

Laird, L. B.; Walters, Kenneth L., 1965, Municipal, industrial, and irrigation water use in Washington, 1965: U.S. Geological Survey Open-File Report 67-142, 13 p. (3 copies)

Lum, W. E., II; Turney, G. L.; Alvord, R. C., 1986, A preliminary evaluation of the geohydrology and water quality of the Greenacres landfill area, Spokane County, Washington: U.S. Geological Survey Open-File Report 85-496, 41 p. (5 copies)

Packard, F. A.; Sumioka, S. S.; Whiteman, K. J., 1983, Ground water-surface water relationships in the Bonaparte Creek basin, Okanogan County, Washington, 1979–80: U.S. Geological Survey Open-File Report 82-172, 46 p. (7 copies)

Prych, E. A.; Haushild, W. L.; Stoner, J. D., 1976, Numerical model of the salt-wedge reach of the Duwamish River estuary, King County, Washington: U.S. Geological Survey Professional Paper 990, 34 p. (6 copies)

Turney, Gary L., 1986, Quality of ground water in the Columbia Basin, Washington: U.S. Geological Survey Water-Resources Investigations Report 85-4320, 172 p., 5 plates. (15 copies) ■

Geological Projects at Washington Colleges and Universities

This list is taken from material submitted by press time by the geology departments of the state's colleges and universities, as well as from their websites.

CENTRAL WASHINGTON UNIVERSITY

Faculty Projects

Magma chamber dynamics—*Dr. Wendy Bohrson*

Magma recharge and eruption—*Dr. Wendy Bohrson*

Open systems magmatic processes—*Dr. Wendy Bohrson*

Lacustrine records of climate change—*Dr. Lisa L. Ely*

Paleoflood studies in India and western United States—*Dr. Lisa L. Ely*

Global biogeochemical cycling—*Dr. Carey Gazis*

Soil geochemistry—*Dr. Carey Gazis*

Weathering and global change—*Dr. Carey Gazis*

Active tectonics of the Basin and Range—*Dr. Jeff Lee*

Active tectonics of the eastern California shear zone—*Dr. Jeff Lee*

Gneiss dome formation in southern Tibet—*Dr. Jeff Lee*

Continental dynamics and surface deformation—*Dr. Timothy Melbourne*

Upper mantle dynamics—*Dr. Timothy Melbourne*

Wave form modeling: Asthenosphere–lithosphere interaction—*Dr. Timothy Melbourne*

Active tectonics of north Baja California—*Dr. M. Meghan Miller and Dr. Timothy Melbourne*

Pacific Northwest Geodetic Array (PANGA)—*Dr. M. Meghan Miller and Dr. Timothy Melbourne*

Southern California, Mojave–Walker Lane GPS network—*Dr. M. Meghan Miller and Dr. Timothy Melbourne*

Active faulting along the eastern California shear zone—*Dr. Charles M. Rubin and Dr. Jeff Lee*

Active tectonics and geodynamics of the Tien Shan—*Dr. Charles M. Rubin and Dr. Jeff Lee*

Los Angeles basin—*Dr. Charles M. Rubin and Dr. Jeff Lee*

Student Projects

Holocene slip rates and fault recurrence along the northern Tarim basin, western China—*Michael August [Dr. Charles Rubin]*

Modeling Cascadia subduction kinematics using GPS geodesy—*Ken Austin [Dr. M. Meghan Miller]*

Geologic controls on water-table elevations, Chelan County, WA—*Jennifer Coen [Dr. Lisa Ely]*

Late Cenozoic shortening across the central Kyryz Tien Shan, central Asia—*Keegan Fengler [Dr. Charles Rubin]*

Glacial retreat of the past 6,000 years in upper Kittitas County, Washington—*Rex Flake [Dr. Lisa Ely]*

Igneous petrogenesis of the Cascades—*Sarah Fowler [Dr. Wendy Bohrson]*

Late Cenozoic slip rates and fault recurrence, Naryn basin, central Tien Shan, Kyrgyzstan—*Mirhya Gould [Dr. Meghan Miller]*

Paleofloods frequency, Deschutes River—*Kurt Hosman [Dr. Lisa Ely]*

XRD analyses of loess from central Tien Shan, Asia—*Mark Knoll [Dr. Jim Hinthorne]*

Kittitas Valley field trips for K–12—*Jana Mabry [Dr. Lisa Ely]*

Instilling a sense of place through K–12 geology curriculum—*Jana Mabry [Dr. Lisa Ely]*

Paleoseismologic studies along the 1999 Hector Mine earthquake surface rupture and adjacent faults, southern California—*Chris Madden [Dr. Charles Rubin]*

Stacking core reflections from TriNet data, southern California—*Yori Otsuka [Dr. Tim Melbourne]*

GPS deformation network at Mount Rainier—*Ben Pauk [Dr. Meghan Miller]*

Environmental geology of Shamlergeeta, using detailed geomorphology using differential GPS—*Sharon Ruth [Dr. Meghan Miller]*

Igneous petrogenesis—*Will Strand [Dr. Wendy Bohrson]*

Comparison of paleomagnetic sampling strategies, Tien Shan, central Asia—*Kevin Weberling [Dr. Charles Rubin]*

Climatic analysis of floods—*Jennifer Wilcox [Dr. Lisa Ely]*

Geoarcheological study of Intzingo (Michoacan, Mexico)—*Jennifer Wilcox [Dr. Wendy Bohrson]*

EASTERN WASHINGTON UNIVERSITY

Faculty Projects

Development of a computer model of the Spokane Valley–Rathdrum Prairie aquifer system, Washington and Idaho, for water budgeting purposes—*John P. Buchanan*

Ground water/surface water interaction between the Spokane River and aquifer in the Spokane valley, Washington—*John P. Buchanan*

Sedimentology of fluvial deposits in cave systems in Belize, Central America—*John P. Buchanan*

Biostratigraphic studies of Pennsylvanian and Permian bryozoans in North America and Pakistan—*Ernest H. Gilmour*

Paleobiogeography of Late Permian Bryozoa—*Ernest H. Gilmour*

Permian bryozoans of the carbonate units of the Mission Argillite, northeastern Washington—*Ernest H. Gilmour*

Permian bryozoans of the Productus Creek Group, South Island, New Zealand—*Ernest H. Gilmour*

Economic geology of the Yellowhead ore zone, the Metaline District, Pend Oreille mine—*James I. Hoffman*

Environmental mitigation practices, Coeur d'Alene mining district, Idaho—*James I. Hoffman*

Interpretive geology, Columbia Plateau Trail, Devils Canyon to Snake River junction—Washington State Parks & Recreation Commission—*James I. Hoffman*

Chemical analysis of ultrapure electronic materials—*Mohammed Ikramuddin*

Chemical analysis of water, wastewater, soil and sediments using EPA methods and EPA quality assurance quality control protocol—*Mohammed Ikramuddin*

Development of new analytical methods by ICP-mass spectrometry, inductively coupled plasma emission spectrometry, and Zeeman graphite furnace atomic absorption—*Mohammed Ikramuddin*

Distribution of metals in the Spokane aquifer and Spokane River, Washington—*Mohammed Ikramuddin*

Isotopic composition of lead in contaminated sediments and soil—*Mohammed Ikramuddin*

Lead isotopes and trace elements in tree rings: chronology of pollution in Coeur d'Alene River, Idaho—*Mohammed Ikramuddin*

Microwave digestion of alloys and analysis of volatile elements—*Mohammed Ikramuddin*

Trace-element geochemistry of water, soil, plants and stream sediments affected by mining activities—*Mohammed Ikramuddin*

Use of inductively coupled plasma mass spectrometry in environmental research and mineral exploration—*Mohammed Ikramuddin*

Use of lead isotopes to identify lead contamination in rivers, lakes, and ground water—*Mohammed Ikramuddin*

Erosion rates along Lake Roosevelt—*Eugene P. Kiver*

Geology of national parks—*Eugene P. Kiver*

Glacial and catastrophic flood history of eastern Washington—*Eugene P. Kiver*

Pattern of extinction and replacement at the Lower–Middle Cambrian boundary in the Great Basin and South China—*Linda B. McCollum*

Compositional zonation and diffusion in Emerald Creek garnets, Idaho—*Jennifer A. Thomson*

Melting of pelitic rocks, south-central Massachusetts—*Jennifer A. Thomson*

Petrologic and geochemical investigation of the Wallace Formation, Fernwood–Clarkia, Idaho—*Jennifer A. Thomson*

THE EVERGREEN STATE COLLEGE

Faculty Projects

Desert ecology of the north Death Valley, Eureka Valley and Saline Valley area of eastern California—*Dr. James Stroh*

Evapotranspiration studies—*Dr. James Stroh*

Geographic Information Systems, especially applications in geology and land resources—*Dr. James Stroh*

Geology of the north Death Valley, Eureka Valley and Saline Valley area of eastern California—*Dr. James Stroh*

Hydrology, particularly ground-water hydrology—*Dr. James Stroh*

Thurston County and vicinity lake heat budgets—*Dr. James Stroh*

Chronostratigraphy—*Ken Tabbutt*

Mobility of rare earth elements—*Ken Tabbutt*

Paleogeographic evolution of South America—*Ken Tabbutt*

PACIFIC LUTHERAN UNIVERSITY

Faculty Projects

Paleontology of the sedimentary rocks on the Olympic Peninsula—*Steve Benham and James Goedert*

UNIVERSITY OF WASHINGTON

Faculty Projects

The Seattle Geologic Mapping Project—*Derek Booth* [for more information check out their web page at http://gneiss.geology.washington.edu/sea-geo/]

Evidence of paleo-earthquakes and paleo-tsunami in Snohomish delta—*Jody Bourgeois*

3.0 to 1.5 Ga synthems and history of Vaalbara (South Africa and W. Australia)—*Eric Cheney (with H. Winter and W. v. d. Westhuizen)*

Age and characterization of an unrecognized terrane(?) near Omak, WA—*Eric Cheney (with H. Hurlow and N. Chutas)*

Age, location, and displacement of the southern end of the Straight Creek fault, central Cascade Range, WA—*Eric Cheney*

Buffalo fluorspar deposit, Bushveld Complex, South Africa—*Eric Cheney (with D. Twist and S. Keith)*

Cenozoic sequence stratigraphy (synthems) and tectonics of the Pacific Northwest—*Eric Cheney (with B. Sherrod)*

Geology and ore controls of the Lamefoot and Overlook gold deposits in Quesnellian rocks, Republic, WA—*Eric Cheney (with M. Rasmussen)*

