WASHINGTON GEOLOGY

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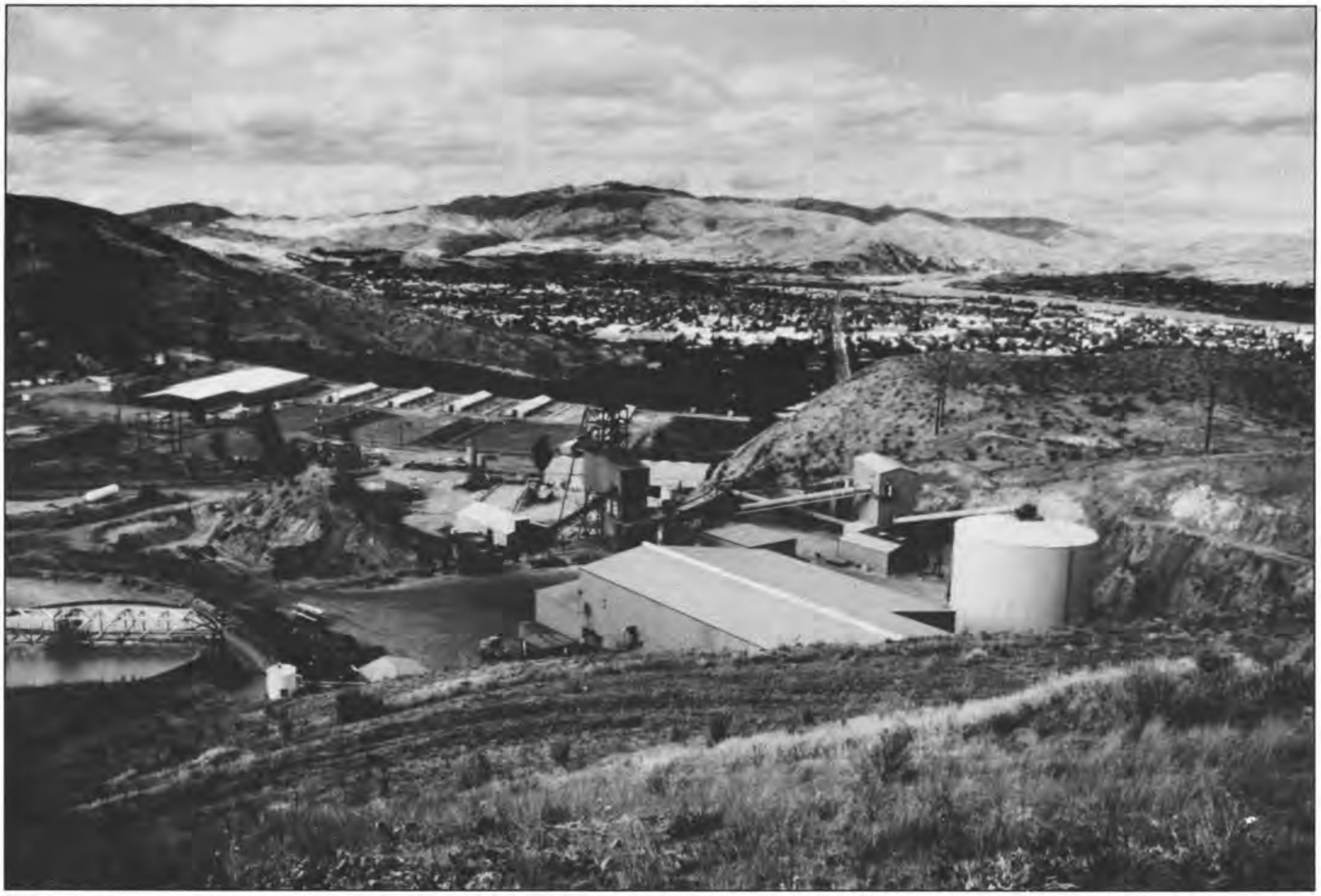

The Cannon mine surface plant at the edge of the city of Wenatchee. Ore is hoisted to the surface from the shaft (center of photo) and is processed in the mill (lower right). The mine has been the largest gold producer in Washington for the past few years, as well as one of the largest underground gold mines in the United States. Production decreased in 1992 due to dwindling ore reserves. If no new reserves are identified, the mine is expected to close in about 2 years.

WASHINGTON GEOLOGY

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Proposed Seismic Zone Changes in Western Washington

by Timothy J. Walsh

In December 1991, Washington's Seismic Safety Advisory Committee presented its report on earthquake preparedness to the legislature. Although the bill to implement its recommendations died in the senate, some recommendations can be implemented with existing authority. (See related story, p. 32.) One of these is the recommendation to expand the boundaries of seismic zone 3 in the Uniform Building Code (UBC) to include all of western Washington (Fig. 1). This was prompted by a growing body of evidence that western Washington and Oregon and northwesternmost California are subject to large subduction zone earthquakes that have not occurred in the region for about 300 years. (See, for instance, Atwater and Yamaguchi, 1991; Clarke and Carver, 1992.) There is also increasing evidence of a greater risk of shallow crustal earthquakes than is commonly reflected in risk assessments for the area. (See, for instance, Yelin and Patton, 1991; Bucknam and others, 1992.)

At present, the Puget Sound region is in zone 3 of the UBC and the rest of western Washington is in zone 2B.

Continued on p. 40.

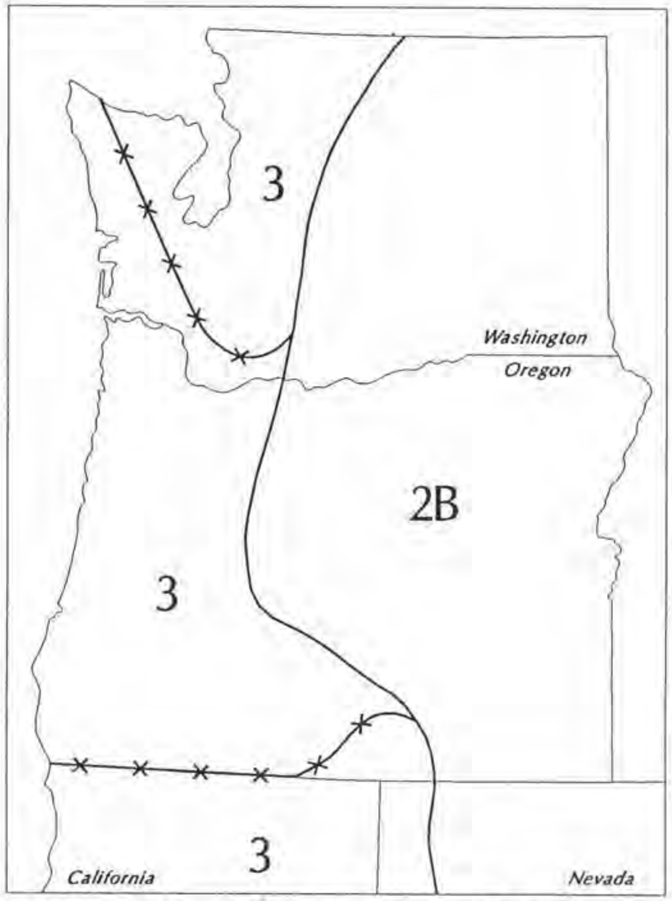

Figure 1. Proposed expansion of Uniform Building Code seismic zone 3 to include all of western Washington and western Oregon. The area between the crossed-out boundaries could be upgraded from zone 2B to zone 3.

Washington's Mineral Industry—1992

by Robert E. Derkey, Charles W. Gulick, and William S. Lingley, Jr.

INTRODUCTION

The value and amount of gold, silver, zinc, and lead production decreased in 1992 relative to 1991. The decrease in gold and silver production (Fig. 1) was a result of mine closures due to depressed metal prices (Van Stone mine), transition to increased production tonnage and decreased ore grade (Republic Unit), and reduced production due to dwindling ore reserves (Cannon mine). The three major precious metal mining operations, the Cannon mine, the Republic Unit, and the Kettle River Project, produced a total of nearly 283,000 ounces of gold and more than 580,000 ounces of silver in 1992.

Exploration activities for metallic mineral deposits in Washington continued at a conservative pace in 1992. There were few new property acquisitions. The majority of activity centered on continued exploration efforts on existing properties. Most of the exploration activity was in the northeastern and north-central parts of the state.

The sand, gravel, and quarried rock industries, which produce construction aggregates, fill, pitrun, riprap, and larger rock products, are a key component of Washington's economy. Rock products provide the basis for infrastructure construction and maintenance, including low-cost housing, highways, and public works.

Per capita demand, based on 1991 data, show that Washingtonians use about 16 tons or 12 cubic yards of construction aggregates, fill, pitrun, and larger rock products annually (Lingley and Manson, 1992). Most aggregate was consumed for general construction: homes, owner-occupied buildings, schools, and offices. An average home requires approximately 50 cubic yards of concrete and a large building requires about 5,000 cubic yards. These are used for footings, stem walls, walls, support, and access.

Though production and some prices declined, 1992 was generally a good year for the sand, gravel, and quarried rock industries in Washington. Estimated statewide production was about 5 percent less than in 1991, the best year on record for round-rock aggregate sales. Ready-mix concrete sales in the Seattle area failed to reach those of the banner years of the 1980s. However, this decline was offset by unanticipated increases in new home construction elsewhere in the Puget lowland, by several large highway overlays (resurfacing), and by private construction projects from the Boeing Company and others. Gravel sales in eastern Washington increased slightly during 1992. These market patterns resulted in aggressive competition during the first half of 1992, and prices for round-rock aggregate fell by about 5 percent in some areas.

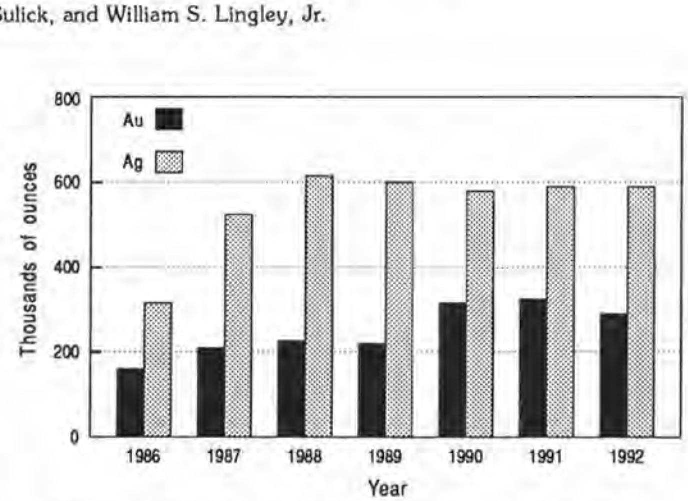

Figure 1. Gold (Au) and silver (Ag) production in Washington, 1986 through 1992.

Construction aggregates and fill are the most valuable mineral commodity in Washington. Department of Natural Resources production estimates together with U.S. Bureau of Mines data (Table 1 and Fig. 2) indicate that the cumulative value (total retail receipts) for all rock products in Washington was probably greater than $200 million.

Figure 2 and Table 1 summarize the consumption of rock products in Washington during 1992. The Department of Natural Resources data presented on Figure 2 are based on a survey of about 23 percent of all mine operations in Washington (Lingley and Manson, 1992) and on interviews with several large aggregate producers. The U.S. Bureau of Mines estimates for sand and gravel (round-rock aggregate) production given on Figure 2 do not include production from some small mines and should be regarded as conservative. Nevertheless, Bureau of Mines data are collected consistently and are useful for comparing annual production from year to year.

The value of other industrial minerals produced in Washington during 1992 increased 6 percent over the 1991 value according to preliminary estimates from the U.S. Bureau of Mines (USBM). This was primarily a result of an increase in the production of portland cement when Ash Grove Cement Co., Western Region, opened its new Seattle plant in May. Industrial minerals comprised 61 percent of the total estimated value of $478.3 million for all nonfuel mineral production in Washington (R. J. Minarik, USBM, written commun., 1993). The USBM estimates of value of mineral production showed increases for all their industrial minerals categories except construction sand and gravel, lime, and gemstones.

Table 1. Preliminary Department of Natural Resources estimates for 1992 construction aggregates, stone, and pit run production, based on data from Lingley and Manson (1992) together with interviews of major producers. Coverage indicates the percentage of producers responding to a Department survey

Commodity	Estimated statewide production	Coverage
Sand and gravel (including fill)	~55,000,000 tons	24%
Crushed rock and stone	~15,000,000 tons	22%
Total	~70,000,000 tons	23%

Employment in the nonfuel mineral industries increased in 1991 (the latest year for which figures are available) relative to 1990. A monthly average of 2,813 people were employed in 1991 compared to 2,628 in 1990. These statistics reflect the average annual employment in Standard Industrial Classification (SIC) code 10 (metal mining) and SIC code 14 (nonmetallic minerals, except fuels) compiled by the Washington State Employment Security Department.

Figure 3 and Table 2 together summarize mining and mineral exploration activities in Washington. The majority of this volunteered information was obtained from an annual survey of mining companies and individuals. Because not all survey questionnaires were returned, Table 2 is only a reliable measure of Washington mineral industry activity, not a complete listing of mineral activity. The table includes map location number, property name, location, commodities, company name, and activities, plus a short description of the geology of the area of the property/mine.

Numbers with the property or mine names in the following parts of the text are keyed to Table 2, and all cited references are listed at the end of this article. However, sand and gravel deposits discussed are not shown on the maps, nor are they listed in Table 2.

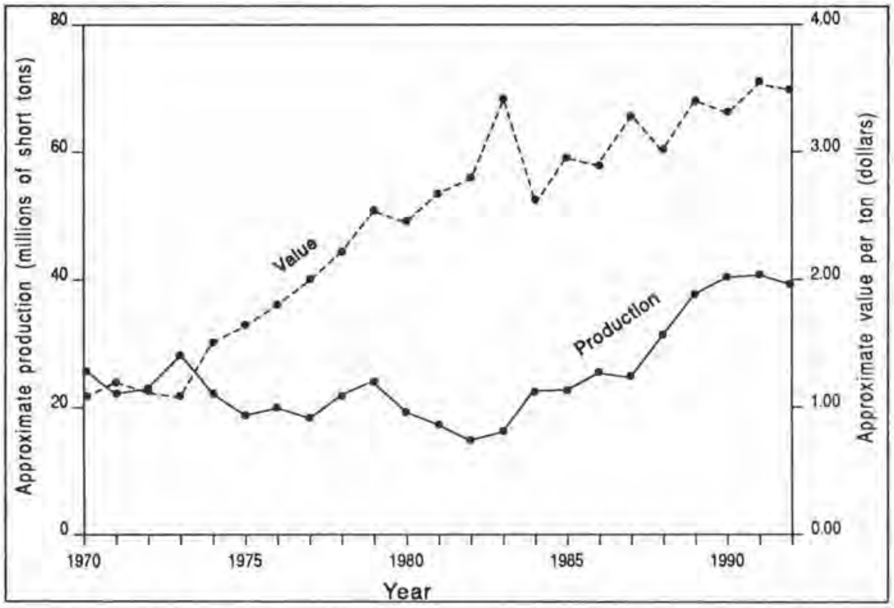

Figure 2. Average annual Washington sand and gravel production and value estimates from the U.S. Bureau of Mines (except the 1992 estimates, which were projected using Department of Natural Resources data). From Babitzke and Bunning, 1984; Davis and Tepordei, 1985; Drake, 1972; Evans, 1978, 1980; Minarik and Joseph, 1991; Pajalich, 1973–1977; Tepordei, 1981–1984, 1987–1990; and U.S. Bureau of Mines, 1991a, 1991b, 1992a.

The authors can be reached at the addresses and phone numbers of the Division of Geology and Earth Resources (DGER) given on p. 2 of this publication.

Metallic Mineral Deposits

by Robert E. Derkey

This discussion of metallic mineral deposits includes descriptions of deposit types: epithermal gold, replacement-type gold, skarn-type gold, Mississippi Valley-type, volcanogenic massive sulfide, porphyry-type, shear zone gold, and gold in alkalic rocks. Each deposit type is introduced with a brief overview of an aspect of the geology or genesis of the deposit type; this is followed by descriptions of deposits and mining or exploration activities. Additional details for each of the deposits are available in Table 2.

EPITHERMAL GOLD DEPOSITS

The majority of Washington's gold production has been from epithermal deposits at Republic (Knob Hill and Golden Promise deposits) and Wenatchee (Cannon mine). Epithermal deposits, which are characterized by extensive surficial and near-surface silicification and widespread hydrothermal brecciation, are also referred to as hot-spring deposits (Berger, 1985). The following paragraphs describe the Golden Promise vein system, a hot-spring deposit (Tschauder, 1989; Barry Devlin, Chief Geologist, Hecla Mining Co., oral commun., 1993). The information is supplemented by observations at Osorezan, Japan (Izawa and Aoki, 1991), and other American deposits (Berger, 1985).

The Golden Promise vein system consists of a large, main vein (called the No.2 vein) and several smaller or secondary veins. The No. 2 vein extends from above the 600 level (the hot-spring paleosurface and ground surface at the time the vein formed) to the 1300 level (approximately 1,100 feet below the hot-spring paleosurface), its maximum exposed depth in the mine (Fig. 4). Between the 900 level and the 1300 level, the No. 2 vein is confined to a relatively narrow fissure and consists of brecciated and mineralized chalcedony.

Boiling was an important ore-forming process at about the 900 level (approximately 500 feet below the paleosurface). The richest gold ores in the mine are found at this level, and many stopes averaged between 2 and 5 ounces of gold per ton. The No. 2 vein increases in width toward the paleosurface, and colloform banding is a dominant feature of the ore (Fig. 5). Above the 900 level, the No. 2 vein branches out and forms a stockwork of anastomosing veins (Fig. 4). Continuity of the stockworks decreases upward.

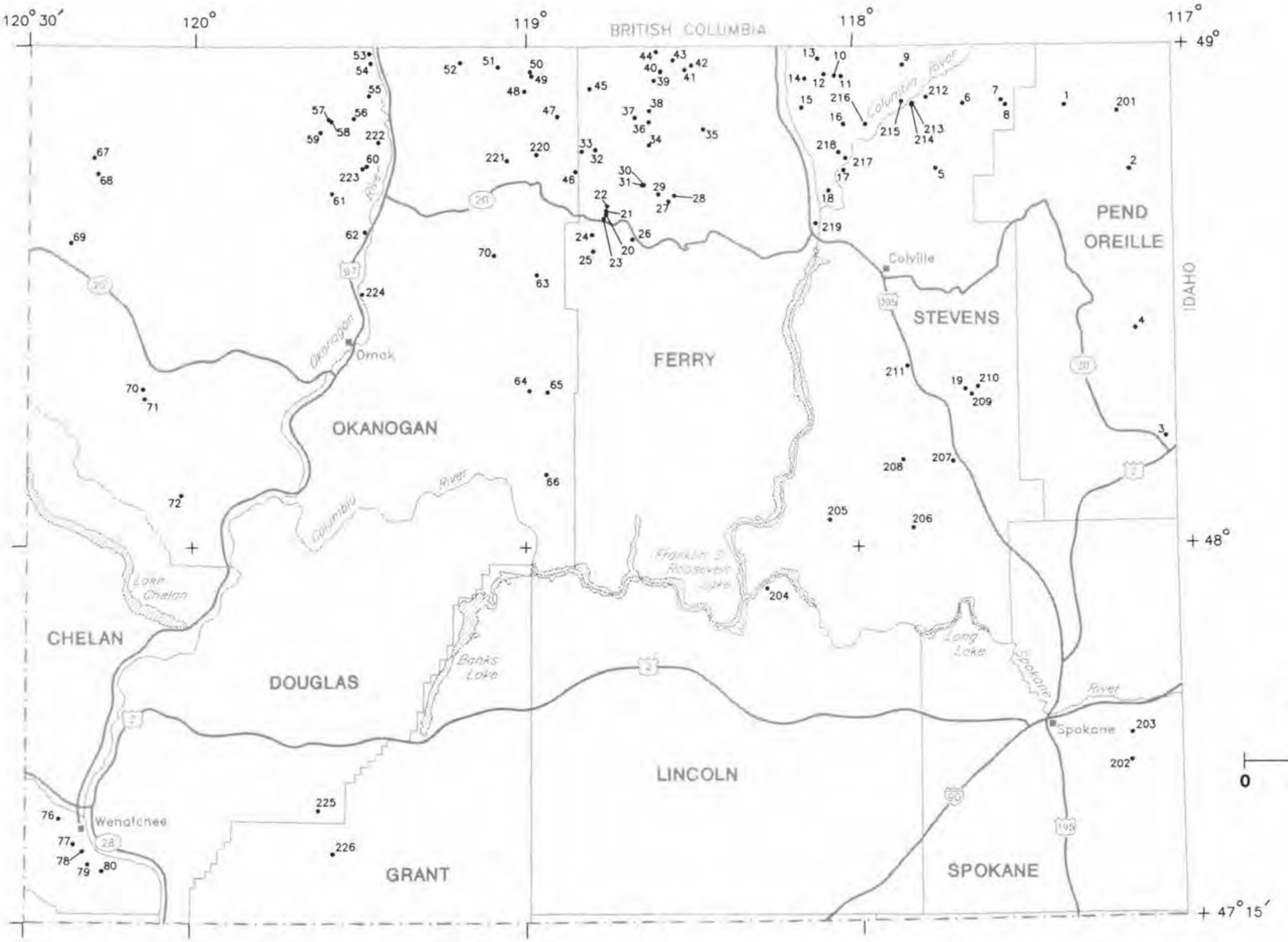

Figure 3a. Location of properties at which mineral exploration, development, or mining took place in 1992 in northeast Washington. See Table 2 for further information about each of these locations.

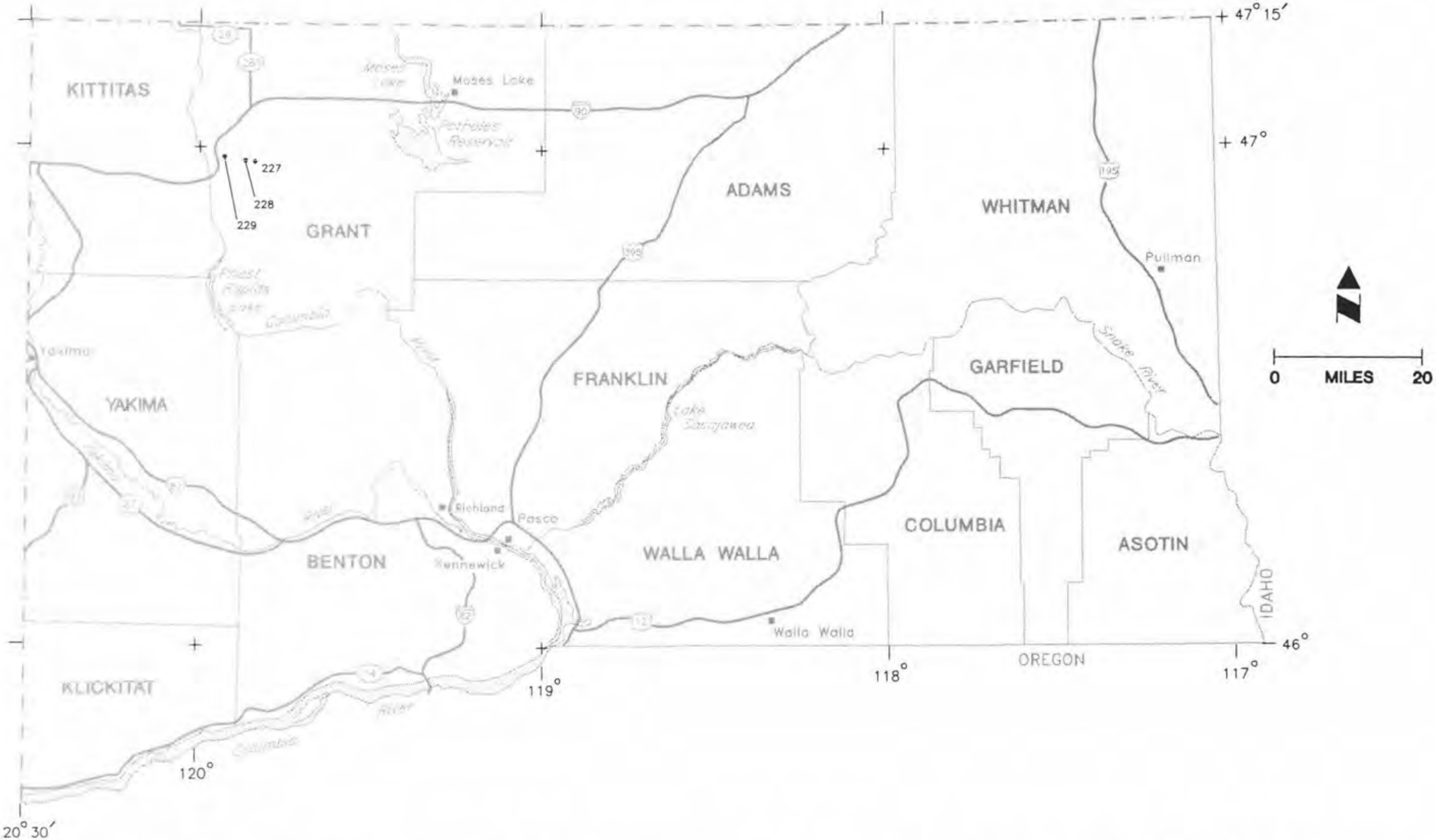

Figure 3b. Location of properties at which mineral exploration, development, or mining took place in 1992 in southeast Washington. See Table 2 for further information about each of these locations.

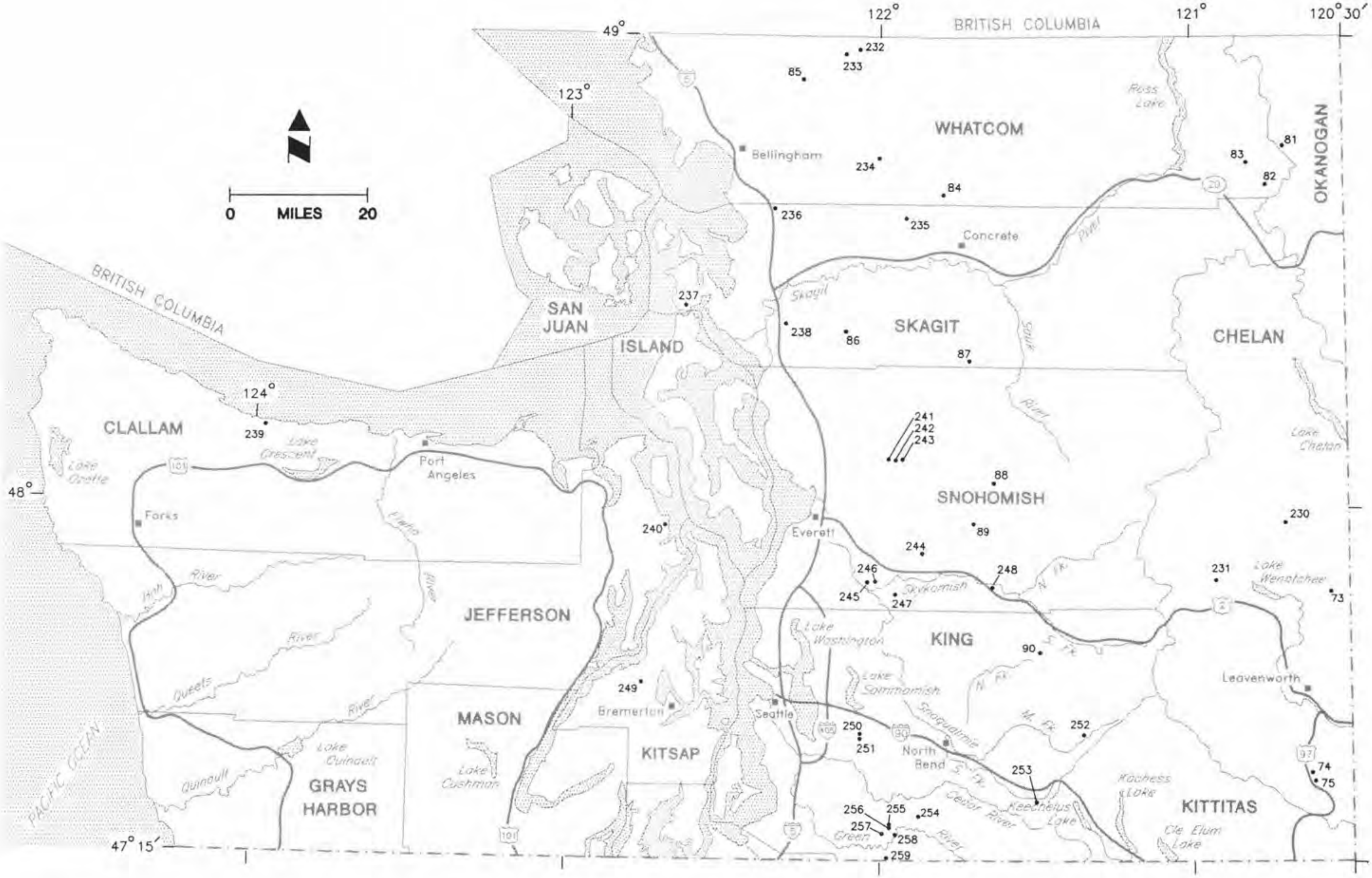

Figure 3c. Location of properties at which mineral exploration, development, or mining took place in 1992 in northwest Washington. See Table 2 for further information about each of these locations.

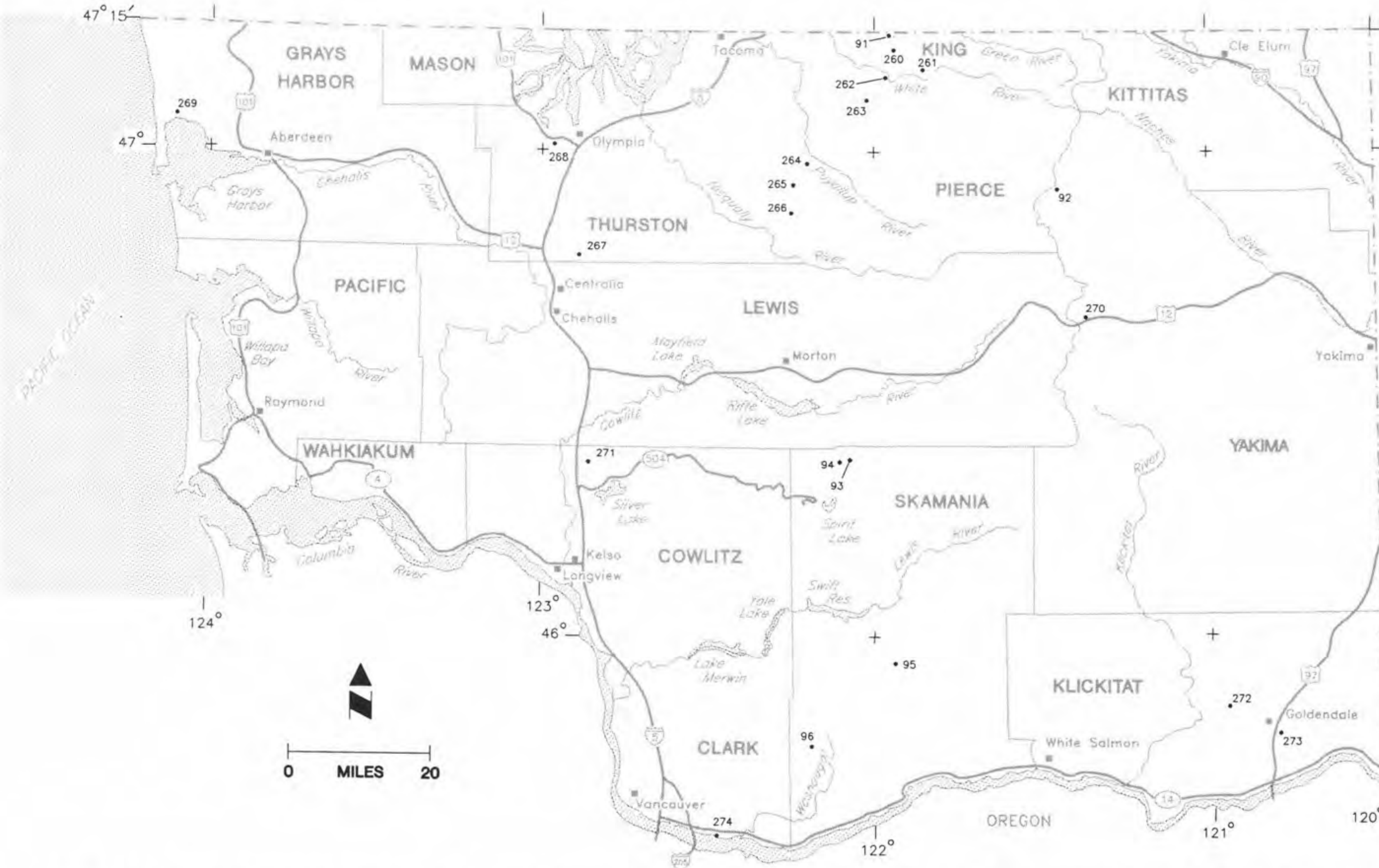

Figure 3d. Location of properties at which mineral exploration, development, or mining took place in 1992 in southwest Washington. See Table 2 for further information about each of these locations.