Stratigraphy and structure of the Swauk fold and thrust belt, central Cascade Range, WA—*Eric Cheney*

Structural geology of fault rocks and related shear zones, Death Valley, California—*Darrel Cowan*

Analysis of the effects of forest clearcutting on flooding—*Alan Gillespie*

Long-term surface and vegetation change in the Amazon Basin and the interaction with climate change—*Alan Gillespie*

Thermal infrared remote sensing (temperature of streams from aircraft or satellites; algorithms to atmospherically correct thermal IR satellite data)—*Alan Gillespie*

Landslide prediction and Digital Elevation Models—*Dave Montgomery* [for more information, check out the web page for the Mountain Drainage Basin Research Group at http://duff.geology.washington.edu/mdbrg/]

Geochemical stratigraphy of La Palma, Canary Islands: Evolution of a low-flux, alkalic volcano—*Bruce Nelson*

Oligocene volcanism in southern Mexico and tectonic implications for Central America—*Bruce Nelson*

Pb and Sr isotope tracing of hydrothermal vent fluids at the mid-ocean ridge—*Bruce Nelson*

Petrogenesis of the Boring Lavas, Cascades—*Bruce Nelson [G. Jones]*

Post-giant-landslide volcanism on Molokai, Hawaii: The submarine record—*Bruce Nelson*

Tholeiitic to alkalic transition on Waianae volcano, Hawaii—*Bruce Nelson*

Sr-Ca-Mg investigation of low-temperature flank flux through oceanic crust and implications for the chemical evolution of seawater—*Bruce Nelson*

Chronology of Quaternary glaciation in the Puget Lowland and Cascade Range—*Steve Porter and Terry Swanson*

Fission track dating of the Olympic Peninsula—*Richard Stewart*

Geochronology of the North Cascades—*Joe Vance (emeritus)*

Analysis of the effects of forest clearcutting on flooding—*Robin Weeks*

Long-term surface and vegetation change in the Amazon Basin and the interaction with climate change—*Robin Weeks*

Thermal infrared remote sensing (temperature of streams from aircraft or satellites; algorithms to atmospherically correct thermal IR satellite data)—*Robin Weeks*

Student Projects

Geology and ore controls of the K-2 epithermal Au deposit, Curlew, WA—*Nathan I. Chutas*

Nonmetallic mineral resources of western Washington—*David A. Knoblach*

Geochemical and thermo-fluid dynamic modeling study with a focus on Popocatepetl (Mexico) and Villarrica (Chile); A new mechanism for degassing at high-sulfur volcanoes—*Jeff Witter*

WASHINGTON STATE UNIVERSITY

Faculty Projects

Assessment and pilot testing of passive soil vapor extraction and bioventing effectiveness at Queen City Farms—*Dr. Richelle Allen-King*

Competitive and nonlinear chlorinated solvent sorption—*Dr. Richelle Allen-King*

Discovering groundwater: Development of interdisciplinary labs for all academic levels—*Dr. Richelle Allen-King (with Keller, Davis, Hathhorn)*

Geochemical and physical aquifer heterogeneity: Correlation with sedimentary facies—*Dr. Richelle Allen-King (with Gaylord)*

IGERT pre-proposal: Training the next generation of environmental professionals—*Dr. Richelle Allen-King (with Peterson, Claiborn, Peyton, and Yonge).*

Mechanisms of pesticide transport to surface water at the field scale in a dryland agriculture region—*Dr. Richelle Allen-King (with Keller, Schaumloffel)*

Surface and subsurface transport pathways of non-point agricultural pollutants: Analysis of the problem over four decades of basin scale—*Dr. Richelle Allen-King (with Keller, Barber, Flury, and Smith).*

Crystal chemistry of tetrahedrite group minerals—*Dr. Franklin F. Foit, Jr.*

Tephra stratigraphy of central Cascade region—*Dr. Franklin F. Foit, Jr.*

Ancient landslides and relations to sedimentary and volcanic strata in the White Lake Basin, near Penticton, British Columbia—*Dr. David Gaylord*

Geochemical and physical aquifer heterogeneity: Correlation with sedimentary facies at the Borden site, Canada—*Dr. David Gaylord (with Dr. Allen-King)*

Sedimentology and stratigraphy of the White Lake Formation near Summerland, British Columbia—*Dr. David Gaylord*

Pathways of agricultural chemicals to surface water—*Dr. C. Kent Keller (with Dr. Allen-King)*

Direct age dating of skarn deposits—*Dr. Lawrence Meinert*

Geology of Mines Gaspe, Quebec—*Dr. Lawrence Meinert*

Geology of the Redline gold skarn prospect, Nevada—*Dr. Lawrence Meinert*

Geology of the Shimyoka prospect, Zambia—*Dr. Lawrence Meinert*

Mineralogy and petrology of gold skarns—*Dr. Lawrence Meinert*

Structure and stratigraphy of Neoproterozoic–Early Paleozoic rocks of the Transantarctic Mountains near Nimrod Glacier—*Dr. Michael C. Pope*

Geochemistry of Lanai, Hawaii magmas; Geochemical and isotopic thermochronology; Low-temperature dating of shallow-crustal processes—*Dr. Peter Reiners*

Mantle melting processes and the origins of basalts; Constraints from temporal-compositional-isotopic trends in individual eruptions of primitive mantle derived magmas—*Dr. Peter Reiners*

Structural and petrologic evolution of Kauai, Hawaii—*Dr. Peter Reiners*

Timing and rates of uplift and exhumation of the Washington Cascades and evolution of climate in eastern Washington—*Dr. Peter Reiners*

Analytical and numerical testing of a viscoelastic model for describing the transition from folding to faulting (Montana) and formation of plates over a mantle convection cell (the Earth)—*Dr. A. John Watkinson (with Regan Patton and V. Manoranjan)*

Emplacement and volumetric strain of Eocene lamprophyre dikes in NE Washington—*Dr. A. John Watkinson (with D. Vanderveen)*

Reactivation of early-formed fractures in major fault zones; Transition from veins and pressure solution seams to faults, Languedoc, South of France and Montana, USA—*Dr. A. John Watkinson*

Bibliography and index of Paleozoic crinoids, 1759–1999—*Dr. G. D. Webster*

Carboniferous crinoid faunas of Algeria—*Dr. G. D. Webster*

Carboniferous crinoid faunas of Montana and Nevada—*Dr. G. D. Webster*

Carboniferous crinoids of southeastern Alaska—*Dr. G. D. Webster*

Devonian and Carboniferous crinoid faunas of Iran—*Dr. G. D. Webster*

Late Devonian crinoids of Morocco—*Dr. G. D. Webster*

Paleobiogeography of Devonian and Carboniferous crinoids—*Dr. G. D. Webster*

Student Projects

Correlation of the Klondike Mountain Formation using geochemistry, Republic basin, Washington—*Nathan Arganbright*

Paleoclimate reconstruction in the Sand Creek portion of the St. Anthony dune field, Idaho—*Angela Coleman*

Sedimentology and provenance of the St. Anthony dune field, Idaho, and relation to Pleistocene–Holocene climate change—*Jeremy Coughlin*

Geochemical heterogeneity in the Borden aquifer, Ontario, Canada—*Dana Divine*

Ecosystem perturbation effects on porewater chemistry and the atmospheric CO_2 sink—*Jeffrey Havig*

Geochemistry of Lanai, Hawaii magmas: Geochemical and isotopic constraints on recycling of ancient pelagic sediments into the mantle—*Hunter Hickes (with Dr. Reiners)*

Sedimentology, stratigraphy, and geomorphology of the North Fork Toutle River since 1980—*Eric Killenbeck*

Hydrostratigraphy of the Pullman–Moscow Basin—*Alexander Kirk*

Late Pleistocene tephra stratigraphy of Newberry Volcano—*Steven Kuehn (with Dr. Foit)*

A quantitative and problem-based hydrogeology experiment for the introductory physical geology course—*Melissa Nihsen*

A hydrogeologic investigation of the geochemical sink for atmospheric CO_2 in experimental ecosystems—*Rachel O'Brien*

Stubblefield Lake: Hydrologic study of an intermittent lake in eastern WA—*John Roland*

Pesticide transport in the vadose zone in Palouse loess—*Kristin Schultheis*

Passive soil vapor extraction and bio-venting effectiveness at a site contaminated with a nonaqueous-phase complex-contaminant mixture—*Rachel Stansbery*

Loess genesis in the Columbia Basin, Washington—*Mark Sweeney*

Carbon fluxes in an experimental forest ecosystem following perturbation—*Timothy White*

WESTERN WASHINGTON UNIVERSITY

Faculty Projects

Eruptive stratigraphy of the Hannegan Caldera (northwest of Mt. Baker)—*Susan DeBari*

Island arc crustal sections: Mesozoic arc systems in the U.S. Cordillera and in Asia—*Susan DeBari* ■

UPCOMING EVENTS

Spokane Aquifer Tour

September 25 and 26, 2000
Spokane, Washington

Contact the Spokane County Water Quality Management Program at (509) 456-6024.

Taking Action to Reduce Nonpoint Water Pollution in Washington

September 27–28, 2000
Everett, Washington

http://www.wa.gov/ecology/wq/nonpoint/taking_action_conf.html or http://www.wsu.edu/swwrc/

Geology of the Salmon River

October 7, 2000
Moscow to Riggins, Idaho

Field trip $49/person. Register through the University of Idaho Enrichment Program, (208) 885-6486.

Northwest Geological Society Field Trip

October 7–8, 2000 (tentative)
Mount Rainier and vicinity, Washington

http://www.scn.org/tech/nwgs/

Northwest Geological Society Meeting

October 10, 2000; 7:30 p.m.
University Plaza Hotel, Seattle, Washington

Tom Brocher (USGS) will speak on seismic data gathered during the King Dome implosion. http://www.scn.org/tech/nwgs/

American Institute of Professional Geologists (AIPG) Annual Meeting

October 10–14, 2000
Milwaukee, Wisconsin

http://www.aipgwis. org/2000.htm

Geological Evidence of the Bretz Floods

October 15–22, 2000
Bend, Oregon, to Missoula, Montana

http://www.cocc.edu/commed/SpecialEvents/index.html (Bretz Floods Geology)

Third Symposium on the Hydrogeology of Washington State

October 16–18, 2000
Tacoma, Washington

http://www.wa. gov/ecology/hg/main.htm

Agriculture and Water Quality in the Pacific Northwest Conference

October 24–25, 2000
Eugene, Oregon

http://www.wsu.edu/swwrc/

Applied Geologic Remote Sensing 14th International Conference and Workshops

November 6, 2000
Las Vegas, Nevada

http://www.erim-int.com/CONF/conf.htm

Sixth International Conference on Seismic Zonation

November 12–15, 2000
Palm Springs, California

http://www. eeri.org

Northwest Geological Society Meeting

November 14, 2000; 7:30 p.m.
University Plaza Hotel, Seattle, Washington

Richard Waitt (USGS) "Channeled Scablands". http://www.scn.org/tech/nwgs/

Northwest Geological Society Meeting

December 12, 2000; 7:30 p.m.
University Plaza Hotel, Seattle, Washington

Orrin Pilkey (Duke University) "Shoreline erosion in southwestern Washington".