Table 2. Mining and mineral exploration in Washington, 1992. Property/project name is supplied by the company responding to the questionnaire. Order of entry is generally from northeast to southwest; location numbers are keyed to Figures 3a through 3d. Entries 1–96 are base and precious metal properties or projects; entries 201–274 are sites of industrial mineral activity

Loc. No.	Property	Location	County	Commodity	Company	Activity	Area geology
1	Pend Oreille mine	secs. 10-11, 14-15, 39N, 43E	Pend Oreille	Zn, Pb, Ag, Cd	Resource Finance Corp.	Underground drilling; considering resumption of mining	Mississippi Valley-type mineralization in Yellowhead zone of Cambrian–Ordovician Metaline Formation
2	Harvey Creek	sec. 17, 38N, 44E	Pend Oreille	Au, Ag, Mo	N. A. Degerstrom Inc.	Exploration	Porphyry- and skarn-type mineralization in Cretaceous–Tertiary granitic rocks
3	Cooks Mountain mine	sec. 2, 31N, 45E	Pend Oreille	Au, Ag, Pb	Raven Hill Mining Co.	Exploration	Veins in shear zone in Proterozoic sedimentary rocks
4	Cooks Copper	sec. 19, 34N, 45E	Pend Oreille	Ag, Cu	Raven Hill Mining Co.	Exploration	Proterozoic rocks intruded by Cretaceous granitic rocks
5	Van Stone mine	sec. 33, 38N, 40E	Stevens	Zn, Pb, Cd	Equinox Resources Ltd.	Resumed mining after winter shutdown; plan to mine through 1992–93 winter	Mississippi Valley-type mineralization in the Cambrian–Ordovician Metaline Formation
6	HC	sec. 18, 39N, 41E	Stevens	Zn, Pb	Bitterroot Resources Ltd.	Exploration	Mineralization in shallow-dipping silicified zone in limestone
7	Leadpoint Consolidated properties	secs. 12-13, 39N, 41E; secs. 7-8, 17-18, 39N, 42E	Stevens	Ag, Pb, Zn	Leadpoint Consolidated Mines Co.	Exploration	Replacement and chimney deposits in the Cambrian–Ordovician Metaline Formation
8	Electric Point	secs. 17-20, 39N, 42E	Stevens	Pb, Ag, Zn, Cu	The State Mining Co.	Exploration	Mississippi Valley-type mineralization in middle dolomite unit of Cambrian–Ordovician Metaline Formation
9	Ambrose Mining	sec. 16, 40N, 39E	Stevens	Au	A. Ambrose	Placer mining and prospecting	Placer deposit
10	Big Iron/McNally	sec. 24, 40N, 37E	Stevens	Au, Fe, W, Ag	Homestake Mining Co./Pathfinder Gold Corp.	Geologic mapping, geochemistry, geophysics, drilling	Skarn- and replacement-type mineralization; porphyry gold in Permian rocks
11	Labor Day	sec. 25, 40N, 37E	Stevens	Au, Ag, Cu, Pb, Zn	Lester Willmann	Exploration, geophysics	Skarn- and replacement-type mineralization in Permian rocks
12	Cleta Group	secs. 22, 27, 40N, 37E	Stevens	Au, Cu, Ag, Pb, Zn, Sb	David Robbins and Associates	Shaft reclamation and exploration	Vein and replacement mineralization in sheared and contact-metamorphosed Permian Mount Roberts Formation
13	Hope Mountain	secs. 4, 5, 8-10, 15, 40N, 37E	Stevens	Au, Ag, Cu	Hope Mountain Mining Ltd.	Exploration	Mineralization in Permian–Jurassic argillite and metavolcanic rocks cut by Eocene monzonite porphyry dikes
14	Copper Penny	secs. 29-30, 40N, 37E	Stevens	Au, Ag, Cu	Vanhorn and Watson Mining Co.	Drilling; underground drifting	Disseminated and replacement mineralization in Jurassic Rossland Group volcanic rocks
15	First Thought	secs. 7, 18, 39N, 37E	Stevens	Au, Ag	Pathfinder Gold Corp./Billiton Minerals	Soil geochemistry, exploration	Epithermal mineralization at the top of the Eocene Sanpoil Volcanics

Table 2. Mining and mineral exploration in Washington, 1992 *(continued)*

Loc. No.	Property	Location	County	Commodity	Company	Activity	Area geology
16	Fifteen Mile Creek	secs. 17-20, 30, 39N, 38E; secs. 13, 24, 39N, 37E	Stevens	Au, Fe	Battle Mountain Gold Corp/ Pathfinder Gold Corp.	Drilling; dropped property	Replacement- and skarn-type mineralization in greenstones of the Jurassic Rossland Group volcanic rocks intruded by Eocene(?) granitic rocks
17	Young America	secs. 28, 33, 38N, 38E	Stevens	Zn, Pb, Ag, Au, Cu	Silver Hill Mines Inc. of Washington	Exploration	Mineralization in two parallel zones in brecciated Permian limestone with interbedded wacke
18	Kelly Hill	secs. 2, 10-11, 37N, 37E	Stevens	Au, Ag, Pb	Noranda Exploration Co., Inc.	Drilling; dropped property	Contact metamorphic/replacement zones in Permian metasedimentary rocks
19	United Copper/ Amazon/Queen	secs. 31-32, 33N, 41E	Stevens	Cu, Ag, Au	Lovejoy Mining, Inc.	Maintaining underground access	Mineralized fracture zone in Proterozoic Wallace Formation argillite near fault contact with Edna Dolomite
20	Republic Unit	secs. 27, 34-35, 37N, 32E	Ferry	Au, Ag	Hecla Mining Co.	Mining; exploration drifts and underground drilling	Epithermal gold veins in dacite and andesite flows, flow breccias, tuffs, and tuff breccias of Eocene Sanpoil Volcanics
21	Golden Eagle	sec. 27, 37N, 32E	Ferry	Au, Ag	Hecla Mining Co.	On hold	Epithermal mineralization in Eocene bedded tuff
22	South Penn	secs. 27-28, 37N, 32E	Ferry	Au, Ag	Sutton Resources Inc./Crown Resources Corp.	Exploration	Epithermal deposit in Eocene Sanpoil Volcanics
23	Seattle	secs. 33-34, 37N, 32E	Ferry	Au, Ag	Sutton Resources Inc./Crown Resources Corp.	Exploration	Epithermal deposit in Eocene Sanpoil Volcanics
24	Copper Mountain	secs. 3-4, 9-10, 15-16, 22, 36N, 32E	Ferry	Au, Ag	Phelps Dodge Mining Co.	Drilling	Replacement-type gold mineralization in Permian greenstone
25	Golden Harvest	numerous sections, 36N, 32E	Ferry	Au	Santa Fe Pacific Mining, Inc./ Pathfinder Gold Corp.	Geologic mapping, geochemistry, geophysics, drilling	Skarn and epithermal mineralization in pre-Eocene metavolcanic and Eocene volcanic rocks of the Republic graben
26	O'Brien Creek	sec. 16, 36N, 33E	Ferry	Au	Orvana Resources Corp.	Exploration	Epithermal mineralization in Eocene Sanpoil Volcanics
27	Overlook mine	sec. 18, 37N, 34E	Ferry	Au, Ag, Cu, Fe	Echo Bay Minerals Co./Crown Resources Corp.	Mining	Gold mineralization associated with massive iron replacement bodies in Permian limestone and stockwork mineralization in Permian clastic rocks
28	Key Project	sec. 18, 37N, 34E	Ferry	Au, Ag, Cu, Fe	Echo Bay Minerals Co./Crown Resources Corp.	Permits obtained; stripping in preparation for mining	Gold mineralization associated with massive iron replacement bodies in Permian limestone
29	Leland	36-38N, 33-34E	Ferry	Au, Ag	Leland Ranch	Property returned to owner	Gold mineralization in Permian limestone and clastic rocks
30	Lamefoot	secs. 4, 8, 37N, 33E	Ferry	Au, Fe, Ag, Cu	Echo Bay Minerals Co.	Driving exploration drift	Gold mineralization associated with massive iron replacement bodies in contact metamorphosed (skarned) Permian limestone and stockwork mineralization in Permian clastic rocks

Table 2. Mining and mineral exploration in Washington, 1992 *(continued)*

Loc. No.	Property	Location	County	Commodity	Company	Activity	Area geology
31	Wardlaw	sec. 4, 37N, 33E	Ferry	Au, Ag	Equinox Resources Ltd.	Drilling	Gold mineralization in Permian limestone and clastic rocks
32	Kelly Camp	sec. 9, 38N, 32E	Ferry	Au, W, Cu, Mo	Orvana Resources Corp.	Geologic mapping, geochemistry	Contact metamorphosed pre-Tertiary rocks are a roof pendant in quartz monzonite and monzonite of Herron Creek igneous suite
33	Manhattan Mountain	secs. 7, 18, 38N, 32E	Ferry Okanogan	Au, Ag, Cu, Pb, Zn, talc	Westmont Gold Inc.	Geologic mapping, trenching, sampling	Epithermal gold in Eocene volcanic rocks of the Toroda Creek graben
34	Republic–Belcher area	37-39N, 33E	Ferry	Au, Ag	Equinox Resources Ltd.	Exploration	Gold mineralization in Permian limestone and clastic rocks
35	Long Alec Creek	secs. 23-28, 35-36, 39N, 34E	Ferry	Au, Cu	Orvana Resources Corp.	Reconnaissance exploration, suction dredge sampling	Porphyry and stockwork gold and copper mineralization in Eocene rocks
36	Franson Peak	numerous sections, 36N, 32E	Ferry	Au	Santa Fe Pacific Mining, Inc./ Pathfinder Gold Corp.	Geologic mapping, geochemistry, geophysics	Skarn and epithermal mineralization in pre-Eocene metavolcanic and Eocene volcanic rocks of the Republic graben
37	K-2	sec. 20, 39N, 33E	Ferry	Au, Ag	Echo Bay Minerals Co./Crown Resources Corp./ Pathfinder Gold Corp.	Drilling, evaluation	Epithermal deposit in Eocene Sanpoil Volcanics
38	Kettle mine	sec. 15, 39N, 33E	Ferry	Au, Ag	Echo Bay Minerals Co./Crown Resources Corp.	Mining	Epithermal veins and sinter in Eocene Sanpoil Volcanics
39	Snow Peak	secs. 13-15, 22-24, 26-27, 33-34, 40N, 33E; secs. 3-4, 39N, 33E	Ferry	Au, Ag	Phelps Dodge Mining Co.	Exploration	Gold mineralization in Permian and Triassic limestone and clastic rocks
40	Goosmus Creek	secs. 13-14, 16, 22-26, 40N, 33E	Ferry	Au, Cu	Orvana Resources Corp.	Geologic mapping, geochemistry	Skarn, replacement, and stockwork mineralization in Permian–Triassic rocks
41	Morning Star	sec. 16, 40N, 34E	Ferry	Au, Ag, Cu, W	Morse Brothers, Morning Star Mines, Inc.	Soil sampling, drilling	Veins at the sheared contact between Permian–Triassic greenstone and serpentinite
42	Irish	sec. 15, 40N, 34E	Ferry	Au	Johnson Explosives	Geological and geochemical exploration	Gold mineralization in alkalic rocks of the Jurassic Shasket Creek complex
43	Gold Mountain	secs. 7-8, 40N, 34E	Ferry	Au, Ag, Cu	Gold Express Corp./N. A. Degerstrom, Inc.	Permitted; mining dependent on gold price	Gold-pyrite mineralization in an alkalic dike of the Jurassic Shasket Creek complex
44	Lone Star	sec. 2, 40N, 33E	Ferry	Au, Cu, Ag	Wilbur Hallauer	Dewatering and sampling old workings	Disseminated and stockwork chalcopyrite and pyrite in Permian–Triassic greenstone, graywacke, argillite, and limestone

Table 2. Mining and mineral exploration in Washington, 1992 *(continued)*

Loc. No.	Property	Location	County	Commodity	Company	Activity	Area geology
45	Toroda	sec. 32, 40N, 32E	Ferry	Au, Ag	Phelps Dodge Mining Co.	Geochemistry, drilling	Epithermal mineralization in Eocene Sanpoil Volcanics
46	Silver Bell area	sec. 25, 38N, 31E	Okanogan	Au, Ag	Pacific Northwest Resources Inc.	Maintained state leases	Epithermal mineralization in Eocene felsic volcanic rocks of Toroda Creek graben
47	Ida	secs. 16, 21, 39N, 31E	Okanogan	Au, Ag, Cu	Lac Minerals (USA), Inc./Crown Resources Corp.	Geochemistry, drilling	Epithermal veins in Eocene Sanpoil Volcanics and Klondike Mountain Formation of the Toroda Creek graben
48	Crystal	sec. 35, 40N, 30E	Okanogan	Au, Ag, Pb, Zn, Cu	Keystone Gold, Inc., optioned to Strongbow Resource Corp. of America Inc., subsidiary of Consolidated Ramrod Corp.	Geochemistry, geophysics, drilling	Skarn-type mineralization in Permian Spectacle Formation intruded by Mesozoic rocks
49	Crown Jewel	sec. 24, 40N, 30E	Okanogan	Au, Cu, Ag, Fe	Battle Mountain Gold Corp./Crown Resources Corp.	Geologic mapping; condemnation drilling; engineering studies in preparation for mining	Gold skarn mineralization in Permian or Triassic metasedimentary rocks adjacent to the Jurassic–Cretaceous(?) Buckhorn Mountain pluton
50	Crown Jewel exploration project	secs. 13-14, 23-26, 40N, 30E	Okanogan	Au, Cu, Ag, Fe	Battle Mountain Gold Corp./Crown Resources Corp.	Activities centered on permitting for the Crown Jewel mine	Gold skarn mineralization in Permian or Triassic metasedimentary rocks adjacent to the Jurassic–Cretaceous(?) Buckhorn Mountain pluton
51	Strawberry Lake	secs. 6-9, 16-21, 29-30, 40N, 30E; sec. 24, 40N, 29E	Okanogan	Au, Ag, Cu	Teck Exploration Ltd./Crown Resources Corp.	Geologic mapping, geochemistry, geophysics, drilling	Gold skarn- and vein-type mineralization in Permian to Triassic metasedimentary and metavolcanic rocks intruded by Mesozoic granitic rocks
52	Molson Gold	numerous sections, 39-40N, 28-29E	Okanogan	Au, Ag	Lac Minerals (USA) Inc./Crown Resources Corp.	Geologic mapping, geochemistry, geophysics	Skarn- and epithermal-type mineralization in Permian to Triassic metasedimentary and metavolcanic rocks intruded by Mesozoic granitic rocks
53	Kelsey	secs. 5-8, 40N, 27E	Okanogan	Cu, Mo, Ag, Au	Weaco Resources, Ltd.	Geophysics, drilling	Porphyry-type mineralization in Jurassic–Cretaceous Silver Nail quartz diorite
54	Hot Lake	secs. 7, 18, 40N, 27E	Okanogan	Cu, Mo, Ag, Au	Wilbur Hallauer	Negotiating agreement	Gold-sulfide replacement zone adjacent to the Kelsey porphyry-type deposit
55	Blue Lake	sec. 5-6, 39N, 27E	Okanogan	Au, Ag	Wilbur Hallauer	Geologic mapping, geochemistry	Gold enrichment zones in Permian–Triassic limestone
56	Cayuse	sec. 23, 38N, 26E	Okanogan	Au	Northwest Minerals Inc.	Exploration	Skarn and replacement mineralization in Permian Spectacle Formation
57	Palmer Mountain	secs. 20, 29, 39N, 26E	Okanogan	Cu, Au, Ag, W, Zn, Fe	Wilbur Hallauer	Geologic mapping, geochemistry	Volcanogenic massive sulfide mineralization in Permian–Triassic Palmer Mountain Greenstone
58	Copper World area	secs. 20, 29, 39N, 26E	Okanogan	Cu, Au, Ag, W, Zn, Fe	Pacific Northwest Resources Inc.	Exploration	Ore lenses in altered andesite of Permian–Triassic Palmer Mountain Greenstone

Table 2. Mining and mineral exploration in Washington, 1992 *(continued)*

Loc. No.	Property	Location	County	Commodity	Company	Activity	Area geology
59	Black Bear	sec. 36, 39N, 25E	Okanogan	Au, Ag, Cu	Wilbur Hallauer	Negotiating	Veins and fracture controlled mineralization in Permian–Triassic Palmer Mountain Greenstone and diorite of probable Jurassic–Cretaceous age
60	Lucky Knock	sec. 19, 38N, 27E	Okanogan	Au, Sb	Magill and Associates	Geochemistry	Stibnite veinlets in fractured and silicified limestone of the Permian Spectacle Formation
61	Starr Molybdenum	secs. 8, 16, 37N, 26E	Okanogan	Mo, Cu, W	Wilbur Hallauer	Geologic mapping, geochemistry	Porphyry-type mineralization in Cretaceous Aeneas Creek quartz monzonite and granodiorite; gold in secondary enriched zone
62	Montgomery	sec. 12, 36N, 26E	Okanogan	Au, Cu, W	McGill and Associates	Exploration, geochemistry	Mineralization in contact-metamorphosed Permian–Triassic Kobau Formation
63	Aeneas Valley property	sec. 8, 35N, 31E	Okanogan	Au, Ag, Cu, silica	Sunshine Valley Minerals, Inc.	Exploration	Large quartz bodies in probable Permian rocks
64	Parmenter Creek	secs. 1, 12, 32N, 30E	Okanogan	Au, Cu, Zn	Colville Confederated Tribes	Property now open for negotiated agreement	Shear zone mineralization in metamorphic rocks
65	Wasco Ridge	secs. 28-33, 33N, 31E; secs. 4-5, 32N, 31E	Okanogan	Au, Ag	Colville Confederated Tribes/Santa Fe Pacific Mining, Inc.	Conditional permit for exploration	Shear zone mineralization in metamorphic rocks adjacent to Eocene intrusive rocks
66	Agency Butte	secs. 31-32, 31N, 31E	Okanogan	Au, Ag	Colville Confederated Tribes/Echo Bay Exploration Inc.	Geologic mapping, geochemistry	Epithermal mineralization in Eocene Sanpoil Volcanics
67	Billy Goat	sec. 15, 38N, 20E	Okanogan	Au, Cu, Ag	Sunshine Valley Minerals, Inc.	Repairing underground workings	Stockwork in Cretaceous(?) andesite tuff and breccia
68	Craggy Peak	secs. 26-27, 34-35, 38N, 20E	Okanogan	Cu, Au, Ag, Fe	R. E. Kucera	Exploration	Disseminated and shear zone Cu-Au, tourmaline breccia pipes, and alteration of Cretaceous(?) andesite of Isabella Ridge
69	Mazama	secs. 17, 19-20, 36N, 20E	Okanogan	Au, Cu, Ag	Centurion Mines Corp.	Geologic mapping; all new and previous data entered into computer	Porphyry-type mineralization in fractures and in a breccia body of a Cretaceous stock
70	Alder area	secs. 23-26, 35-36, 33N, 21E	Okanogan	Au, Ag, Cu, Zn	Pacific Northwest Resources Inc.	Exploration	Replacement and volcanogenic massive sulfide mineralization in dacitic breccias of the Jurassic–Cretaceous Newby Group
71	Smith Canyon	sec. 1, 32N, 21E	Okanogan	Au, Ag	Northwest Minerals Inc.	Exploration	Vein and disseminated mineralization in Jurassic–Triassic volcaniclastic rocks
72	Say Energy	secs. 9-16, 24, 30N, 22E	Okanogan	Au, Ag, Cu	Hunter Mines Inc., subsidiary of Waseco Resources, Inc.	Underground development, trenching, repair and maintenance, dewatering shaft	Veins in Jurassic–Cretaceous Methow Gneiss