Geological Society of America (GSA) Annual Meeting and Exhibition

November 12–15, 2000
Reno, Nevada

http://www.geosociety.org

Northwest Mining Association (NWMA) 106th Annual Meeting

December 4–8, 2000
Spokane, Washington

http://www.nwma.org/

American Geophysical Union (AGU) Fall Meeting

December 15–19, 2000
San Francisco, California

http://www.agu.org/meetings/fm00top.html

Symposium on the Application of Geophysics to Engineering and Environmental Problems

March 4–7, 2001
Denver, Colorado

http://www.sageep.com/

Canadian Dam Association 2001 Annual Conference

September 30–October 4, 2001
Fredericton, New Brunswick, Canada

http://www.cda.ca/cda2001/

Geological Society of America National Conference

November 2–5, 2003
Seattle, Washington

http://www.geosociety.org/meetings/index.htm ■

GEOGRAPHIC/GEOLOGIC NAMES ON THE WEB

The U.S. Geological Survey now has two databases that make it easy to look up information on Washington State. You may want to bookmark these sites.

The Geographic Names Information System (GNIS), developed by the USGS in cooperation with the U.S. Board on Geographic Names, contains information about almost 2 million physical and cultural geographic features in the U.S. and its territories. The GNIS is our nation's official repository of domestic geographic names information. It contains the following geographic information:

- federally recognized feature name,
- feature type,
- feature description,
- elevation (where available),
- 1994 population of incorporated cities and towns,
- state(s) and county(s) in which the feature is located,
- latitude and longitude of the feature location,
- USGS 7.5 x 7.5-minute topographic maps on which the feature is shown, and
- names other than the federally recognized name by which the feature may be or have been known.

For any feature selected, links to sites offering map viewers are provided to enable graphical display of the feature's location. A link to a site offering information about the watershed area in which the feature is located is also provided.

The GNIS website is http://mapping.usgs.gov/www/gnis.

There is also a geologic units lexicon (Geolex) being built where you can search for information about lithographic or geochronologic units. The National Geologic Map Database, of which Geolex is a part, is managed by the USGS's National Cooperative Geologic Mapping Program in cooperation with the Association of American State Geologists. Geolex can be searched by geologic age, unit name, citation author (not available yet), geologic province, and state or territory.

The Geolex website is http:// ngmsvr.wr.usgs.gov/Geolex/.

Selected Additions to the Library of the Division of Geology and Earth Resources

December 1999 through April 2000

THESES

Bakewell, E. F., 1995, Petrographic and geochemical discrimination of chert using texture and major element geochemistry—An archaeometric application: University of Washington Master of Science thesis, 94 p.

Beechie, T. J., 1998, Rates and pathways of recovery for sediment supply and woody debris recruitment in northwestern Washington streams, and implications for salmonid habitat restoration: University of Washington Doctor of Philosophy thesis, 199 p.

Chrisfield, R. A., 1998, Depositional age of the Montesano Formation, southwest Washington, as determined from fission-track dating of detrital zircons: University of Washington Master of Science thesis, 176 p.

Cordero, D. I., 1997, Early to middle Pleistocene catastrophic flood deposits, The Dalles, Oregon: Portland State University Master of Science thesis, 162 p.

Eror, Ellyssa, 1991, Continentality of early-Eocene pelagic sediments associated with the Crescent Formation, Olympic Peninsula, Washington—Tectonic implications: Yale University Bachelor of Science thesis, 43 p.

Heine, J. T., 1997, Glacier advances at the Pleistocene/Holocene transition near Mount Rainier volcano, Cascade Range, USA: University of Washington Doctor of Philosophy thesis, 138 p.

Hou, Jianxin, 1998, Computer based lineament detection system for aeromagnetic data, with a case study in the area around Hanford site, Washington: Washington State University Doctor of Philosophy thesis, 209 p.

Lawrence, R. L., 1998, A landscape-scale analysis of vegetation recovery at Mount St. Helens: Oregon State University Doctor of Philosophy thesis, 127 p.
Includes:

- Lawrence, R. L.; Ripple, W. J., Comparisons among vegetation indices and bandwise regression in a highly disturbed, heterogeneous landscape—Mount St. Helens, Washington. p. 4-37.
- Lawrence, R. L.; Ripple, W. J., Fifteen years of succession at Mount St. Helens—A landscape perspective. p. 73-114.
- Lawrence, R. L.; Ripple, W. J., Use of growth curves to characterize succession with multitemporal satellite imagery—Mount St. Helens 1980–1995. p. 38-72.

Myers, E. P., III, 1994, Numerical modeling of tsunamis with applications to the Sea of Japan and the Pacific Northwest: Oregon Graduate Institute of Science and Technology Master of Science thesis, 161 p.

Neri, Augusto, 1998, Multiphase flow modeling and simulation of explosive volcanic eruptions: Illinois Institute of Technology Doctor of Philosophy thesis, 172 p.

Peterson, J. J., 1999, Stratigraphy and sedimentology of the Pipestone Canyon Formation, north central Washington: Western Washington University Master of Science thesis, 122 p., 3 plates.

Pittman, P. D., 1998, A neotectonic investigation of Shallow Bay marsh, Sucia Island, Washington: Western Washington University Master of Science thesis, 128 p.

Serdar, C. F., 1999, Description, analysis and impacts of the Grouse Creek landslide, Jefferson County, Washington, 1997–98: The Evergreen State College Master of Environmental Studies thesis, 171 p.

Sherrod, B. L., 1998, Late Holocene environments and earthquakes in southern Puget Sound: University of Washington Doctor of Philosophy thesis, 159 p.

Stevenson, B. A., 1997, Stable carbon and oxygen isotopes in soils and paleosols of the Palouse loess, eastern Washington State—Modern relationships and applications for paleoclimatic reconstruction: Colorado State University Doctor of Philosophy thesis, 128 p.

Tate, T. A., 1998, Micromorphology of loessial soils and paleosols on aggrading landscapes on the Columbia Plateau: Washington State University Master of Science thesis, 192 p.

Titus, J. H., 1995, The role of mycorrhizae and microsites in primary succession on Mount St. Helens: University of Washington Doctor of Philosophy thesis, 245 p.

Woxell, L. K., 1998, Prehistoric beach accretion rates and long-term response to sediment depletion in the Columbia River littoral system, USA: Portland State University Master of Science thesis, 206 p.

U.S. GEOLOGICAL SURVEY

Published Reports

Jones, M. A., 1999, Geologic framework for the Puget Sound aquifer system, Washington and British Columbia: U.S. Geological Survey Professional Paper 1424-C, 31 p., 18 plates.

Pierson, T. C., editor, 1999, Hydrologic consequences of hot-rock/snowpack interactions at Mount St. Helens volcano, Washington 1982–84: U.S. Geological Survey Professional Paper 1586, 117 p.
Includes:

- Dinehart, R. L., Sediment transport in the hyperconcentrated phase of the March 19, 1982, lahar. p. 37-52.
- Major, J. J.; Pringle, P. T., Rock avalanches, rockfalls, and associated processes induced by spreading of the lava dome, March 1984. p. 69-80.
- Pierson, T. C., Transformation of water flood to debris flow following the eruption-triggered transient-lake breakout from the crater on March 19, 1982. p. 19-36.
- Pierson, T. C.; Waitt, R. B., Dome-collapse rockslide and multiple sediment–water flows generated by a small explosive eruption on February 2–3, 1983. p. 53-68.
- Pringle, P. T.; Cameron, K. A., Eruption-triggered lahar on May 14, 1984. p. 81-103.
- Walder, J. S., Nature of depositional contacts between pyroclastic deposits and snow or ice. p. 9-18.

Rau, W. W.; Johnson, S. Y., 1999, Well stratigraphy and correlations, western Washington and northwestern Oregon: U.S. Geological Survey Geologic Investigations Series Map I-2621, 3 sheets, with 31 p. text.

Fact Sheets, Open-File Reports, and Water-Resources Investigations Reports

Black, R. W.; MacCoy, D. E., 1999, The development and evaluation of a benthic index of biological integrity for the Cedar River watershed, Washington: U.S. Geological Survey Water-Resources Investigations Report 99-4203, 92 p.

Boleneus, D. E., 1999, Geologic datasets for weights-of-evidence analysis in northeast Washington—2. Mineral databases: U.S. Geological Survey Open-File Report 99-384, 34 p., 1 disk.

Boleneus, D. E., 1999, Geologic datasets for weights of evidence analysis in northeast Washington—3. Minerals-related permits on national forests, 1967 to 1998: U.S. Geological Survey Open-File Report 99-414, 32 p., 1 disk.

Campbell, H. W.; Hyndman, P. C., 1996, Digital mining claim density map for federal lands in the Pacific Northwest: U.S. Geological Survey Open-File Report 96-737, 11 p.

Collins, C. A.; Broad, T. M., 1996, Ground-water pumpage in the Willamette Lowland regional aquifer system, Oregon and Washington: U.S. Geological Survey Water-Resources Investigations Report 96-4111, 27 p.

Cox, S. E.; Liebscher, Hugh, 1999, Ground-water quality data from the Abbotsford–Sumas aquifer of southwestern British Columbia and northwestern Washington State, February 1997: U.S. Geological Survey Open-File Report 99-244, 28 p.

Fisher, B. J., 1996, Methodology used to produce an encoded 1:100,000-scale digital hydrographic data layer for the Pacific Northwest: U.S. Geological Survey Water-Resources Investigations Report 94-4043, 84 p.

Kresch, D. L., 1999, Equations for estimating fish passage design flows at ungaged streams in eastern Washington: U.S. Geological Survey Water-Resources Investigations Report 99-4186, 26 p.

McGee, K. A.; Gerlach, T. M., 1995, Volcanic gas: U.S. Geological Survey Open-File Report 95-85, 2 p.

Munn, M. D., 2000, Contaminant trends in sport fish from Lake Roosevelt and the upper Columbia River, Washington, 1994–1998: U.S. Geological Survey Water-Resources Investigations Report 00-4024, 12 p.

Prych, E. A., 1999, A tracer test to estimate hydraulic conductivities and dispersivities of sediments in the shallow aquifer at the East Gate Disposal Yard, Fort Lewis, Washington: U.S. Geological Survey Water-Resources Investigations Report 99-4244, 48 p.

Reid, M. E.; LaHusen, R. G.; Ellis, W. L., 1999, Real-time monitoring of active landslides: U.S. Geological Survey Fact Sheet 091-99, 2 p.

Ryker, S. J.; Frans, L. M., 2000, Summary of nitrate concentrations in ground water of Adams, Franklin, and Grant Counties, Washington, Fall 1998—A baseline for future trend analysis: U.S. Geological Survey Water-Resources Investigations Report 99-4288, 39 p.

Rystrom, V. L.; Finn, C. A.; Descsz-Pan, Maryla, 2000, High resolution, low altitude aeromagnetic and electromagnetic survey of Mt. Rainier: U.S. Geological Survey Open-File Report 00-27, 10 p. [downloaded March 22, 2000, from http://greenwood.cr.usgs.gov/pub/open-file-reports/ofr-00-0027/]

Schmoker, J. W.; Dyman, T. S.; Dolton, G. L.; Fox, J. E.; Law, B. E.; Peterson, J. A.; Tennyson, M. E., 1996, Gas plays of the U.S. Geological Survey 1995 national assessment that underlie regionally extensive surface volcanics: U.S. Geological Survey Open-File Report 96-99, 13 p.

Sisson, T. W., 1995, History and hazards of Mount Rainier, Washington: U.S. Geological Survey Open-File Report 95-642, 2 p.

Soller, D. R., editor, 1999, Digital mapping techniques '99—Workshop proceedings: U.S. Geological Survey Open-File Report 99-386, 216 p.

Uhrich, M. A.; McGrath, T. S., 1997, Conversion of environmental data to a digital-spatial database, Puget Sound area, Washington: U.S. Geological Survey Open-File Report 95-359, 117 p.

U.S. Geological Survey, 2000, Washington: U.S. Geological Survey Fact Sheet 049-99, 4 p.

OTHER REPORTS ABOUT WASHINGTON GEOLOGY

Associated Earth Sciences, Inc., 1999, Snohomish County mineral resource study, Snohomish County, Washington—Prospect identification and preliminary classification: Associated Earth Sciences, Inc. [under contract to] Huckell/Weinman Associates, Inc., 37 p., 2 plates.

Brown, David, and Associates, Inc., 2000, Thermal transport study of the Selah Lakes gravel mine, 1999 annual report: David Brown & Associates [under contract to] Central Pre-Mix Concrete Company, 1 v., 1 CD-ROM, 1 plate.

Carey, B. M., 1995, Evaluation of the potential for ground water contamination at Sunland land application site: Washington Department of Ecology Report 95-312, 24 p.

Crosson, R. S.; Creager, K. C., 1999, SHIPS collaborative investigations—3-D seismic tomography and 3-D seismic reflection analysis: University of Washington Geophysics Program, 4 p. [downloaded Jan. 7, 2000, from http://www.geophys.washington.edu/SEIS/PNSN/REPTS/Sum99/G0036.htm]

Daniels, R. C.; Ruggiero, Peter; Weber, L. E., 1999, Washington coastal geodetic control network—Report and station index: Washington Department of Ecology Publication 99-103, 268 p.

Erickson, Karol; Davis, Dale; Dutch, Margaret; Ehinger, William; Erickson, Denis; Hopkins, Brad; Hoyle-Dodson, Guy; Newton, Jan; and others, 1997, Watershed briefing paper for the Cedar/Green Water Quality Management Area: Washington Department of Ecology Publication 97-335, 62 p.
Includes:
Erickson, Denis, Ground water investigations. p. 45-46.
Erickson, Karol, Watershed assessments and TMDLs. p. 11-16.
Hopkins, Brad; Ehinger, William, River and stream ambient monitoring. p. 1-10.

Hart-Crowser, 1994, Hydrogeologic characterization for protection of the Wildcat Creek aquifer, Grays Harbor County, Washington, Centennial Clean Water Fund Grant G93: Hart-Crowser [under contract to City of McCleary], 1 v., 5 plates.

Hartshorn, D. C.; Reidel, S. P.; Rohay, A. C., 1999, Second and third quarters Hanford seismic report for fiscal year 1999: Pacific Northwest National Laboratory PNNL-11557-11, 1 v.

Hayes, Derek, 1999, Historical atlas of the Pacific Northwest—Maps of exploration and discovery, British Columbia, Washington, Oregon, Alaska, Yukon: Sasquatch Books, 208 p.

Johnson, Art, 2000, Water and sediment quality in the vicinity of Cleveland mine, Hunters Creek drainage, Stevens County: Washington Department of Ecology Publication 00-03-013, 1 v.

Klingeman, P. C.; Beschta, R. L.; Komar, P. D.; Bradley, J. B., editors, 1998, Gravel-bed rivers in the environment: Water Resources Publications, LLC, 832 p.
Includes:
Bradley, J. B.; Williams, D. T.; Walton, R., Applicability and limitations of sediment transport modeling in gravel-bed rivers. p. 543-578.
Komar, P. D., Cataclysmic floods on Earth and Mars—Morphology and hydraulic interpretations. p. 677-704.
Milhous, R. T.; Miller, S.; Galay, V. J., Case study of gravel-bed river management—The Skykomish River near Gold Bar, Washington. p. 705-724.
Seal, Rebecca; Toro-Escobar, C.; Cui, Y.; Paola, Christopher; Parker, Gary; Southard, J. B.; Wilcock, P. R., Downstream fining by selective deposition—Theory, laboratory, and field observations. p. 61-84.

Larson, A. G., 1996, Pesticides in Washington State's ground water—A summary report, 1988–1995: Washington Department of Ecology Publication 96-303; Washington Department of Ecology Pesticides in Ground Water Report 9, 22 p.

Malone, S. D.; Crosson, R. S.; Qamar, A. I., 1999, Cooperative operation of the Pacific Northwest Seismograph Network: University of Washington Geophysics Program, 1 v.

Malone, S. D.; Crosson, R. S.; Qamar, A. I., 1999, Pacific Northwest Seismograph Network operations: University of Washington Geophysics Program, 6 p. [downloaded Jan. 7, 2000, from http://www.geophys.washington.edu/SEIS/PNSN/REPTS/Sum99/A1302.htm]

Mofjeld, H. O.; Titov, V. V.; Gonzalez, F. I.; Newman, J. C., 2000, Analytic theory of tsunami wave scattering in the open ocean with application to the North Pacific: U.S. National Oceanic and Atmospheric Administration NOAA Technical Memorandum OAR PMEL-116, 38 p.

Northwest Scientific Association, 1999, A century of resource stewardship and beyond—Mount Rainier National Park 100th anniversary symposium: Northwest Scientific Association, 57 p.

Qamar, A. I., 1998, GPS investigations of Holocene fault zones in the Puget Sound basin, Washington: University of Washington Geophysics Program, 5 p. [downloaded Jan. 7, 2000, from http://www.geophys.washington.edu/SEIS/PNSN/REPTS/Sum97/GR03092.htm]

Qamar, A. I.; Ludwin, R. S., 1999, Database catalog of Cascadia earthquakes: University of Washington Geophysics Program, 3 p. [downloaded Jan. 7, 2000, from http://www.geophys.washington.edu/SEIS/PNSN/REPTS/Sum99/G03166.htm]

Raforth, R. L.; Johnson, Art; Norman, D. K., 2000, Screening level investigation of water and sediment quality of creeks in ten eastern Washington mining districts, with emphasis on metals: Washington Department of Ecology Publication 00-3-004, 1 v.

Raines, Mary; and others, 1997, Onion Creek watershed analysis: Boise Cascade Corporation, 1 v.

Rygle, K. J.; Pedersen, S. F., 1999, The treasure hunter's gem and mineral guides to the U.S.A.—Where and how to dig, pan, and mine your own gems and minerals; Vol. 1—Northwest states: GemStone Press, 157 p.

Sakrison, Rodney; Sturtevant, Peter, editors, 1999, Watershed management to protect declining species; Proceedings—AWRA's annual water resources conference: American Water Resources Association, 561 p.

Includes:

Ablow, Elizabeth; Landau, Brian; Olson, Alan; Fairbanks, Randal, Use of GIS indicators for landscape-level watershed assessments—The I-90 land exchange as an example. p. 241-244.

Alb, J. W., The Washington State Department of Transportation's comprehensive approach to salmon recovery through the creation of environmental partnerships. p. 55-58.

Anderson, R. H., The importance of groundwater to municipal water supply in Washington. p. 493-496.

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Beamer, E. M.; Beechie, T. J.; Perkowski, Ben; Klochak, John, Restoration of habitat-forming processes in a large river basin—An applied restoration strategy for the Skagit River basin, Washington. p. 71-74.

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Dinicola, R. S., Validation of a rainfall-runoff modeling method using regionalized HSPF parameter values for King and Snohomish Counties, Washington. p. 295-298.

Doyle, J. E., Aquatic conservation on federal lands—A strategy for the recovery of Puget Sound native salmonids. p. 63-66.

Gersib, Richard; Wildrick, L. L.; Freeland, Cygnia; Grigsby, Susan; Brown, Jennifer, River basin characterization, a case study in the Snohomish River basin, Washington. p. 225-228.

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Henshaw, P. C., Restabilization of stream channels in urban watersheds. p. 425-428.

Larson, M. G., Effectiveness of LWD in stream rehabilitation projects in urban basins. p. 377-380.

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Macklin, J. D.; Plumb, P. J., Building a better salmon stream. p. 385-388.

McCarthy, Edward; Lenth, John; Flewelling, James, Evaluating stormwater treatment technologies with a statistical sampling approach. p. 473-476.

McConnaha, W. E., The Columbia River multi-species framework—Principles and progress. p. 83-86.

Nelligan-Doran, S. E.; Palmer, R. N.; Groome, A. R., Allocating water between folks and fish—The Endangered Species Act and Puget Sound water supplies. p. 489-492.

Nelson, Erin, Sediment budget of a mixed-use, urbanizing watershed p. 469-472.

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Perkins, Ted; Barber, M. E., Hemlock dam fish passage evaluation and restoration. p. 437-440.