Table 2. Mining and mineral exploration in Washington, 1992 *(continued)*

Loc. No.	Property	Location	County	Commodity	Company	Activity	Area geology
73	Raven group	sec. 21, 27N, 18E	Chelan	Au, Ag	Raven Hill Mining Co.	Exploration	Vein in Cretaceous schist and gneiss
74	Gold Bond	secs. 2-3, 22N, 17E	Chelan	Au	Gold Bond Mining Co.	Exploration, geochemistry, rehabilitation work	Vein mineralization in rocks of the Ingalls ophiolite complex
75	MDO #1	secs. 1-3, 22N, 17E	Chelan	Au, Ag, Hg, Cu	Montana d'Oro, Inc.	Exploration	Veins in serpentinite and metasedimentary and metavolcanic rocks of the Ingalls Complex
76	Wallace	sec. 25, 23N, 19E	Chelan	Au, Ag	Asamera Minerals (U.S.) Inc.	Drilling	Mineralization in silicified intervals in Eocene arkosic sandstone
77	Simon-Cumbo	secs. 8-9, 22N, 20E	Chelan	Au, Ag	Asamera Minerals (U.S.) Inc.	Drilling	Mineralization in altered (commonly silicified) horizons in Eocene arkosic sandstone
78	Cannon mine	sec. 16, 22N, 20E	Chelan	Au, Ag	Asamera Minerals (U.S.) Inc./ Breakwater Resources Ltd.	Mining; surface and underground drilling	Mineralization in altered (commonly silicified) horizons in Eocene arkosic sandstone
79	Compton	sec. 27, 22N, 20E	Chelan	Au, Ag	Wilbur Hallauer	Negotiating	Mineralization in altered (commonly silicified) horizons in Eocene arkosic sandstone
80	Sec. 36 lease	sec. 36, 22N, 20E	Chelan	Au, Ag	Wilbur Hallauer	Geophysics	Mineralization in Eocene arkosic sandstone
81	New Light	sec. 27, 38N, 17E	Whatcom	Au, Ag, Cu, Ni, Pt, Pb	Western Gold Mining, Inc.	Exploration	Quartz-carbonate-cemented slate-argillite breccia in the Lower Cretaceous Harts Pass Formation
82	Azurite	sec. 30, 37N, 17E	Whatcom	Au, Ag, Cu, Zn, Pb, Pt	Double Dragon Exploration Inc.	Road repair; sampled old tailings; cleaned up mill site	Veins in sedimentary rocks of the Cretaceous Virginian Ridge Formation
83	Minnesota	sec. 2, 37N, 16E	Whatcom	Au, Ag, Cu	Seattle–St. Louis Mining Co.	Geologic mapping, geochemistry, maintenance/renovation	Quartz veins in argillite and feldspathic sandstone of the Lower Cretaceous Harts Pass Formation
84	Loomis Mountain	secs. 19-20, 29-30, 32, 37N, 8E	Whatcom	Cu, Au, Ag, Pb, Zn	Cannon Minerals	Geologic mapping, trenching	Massive sulfide mineralization in intermediate-composition volcanic rocks
85	South Pass Nickel	sec. 2, 39N, 4E; sec. 35, 40N, 4E	Whatcom	Ni, Co, Cr	Jackpine Mining Co., Inc.	Geologic mapping, geochemistry, geophysics	Laterite developed in peridotite at the base of Eocene sedimentary rocks
86	Skagit Copper	secs. 1-3, 33N, 5E	Skagit	Cu, Au, Ag, Pb, Zn	Cannon Minerals	Geologic mapping, trenching	Massive sulfide mineralization in accreted terrane (melange?) rocks
87	Telstar	secs. 25-26, 33N, 8E	Skagit	Cu, Au, Ag, Zn, Pb	Cannon Minerals	Exploration, trenching	Mineralization in altered ultramafic rocks
88	Tri-Lux	secs. 27-28, 32-34, 30N, 9E	Snohomish	Au, Ag, Pb, Zn	Cannon Minerals	Exploration, trenching	Stockwork mineralization in a subaqueously extruded dome
89	Lockwood	secs. 25, 30-32, 29N, 9E	Snohomish	Au, Cu, Zn, Fe, S, Ag	Kennecott Corp./ Island-Arc Resources Corp./Formosa Resources Corp.	Drilling	Kuroko-type volcanogenic massive sulfide mineralization in Jurassic volcanic rocks of the Western melange belt

Table 2. Mining and mineral exploration in Washington, 1992 *(continued)*

Loc. No.	Property	Location	County	Commodity	Company	Activity	Area geology
90	Apex-Damon	sec. 34, 26N, 10E	King	Au, Ag, Cu, Pb	CSS Management Corp.	Milling; mine repair and development	Quartz vein in granodiorite of the Miocene Snoqualmie batholith
91	Weyerhaeuser properties	Cascades area	King	Au, Ag, Cu, Mo, Pb, Zn, clay, silica	Weyerhaeuser Co.	Inventory and evaluation of mineral potential of company-owned forest lands	Cascades province and adjacent volcanic, volcaniclastic, and intrusive rocks
92	Morse Creek	sec. 31, 17N, 11E	Yakima	Au, Ag	Ardic Exploration and Development, Ltd.	Drilling	Tuffs of the Oligocene Ohanapecosh Formation
93	Margaret	secs. 8, 17, 10N, 6E	Skamania	Cu, Mo, Ag, Au	Teck Exploration, Inc.	Property acquisition dependent on obtaining prospecting permits	Porphyry deposit in quartz diorite of the Miocene Spirit Lake pluton
94	Polar Star	sec. 18, 10N, 6E	Skamania	Cu, Mo, Ag, Au	Champion International Corp.	Drilling	Breccia pipes and porphyry-type deposit in quartz diorite of the Miocene Spirit Lake pluton
95	Wind River	sec. 9, 5N, 7E	Skamania	Au, Ag	DeLano Wind River Mining Co.	Drilling	Epithermal mineralization in Oligocene–Miocene volcanic rocks
96	Silver Star	secs. 3-5, 8-9, 3N, 5E	Skamania	Cu, Ag, Au, Mo	Plexus Resources Corp.	Geologic mapping, geochemistry, drilling, baseline studies	Tourmaline-bearing breccia pipe associated with porphyritic phases of the Miocene Silver Star pluton
201	Totem talc	secs. 23, 25-26, 39N, 44E	Pend Oreille	talc	First Miss Gold Inc./ United Catalysts Inc.	Geotechnical and engineering studies	Talc along a high-angle fault in altered dolomites of the Late Proterozoic Monk Formation (Windermere Group)
202	Mica mine	sec. 14, 24N, 44E	Spokane	clay	Mutual Materials Co.	Using stockpiled clay; some new mining at Mica pit; production of bricks	Lacustrine clay of the Miocene Latah Formation overlying saprolitic, pre-Tertiary felsic gneiss and locally underlying silty clay of the Pleistocene Palouse Formation
203	Somers clay pit	sec. 35, 25N, 44E	Spokane	clay	Quarry Tile Co.	Mining	Lacustrine clay of the Miocene Latah Formation overlain by silty clay of the Pleistocene Palouse Formation
204	Blue Silver quarry	sec. 21, 28N, 36E	Lincoln	dolomite	Blue Silver Mining	Mining, milling	Dolomite of the Cambrian–Ordovician Metaline Formation
205	Turk Magnesite	sec. 36, 30N, 37E	Stevens	magnesite	Osprey Resources	Evaluation	Magnesitization of the Middle Proterozoic Stensgar Dolomite (Deer Trail Group) at the southwestern end of the magnesite belt
206	Gehrke quarry	sec. 2, 29N, 39E	Stevens	dolomite	Allied Minerals Inc.	Mining, milling	Isolated pod of Middle Proterozoic Stensgar Dolomite(?) (Deer Trail Group)
207	Nine quarries		Stevens	dolomite	Nanome Aggregates, Inc. (division of International Marble & Stone Co. Ltd. [IMASCO])	Mining, milling	Colored dolomite or dolomitic marble is mined at nine sites: China White, Black, Lolo Martin, Primavera/Sage Green, Cream, Rose/Red, Grey/Chartreuse, Farnsworth, and Watermary

Table 2. Mining and mineral exploration in Washington, 1992 *(continued)*

Loc. No.	Property	Location	County	Commodity	Company	Activity	Area geology
208	Lane Mountain quarry	secs. 22, 34, 31N, 39E	Stevens	silica	Lane Mountain Silica Co. (divn. of Hemphill Brothers, Inc.)	Mining, milling	Cambrian Addy Quartzite
209	Chewelah Eagle quarry	sec. 5, 32N, 41E	Stevens	dolomite	Chewelah Eagle Mining Co.	Mining by Nanome Aggregates for their Sunlit White product	Devonian(?)–Carboniferous(?) metacarbonate rocks
210	Eagle Mountain mine	sec. 33, 33N, 41E	Stevens	barite	Lovejoy Mining	Assessment work, shipped two truckloads	Massive to brecciated barite veins in sheared argillite of the Middle Proterozoic Striped Peak Formation (Belt Supergroup)
211	Addy dolomite quarry	secs. 13-14, 33N, 39E	Stevens	dolomite	Northwest Alloys, Inc.	Mining, production of magnesium metal	Dolomite of the Cambrian–Ordovician Metaline Formation
212	Sherve quarry	sec. 8, 39N, 40E	Stevens	limestone	Northport Lime-stone Co. (division of Hemphill Brothers, Inc.)	Mining, milling	Limestone in the upper unit of the Cambrian–Ordovician Metaline Formation
213	Janni limestone quarry	sec. 13, 39N, 39E	Stevens	limestone	Peter Janni and Sons	Leased to Pluess-Staufer Industries, Inc.	Cambrian Reeves Limestone Member of the Maitlen Phyllite
214	Joseph & Jeanne Janni property	sec. 13, 39N, 39N	Stevens	limestone	Fortuna Mines	Leased to Pluess-Staufer Industries, Inc	Cambrian Reeves Limestone Member of the Maitlen Phyllite
215	Flagstaff Mountain	secs. 4, 9, 39N, 39E	Stevens	barite	Mountain Minerals Co. Ltd. *dba* Mountain Minerals Northwest	Startup mill; sub-sequent shutdown, project on hold	Massive bedded barite in the Devonian–Carboniferous Flagstaff Mountain sequence
216	Whitestone quarry	sec. 34, 39N, 38E	Stevens	decorative stone	Whitestone Co.	Mining	Recrystallized limestone (marble) in the Cambrian Maitlen Phyllite
217	Northwest marble mine; other quarries	sec. 19, 38N, 38E	Stevens	dolomite	Northwest Marble Products Co.	Mining, milling, custom milling for Northwest Alloys	Dolomite of the Cambrian–Ordovician Metaline Formation; additional colored dolomite products are quarried at several locations
218	Moonlight quarry	sec. 24, 38N, 37E	Stevens	decorative stone	Whitestone Co.	Mining	Dolomite
219	Kifer quarry	sec. 2, 36N, 37E	Ferry	decorative stone	Raymond Fosback Masonry	Mining	Foliated and lineated, thin bedded, white to light brown, micaceous quartzite forming a belt along the eastern margin of the Kettle metamorphic core complex
220	Wauconda quarry	sec. 13, 38N, 30E	Okanogan	limestone	Columbia River Carbonates	Mining, milling	High-calcium, pre-Tertiary white marble lenses in mica schist, calc-silicate rocks, and hornfels
221	Bonaparte Meadows peat	sec. 20, 38N, 30E	Okanogan	peat moss	The Bonaparte Co.	Mining	*Hypnum* moss in a peat bog south of Bonaparte Lake
222	Poison Lake	secs. 4-5, 38N, 27E	Okanogan	gypsite	Agro Minerals, Inc.	Mining	Evaporitic lake in a small basin at the convergence of several ravines dammed by glacial deposits

Table 2. Mining and mineral exploration in Washington, 1992 *(continued)*

Loc. No.	Property	Location	County	Commodity	Company	Activity	Area geology
223	Tonasket limestone quarry	sec. 25, 38N, 26E	Okanogan	limestone	Pacific Calcium, Inc.	Mining, milling	Metacarbonate rocks in the conglomerate-bearing member of the Permian Spectacle Formation (Anarchist Group)
224	Brown quarry	sec. 26, 35N, 26E	Okanogan	dolomite	Pacific Calcium, Inc.	Mining	Metadolomite member of the Triassic Cave Mountain Formation
225	Coulee Chief	sec. 24, 23N, 25E	Douglas	clay	Basic Resources Corp.	Development planning	Sedimentary interbeds in the Miocene Columbia River Basalt Group near Moses Coulee
226	Rock Top	sec. 20, 22N, 26E	Grant	clay	Basic Resources Corp.	Preliminary development	Montmorillonite-group clays (bentonite) as interbeds within the Columbia River Basalt Group
227	Sec. 8 pit	sec. 8, 17N, 24E	Grant	diatomite	Celite Corp.	Mining, milling	Miocene "Quincy Diatomite Bed", a sedimentary interbed occurring locally at the base of the Priest Rapids Member (Columbia River Basalt Group)
228	Sec. 7 pit	sec. 7, 17N, 24E	Grant	diatomite	Celite Corp.	Mining, milling	Miocene "Quincy Diatomite Bed", a sedimentary interbed occurring locally at the base of the Priest Rapids Member (Columbia River Basalt Group)
229	Sec. 3/10 pit	secs. 3, 10, 17N, 23E	Grant	diatomite	Celite Corp.	Mining, milling	Miocene "Quincy Diatomite Bed", a sedimentary interbed occurring locally at the base of the Priest Rapids Member (Columbia River Basalt Group)
230	Chikamin quarry	sec. 22, 29N, 17E	Chelan	decorative stone	Juanita Trucking	Mining	Extensive pumice deposits in cinder cones of Glacier Peak origin
231	Nason Ridge	secs. 10, 14-15, 27N, 15E	Chelan	marble	ECC International (English China Clay)	Assessment work	Podiform bodies of high-calcium, high-brightness marble in pegmatitic tonalite and tonalite gneiss of the Chelan complex
232	Silver Lake quarry	sec. 7, 40N, 6E	Whatcom	limestone	Clauson Lime Co.	Mining	Sheared, jointed Lower Pennsylvanian limestone overlain by sheared argillite and underlain by argillite, graywacke, and volcanic breccia of the Chilliwack Group
233	Kendall quarry	secs. 14-16, 22-23, 40N, 5E	Whatcom	limestone	Tilbury Cement Co.	Mining	Lower Pennsylvanian limestone
234	Swen Larsen quarry	sec. 34, 38N, 6E	Whatcom	olivine	Olivine Corp.	Mining, milling, production of olivine	A portion of the >36-mi^2 outcrop area of the Twin Sisters dunite, Whatcom and Skagit Counties
235	Hamilton plant	sec. 17, 36N, 7E	Skagit	olivine	Applied Industrial Materials Corp. (AIMCOR)	Milling, production of olivine products	Twin Sisters dunite
236	Whatcom and Skagit quarry	sec. 6, 36N, 4E	Skagit	decorative stone	Whatcom Skagit Quarry	Mining	Darrington Phyllite
237	unnamed quarry	sec. 13, 34N, 1E	Skagit	decorative stone	Island Frontier Landscape Construction Co.	Mining	Andesite
238	Pacific quarry	sec. 33, 34N, 4E	Skagit	decorative stone	Meridian Aggregates Inc.	Mining	Diorite

Table 2. Mining and mineral exploration in Washington, 1992 *(continued)*

Loc. No.	Property	Location	County	Commodity	Company	Activity	Area geology
239	Twin River quarry	secs. 22-23, 31N, 10W	Clallam	clay	Holnam, Inc.	Mining	Mudstone(?) in three members of the upper Eocene to lower Miocene Twin River Group[
240	Mats Mats quarry	sec. 33, 29N, 1E	Jefferson	decorative stone	General Construction Co.	Mining	Eocene basalt of the Crescent Formation
241	Mandan quarry	sec. 12, 30N, 6E	Snohomish	decorative stone	Universal Land Construction Co.	Mining	Basalt
242	Iron Mountain quarry	sec. 17, 30N, 7E	Snohomish	decorative stone	Iron Mountain Quarry	Mining	Andesite
243	Granite Falls quarry	sec. 8, 30N, 7E	Snohomish	decorative stone	Meridian Aggregates Inc.	Mining	Andesite
244	AAA Diorite quarry	sec. 23, 28N, 7E	Snohomish	decorative stone	AAA Monroe Rock Corp.	Mining	Diorite
245	Twin Rivers quarry	sec. 9, 27N, 6E	Snohomish	decorative stone	Twin Rivers Quarry	Mining	Basalt with clay
246	Monroe Rock quarry	sec. 10, 27N, 6E	Snohomish	decorative stone	AAA Monroe Rock Corp.	Mining	Basalt
247	Cadman Rock quarry	sec. 19, 27N, 7E	Snohomish	decorative stone	Cadman Rock Co. Inc.	Mining	Basalt
248	Miller Lime quarry	secs. 15-16, 27N, 9E	Snohomish	decorative stone	Alpine Rockeries Inc.	Mining	Lenticular beds of folded and faulted, Late Jurassic or Early Cretaceous fossiliferous limestone interbedded with graywacke, argillite, and volcanic rocks
249	Newberry Hill peat	sec. 26, 24N, 1W	Kitsap	peat moss	Asbury's Topsoil	Mining	Bog contains peat, humus, *Sphagnum* moss, and clay, to which sandy loam is added for a topsoil product
250	Sec. 31 pit	sec. 31, 24N, 6E	King	shale	Mutual Materials Co.	Mining	Shale and sandstone of the Eocene Puget Group
251	Hazen quarry	sec. 6, 23N, 6E	King	decorative stone	Universal Land Construction Co.	Mining	Basalt
252	Spruce claim	secs. 29, 30, 24N, 11E	King	crystals	Robert Jackson	Mining, guided mineral collecting fieldtrips	Quartz and pyrite crystals in large, open voids along faulted mega-breccia in the northern phase granodiorite and tonalite of the Snoqualmie batholith (25 Ma)
253	unnamed quarry	sec. 22, 22N, 10E	King	decorative stone	Manufacturers Mineral Co.	Mining	Granite
254	Elk pit	sec. 34, 22N, 7E	King	shale	Mutual Materials Co.	Mining	Illite- and kaolinite-bearing shales of the Eocene Puget Group
255	Ravensdale pit	sec. 1, 21N, 6E	King	silica	Reserve Silica Corp.	Mining, washing	Sandstone of the Eocene Puget Group
256	John Henry #1	sec. 12, 21N, 6E	King	clay	Pacific Coast Coal Co.	Mining	Upper middle Eocene silty clay near the base of the Puget Group comprising a 30-ft-thick zone above the Franklin #9 coal seam