Pess, G. R.; Bilby, R. E.; Montgomery, D. R., Stream-reach and watershed-scale variables and salmonid spawning distribution and abundance in the Puget Sound region. p. 397-400.

Pickett, P. J., Lower Skagit River dissolved oxygen model. p. 273-276.

Ring, T. E.; Watson, Bruce, Effects of geologic and hydrologic factors and watershed change on aquatic habitat in the Yakima River basin, Washington. p. 191-194.

Seiter, Ann; Newberry, Linda; Edens, Pam, Moving from process to progress—The Dungeness watershed. p. 59-62.

Shaul, Warren, Riparian and floodplain restoration—Real actions that integrate flood protection with benefits to chinook salmon and steelhead. p. 361-364.

Shaw, S. C.; Vaugeois, L. M., Role of predictive landslide models in watershed management—A comparative test of GIS-based models for shallow landsliding. p. 245-248.

Skidmore, Peter; Cooper, Paula; Boyd, Karin, Methodology for determining meander corridor limits. p. 421-424.

Skillings, T. E., Water reuse—The wave of the future. p. 481-484.

Smith, D. L.; Brannon, E. L.; Kinsel, W. F.; Manuel, Chris; Medina, Victor, Return flow water quality in the Columbia Basin Irrigation Project with implications for fall chinook salmon habitat. p. 87-90.

Soscia, M. L., The role of the Clean Water Act in upcoming Columbia River Endangered Species Act decisions. p. 79-82.

Steel, E. A., Effects of temperature and water clarity on juvenile hatchery chinook salmon migration patterns. p. 401-404.

Sturhan, Nancy, Washington's watershed analysis—Results. p. 213-216.

Vaccaro, J. J.; Lynch, C. J.; Mastin, M. C.; Sharp, W.; Schurr, K. M., Constructing a decision support system for the Yakima River basin. p. 183-186.

Wagner, Paul, Salmon flow augmentation in the Columbia and Snake Rivers. p. 75-78.

Wicklein, E.; Papanicolaou, A. N.; Richmond, M., Limitations of existing sediment transport models in Northwest rivers. p. 291-294.

Zisette, Rob; Trial, W. T.; Samadpour, Mansour, The use of microbial source tracking to identify fecal contamination in the Drayton Harbor watershed. p. 445-448.

Shannon & Wilson, Inc., 1999, Phase 1 reconnaissance report, landslide at Sunrise Beach Road NW, Thurston County, Washington: Shannon & Wilson, Inc. [under contract to] Thurston County Department of Roads & Transportation Services, 20 p.

Shannon & Wilson, Inc., 2000, Seattle landslide study: Shannon & Wilson, Inc. [under contract to] Seattle Public Utilities, 2 v.

Sigurdsson, Haraldur; and others, editors, 2000, Encyclopedia of volcanoes: Academic Press, 1417 p.

Includes:

Baxter, P. J., Impacts of eruptions on human health. p. 1035-1043.

Beget, J. E., Volcanic tsunamis. p. 1005-1013.

Carey, S. N.; Bursik, M. I., Volcanic plumes. p. 527-544.

Cioni, Raffaello; Marianelli, Paola; Santacroce, Roberto; Sbrana, Alessandro, Plinian and subplinian eruptions. p. 477-494.

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Rutherford, M. J.; Gardner, J. E., Rates of magma ascent. p. 207-217.

Sigurdsson, Haraldur; Lopes-Gautier, Rosaly, Volcanoes and tourism. p. 1283-1299.

Thornton, I. W. B., The ecology of volcanoes—Recovery and reassembly of living communities. p. 1057-1081.

Ui, Tadahide; Takarada, Shinji; Yoshimoto, Mitsuhiro, Debris avalanches. p. 617-626.

Vallance, J. W., Lahars. p. 601-616.

Sinclair, K. A.; Pitz, C. F., 1999, Estimated baseflow characteristics of selected Washington rivers and streams: Washington Department of Ecology Water Supply Bulletin 60; Publication 99-327, 1 v., 5 plates, 1 disk.

U.S. Federal Highway Administration; Washington Department of Transportation, 2000, SR 16/Union Avenue vicinity to SR 302 vicinity—Final environmental impact statement: Washington Department of Transportation, 1 v.

U.S. Federal Highway Administration; Washington Department of Transportation, 2000, SR 16/Union Avenue vicinity to SR 302 vicinity—Responses to comments on draft EIS: Washington Department of Transportation, 1 v.

U.S. Federal Highway Administration; Washington Department of Transportation, 2000, SR 16/Union Avenue vicinity to SR 302 vicinity—Appendices: Washington Department of Transportation, 1 v.

U.S. Geological Survey; University of Washington Geophysics Program, 2000, Cascadia quakes—A tricentennial exposition: University of Washington Geophysics Program, 24 p.

U.S. National Tsunami Hazard Mitigation Program, 1999, Tsunami information forums, Grays Harbor and Pacific Counties, November 15–18, 1999: U.S. National Tsunami Hazard Mitigation Program, 1 v.

University of Washington Geophysics Program, 1999, Quarterly network report 98-C on seismicity of Washington and Oregon, July 1 through September 30, 1998. *In* Malone, S. D.; Crosson, R. S.; Qamar, A. I., Cooperative operation of the Pacific Northwest Seismograph Network: University of Washington Geophysics Program, 38 p.

University of Washington Geophysics Program, 1999, Quarterly network report 99-C on seismicity of Washington and Oregon, July 1 through September 30, 1999: University of Washington Geophysics Program, 24 p.

Washington Department of Ecology, 1999, Everett Smelter Site, Everett, Washington, integrated draft cleanup action plan and draft environmental impact statement for the uplands area: Washington Department of Ecology, 1 v., 3 plates.

Washington Department of Natural Resources, 1998, South Fork Touchet watershed analysis; Watershed administrative units—South Fork Touchet, Wolf Fork: Washington Department of Natural Resources, 1 v.

Washington Department of Transportation, 1999, Standard specifications for road, bridge, and municipal construction, 2000—English units: Washington Department of Transportation, 1 v.

Washington Department of Transportation, 1999, Standard specifications for road, bridge, and municipal construction, 2000—Metric units: Washington Department of Transportation, 1 v.

Washington Department of Transportation, 2000, Materials manual, M 46-01: Washington Department of Transportation, 1 v.

Washington Emergency Management Division, 1999, 1999 Washington State recovery plan; Coordinating draft: Washington Emergency Management Division, 1 v.

Western States Seismic Policy Council, 2000, WSSPC awards excellence, 1999: Western States Seismic Policy Council, 1 v.

Whatcom County Department of Public Works, 1992, Draft environmental impact statement, Columbia Aggregates gravel surface mine: Whatcom County Department of Public Works, 82 p.

Whatcom County Planning and Development Services, 1994, Whatcom County natural resources report—Mineral resources: Whatcom County Planning and Development Services, 26 p.

Wills, M. T.; Purdy, J. W., 1999, Wellhead protection area delineation for the City of Shelton: Robinson & Noble, Inc., 1 v.

PAPERS ABOUT WASHINGTON GEOLOGY

Alonso, C. V.; Theurer, F. D.; Havis, R. N., 1998, Simulating sedimentation in salmonid redds. *In* Interagency Advisory Committee on Water Data Subcommittee on Hydrology, Proceedings of the first federal interagency hydrologic modeling conference: U.S. Interagency Advisory Committee on Water Data, p. 8-1–8-8.

Bacon, C. R.; Bruggman, P. E.; Christiansen, R. L.; Clynne, M.A.; Donnelly-Nolan, J. M.; Hildreth, Wes, 1997, Primitive magmas at five Cascade volcanic fields—Melts from hot, heterogeneous sub-arc mantle: Canadian Mineralogist, v. 35, Part 2, p. 397-423.

Bacon, D. H.; Keller, C. K., 1998, Carbon dioxide respiration in the deep vadose zone—Implications for groundwater age dating: Water Resources Research, v. 34, no. 11, p. 3069-3077.

Becker, Keir; Fisher, A. T., 2000, Permeability of upper oceanic basement on the eastern flank of the Juan de Fuca Ridge determined with drill-string packer experiments: Journal of Geophysical Research, v. 105, no. B1, p. 897-912.

Briggs, M. J., 1999, Recent studies on tsunami runup at WES: Shore & Beach, v. 67, no. 1, p. 34-40.

Brodsky, E. E.; Kanamori, Hiroo; Sturtevant, Bradford, 1999, A seismically constrained mass discharge rate for the initiation of the May 18, 1980 Mount St. Helens eruption: Journal of Geophysical Research, v. 104, no. B12, p. 29,387-29,400.

Davis, E. E., 2000, Volcanic action at Axial Seamount: Nature, v. 403, no. 6768, p. 379-380.

Dinehart, R. L., 1999, Correlative velocity fluctuations over a gravel river bed: Water Resources Research, v. 35, no. 2, p. 569-582.

Ertan, I. E.; Leeman, W. P., 1999, Fluid inclusions in mantle and lower crustal xenoliths from the Simcoe volcanic field, Washington: Chemical Geology, v. 154, no. 1-4, p. 83-95.

Evans, M. E., 1999, Magnetoclimatology—A test of the wind-vigour model using the 1980 Mount St. Helens ash: Earth and Planetary Science Letters, v. 172, no. 3-4, p. 255-259.

Fenical, S.; Bermudez, H.; Shepsis, Vladimir, 1999, Erosion control at the entrance to Willapa Bay, Washington. *In* Kraus, N. C.; McDougal, W. G., editors, Coastal sediments '99—Proceedings of the 4th International Symposium on Coastal Engineering and Science of Coastal Sediment Processes: American Society of Civil Engineers, v. 3, p. 1936-1945.

Fuhrer, G. J.; McKenzie, S. W.; Rinella, J. F.; Skach, K. A., 1997, Effects of geology and human activities on the distribution of trace elements in water, sediment, and aquatic biota, Yakima River Basin, Washington (1987–1991). *In* Laenen, Antonius; Dunnette, D. A., editors, River quality—Dynamics and restoration: Lewis Publishers, p. 187-204.

Geist, E. L.; Yoshioka, Shoichi, 1996, Source parameters controlling the generation and propagation of potential local tsunamis along the Cascadia margin: Natural Hazards, v. 13, no. 2, p. 151-177.

Gelfenbaum, Guy; Sherwood, C. R.; Peterson, C. D.; Kaminsky, G. M.; Buijsman, M. C.; Twichell, D. C.; Ruggiero, Peter; Gibbs, A. E.; Reed, Christopher, 1999, The Columbia River littoral cell—A sediment budget overview. *In* Kraus, N. C.; McDougal, W. G., editors, Coastal sediments '99—Proceedings of the 4th International Symposium on Coastal Engineering and Science of Coastal Sediment Processes: American Society of Civil Engineers, v. 2, p. 1660-1675.