Table 2. Mining and mineral exploration in Washington, 1992 *(continued)*

Loc. No.	Property	Location	County	Commodity	Company	Activity	Area geology
257	Mine 11	sec. 11, 21N, 6E	King	decorative stone	Palmer Coking Coal Co.	Drawing from stockpile	Cinders accidently produced decades ago when stockpiles of inferior quality coal and slag (shale, sandstone, clay) underwent spontaneous combustion and smoldered for years at temperatures exceeding 2,000°F, thereby producing so-called "nature's brick"
258	Franklin Rock quarry	sec. 18, 21N, 7E	King	decorative stone	Palmer Coking Coal Co.	Mining	Andesite
259	Enumclaw quarry	sec. 1, 20N, 6E	King	decorative stone	Enumclaw Quarry Inc.	Mining	Andesite flows as interbeds within volcanic breccia and sandstone
260	410 quarry	sec. 20, 20N, 7E	King	decorative stone	410 Quarry Inc.	Mining	Miocene andesite flows
261	Superior quarry	sec. 1, 19N, 7E	King	silica	Ash Grove Cement Co., Western Region	Mining, milling	Silica cap in hydrothermally altered Miocene andesites on a caldera margin
262	Buckley quarry	sec. 7, 19N, 7E	Pierce	decorative stone	Washington Rock Quarries Inc.	Mining	Miocene andesite
263	Wilkeson quarry	sec. 27, 19N, 6E	Pierce	decorative stone	Rockeries Inc.	Mining	Eocene continental sandstone
264	Kapowsin quarry	sec. 8, 17N, 5E	Pierce	decorative stone	Washington Rock Quarries Inc.	Mining	Oligocene–Miocene intrusive andesite
265	Clay City pit	sec. 25, 17N, 4E	Pierce	clay	Mutual Materials Co.	Mining	Oligocene–Miocene kaolin-bearing, altered andesite
266	Lynch Creek quarry	sec. 13, 16N, 4E	Pierce	decorative stone	Randles Sand and Gravel Inc.	Mining	Eocene–Oligocene andesite flows
267	Bucoda pit	sec. 14, 15N, 2W	Thurston	clay	Mutual Materials Co.	Mining	Glacial clay of the Pliocene–Pleistocene Logan Hill Formation overlying silty clay of the Eocene Skookumchuck Formation
268	Jones quarry	sec. 29, 18N, 2W	Thurston	decorative stone	Jones Quarry	Mining	Eocene basalt of the Crescent Formation
269	North Bay peat	sec. 13, 18N, 12E	Grays Harbor	peat moss	Ocean Farms and Soils	Mining	*Sphagnum* moss produced as a component for topsoil product
270	Snow Queen quarry	sec. 36, 14N, 11E	Yakima	decorative stone	Heatherstone Inc.	Mining	Quaternary andesite flows
271	Castle Rock Clay pit	sec. 18, 10N, 1W	Cowlitz	clay	Ash Grove Cement Co., Western Region	Mining	Eocene–Oligocene nearshore sedimentary rocks
272	Blockhouse quarry	secs. 5, 8-9, 4N, 15E	Klickitat	decorative stone	D. M. Layman Inc.	Mining	Pliocene–Quaternary scoriaceous basalt (cinder)
273	Red Rock quarry	sec. 27, 4N, 16E	Klickitat	decorative stone	Bishop Red Rock Inc.	Mining	Near-vent scoriaceous Pliocene–Quaternary basalt (cinder)
274	Fisher quarry	sec. 8, 1N, 3E	Clark	decorative stone	Gilbert Western Corp.	Mining	Pliocene–Quaternary andesite flows

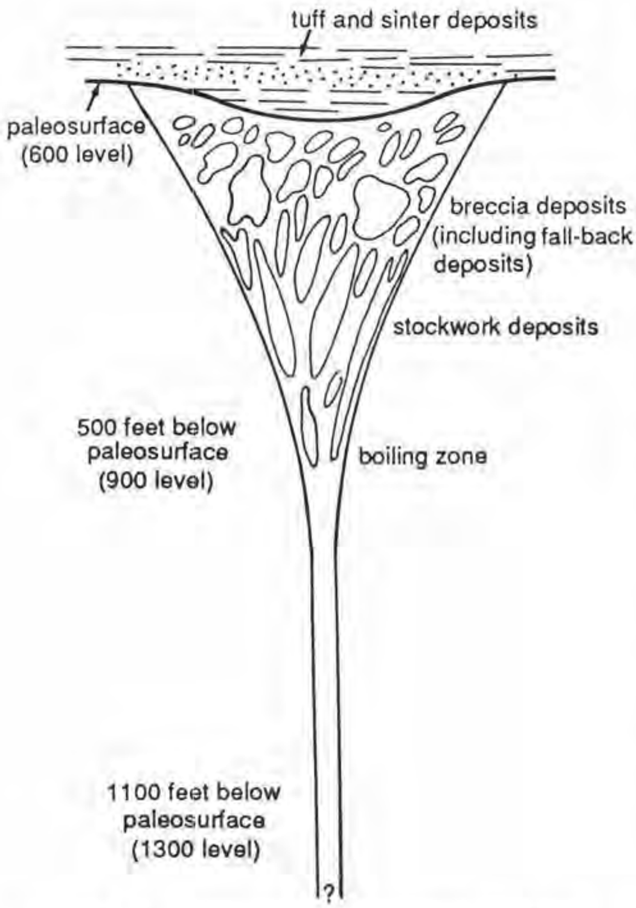

Figure 4. Schematic cross-section through the Golden Promise vein system depicting where the various types of mineralization are found. The section is not to scale and is based on figures by Tschauder (1989), Berger (1985), personal communication with Hecla's chief geologist, Barry Devlin, and tours of the mine by R. E. Derkey.

Near the paleosurface are deposits of tuff and sinter, which are made up of brecciated country rock and vein materials (Fig. 4).

Fluids in the Golden Promise hot spring contained abundant silica, and fluid temperatures may have reached 300°C. Silica was actively precipitating from the fluids, resulting in self-sealing of the conduit. Self-sealing combined with high temperatures resulted in fluid pressures that exceeded the confining pressure in the hot-spring conduit. This caused intermittent explosive release of pressure. These explosions brecciated both the vein materials and country rocks.

During this explosive release of pressure, the hot-springs fluids boiled as much as 500 feet below the surface. These fluids were carrying gold, and when they began to boil, they also began to precipitate gold. This boiling is what produced the colloform banding (also called baroque structure)—dark gray bands consisting of chalcedony with finely disseminated pyrite interspersed with white chalcedony (Fig. 5). Colloform banded ores from stopes on the 900 level have the highest grades in the Golden Promise vein system. Bedded deposits at the paleosurface suggest the Golden Promise hot spring vented into a lake, at least during part of its history. The hydrothermal explosions ejected material from the hot-spring vent onto the lake floor. Some of the ejected material fell back into the vent, forming deposits commonly called fall-back deposits. Vented and fall-back material at the Golden Promise include boulder to pebble breccias and bedded tuff and sinter (Fig. 6). While unconsolidated, these permeable deposits were the loci for passage of hydrothermal solutions and continued precipitation of gold.

Hecla Mining Co.'s Republic Unit (no. 20) continued to produce primarily from the Golden Promise deposit. In 1992, production totaled 58,343 ounces of gold and 299,957 ounces of silver from 102,631 tons of ore milled. This represents the largest annual tonnage ever mined from underground mines by Hecla or its predecessors at Republic. Hecla reported that the ore grade at the mill averaged 0.596 ounces of gold per ton and 3.57 ounces of silver per ton.

The mill at Hecla's operation near Republic increased its capacity to 325 tons per day; previous mill capacity was 270 tons per day. The expansion resulted in processing of more than 100,000 tons of ore from underground mining operations for the first time in the history of the mine. The ore grade has decreased, and gold production for the year decreased (from 77,736 ounces in 1991), as did silver production (from 311,000 ounces). An onsite refinery was completed for a first-level refining of ore concentrates from the mill. The mine now ships dore for further refinement into gold and silver bars.

Hecla Mining Co. continued their underground exploration and development program and the remapping of surface geology on their extensive holdings in the district. If this program is successful, there is likely to be additional expansion of the mill at Republic.

Hecla's Golden Eagle property (no. 21) remains on hold because an economical means of extracting gold from this type of deposit has not been developed. The property contains a reported reserve of more than 1 million ounces of gold in ore grading 0.13 ounces per ton (Phelps, 1991).

The Cannon mine (no. 78), located near the southwest corner of the town of Wenatchee (cover photo), continued as Washington's largest gold producer. However, the joint venture mining operation between Asamera Minerals (U.S.) Inc. (operator) and Breakwater Resources Ltd., scaled down operations in anticipation of depletion of ore reserves in about 2 years. The mine continues to operate 7 days per week; however, the mill now operates only 5 days per week, 24 hours per day.

Production at the Cannon mine for 1992 was 134,786 ounces of gold and 243,498 ounces of silver from 495,090 tons of ore. This is an average grade of 0.272 ounces per ton for gold and 0.492 ounces per ton for silver. Host rocks for this epithermal gold deposit (Ott and others, 1986) are Eocene clastic rocks of the Chiwaukum graben, which is a northwest-trending strike-slip basin (Evans and Johnson, 1989).

Asamera Minerals closed its exploration office in Wenatchee in late 1992 after completing exploration on properties in the region. Other companies and individuals, however, maintain properties in the Wenatchee area.

The only other Washington production of gold from an epithermal deposit was from the Kettle mine (no. 38) located west of Curlew in the Republic graben. This deposit was mined out in 1992. Total production for the life of the Kettle mine (Fig. 7) was 63,846 ounces of gold. A total of 245,300 tons was mined, with an average grade of 0.260 ounces of gold per ton. The mine was part of the Kettle River Project, a joint venture between Echo Bay Minerals Co. (operator) and Crown Resources Corp. Ore was stockpiled at the joint venture's Overlook mill, where processing of the Kettle ore continued into the fall. Ore from the Key deposits was available to replace ore from the Kettle deposit when processing of the Kettle ore was completed.

Echo Bay/Crown Resources continued drilling with promising results on the K-2 deposit (no. 37) located 2 miles west-southwest of the Kettle mine. This deposit, along with the nearby Lamefoot deposit, are expected to contribute higher grade ore and significantly extend ore reserves for the Kettle River Project.

Exploration and maintenance of claims continued on numerous other epithermal deposits in Washington. In addition to those of the Republic area (nos. 22, 23, 25, 26, 33,and 36), they include the First Thought (no. 15), Toroda Creek Graben area (nos. 45, 46, and 47), Agency Butte (no. 66), the Wenatchee area (nos. 76, 77, and 79), and the Wind River deposit (no. 95). The Agency Butte deposit is a new discovery on the Colville Indian Reservation.

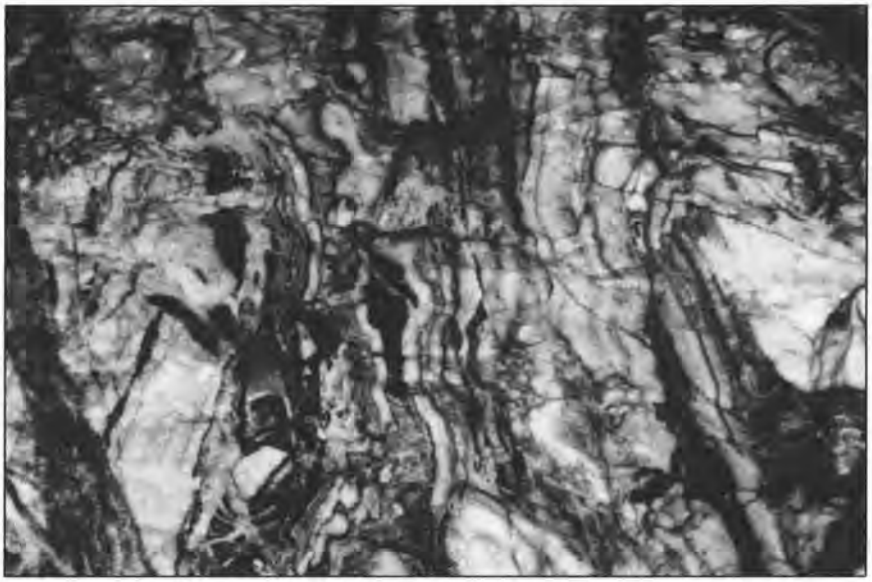

Figure 5. Irregular colloform banding (also called baroque structure) at the 900 level of the mine in the main Golden Promise vein, where boiling was instrumental in producing some of the highest grade ores of the Golden Promise vein system. The dark bands consist of chalcedony with finely disseminated pyrite, and the white bands are chalcedony only. The dark chalcedony bands contain most of the gold mineralization. The area shown in the figure is 2 feet by 4 feet.

REPLACEMENT-TYPE GOLD DEPOSITS

Several gold deposits along the eastern margin of the Republic graben are classified as replacement-type gold deposits, using criteria of the prevailing theory for their origin. All of the Washington deposits are found in a sequence of accreted Permian carbonate, volcaniclastic, and epiclastic sedimentary rocks (Tschauder, 1989). Locally, the deposits occur at the contact between carbonate and clastic sedimentary rocks. Gold is sporadically distributed in massive iron oxide-sulfide zones in carbonate rocks and in stockworks of pyrrhotite and quartz-sulfide veinlets (largely pyrite) in clastic sedimentary rocks. Another theory for the origin of these deposits postulates that they are sea-floor exhalative accumulations of massive iron oxides and sulfides fed by a stockwork of pyrrhotite and quartz-sulfide veinlets (Rasmussen and Hunt, 1990). Gold may have been deposited synchronously with the iron oxides-sulfides or by later hydrothermal activity.

Ore grade at the Overlook mine (no. 27) was among the lowest for underground gold mines operating in the U.S. in 1992. As in the previous 2 years of operation, the ore was processed at the nearby Overlook mill. Combined production from both the Kettle and Overlook mines in 1992 was 89,848 ounces of gold from 657,099 tons of ore that had a head grade of 0.155 ounces of gold per ton.

Echo Bay Minerals elected to close the Overlook mine (Fig. 8) at the end of 1992. A major factor in this decision was the availability of ore from the nearby Key deposits. The shutdown resulted in a layoff of 68 workers at the mine.

Figure 6. Underground exposure of bedded tuff and sinter (upper part of photo) and hydrothermal explosion breccias (lower part of photo). Breccia fragments consist of country rock and vein materials. Golden Promise deposit, just below the 600 level.

Another major change in Kettle River Project operations was the withdrawal of Crown Resources Corp. from the joint venture near the end of 1992. The Kettle River Project is now solely owned by Echo Bay Minerals.

Stripping and mining commenced at the Key East and Key West (Fig. 9) deposits (no. 28) following issuance of permits to mine. The two deposits, located about ¼ mile apart, are open-pit mining operations and are about a mile northeast of the Overlook mine. Reserves at the Key deposits are almost 900,000 tons of ore at a grade of 0.13 ounces of gold per ton, or more than 100,000 ounces of gold. Mining here has been contracted to M. A. Segale Inc. of Tukwila, WA, and is scheduled to be completed by early fall of 1993. The Key deposits, like the Overlook mine, are in Permian rocks.

Following issuance of permits in 1992, underground development commenced on the Lamefoot deposit (no. 30), which had been the major exploration project of Echo Bay Minerals in the area. Announced reserves at the Lamefoot (Fig. 10) fall into two categories, probable and possible ore reserves. The probable ore reserve is 917,000 tons at 0.161 ounces of gold per ton (147,800 ounces of contained gold). The possible ore reserve is 2,087,400 tons at 0.165 ounces of gold per ton (344,600 ounces of contained gold). Full-scale mining of the Lamefoot deposit is projected to begin in 1994. Ore removed during development at Lamefoot is being stockpiled, and when mining begins, all ore will be transported to the Overlook mill. The Lamefoot deposit, like the Overlook and Key deposits, is in Permian rocks.

Echo Bay Minerals (operator) and all of its joint venture partners dropped their option to explore the Leland property (no. 29), located between Lamefoot and the Overlook mine.

Numerous exploration projects continued for replacement-type deposits in northeastern Washington in 1992. The majority of these projects were in the northern part of the Republic graben (nos. 24, 25, 29, 31, 34, 39, and 40) and to the east, between the Kettle and Columbia Rivers (nos. 10, 11, 12, 13, 14, 16, and 18). Several of these properties also have potential for skarn-type mineralization.

Figure 7. This portal to the Kettle mine is no longer in use; the deposit was mined out in 1992. Over its 2-year mine life, the deposit produced 63,846 ounces of gold from 245,300 tons of ore for an average grade of 0.260 ounces of gold per ton. Exact figures for silver production are not available; however, the ratio of silver to gold at the deposit was in the range of 8–10 to 1.

SKARN-TYPE GOLD DEPOSITS

The Crown Jewel deposit (no. 49) is the type example of a skarn-type gold deposit in Washington. Ettlinger and Ray (1989), in their extensive study of skarns in British Columbia, note unique characteristics of precious-metal-enriched (PME) skarns. Those that characterize the Crown Jewel deposit (Hickey, 1992) are: (1) the majority of producing deposits are found in island-arc and back-arc basin assemblages and arc-related comagmatic intrusions; (2) most PME skarns have a spatial affinity to iron- or copper-bearing skarns; (3) gold is found in garnet skarn, in pyroxene skarn, and in skarn containing iron and copper minerals; and (4) the presence of bismuth in a skarn is regarded as indicative of high precious metal potential.

Battle Mountain Gold (operator) and Crown Resources, joint venture partners, initiated the permitting process for the Crown Jewel deposit in 1992. A draft environmental impact statement is expected in 1993; this begins a review

Figure 8. The Overlook mine of Echo Bay Minerals was closed at the end of 1992. A reserve of good grade ore remains; however, Echo Bay is now getting all of its ore from the nearby Key deposits, which are open pits.

leading to preparation of a final environmental impact statement, which must be competed before mining permits can be issued. Reserves are 8.7 million tons of ore at a grade of 0.186 ounces of gold per ton, or more than 1.6 million ounces of gold. Activities in 1992 centered on condemnation drilling, that is, drilling to insure that no significant amount of mineralized rock is present under areas planned for mine structures, such as tailings ponds and waste dumps.

Industry geologists regard the potential for additional PME skarn deposits in Washington as high. Accreted terranes of northeastern and north-central Washington contain Permian to Jurassic volcanic, volcaniclastic, epiclastic, and carbonate rocks originally deposited in island arcs and back-arc basins. Widespread intrusive bodies in these accreted terranes are Jurassic to Eocene plutons of granitic to dioritic composition. The Jurassic plutons may be extrusive equivalents of volcanic rocks of the island arcs. Although the Buckhorn Mountain pluton that formed the Crown Jewel deposit has not been dated, Jurassic plutons are known in the area (Holder and others, 1989), and it seems likely that the Buckhorn Mountain pluton is Jurassic.

All exploration projects on known skarn deposits with potential for precious metal enrichment were in northeastern Washington. The Crown Jewel deposit is only a 100-acre part of holdings that exceed 8,000 acres, known as the Crown Jewel exploration project (no. 50). During 1992, the majority of the Battle Mountain Gold/Crown Resources effort centered on fulfilling obligations for permitting the proposed Crown Jewel mining operation.

Other companies evaluating properties for PME skarns concentrated their efforts in northeastern and north-central Washington (nos. 10, 11, 16, 25, 32, 34, 36, 39, 40, 48, 51, 52, and 56).

Figure 9. Stripping overburden and mining began in the fall of 1992 at the Key West deposit owned by Echo Bay Minerals. Ore, exposed in the center of the photo, consists of magnetite with subordinate pyrite, pyrrhotite, and chalcopyrite. Mining at this and the nearby Key East desposit is scheduled to be completed in early fall of 1993. Ore reserves at these deposits are almost 900,000 tons and contain more than 100,000 ounces of gold.

MISSISSIPPI VALLEY-TYPE DEPOSITS

The predominant, yet simple, ore mineralogy of Mississippi Valley-type (MVT) deposits consists of low-silver galena, low-iron sphalerite, barite, and fluorite. In addition to lead and zinc in MVT deposits (lead is subordinate to zinc in Washington deposits), trace amounts of copper, nickel, cobalt, cadmium, indium, germanium, and gallium are known (Guilbert and Park, 1986). Ore solutions that formed MVT deposits were hot (90–150°C), sodium-calcium-chlorine brines that are commonly found as connate or oilfield waters. MVT deposits tend to accumulate at basin margins rather than within the basin. They also occur at unconformities, commonly with resultant karst openings (Sangster, 1983).

MVT deposits in Washington are found in Cambrian–Ordovician Metaline Formation (Mills, 1977; Dings and Whitebread, 1965) in the northeastern corner of the state. The economic focus in these types of deposits is zinc, which in the larger deposits generally exceeds lead by a ratio of between 2 and 6 to 1. Morton (1992) provides additional details about, and a re-evaluation of the deposits of northeastern

Figure 10. This adit was collared and driven 2,000 feet in 1992 to reach ore of the Lamefoot deposit northeast of Republic. The first mineralization encountered arrived at the surface in late October. The purpose of the adit was to confirm drill-indicated ore reserves: if ore reserves prove out, the adit will be converted to a full production adit in 1994. Seventy-five percent of all ore is above the level of this adit. Ore from below the adit level will be mined by ramping down to the level of the ore.

Washington, especially those of the Metaline mining district.

Equinox Resources Ltd. re-opened the Van Stone mine (no. 5) in northern Stevens County (Fig. 11) after a shutdown in late 1991 due to depressed zinc prices. They produced 8,615 tons of zinc concentrates that averaged 55 percent zinc and 2,190 tons of lead concentrates that averaged 70.5 percent lead. The mine again operated at a rate of 150,000 tons of ore plus waste per month; ore grades averaged 4.0 percent zinc and 1.5 percent lead. However, the mine shut down in mid-January 1993, again because of depressed zinc prices.

The Pend Oreille mine (no. 1), another MVT deposit near Metaline Falls, was the site of underground exploratory drilling by Resource Finance Corp. The target is zinc-rich ores of the Yellowhead horizon. Most previous production from the Pend Oreille mine was from the Josephine horizon; however, the zinc-rich ores of the Yellowhead horizon have become increasingly important as demand for, and the price of, zinc rise. Thirteen holes were drilled in 1992, with favorable results. Work was to begin in late January 1993 on a 6- to 8-month development project to drift into the ore and establish additional drill stations. When this work is completed, Resource Finance will evaluate the feasibility of mining.

Figure 11. Loading zinc-lead ore at the Van Stone mine north of Colville. Equinox Resources produced 8,615 tons of zinc concentrates and 2,190 tons of lead concentrates in 1992. The concentrates were shipped to a smelter in Trail, BC.

Exploration of MVT deposits was severely limited in 1992 compared to 1991. The only known actively explored deposits, in addition to the Pend Oreille mine, were in Stevens County (nos. 6, 7, and 8).

VOLCANOGENIC MASSIVE SULFIDE DEPOSITS

Volcanogenic massive sulfide (VMS) deposits are stratiform accumulations of sulfide minerals; they are termed "massive" when they contain 60 percent or more sulfide. They formed adjacent to hot-spring vents (or black smokers) that spewed sulfides onto the sea floor. A typical VMS deposit consists of a concordant bed(s) of massive sulfide underlain by discordant vein and stringer (feeder) mineralization (Franklin and others, 1981). The bedded mineralization may be offset or displaced from its feeder. Displacement may have been caused by slumping on the sea floor or by deformation during accretion to a continental mass; the latter seems to be common in rocks of late Paleozoic and Mesozoic age in Washington.

At the Lockwood deposit (no. 89), a large concordant body of mineralization has been identified. However, the feeder system for that mineralization has not. The extent of mineralization and structural disruption is not yet known.

Interest in volcanogenic massive sulfide deposits waned only slightly following Kennecott Corp.'s decision to drop their option on the Lockwood deposit in Snohomish County. According to the joint owners (Island-Arc Resources Corp. and Formosa Resources Corp.), there is considerable interest in the property. Recent (1990–91) exploratory drilling has located base- and precious-metal mineralization in the largely pyrite-rich sequence.

Exploratory work on other potential volcanogenic massive sulfide deposits in Washington (nos. 57, 58, 70, 84, and 86) consisted largely of assessment work or of staking and acquisition of property.

PORPHYRY-TYPE DEPOSITS

Ore deposits that are termed porphyry-type deposits were formed by extensive hydrothermal systems that altered and mineralized cubic miles of intrusive igneous bodies (such as batholiths, stocks, and dikes) and the country rocks they intrude. The intrusive bodies range from hypabyssal dacite, latite, quartz latite, and rhyolite to their plutonic equivalents, quartz diorite, monzonite, quartz monzonite, and granite (Guilbert and Park, 1986). The largest known metallic ore deposits in Washington are porphyry-type deposits. The Mount Tolman deposit, for example, contains 2 billion tons of ore (Ray Lasmanis, DGER, oral commun., 1993). Included in this category for Washington are the tourmaline breccia pipe deposits associated with large intrusive porphyry bodies in the central and southern Cascades.

Companies continue to express interest in Washington's numerous porphyry-type deposits. These properties are being explored not only for their copper and molybdenum resource potential, but also for their precious metals. Perhaps the most active of these properties is Centurion Mines Corp.'s Mazama property (no. 69). Plexus Resources Corp. maintained their Silver Star property (no. 96). They currently are working on getting their Bornite property, a similar type deposit in Oregon, into production. Teck Exploration, Inc., is seeking prospecting permits for the Margaret deposit (no. 93), and Champion International continued to evaluate their Polar Star property (no. 94), which is near the Margaret deposit. Other porphyry-type deposits where exploratory work was done are the Hot Lake property (no. 54), the Kelsey deposit (no. 53), and the Starr Molybdenum property (no. 61).

SHEAR ZONE GOLD DEPOSITS

Exploration for shear zone (also termed mesothermal) gold deposits has been active in Washington over the past 2 years. These deposits typically formed at greater depths and higher temperatures than epithermal deposits. Two properties on the Colville Indian Reservation, Parmenter Creek (no. 64) and Wasco Ridge (no. 65), appear to be typical of these deposits in Washington. They are in pre-Tertiary rocks just west of the western margin of the Republic graben.

Exploration activities for gold in shear zones west of Oroville and Tonasket was limited in 1992. Districts such as the Nighthawk, Palmer Mountain, and Conconully continue to be attractive target areas for this type of deposit. Host rocks in these districts are accreted terrane, island-arc, and back-arc basin deposits, which also have potential for volcanogenic massive sulfide, porphyry-type, and skarn-type mineral deposits.

GOLD IN ALKALIC ROCKS

Several deposits in and adjacent to rocks of the Shasket Creek alkalic complex were actively mined or explored over the past few years. The most notable are the Gold Mountain mine (Herdrick and Bunning, 1984) (no. 43), the Irish mine (no. 42), and the Lone Star mine (no. 44). The Gold Mountain mine, a joint venture project of Gold Express Corp. and N. A. Degerstrom, Inc., has obtained permits to mine and is awaiting higher gold prices. The deposit consists of disseminated pyrite and gold in a dike of the Shasket Creek alkalic complex.

Sand and Gravel, Quarried Rock, and Industrial Minerals

by Charles W. Gulick and William S. Lingley, Jr.

CONSTRUCTION MATERIALS

Aggregates

Washington's largest mines, the Lonestar Northwest Steilacoom pit and the Associated Sand and Gravel, Inc., Everett pit, produced 3.5 and 2.5 million tons of sand, gravel, and crushed rock, respectively. Mines reporting production between 700,000 and 1,100,000 tons of sand and gravel include the Pacific Rock Products, Inc., English pit (east of Vancouver); the Acme Construction, Inc./Inland Asphalt Park Road pit (Spokane); the Central Pre-Mix Concrete Co. Sullivan Road pit (Spokane); the Lakeside Sand and Gravel, Inc., Issaquah pit; and the Lone Star Northwest Snoqualmie pit (eastern King County).

Quarries reported as producing at least 200,000 tons of rock during 1992, include the Cadman (Rock), Inc., Highrock quarry (eastern Snohomish County); the Gilbert Western, Inc., Fisher quarry (Clark County); the Meridian Aggregates Co. Granite Falls (Snohomish County), Cactus (Franklin County), and Pacific quarries (Skagit County); the General Construction Co. Mats Mats quarry (Jefferson County); and the Aqua-Marine Construction, Inc., Twin River quarry (Snohomish County).

The Washington Department of Transportation (DOT) had several major construction projects in 1992, including the Renton "S-curves" on Interstate Highway (I-) 405, the high occupany vehicle (HOV) lanes on I-5 in Seattle, and the I-405/State Route 520 interchange in Bellevue. The DOT also awarded several contracts for overlays (highway resurfacing), each of which exceeded 200,000 tons of various rock products. Each mile of highway resurfacing consumes about 5,000 tons of concrete (round-rock) and/or asphalt (crushed) aggregate as well as fill. A 30-mile overlay consumes the annual production of a typical moderately sized mine.

Demand for crushed rock in forest road construction or maintenance has fallen markedly as a result of logging restrictions on public lands. The U.S. Forest Service, which used 18 percent of all crushed rock in Washington during 1983 (Babitzki and Bunning, 1984), built very few forest roads during 1992.

Conservation

Opportunities for conservation of rock resources are frequently overlooked. Improved construction techniques, recycling, and planning for growth are three means of achieving conservation. In Europe, most new highways use significantly more aggregate than equivalent American roads because research has shown that thicker construction results in markedly improved durability. In contrast, roads in some of Washington's housing developments have only 2-inch asphalt pours and do not withstand repeated freeze–thaw cycles and use by larger vehicles.

Several Washington companies are recycling concrete by crushing demolition fragments to create new aggregate. Expenditures for appropriate solid waste permits are currently an obstacle to recycling aggregate.

Industry Issues

Industry representatives we interviewed anticipate that 1993 will be a good year for sand and gravel sales, owing to an aggressive construction and maintenance program by the DOT. In addition, efforts to improve the national economy through infrastructure maintenance hinge on increased construction aggregate production. However, increased production is likely to face resistance from community action groups, some local governments, and mine neighbors who could be affected by new or expanded mines. This situation could be mitigated through conservation of resources.

Though Washington has an abundance of quality rock resources (for example, Gence, 1934; Kroft, 1972; Lingley and Manson, 1992; Dupont, 1993; King County, 1988), many deposits have been covered by urban sprawl. Some huge round-rock deposits, such as the Friday Harbor pit in San Juan County and the Redmond deposit east of Seattle, are essentially depleted. Other large undeveloped deposits are in scenic areas along the eastern Olympic Peninsula or within other environmentally sensitive areas, such as the coarse flood gravels that constitute the Spokane Valley–Rathdrum Prairie aquifer (Lingley and Norman, 1991; Lingley and Manson, 1992). Most other undeveloped deposits are of poorer quality and much thinner. Exceptions are Dupont in Pierce County and Shelton in Mason County.

Figure 13. Ash Grove Cement Co., Western Region's 750,000 ton per year portland cement plant, located on the Duwamish River in Seattle. The plant operated for decades at this site and began producing again in May 1992 after a 5-year hiatus during which portions of the plant were either upgraded (finish grinding circuits) or demolished and totally rebuilt (clinkering plant/kilns). With its higher production capacity, the new facility is the largest dry-process portland cement plant in the northwestern U.S.

Careful planning by local government could reduce mine-related land-use conflict and assure that mineral resources of long-term commercial benefit are extracted prior to implementing other lands uses that would preclude mining. The Growth Management Act (RCW 36.70A) outlined a framework for protecting the best mineral resources. However, many local jurisdictions have opted to protect existing (and largely depleted) resources only.

Inter-county, interstate, and international rock export has become a growth management issue because some local governments must decide whether to plan for rock consumption outside their jurisdiction. Mason County has abundant high-quality round-rock aggregate and currently exports rock to Kitsap County where deposits are of poorer quality owing to high clay contents. Concrete plants in Seattle are currently supplied with inexpensive rock from the Lone Star Northwest Steilacoom pit. This procedure minimizes environmental impacts relating to truck transport of rock from eastern King County. However, the Steilacoom pit will be depleted within 10 years and alternative sources at Dupont and Shelton face protracted permitting processes. Whatcom and Clark Counties are facing such decisions as whether to designate resources that could be used in Oregon and Canada, respectively. Paradoxically, Washington currently imports limestone for all of our portland cement production, and occasionally imports sand and gravel, from Canada. Some clay for cement production is barged from Clallam County to Seattle.

Another key issue during 1992 was revision of the Surface Mining Act (RCW 78.44). Comprehensive amendments to this reclamation act (Lingley and Norman, 1991) failed to pass out of legislative committee during 1992. During the 1993 Session, the legislature will try to resolve issues that impeded passage of the bill during the 1992 Session.

Portland Cement

A major 1992 development for Washington's industrial minerals was the completion of Ash Grove Cement Company, Western Region's new 750,000-ton-per-year (tpa) portland cement plant in Seattle (Fig. 13). This largely new plant was "shoehorned" onto a site that held an antiquated portland cement plant, operated for decades by Lonestar Industries, Oregon Portland Cement, and others. After acquiring Oregon Portland Cement in the mid-1980s, Ash Grove closed the old plant and subsequently demolished the clinkering plant (kilns) in 1987. Unlike sprawling portland cement plants that are situated directly adjacent to limestone quarries in unrestricted "green field" designs, the new facilities of the Seattle plant were designed to fit in a tight space. This site, on the Duwamish River near its outlet in Elliott Bay, affords access to the barges that transport raw limestone from Texada Island in British Columbia.