Giambalvo, E. R.; Fisher, A. T.; Martin, J. T.; Darty, Lisa; Lowell, R. P., 2000, Origin of elevated sediment permeability in a hydrothermal seepage zone, eastern flank of the Juan de Fuca Ridge, and implications for transport of fluid and heat: Journal of Geophysical Research, v. 105, no. B1, p. 913-928.

Gibbs, A. E.; Gelfenbaum, Guy, 1999, Bathymetric change off the Washington–Oregon coast. *In* Kraus, N. C.; McDougal, W. G., editors, Coastal sediments '99—Proceedings of the 4th International Symposium on Coastal Engineering and Science of Coastal Sediment Processes: American Society of Civil Engineers, v. 2, p. 1627-1642.

Hands, E. B.; Shepsis, Vladimir, 1999, Cyclic channel movement at the entrance to Willapa Bay, Washington, USA. *In* Kraus, N. C.; McDougal, W. G., editors, Coastal sediments '99—Proceedings of the 4th International Symposium on Coastal Engineering and Science of Coastal Sediment Processes: American Society of Civil Engineers, v. 2, p. 1522-1536.

Haug, B. J., 1998, High resolution seismic reflection interpretations of the Hood Canal–Discovery Bay fault zone, Puget Sound, Washington. *In* Puget Sound Water Quality Action Team, Puget Sound research '98; Proceedings: Puget Sound Water Quality Action Team, p. 217-227 [downloaded Feb. 4, 2000, from http://www.wa.gov/puget_sound/98_proceedings/sessions/physical_sound.html]

Hedges, J. I.; Hu, F. S.; Devol, A. H.; Hartnett, H. E.; Tsamakis, Elizabeth; Keil, R. G., 1999, Sedimentary organic matter preservation—A test for selective degradation under oxic conditions: American Journal of Science, v. 299, no. 7-9, p. 529-555.

Heusser, C. J.; Heusser, L. E.; Peteet, D. M., 1999, Humptulips revisited—A revised interpretation of Quaternary vegetation and climate of western Washington, USA: Palaeogeography, Palaeoclimatology, Palaeoecology, v. 150, no. 3-4, p. 191-221.

Housen, B. A.; Beck, M. E., Jr., 1999, Testing terrane transport—An inclusive approach to the Baja B.C. controversy: Geology, v. 27, no. 12, p. 1143-1146.

Huggett, D. B.; Gillespie, W. B., Jr.; Rodgers, J. H., Jr., 1999, Copper bioavailability in Steilacoom Lake sediments: Archives of Environmental Contamination and Toxicology, v. 36, no. 2, p. 120-123.

Jangaard, Loren, 1998, Additional storage study of Hanson reservoir, Green River, WA. *In* Interagency Advisory Committee on Water Data Subcommittee on Hydrology, Proceedings of the first federal interagency hydrologic modeling conference: U.S. Interagency Advisory Committee on Water Data, p. 2-77–2-84.

Jol, H. M.; Peterson, C. D.; Vanderburgh, Sandy; Phipps, J. B., 1998, GPR as a regional geomorphic mapping tool—Shoreline accretion/erosion along the Columbia River littoral cell: International Conference on Ground-Penetrating Radar, 7th, Proceedings, v. 2, p. 257-262.

Kaminsky, G. M.; Buijsman, M. C.; Gelfenbaum, Guy; Ruggiero, Peter; Jol, H. M.; Gibbs, A. E.; Peterson, C. D., 1999, Synthesizing geological observations and processes—Response data for modeling coastal change at management scale. *In* Kraus, N. C.; McDougal, W. G., editors, Coastal sediments '99—Proceedings of the 4th International Symposium on Coastal Engineering and Science of Coastal Sediment Processes: American Society of Civil Engineers, v. 2, p. 1708-1723.

Komar, P. D., 1999, Coastal change—Scales of processes and dimensions of problems. *In* Kraus, N. C.; McDougal, W. G., editors, Coastal sediments '99—Proceedings of the 4th International Symposium on Coastal Engineering and Science of Coastal Sediment Processes: American Society of Civil Engineers, v. 1, p. 1-17.

Komar, P. D., 2000, Coastal erosion—Underlying factors and human impacts: Shore & Beach, v. 68, no. 1, p. 3-16.

Kraus, N. C.; Wiegel, R. L.; Bascom, W. N., 1997, Beach profile surveys along the U.S. Pacific coast 1945–1947. *In* Edge, B. L., editor, Coastal engineering 1996—Proceedings of the twenty-fifth international conference: American Society of Civil Engineers, p. 3020-3033.

Lancaster, Nicholas, 2000, Dating eolian features by correlations with global climatic changes. *In* Noller, J. S.; Sowers, J. M.; Lettis, W. R., editors, Quaternary geochronology—Methods and applications: American Geophysical Union AGU Reference Shelf 4, p. 465-469.

Langenheim, J. H., 1995, Biology of amber-producing trees—Focus on case studies of *Hymenaea* and *Agathis*. *In* Anderson, K. B.; Crelling, J. C., editors, Amber, resinite, and fossil resins: American Chemical Society Symposium Series 617, p. 1-31.

Larson, D. W., 1998, Volcanic lakes of the Pacific Northwest: Lake Line, v. 18, no. 3, p. 10-19.

Lindell, M. K.; Perry, R. W., 1993, Risk area residents' changing perceptions of volcano hazard at Mt. St. Helens. *In* Nemec, Jaromir; Nigg, J. M.; Siccardi, Franco, editors, Prediction and perception of natural hazards: Kluwer Academic Publishers, p. 159-166.

Lins, Harry; Frevert, Donald, 1998, The Watershed and River Systems Management Program—An overview. *In* Interagency Advisory Committee on Water Data Subcommittee on Hydrology, Proceedings of the first federal interagency hydrologic modeling conference: U.S. Interagency Advisory Committee on Water Data, p. 5-101–5-104.

Massong, T. M.; Montgomery, D. R., 2000, Influence of sediment supply, lithology, and wood debris on the distribution of bedrock and alluvial channels: Geological Society of America Bulletin, v. 112, no. 4, p. 591-599.

McNeill, L. C.; Goldfinger, Chris; Yeats, R. S.; Kulm, L. D., 1998, The effects of upper plate deformation on records of prehistoric Cascadia subduction zone earthquakes. *In* Stewart, I. S.; Vita-Finze, Claudio, editors, Coastal tectonics: Geological Society Special Publication 146, p. 321-342.

Meselhe, E. A.; Weber, L. J., 1997, Validation of a three-dimensional numerical model using field measurements in a large scale river reach. *In* Holly, F. M., Jr.; Alsaffar, Adnan; and others, editors, Environmental and coastal hydraulics—Protecting the aquatic habitat: American Society of Civil Engineers, v. 2, p. 827-832.

Moritz, H. R.; Kraus, N. C.; Hands, E. B.; Slocum, D. B., 1999, Correlating oceanographic processes with seabed change, mouth of the Columbia River, USA. *In* Kraus, N. C.; McDougal, W. G., editors, Coastal sediments '99—Proceedings of the 4th International Symposium on Coastal Engineering and Science of Coastal Sediment Processes: American Society of Civil Engineers, v. 2, p. 1643-1659.

Moritz, H. P.; Kraus, N. C.; Siipola, M. D., 1999, Simulating the fate of dredged material, Columbia River, USA. *In* Kraus, N. C.; McDougal, W. G., editors, Coastal sediments '99—Proceedings of the 4th International Symposium on Coastal Engineering and Science of Coastal Sediment Processes: American Society of Civil Engineers, v. 3, p. 2487-2503.

Myers, E. P.; Baptista, A. M.; Priest, G. R., 1999, Finite element modeling of potential Cascadia subduction zone tsunamis: Science of Tsunami Hazards, v. 17, no. 1, p. 3-18. [additional materials at http://www.ccalmr.ogi.edu/STH/online/volume17/number1/mbp/]

Neumann, Udo; Zürn, Walter, 1999, Gravity signals from atmospheric waves and their modeling: Marees Terrestres, Bulletin d'Informations, v. 131, p. 10,139-10,152.

Oil & Gas Journal, 2000, Gas line to Vancouver Island proposed: Oil & Gas Journal, v. 98, no. 6, p. 40.

Parvey, J. G.; Strout, J. M., 1998, Landfill cap design at the Tacoma Landfill Superfund site. *In* Sarsby, R. W., editor, Contaminated and derelict land—The proceedings of GREEN 2; The second international symposium on geotechnics related to the environment: Thomas Telford [London], p. 361-367.

Paterson, S. R.; Miller, R. B., 1998, Mid-crustal magmatic sheets in the Cascades mountains, Washington—Implications for magma ascent: Journal of Structural Geology, v. 20, no. 9/10, p. 1345-1363.

Paterson, S. R.; Miller, R. B., 1998, Stoped blocks in plutons—Paleo-plumb bobs, viscometers, or chronometers?: Journal of Structural Geology, v. 20, no. 9/10, p. 1261-1272.

Peck, H. W.; Duffe, B. J., 1998, Cowlitz River flood hazard study. *In* Interagency Advisory Committee on Water Data Subcommittee on Hydrology, Proceedings of the first federal interagency hydrologic modeling conference: U.S. Interagency Advisory Committee on Water Data, p. 4-69–4-76.

Peterson, C. D.; Gelfenbaum, Guy; Jol, H. M.; Phipps, J. B.; Reckendorf, Frank; Twichell, D. C.; Vanderburgh, Sandy; Woxell, L. K., 1999, Great earthquakes, abundant sand, and high wave energy in the Columbia cell, USA. *In* Kraus, N. C.; McDougal, W. G., editors, Coastal sediments '99—Proceedings of the 4th International Symposium on Coastal Engineering and Science of Coastal Sediment Processes: American Society of Civil Engineers, v. 2, p. 1676-1691.

Pitlick, John, 1993, Reply [to comment on "Flow resistance under conditions of intense gravel transport," by George A. Griffiths]: Water Resources Research, v. 29, no. 7, p. 2459.

Pyrah, James; Davis, Angela; Huws, Dei, 1998, A combined geotechnical/geophysical method for the prediction of liquefaction, with particular reference to the Fraser River delta, British Columbia. *In* Maund, J. G.; Eddleston, Malcolm, editors, Geohazards in engineering geology: Geological Society of London Engineering Geology Special Publication 15, p. 11-23.