The new plant is a dry process plant and opened at the end of May 1992. Its production capacity is greater than any wet or dry process portland cement plant in the northwest United States and second only to Tilbury's 1,500,000 tpa dry process plant at Delta, BC, in the entire northwest region. Severe damage to a dust collector in August forced a closure until October. Despite the downtime, USBM statistics for production and value of nonfuel minerals illustrate the positive contribution of the plant. USBM statistics for Washington include production of commodities, specifically portland cement and lime, for which the majority of raw materials is derived from Canada. However, other important Washington commodities, such as silicon and aluminum metals, also largely derived from imported raw materials are excluded from the agency's statistics. (See discussion in Derkey and Gulick, 1992.) Nonetheless, Ash Grove's raw material requirements did stimulate significant new production and purchase of in-state industrial minerals. (See section for clay, below.)

Holnam, Inc., was Washington's second most active portland cement producer, operating a 500,000-tpa plant at Seattle. The 25-year-old, wet process plant does not enjoy the fuel savings in BTU/ton that Ash Grove's dry process affords. However, the wet process allows the company to explore alternate materials. (See clay section.) The re-entry of Ash Grove in the Seattle market has not as yet affected Holnam, which has traditionally oversold its Seattle production and augmented it with product from other plants that carried high transportation costs and thus low profitability.

Holnam's Canadian subsidiary, Rock Products, operated one of four major Texada Island limestone quarries in British Columbia. Because their limestone is of good quality and has low magnesium content, they supplied their competitors, Ash Grove, LaFarge Corporation (Canada), and Tilbury Cement (Canada), with crushed limestone. Ash Grove uses this material to "sweeten" limestone from their own Texada Island quarry.

Building Stone

Many suppliers of crushed rock for landscaping, rockery, large landscaping boulders, and rough construction stone such as rubble, ashlar, veneer, flagstone, and hearthstone were active in 1992 (Gulick, 1992). For some companies, production of decorative or building stone is a small sideline relative to the volume of crushed aggregate, rip-rap, and similar products. Producers of decorative stone, such as Whitestone Co. (no. 218) and Meridian Aggregates Inc. (no. 238), have been included for the first time in Table 1.

DOLOMITE AND LIMESTONE

Dolomite production was once again dominated by Northwest Alloys, Inc. (no. 211), which quarried nearly 500,000 tons near their plant at Addy. Northwest Alloys, a wholly owned subsidiary of Alcoa, produces magnesium metal from dolomite and ferrosilicon. Despite the fact that sales and production of magnesium were down in 1992, the half million tons of raw dolomite is typical production for a good year. Some lower grade (waste rock) was intercepted in the 1992 mining so that more production was required to meet the ore grade requirements of the plant.

Business developments for Northwest Alloys were encouraging during 1992. The anticipated 50 percent cutback in the total workforce of 500 was not fully instituted, and the company was able to bring approximately 50 people back to work during the year. Alcoa consumes a majority of the plant's magnesium output, and the remainder is offered for outside sales. This open-market sales segment benefitted when a Canadian operation of Norsk Hydro had a tariff imposed on its exports to the U.S. after being cited for dumping magnesium metal. Norsk Hydro subsequently reduced production at a plant in Quebec by about half.

Northwest Alloys continues to purchase ferrosilicon from Norway in lieu of their in-house production capability. Prohibitively expensive local electrical power rates drove the decision to purchase the Norwegian material, which is shipped by boat to Chicago or New Orleans and then by rail to Washington state.

L-Bar Industries at Chewelah, which processes sludge bar residue from the Northwest Alloys plant, entered Chapter 11 bankruptcy.

Nanome Aggregates (no. 207), now part of International Marble & Stone Company Ltd., mined colored dolomite and dolomitic marble from several locations in Stevens County and processed the material at their Valley, WA, plant. Noteworthy uses of their product included "pearl gray" terrazzo flooring in the new terminal at the Denver airport and "valley cream" used in precast, exposed aggregate panels in walls for the new prison at Airway Heights near Spokane. Research on possible new colors for the product line was conducted during 1992. Nanome had hoped to supply dolomite to the PPG glass plant at Chehalis; however, that plant remains closed because their glass customers are being supplied through production from PPG's California operations.

Northwest Marble Products Co. (no. 217) produced various colors of crushed dolomite and limestone chips mainly for exposed aggregate and terrazzo applications. Much of their product is marketed by Manufacturers Mineral Company of Renton.

Allied Minerals Inc. of Springdale (no. 206) mined, crushed, and bagged approximately 4,000 tons of dolomite during 1992. Most of Allied's production is marketed as 40- or 80-lb sacks, privately labeled, for the lawn and garden pack-out trade. Golf courses and cemeteries are important additional markets for this soil amendment. Sales tapered off during the fall of 1992 because yard watering restrictions were imposed throughout much of the western population corridor, including Seattle and Portland.

Pacific Calcium, Inc., located near Tonasket, mined 3,000 tons of dolomite from its Brown quarry near Riverside (no. 224) and 13,000 tons of high-calcium limestone from the Tonasket quarry (no. 223) adjacent to the plant site. Pacific Calcium crushes, screens, and packages carbonate products for agricultural applications, primarily fertilizers or soil conditioners for commercial orchards, while also serving subordinate markets such as poultry grit.

Blue Silver Mining of Davenport (no. 204) produced several colors and sizes of dolomitic decorative stone, primarily for landscaping. Their rock is mined near the confluence of the Spokane River and Franklin D. Roosevelt Lake at Miles, WA.

Limestone was produced on both the east and west sides of the state. Northport Limestone Co., a division of Hemphill Bros. Inc., produced 35,000 tons of limestone at the Sherve quarry (no. 212) near Northport. Their primary product is a fluxing grade of crushed limestone that is used at Cominco's Trail, BC, smelter in lead production.

Columbia River Carbonates was active during 1992 quarrying high-calcium, high-brightness limestone at their deposit near Wauconda (no. 220). Their processing plant at

Woodland reduces 6-inch-diameter run-of-mine rock to fine and ultrafine ground calcium carbonate (GCC) in both filler and coating grades. GCC is competing effectively with precipitated calcium carbonate (PCC) for a growing share of the lucrative acid-free paper coatings and filler market. That market contracted slightly in 1992 when the Grays Harbor paper mill at Hoquiam closed, a result of intense competition from new mills producing comparable free-sheet (copy machine) paper. Nonetheless, inherent properties of naturally occurring GCC mineral products have demonstrated advantages for paper making relative to PCC products, particularly in the areas of pitch (resin or "stickies") control, sizing effectiveness, and water drainage during the paper manufacturing process. Columbia River Carbonates began exporting GCC to both Canada and China during 1992.

Chemstar Lime Co. dropped their option on the White Rock deposit, northwest of Tonasket, after completing a confirmation drilling program in which 3,000 feet of core was drilled since 1991.

In western Washington, Tilbury Cement Co. mined 10,000 tons of limestone (no. 233) and, nearby, Clauson Lime Co. (no. 232) was similarly active in producing limestone for rip-rap and pulp mills. Alpine Rockeries Inc. of Woodinville produced limestone rockery products at the Miller Lime quarry in Snohomish County (no. 248).

DIATOMITE

Celite Corp.'s 1991 acquisition of the diatomite operations (formerly owned by Witco Chemical Corp.) at Quincy has not markedly affected production. During 1992, Celite extracted diatomite from two pits and hauled from stockpiles at a third pit in the Frenchman Hills (nos. 227–229). These materials kept the #2 plant at near capacity operation (60,000 tpa) during the year. The #1 plant remains closed, and reclamation was conducted on the inactive Section 17 pit that lies north of Interstate Highway 90. As much as 25 percent of Celite's output at Quincy is shipped to Europe from the Port of Seattle via Cape Horn. This suggests that the two types of freshwater diatoms characteristic of the Frenchman Hills diatomite beds are ideally suited to certain filtration applications; otherwise, Celite could effectively supply European customers with material from one of its many other plants, including those in England, Spain, Greenland, or Mexico.

SILICA

Silica was produced by two companies during 1992. Lane Mountain Silica Co. mined 300,000 tons from their deposit on Lane Mountain (no. 208). They produced 230,000 tons of finished product at their plant site in Valley, WA. Reserve Silica Corp. of Ravensdale, WA (no. 255), mined 60,000 tons. Both Lane Mountain and Reserve sell a majority of their product to Ball-Incon Glass in Seattle for manufacturing packaging glass. Silica product demand from this primary market has been diminished by the wide availability of recycled glass. Important secondary markets for silica include golf course sand traps and as a component of portland cement products.

Ash Grove Cement Co., Western Region, was the third company processing silica last year. Ash Grove did not mine new material at its Superior quarry (no. 261) in 1992 but shipped approximately 70,000 tons from stockpiled inventory. Much of this material was used in-house by Ash Grove at their recently commissioned portland cement plant in Seattle.

OLIVINE

Olivine Corp. mined 85,000 tons of high-purity olivine from the Swen Larsen quarry (no. 234) in the world-class Twin Sisters dunite deposit southwest of Mount Baker. Much of the company's production is sold to AIMCOR as 1.25-inch-diameter crushed rock. AIMCOR processes the crushed olivine to manufacture a variety of refractory products, predominantly foundry sands, at their Hamilton, WA, plant (no. 235). Olivine Corp. uses a small percentage of production for in-house fabrication of waste burners. These are cylindrical incinerators in which the V-shaped hearth and the panels lining the burn chamber are made of olivine bonded in high-temperature cement. During 1992, Olivine Corp. sold and installed their first olivine burner in Chile (Fig. 14). A flourishing wood products industry in that country has opened a potentially large market for these burners, which are already in service at many sawmills for eliminat-

Figure 14. A newly constructed wood waste burner in Chile, the first of many that Olivine Corp. of Bellingham anticipates selling in South America. The burner runs continuously to eliminate sawmill waste from present and past production of extensive planted Radiata pine (Monterey pine hybrid) forests. The burner is made of refractory (heat resistant) olivine bonded in cement. The olivine is produced in the Cascade Range southwest of Mount Baker.

ing bark, sawdust, and chipper fines. Olivine Corp. anticipates sales of 50 more units in Chile alone and began marketing efforts in Peru and Mexico.

CLAY

Portland cement production and brickmaking were the two main uses for clays mined in Washington in 1992. Holnam, Inc., was the largest producer, having mined 90,000 tons at the Twin River quarry along the Strait of Juan de Fuca west of Port Angeles, WA (no. 239). Holnam barges the clay to its cement plant at Seattle. The access to the Twin River quarry is located between the mouths of two rivers and must be cleared frequently to control natural siltation at the approach to their dock. Concerns over the effects of turbidity from clearing by wheel washing (purging by jets from tugboat motors) upon the local fishery have resulted in a recommendation to implement clam-shell dredging. Attendant costs for the new dredging method may make the clay uneconomic to produce and ultimately shut down the quarry. The company has reduced its estimate of production in 1993 to 60,000 tons. This situation has resulted in technological investigations of alternative alumina sources to supplant the high-alumina, low-alkali clays of the Twin River Group. Materials that have proven successful as substitutes for clay (alumina) in the formulation of portland cement include fly ash and petroleum-contaminated soils. The cost of putting some of these waste products in landfills is so high that Holnam may establish positive cash flow by using these materials and thereby relieving the generators of the onerous "cradle to grave" financial liability.

Ash Grove Cement Co., Western Region, blended clay from two sources to supply their new portland cement plant in Seattle. Ash Grove re-opened a clay pit in Cowlitz County near Castle Rock (no. 271) (Popoff, 1955) that had been idle for many years (although extensively worked in the 1940s and 1950s by Gladding, McBean & Co. and Columbia Metals Corp.). These high alumina clays are blended with clay produced by the Pacific Coast Coal Co. at Black Diamond, WA (no. 256). Pacific Coast Coal produced 28,000 tons for Ash Grove and Holnam in 1992. The clay occurs in a 30-foot-thick silty clay zone in or above the Franklin #9 coal seam. (See also p. 31.) Mutual Materials Co. mined approximately 135,000 tons of clay or shale from four pits in western Washington for brickmaking (nos. 250, 254, 265, and 267). The company, headquartered in Bellevue, also operates the Mica mine and brickmaking plant at Mica, south of Spokane (no. 202). The last 12 months saw diminished demand, and only 30,000 tons were mined at the Mica pit. However, a stockpile pad and creek crossing were constructed on the Fruin deposit, 7 miles southeast of Mica, in anticipation of future production. Mutual Materials currently blends clays from the Mica pit with those from several pits in Idaho and makes more than 50 colors of bricks, some of which are one-time runs.

North of the Mica pit, Quarry Tile Co. excavated Vera Red clay and hauled Vera White clay from existing stockpiles at the Somers clay pit (no. 203). Quarry Tile makes a wide selection of ceramic flooring tiles at their facility in the Spokane Industrial Park.

In the Columbia Basin, Basic Resources Corp., of Ephrata, WA, continued to explore and evaluate the Rock Top (no. 226) and Coulee Chief (no. 225) clay deposits. These bentonitic beds between flows of the Columbia River Basalt Group are being developed for potential environmental applications at the Hanford nuclear reservation and elsewhere. Preliminary development work was under way in 1992, and some high-purity intervals of calcium-montmorillonite were identified.

GYPSITE AND PEAT

Agro Minerals, Inc., sold 2,500 tons of an earthy form of gypsum called gypsite. This material is excavated from the Poison Lake deposit west of Tonasket (no. 222) and is used as fertilizer.

Peat was produced by at least three companies in Washington in 1992. Because most peat-producing companies are small, it is likely that many more are active. However, no comprehensive list has been assembled by the USBM or DGER. Initial research indicates that along Hood Canal alone, peat producers are operating at Port Orchard, Belfair, and Poulsbo. These have not yet been recorded in the literature covering Washington.

BARITE

Lovejoy Mining of Chewelah shipped two truckloads of barite from the Eagle barite deposit (no. 210) to Missoula, MT, where it was ground for ceramic glaze.

Early in 1992, Mountain Minerals Northwest processed 25 tons of barite from Flagstaff Mountain in their mill on Sheep Creek. The mill was subsequently shut down, and the project is on hold, pending any turnaround in a depressed market for drilling mud.

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Coal Activity in Washington—1992

by Henry W. Schasse

Washington's coal activity for 1992 centered on its two operating coal mines, but also included the sale of coal reserves by the state's major coal-land owner and the abandonment of plans to build a coal-fired plant in Lincoln county. The combined production from both Washington coal mines reached 5,251,336 short tons, a record production high in the history of Washington coal mining.

Washington's largest coal mine, the Centralia Coal Mine, located 5 miles northeast of Centralia in Lewis County (Fig. 1) completed its 22nd year of production by surface mining 4,941,099 clean short tons of coal in 1992. The mine's annual production has averaged 4.9 million tons over the past 5 years and 4.2 million tons over its lifetime. The 1992 production surpassed that of 1991 by about 49,000 tons. The mine supplies coal to the Centralia Steam Plant, the mine's sole customer, located about a mile from the mine.

Coal mined at Centralia is subbituminous rank. During the past year, coal was mined from 11 coal beds representing six coal seams and splits of three of those seams. The coal was mined out of three pits. The coal comes from the middle of the Skookumchuck Formation, which is composed of nearshore marine and nonmarine sedimentary rocks. The Skookumchuck is a member of the Eocene Puget Group.

Figure 1. Active coal-producing areas and districts of western Washington.

The state's other coal mine, the John Henry No. 1 open-pit mine (Figs. 1 and 2), reached its highest production level of 310,237 short tons of bituminous coal since the mine opened in June 1986. This production surpasses its 1991 level by 58,778 short tons.

The John Henry No. 1, located 2 miles northeast of Black Diamond in King County, is operated by The Pacific Coast Coal Company (PCCC). In 1992, it exported to Japan and Korea 77 percent of the coal it sold. Exports were down 22 percent from 1991 due largely to increased competition from Australia in supplying coal to Pacific Rim countries. The mine supplied the industrial sector with 10.3 percent of its sales tonnage, and 12.6 percent of that tonnage went to the Centralia Steam Plant and a Tacoma public utility for use in electric power generation. The remaining 0.1 percent was supplied to public institutions and residential customers for space heating.

PCCC continued to mine from the Franklin Coal Series which includes the Franklin Nos. 7, 8, 9, 810, 11, and 12 coalbeds, which are stratigraphically near the base of the Eocene undivided Puget Group in nonmarine deltaic sedi-

Figure 2. John Henry No. 1 mine, Pit No. 1, January 1993. Coal from the Franklin Nos. 7, 8, and 9 coal seams where they have merged on the southeast limb of an anticlinal fold is being mined with a mass excavator. The thin, light-colored bands within these bituminous coal measures are volcanic ash beds. Coal is hauled by truck to a beneficiation plant located ⅓ mile from the pit. For other views of the anticline as it was exposed in the pit, see p. 31, vol. 17, no. 1 (photo taken August 1988); p. 27, vol. 19, no. 1 (November 1990); and p. 26, vol. 20, no. 1 (January 1992).

mentary rocks. Mining in Pit No. 1 has reached its designed depth of 250 to 300 feet. The company will begin the next stages of mining to the southwest by first mining the higher portions of an anticlinal structure (Fig. 2) while it begins to backfill the first stages of mining in the pit.