Romanyuk, T. V.; Blakely, R. J.; Mooney, W. D., 1998, The Cascadia subduction zone—Two contrasting models of lithospheric structure: Physics and Chemistry of the Earth, v. 23, no. 3, p. 297-301.

Ruggiero, Peter; Côté, J. M.; Kaminsky, G. M.; Gelfenbaum, Guy, 1999, Scales of variability along the Columbia River littoral cell. *In* Kraus, N. C.; McDougal, W. G., editors, Coastal sediments '99—Proceedings of the 4th International Symposium on Coastal Engineering and Science of Coastal Sediment Processes: American Society of Civil Engineers, v. 2, p. 1692-1707.

Ruggiero, Peter; Kaminsky, G. M.; Plant, Nathaniel, 1998, Coastal morphologic variability of high energy dissipative beaches. *In* Edge, B. L., editor, Coastal engineering 1998—Conference proceedings: American Society of Civil Engineers, v. 3, p. 3238-3251.

Schoch, G. C.; Dethier, M. N., 1998, Mapping shorelines in Puget Sound I—A spatially nested geophysical shoreline partitioning model. *In* Puget Sound Water Quality Action Team, Puget Sound research '98; Proceedings: Puget Sound Water Quality Action Team, p. 559-565 [downloaded Feb. 4, 2000, from http://www.wa.gov/puget_sound/98_proceedings/sessions/studying_nearshore.html].

Sherrod, B. L., 1999, Gradient analysis of diatom assemblages in a Puget Sound salt marsh—Can such assemblages be used for quantitative paleoecological reconstructions?: Palaeogeography, Palaeoclimatology, Palaeoecology, v. 149, no. 1-4, p. 213-226.

Sinitshenkova, N. D., 1999, A new mayfly species of the extant genus *Neoephemera* from the Eocene of North America (Insecta: Ephemerida=Ephemeroptera: Neoephemeridae): Paleontological Journal, v. 33, no. 4, p. 403-405.

Sokolowski, T. J., 1999, The U.S. west coast and Alaska Tsunami Warning Center: Science of Tsunami Hazards, v. 17, no. 1, p. 49-55.

Stoner, Mike; Pebles, Lucy; Friedman-Thomas, Rachel; Schadt, Tom, 1998, Bellingham Bay demonstration pilot. *In* Puget Sound Water Quality Action Team, Puget Sound research '98; Proceedings: Puget Sound Water Quality Action Team, p. 611-621. [downloaded Feb. 4, 2000, from http://www.wa.gov/puget_sound/98_proceedings/sessions/sediment-eval.html]

Thackray, G. D., 1998, Convergent-margin deformation of Pleistocene strata on the Olympic coast of Washington, USA. *In* Stewart, I. S.; Vita-Finze, Claudio, editors, Coastal tectonics: Geological Society Special Publication 146, p. 199-211.

Thompson, E. F.; Brooks, R. M., 1999, Evaluation of two new decades of WIS Pacific coast wave hindcasts: Shore & Beach, v. 67, no. 1, p. 29-33.

Thompson, R. S.; Whitlock, Cathy; Bartlein, P. J.; Harrison, S. P.; Spaulding, W. G, 1993, Climatic changes in the western United States since 18,000 yr B.P. *In* Wright, H. E., Jr.; Kutzbach, J. E.; and others, editors, Global climates since the last glacial maximum: University of Minnesota Press, p. 468-513.

Thouret, J.-C., 1990, Contribution a la definition des formations issues des interactions volcaniques et glaciaires [Defining the formations resulting from volcanic and glacial interactions]. *In* La Terre et les Hommes—Mélanges offerts à Max Derruau: Faculté des Lettres et Sciences humaines de l'Université de Clermont-Ferrand II, Nouvelle Serie 32, p. 221-236.

Vaccaro, J. J.; Lynch, C. J.; Schurr, K. M.; Sharp, W.; Mastin, M. C.; Schramm, D., 1998, The Yakima River basin watershed and river system management program. *In* Interagency Advisory Committee on Water Data Subcommittee on Hydrology, Proceedings of the first federal interagency hydrologic modeling conference: U.S. Interagency Advisory Committee on Water Data, p. 5-105–5-111.

Veirs, S. R.; McDuff, R. E.; Lilley, M. D.; Delaney, J. R., 1999, Locating hydrothermal vents by detecting buoyant, advected plumes: Journal of Geophysical Research, v. 104, no. B12, p. 29,239-29,247.

Voight, B. G., 1998, Merging coastal research with land-use planning for improved coastal hazard management. *In* Minding the coast—It's everybody's business: Coastal Society, International Conference, 16th, Proceedings, [6 p., unpaginated].

Willett, S. D., 1999, Orogeny and orography—The effects of erosion on the structure of mountain belts: Journal of Geophysical Research, v. 104, no. B12, p. 28,957-28,981.

Zarriello, P. J., 1998, Comparison of nine uncalibrated runoff models to observed flows in two small urban watersheds. *In* Interagency Advisory Committee on Water Data Subcommittee on Hydrology, Proceedings of the first federal interagency hydrologic modeling conference: U.S. Interagency Advisory Committee on Water Data, p. 7-163–7-170.

OTHER INTERESTING MATERIALS

Aalto, K. R.; Aalto, R.; Garrison-Laney, C. E.; Abramson, H. F., 1999, Tsunami(?) sculpturing of the Pebble Beach wave-cut platform, Crescent City area, California: Journal of Geology, v. 107, no. 5, p. 607-622.

AAPG Explorer, 2000, Special issue—A century: American Association of Petroleum Geologists, 1 v.

Baptista, M. A.; Heinrich, Philippe; Massinon, B.; Tinti, Stefano, editors, 1997, Tsunamis impacting on the European coasts—Modelling, observation and warning: Physics and Chemistry of the Earth, v. 21, no. 1/2, 91 p.

Beaulieu, J. D.; Olmstead, D. L., 1999, Geologic hazards—Reducing Oregon's losses: Oregon Department of Geology and Mineral Industries Special Paper 32, 27 p.

Beaulieu, J. D.; Olmstead, D. L., 1999, Mitigating geologic hazards in Oregon—A technical reference manual: Oregon Department of Geology and Mineral Industries Special Paper 31, 60 p.

Bernard, E. N.; Mader, C. L.; Curtis, George; Satake, Kenji, 1994, Tsunami inundation model study of Eureka and Crescent City, California: U.S. National Oceanic and Atmospheric Administration NOAA Technical Memorandum ERL PMEL 103, 80 p.

BFA Educational Media, 1998?, The wave—A Japanese folktale: Phoenix Learning Group, 1 video, 9 min.

Cooke, H. G.; Mitchell, J. K., 1999, Guide to remedial measures for liquefaction mitigation at existing highway bridge sites: Multidisciplinary Center for Earthquake Engineering Research Technical Report MCEER-99-0015, 1 v.

Der Kiureghian, Armen; Sackman, J. L.; Hong, K.-J., 1999, Interaction in interconnected electrical substation equipment subjected to earthquake ground motions: Pacific Earthquake Engineering Research Center, 94 p.

Klutz, 1998, Disaster science: Klutz, 80 p.

KUED Media Solutions, 1997, Women who walk through time: Video West Productions, 1 video, 30 min.

Marriott, S. B.; Alexander, Jan, editors, 1999, Floodplains—Interdisciplinary approaches: Geological Society Special Publication 163, 330 p.

Maund, J. G.; Eddleston, Malcolm, editors, 1998, Geohazards in engineering geology: Geological Society Engineering Geology Special Publication 15, 448 p.

Monmonier, Mark, 1996, How to lie with maps; 2nd ed.: University of Chicago Press, 207 p.

Montgomery, D. R.; Schmidt, K. M.; Greenberg, H. M.; Dietrich, W. E., 2000, Forest clearing and regional landsliding: Geology, v. 28, no. 4, p. 311-314.

National Research Council Committee on U.S. Geological Survey, 1997, Watershed research in the U.S. Geological Survey: National Academy Press, 86 p.

Newton, Lesley, 1990, Devastation! The world's worst natural disasters: DL Publishing, Inc., 159 p.

Noller, J. S.; Sowers, J. M.; Lettis, W. R., editors, 2000, Quaternary geochronology—Methods and applications: American Geophysical Union AGU Reference Shelf 4, 582 p.

O'Rourke, M. J.; Liu, Xuejie, 1999, Response of buried pipelines subject to earthquake effects: Multidisciplinary Center for Earthquake Engineering Research MCEER Monograph 3, 249 p.

Oakland, Mike, editor; and others, 2000, Images of South Sound: Pediment Publishing, 143 p.

Oregon Emergency Management; U.S. Federal Emergency Management Agency, 1997?, Homeowner's landslide guide—For hillside flooding, debris flows, erosion, and landslide control: Oregon Emergency Management, 10 p.

Pini, G. A., 1999, Tectonosomes and olistostromes in the argille scagliose of the northern Apennines, Italy: Geological Society of America Special Paper 335, 70 p., 1 plate.

Roth, R. J., Jr., 1997, Earthquake basics—Insurance: Earthquake Engineering Research Institute, Earthquake Basics Brief 3, 16 p.

Webb, R. H.; Schmidt, J. C.; Marzolf, G. R.; Valdez, R. A., 1999, The controlled flood in Grand Canyon: American Geophysical Union Geophysical Monograph 110, 367 p., 3 plates.

Youd, T. L., 1998, Screening guide for rapid assessment of liquefaction hazard at highway bridge sites: Multidisciplinary Center for Earthquake Engineering Research Technical Report MCEER-98-0005, 1 v. ■

GLACIER PEAK LAHAR

(continued from p. 21)

numerous discussions regarding the volcanic deposits emanating from Glacier Peak.

References

Beget, J. E., 1981, Postglacial eruption history and volcanic hazards at Glacier Peak, Washington: University of Washington Doctor of Philosophy thesis, 192 p.

Beget, J. E., 1982, Postglacial volcanic deposits at Glacier Peak, Washington, and potential hazards from future eruptions: U.S. Geological Survey Open-File Report 82-830, 77 p.

Dragovich, J. D.; Grisamer, C. L., 1998, Quaternary stratigraphy, cross sections, and general geohydrologic potential of the Bow and Alger 7.5-minute quadrangles, western Skagit County, Washington: Washington Division of Geology and Earth Resources Open File Report 98-8, 29 p., 6 plates.

Dragovich, J. D.; Norman, D. K.; Anderson, Garth, 2000a, Interpreted geologic history of the Sedro-Woolley North and Lyman 7.5-minute quadrangles, western Skagit County, Washington: Washington Division of Geology and Earth Resources Open File Report 2000-1, 71 p., 1 plate.

Dragovich, J. D.; Norman, D. K.; Grisamer, C. L.; Logan, R. L.; Anderson, Garth, 1998, Geologic map and interpreted geologic history of the Bow and Alger 7.5-minute quadrangles, western Skagit County, Washington: Washington Division of Geology and Earth Resources Open File Report 98-5, 80 p., 3 plates.

Dragovich, J. D.; Norman, D. K.; Lapen, T. J.; Anderson, Garth, 1999, Geologic map of the Sedro-Woolley North and Lyman 7.5-minute quadrangles, western Skagit County, Washington: Washington Division of Geology and Earth Resources Open File Report 99-3, 37 p., 4 plates.

Dragovich, J. D.; McKay, D. T., Jr.; Dethier, D. P.; Beget, J. E., 2000b, Voluminous laharic inundation of the lower Skagit River valley, Washington—A product of a single large mid-Holocene Glacier Peak eruptive episode? [abstract]: Geological Society of America Abstracts with Programs, v. 32, no. 6, p. A-11.

Dragovich, J. D.; Pringle, P. T.; Dunn, Andrew; Parkinson, K. T.; Kahle, S. C., 1997, Quaternary geologic mapping and stratigraphy in the Deming and Kendall 7.5-minute quadrangles, Whatcom County, Washington—Implications for valley hydrostratigraphy in the foothills of the North Cascades [abstract]. *In* Washington Department of Ecology; Washington Hydrological Society, Abstracts from the 2nd symposium on the hydrogeology of Washington State: Washington Department of Ecology, p. 18.

Dragovich, J. D.; Troost, M. L.; Norman, D. K.; Anderson, Garth; Cass, Jason; McKay, D. T., in press, Geologic map of the Anacortes South and La Conner 7.5-minute quadrangles, western Skagit County, Washington: Washington Division of Geology and Earth Resources Open File Report.

Palmer, S. P.; Pringle, P. T.; Dragovich, J. D.; Walsh, T. J., 1994, Relation of volcanic debris flows and liquefaction hazard in western Washington [abstract]: Geological Society of America Abstracts with Programs, v. 26, no. 7, p. A-253.

Tabor, R. W.; Booth, D. B.; Vance, J. A.; Ford, A. B.; Ort, M. H., 1988, Preliminary geologic map of the Sauk River 30 by 60 minute quadrangle, Washington: U.S. Geological Survey Open-File Report 88-692, 50 p., 2 plates.

Tabor, R. W.; Crowder, D. F., 1969, On batholiths and volcanoes—Intrusion and eruption of late Cenozoic magmas in the Glacier Peak area, North Cascades, Washington: U.S. Geological Survey Professional Paper 604, 67 p., 1 plate. ■

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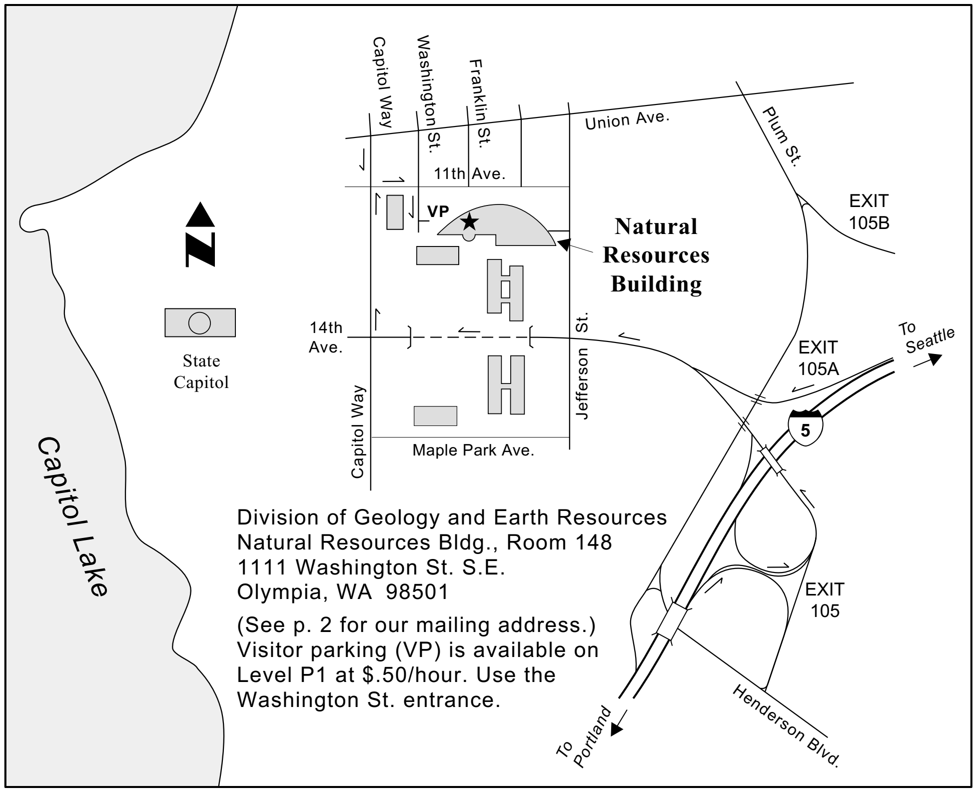

STAFF NOTES *(continued from p. 60)*

Washington University and a master of music from University of Minnesota in 1996. She is working with Joe Dragovich on mapping in the Anacortes area.

Josh Brown is our new Office Assistant Senior. He previously worked for Department of Labor and Industries as an Office Assistant. We rely on Josh to pay our bills, provide purchasing expertise and service, and keep our vehicle running. He maintains our (~7,000) Washington Geology mailing list and, among other duties, is a clerical/administrative backup for our Surface Mining Program. Josh is getting firefighting training and experience through DNR and is excited about the opportunities that are available in that area.

Tara Salzer has been hired as our Office Assistant/Receptionist. Among her many responsibilities, she is required to maintain our publication inventory and see that all of the orders are processed and mailed in a timely manner. Tara is likely to be the person who answers the phone when it rings and greets our customers when they come into the office. She previously worked for the Liquor Control Board. ■

STAFF NOTES

Michael Polenz received his B.A. in 1992 at Franklin & Marshall College in Lancaster, Penn., with majors in geology and economics. In 1997, he received an M.S. in the geology option of the Environmental Systems Program at Humboldt State University in Arcata, Calif. His thesis research on the stratigraphy of the Crescent City coastal plain led to publication in *Quaternary Research* in 1999. From 1997 to 1999, he worked as consulting geologist with Versar, Inc., primarily in northern California. During the summer and fall of 1997, he volunteered at the U.S. Forest Service in Ely, Nevada. In early March, he began to help Josh Logan and Tim Walsh map the Longbranch and McNeil Island 7.5-minute quadrangles in the South Sound region as volunteer. He was hired by the end of the month. He is currently dividing his time between mapping the above mentioned quadrangles, the adjacent Squaxin Island quadrangle, and helping Hank Schasse map the Morse River 7.5-minute quadrangle in Clallam County.

Carol Serdar has been hired as the Southwest Region geologist working in the Surface Mine Reclamation Program. Carol began her undergraduate work at Western Washington University and finished at The Evergreen State College in 1985. She received her teachers certification from the University of Puget Sound in 1985. Carol was awarded a Masters of Environmental Studies from The Evergreen State College in 1999. Her thesis was on “Description, analysis and impacts of the Grouse Creek landslide, Jefferson County, Washington, 1997–98”. She taught earth science for 5 years in the Tacoma Public Schools and life science for 5 years in the Tumwater School District.

Phung Ho graduated in 1968 with a B.S. in Forestry Science. In 1972, he earned an M.B.A. During his professional career in South Vietnam, Phung held senior management positions in the forestry industry, including Controller of the Land for the Tillers Program, which was sponsored by the American government. Phung came to the U.S. in 1989 under the Orderly Departure Program, reserved for prisoners of war who were associated with the American government’s policies and projects. Phung has worked for the state since February 1991 and began working for DNR in 1993. He began working at the Forest Land Management Research Center as a scientific technician, collecting data from the field. In 1997, he transferred to Forest Inventory as a forest technician and worked with GIS. On March 1, 2000, Phung began a developmental assignment with the Geology and Earth Resources Division, where he has working on a GIS layer for sand and gravel resources. He will prepare and register overlays of mining data for scanning and/or digitizing. Recently, his developmental assignment was extended from July 1 to October 1, 2000.

Richard W. Phipps is working on a 12-month project position as an Environmental Specialist 3. The purpose of the project is to prepare an inventory of abandoned metal mines throughout the state. His educational background is as a Forest Technician in 1980 and more recently has been attending The Evergreen State College, where he expects to receive a B.S. in Environmental Studies this year. He has been with the DNR for 24 years; previously working with the property management and environmental risk management programs in aquatic and upland programs, as well as field forestry positions in Mason, Kitsap, Jefferson and Pend Oreille Counties.

Donald ‘Mac’ McKay is a Natural Resources Research Technician 2 working with Rich Phipps under the direction of Dave Norman to produce a GIS linked abandoned metal mine lands inventory for the state. Mac began as a volunteer with DGER in the Fall of 1999. He worked with Joe Dragovich mapping and producing a report on a large lahar in the Skagit River valley. Mac holds a B.A. in anthropology from the University of Colorado, Boulder and a B.S. in natural science/geology from The Evergreen State College, Olympia.

Lea Gilbertson started with the Division as a geology intern on July 3, 2000. She lives in Bellingham. Lea received a B.A. in geology and music from Western Washington University in 1991. She received an M.S. in Geology in 1994 from Western

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DIVISION PUBLICATIONS

New Release

Interpreted Geologic History of the Sedro-Woolley North and Lyman 7.5-minute Quadrangles, Western Skagit County, Washington, Open File Report 2000-1, by Joe D. Dragovich, David K. Norman, and Garth Anderson. This report covers lahar deposition and infilling of the Skagit River valley during the Holocene, Pleistocene glacial deposits, and structural and metamorphic development of pre-Tertiary rocks in the lower Skagit Valley. 71 p. text, 10 figures, 4 tables, 6 appendices, 1 plate. $2.78 + .22 tax (Wash. residents only) = $3.00.

(Our address and phone number are on p. 2. Orders must be prepaid. Make check or money order payable to the Department of Natural Resources. Taxes apply to Washington residents only. Please include $1.00 for postage and handling of orders to be sent by mail.)

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