Burlington Resources, the state's largest coal-land owner, sold most of its western reserve coal holdings this past year to Great Northern Properties, a West Virginia Company limited partnership. Burlington had 4.7 million acres of coal holdings in Montana, North Dakota, and Washington State. The deal included $80 million and production royalties on future coal sales from currently unleased properties (*Western Coal*, 1992). Burlington Resources is divesting itself of nearly all its coal properties in an ongoing effort to sell or spin off its businesses not related to oil and gas. Spokesman for Burlington Resources, Don Pope, in an October 29, 1992, article in the *Tacoma News Tribune* (Hatch, 1992), reported that the company will retain oil and gas drilling rights to the land. Land in Washington State totaled 140,000 acres. None of those coal lands are being mined. The coal rights originally belonged to Burlington Northern Railroad (formerly Northern Pacific Railway), which created Burlington Resources in 1988.

In another coal-related issue this past year, Washington Water Power Co. announced that it has halted its plans to build a coal-fired electrical generating plant in Lincoln County. The project, first proposed 15 years ago, was designed to produce 2,000 megawatts of electricity. The location of the four-plant cluster was to be near Creston, about 45 miles west of Spokane. To meet regional energy needs, the utility plans to pursue less expensive alternatives, including energy efficiency programs, hydropower, and natural-gas-fired combustion turbines.

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Strong Motion System Installed in Natural Resources Building

by Timothy J. Walsh

In December 1991, the Seismic Safety Advisory Committee presented its report on earthquake preparedness to the Washington legislature. Although the bill to implement the committee's recommendations died in the senate, some of the recommendations can be implemented with existing authority. One of these is the recommendation to expand the strong motion instrumentation program in the Puget Sound area.

To this end, the Department of Natural Resources entered into an agreement with the U.S. Geological Survey to share the cost of installing strong motion accelerometers in the Natural Resources Building. Dennis Johnson, Mehmet Celebi, Marion Salzman, Leroy Foote, Ron Porcello, and Dick Maley of the U.S. Geological Survey participated in this work.

In November 1992, installation of all the instruments above the parking garage was completed. Those instruments in the parking garage will be deployed once conduit is installed. In all, twelve instruments will be emplaced from the third (lowest) level of the parking garage to the roof of the six-story building.

At present, records must be retrieved manually from the controller (Fig. 1), but eventually they will be retrievable by telemetry.

Figure 1. Leroy Foote of the U.S. Geological Survey tests the controller station for the strong-motion accelerometers in the Natural Resources Building.

Oil and Gas Exploration Activity in Washington, 1991 and 1992

FEL, from east line; FNL, from north line; FSL, from south line; FWL, from west line; P&A, plugged and abandoned; TD, total depth; all distances in feet

Company	Permit no.	Unique no.	Well name	Legal description	Ground elevation	Total depth (estimated)	Spud date	Date issued	Status
Carbon River Energy Partnership (coalbed methane)	414	053-00042	Carbon River #2-20	715′ FSL, 1232′ FEL, sec. 20, T18N, R6E, Pierce County	1918′	6,000′	01-02-87	12-03-86	P&A 11-09-89 TD 3,938′
Carbon River Energy Partnership (coalbed methane)	415	053-00043	Carbon River #3-29	382′ FNL, 420′ FEL, sec. 29, T18N, R6E, Pierce County	2054′	6,000′	01-17-87	12-03-86	P&A 11-09-89 TD 4,259′
Carbon River Energy Partnership (coalbed methane)	416	053-00044	Carbon River #5-20	1918′ FSL, 1662′ FEL, sec. 20, T18N, R6E, Pierce County	1918′	6,000′	02-02-87	12-03-86	P&A 11-09-89 TD 3,845′
Carbon River Energy Partnership (coalbed methane)	417	053-00045	Carbon River #4-29	823′ FEL, 1416′ FNL, sec. 29, T18N, R6E, Pierce County	2092′	(6,000′)		02-03-87	Cancelled
Carbon River Energy Partnership (coalbed methane)	418	053-00046	Carbon River #4-20	1778′ FNL, 1969′ FEL, sec. 20, T18N, R6E, Pierce County	1887′	6,000′	02-13-87	02-13-87	P&A 11-09-89 TD 4,147′
Shell Western E & P Inc.	419	071-00003	Darcell-Western #1	1740′ FSL, 1060′ FWL, sec. 10, T10N, R33E, Walla Walla County	868.3′	15,000′	08-24-87	06-08-87	P&A 01-01-88 TD 8,556′
American Hunter Exploration Ltd.	420	073-00095	American Hunter Birch Bay #1	2310′ FSL, 660′ FWL, sec. 32, T40N, R1E, Whatcom County	85′	7,000′	02-22-88	02-01-88	P&A 06-11-90 TD 9,126′
Twin River Oil & Gas Inc.	421	009-00052	Merrill & Ring Co. #25-1	975′ FNL, 111′ FEL, sec. 25, T31N, R10W, Clallam County	375′	3,500′	04-14-89	02-06-89	Preparing to P&A
Shell Western E & P Inc.	422	025-00014	Quincy #1	2532′ FNL, 1176′ FEL, sec. 22, T18N, R25E, Grant County (Federal Land)	1158′	15,000′	05-11-88	03-01-88	P&A 02-08-89 TD 13,200′
Meridian Oil Inc. (coalbed methane)	423	053-00047	Plum Creek #23-2	2050′ FSL, 1650′ FWL, sec. 2, T18N, R6E, Pierce County	1679′	4,000′	08-05-88	07-11-88	P&A 08-23-88 TD 4,600′
Meridian Oil Inc.	424	037-00009	23-35 BN	2000′ FWL, 1800′ FSL, sec. 35, T17N, R20E, Kittitas County	2840′	13,000′	12-16-88	10-28-88	P&A 05-04-89 TD 12,584′
Meridian Oil Inc.	425	041-00164	42-14 State	1750′ FNL, 650′ FEL, sec. 14, T13N, R6E, Lewis County	2950′	6,000′	07-25-89	06-26-89	P&A 09-12-89 TD 8,271′
Palo Petroleum Inc. and Texaco Exploration and Production Inc.	426	033-00044	Palo - Texaco Black Diamond #13-1	2668′ FNL, 2405′ FSL, NW¼, sec. 13, T21N, R6E, King County	975′	(3,500′)	06-04-92	06-10-90	P&A 12-18-92 TD 3,800′
Palo Petroleum Inc. and Texaco Exploration and Production Inc.	427	033-00045	Palo - Texaco Black Diamond #14-1	SW¼, sec. 14, T21N, R6E, King County	600′	(3,500′)		06-10-90	
Palo Petroleum Inc. and Texaco Exploration and Production Inc.	428	033-00046	Palo - Texaco Black Diamond #14-2	150′ FSL, 2512′ FWL, SW¼, sec. 14, T21N, R6E, King County	600′	(3,800′)	10-01-92	06-10-90	P&A 02-08-93
Palo/Eagle Joint Venture (PEJV)	429	053-00048	Palo/Eagle Joint Venture Carbonado #33-1	2000′ FSL, 1000′ FWL (approx), sec. 33, T19N, R6E, Pierce County	1125′	(2,500′)			Cancelled

Oil and Gas Exploration Activity in Washington, 1991 and 1992 *(Continued from preceding page.)*

Company	Permit no.	Unique no.	Well name	Legal description	Ground elevation	Total depth (estimated)	Spud date	Date issued	Status
Palo Petroleum Inc. and Texaco Exploration and Production Inc.	430	033-00047	Palo - Texaco Black Diamond #14-3	112′ FNL, 1281′ FEL, NE¼, sec. 14, T21N, R6E, King County	745′	(3,528′)	04-27-92	06-10-90	P&A 12-30-92 TD 3,528′
American Hunter Exploration Ltd.	431	073-00096	Terrell #1	1525.6′ FNL, 539.3′ FEL, NW¼, sec. 23, T39N, R1E, Whatcom County	250′	(6,000′)		05-31-91	P&A 11-09-91
American Hunter Exploration Ltd.	432	073-00097	Ferndale #1	644.4′ FSL, 2442′ FEL, NW¼, sec. 26, T39N, R2E, Whatcom County	90′	4,422′	11-14-91	07-09-91	P&A 11-29-91 TD 4422′
Para Magnetic Logging Inc.	433	033-00048	PML-Testwell	SE¼, sec. 3, T26, R5E, King County	217′	(300′)			Cancelled; drilled as "water well"
Palo Petroleum Inc. and Texaco Exploration and Production Inc.	434	053-00050	Palo - Texaco Wilkeson #27-2	1875.16′ FSL, 1527.40′ FEL, sec. 27, T19N, R6E, Pierce County	1,100′	(4,000′)		05-08-92	
Palo Petroleum Inc. and Texaco Exploration and Production Inc.	435	053-00049	Palo - Texaco Wilkeson #27-1	1,150′ FNL, 750′ FWL, sec. 27, T19N, R6E, Pierce County	1,200′	(1,411′)	06-27-92	05-08-92	Preparing to P&A
Palo Petroleum Inc. and Texaco Exploration and Production Inc.	436	053-00051	Palo - Texaco Wilkeson #21-1	500′ FSL, 100′ FEL, sec. 21, T19N, R6E, Pierce County	1,000′	(4,000′)		07-13-92	
Palo Petroleum Inc. and Texaco Exploration and Production Inc.	437	053-00052	Palo - Texaco Wilkeson #34-1	2113′ FSL, 1995′ FWL, sec. 34, T18N, R6E, Pierce County	1,350′	(3,118′)	07-22-92	06-30-92	P&A 02-10-93
Washington Natural Gas–Jackson Prairie Gas Storage	438	041-00165	Manke #1 Su #913	373′ FNL, 1105′ FWL sec. 21, T12N, R1W, Lewis County	375′	(3,500′)			Pending
Washington Natural Gas–Jackson Prairie Gas Storage	439	041-00166	R. Gunther #3 Su #910	2918′ FSL, 1099′ FEL, sec. 8, T12N, R1W, Lewis County	535′	(3,500′)			Pending
Washington Natural Gas–Jackson Prairie Gas Storage	440	041-00167	Longview Fibre #17; Su #912	201′ FEL, 736′ FSL, sec. 17, T12N, R1W, Lewis County	522′	(3,500′)			Pending
Washington Natural Gas–Jackson Prairie Gas Storage	441	041-00168	J. Alexander #1 Su #911	1158′ FSL, 1093′ FWL, sec. 9, T12N, R1W, Lewis County	530′	(3,500′)			Pending
Palo Petroleum Inc. and Texaco Exploration and Production Inc.	442	033-00049	Palo - Texaco Black Diamond #6-1	2300′ FSL, 400′ FWL,sec. 6, T21, R7E, King County	860′	(4,000′)		08-04-92	
Palo Petroleum Inc. and Texaco Exploration and Production Inc.	443	033-00050	Palo - Texaco Black Diamond #11-1	660′ FSL, 1605 FEL, sec. 11, T21N, R6E, King County	700′	(4,000′)		08-04-92	
Rival Resources Inc.	444	073-00098	Ferndale #2	1320′ FEL, 1320′ FSL, sec. 25, T39N, R2E, Whatcom County	100′	(1,850′)		11-19-92	

Fossil Mayflies from Republic, Washington

by

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Paleontologists continue to find "firsts" among the fossils at Republic. Collections made over the last 15 years have yielded the first representatives of the mayfly family Heptageniidae found in North America. These fossils are also the first Eocene mayflies to be recorded in North America since Scudder's finds of Ephemeridae (identification now questioned) more than century ago in the Eocene Green River Formation of Wyoming (Scudder, 1890). The four Washington specimens are impressions of three nymphs and a partial forewing. The fossils, from three sites in Republic (Fig. 1), were found in the lacustrine beds in the lower part of the Klondike Mountain Formation.

The order Ephemeroptera has a long history. It is known from the Carboniferous (Kulakova-Peck, 1985), the Permian (Hubbard and Kulakova-Peck, 1980), the Jurassic in Europe (Demoulin, 1970) and Asia (Sinitshenkova, 1985; Demoulin, 1954), lower Cretaceous rocks in the southern hemisphere (Grimaldi, 1990; McCafferty, 1990; Jell and Duncan, 1986), and in Eocene strata in Argentina (Rossi de Garcia, 1983), as well as in European amber (upper Eocene – Klyuge, 1986; Oligocene – Demoulin, 1974). The oldest mayfly in North America is a nymph in the Paleocene Paskapoo Formation of Alberta (Mitchell and Wighton, 1979, table 1). Mayflies have also been found in younger Tertiary deposits in North America: in the Oligocene beds in the Ruby River basin of southwestern Montana (Lewis, 1977a and b, 1989; Lewis and Swanson, 1992), and the upper Eocene or lower Oligocene Florissant beds of Colorado (Cockerell, 1923). They have also been recovered from numerous younger deposits on other continents.

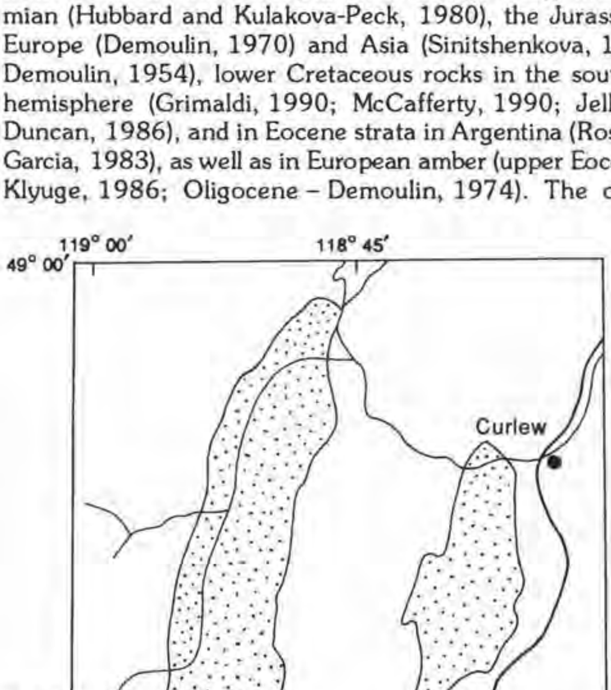

Figure 1. Location of Republic, Washington, and outcrops of middle Eocene lakebeds (modified from Wolfe and Wehr, 1987).

Today, there are about 190 genera and more than 2,000 species worldwide, and they are found on every landmass except Antarctica (Campbell, 1990). They inhabit both running water and ponds and lakes. More mayfly species live in warm or tropical areas than at high altitudes or in cold regions.

As the name of the order implies, winged mayflies live for a short time, about a day or long enough to mate in flight and lay eggs. Mature mayflies are normally found over water, usually in mating swarms. The swarms most often consist of males; females enter the swarm to locate a mate. Some species lay their eggs on the water surface, others lay eggs under water on logs, stones, or mud. The eggs of most mayflies hatch as nymphs within 10 to 20 days.

The pace of egg hatching is determined by water temperature. The aquatic nymphs may burrow into bottom sediments, attach themselves to rocks or logs, or cling to aquatic plants in fast-moving streams. Nymphs possess gills, and they molt several times (as many as 30 times in some species). Most nymphs mature in standing water as in a pond, but their survival depends on the water not drying up. The process of becoming an adult may take a year or more. The nymphs feed on algae, which are more abundant in warm waters, and other plant and animal microorganisms. Mayfly nymphs make up a large part of the freshwater fish diet.

Mayflies are unique in molting in their adult stage. After the mayfly nymph rises to the surface and molts, the winged form (subimago) flies a short distance to shore and lights on vegetation. These forms generally have dull colors and are covered with fine, short hairs. The next day the subimago molts to the last form, the imago. Imagoes are smooth and shiny, and they have a longer tail and longer legs than the subimago.

These mayfly fossils are significant for insect evolution, but they also may help us investigate the aquatic environment of the area at about 49 million years ago. We know from the flora that the climate at Republic was like that of the modern southern coastal area of Oregon (Wolfe and Wehr, 1991), with an annual mean temperature of about 10°C and an annual range of about 10°C. Since mayflies swarm and mate only in the warm months, the bed that contained the forewing must have been deposited at that time of year, probably summer. The nymph stages, however, could have been washed into the lake at other times.

A

B

C

D

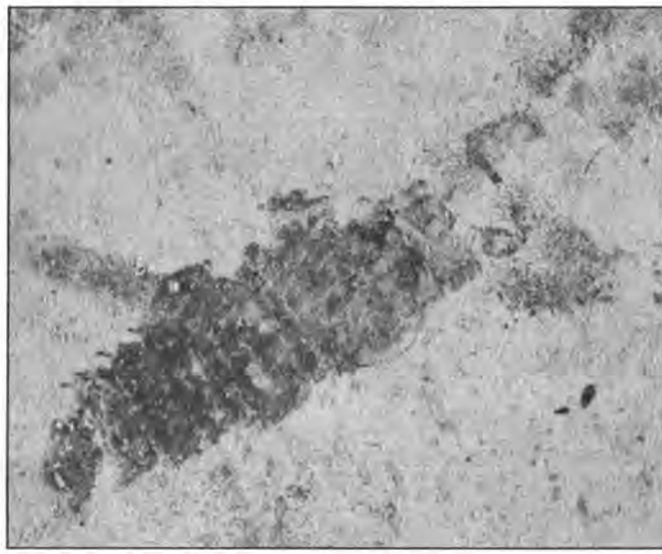

Figure 2. Eocene Ephemeroptera from Republic, WA. **A**, Nymph, Heptageniidae, genus ?Stenonema or ?Heptagenia; body length, 7 mm; filament length, 8 mm; Univ. of Wash. [W. C. Wehr, collector] UWBM 57158. **B**, Partial forewing 15 mm long; indeterminate taxon; Univ. of Wash. [W. C. Wehr, collector] UWBM 57198. **C**, Abdomen of nymph, undetermined genus, 11 mm long; Paleobiology Museum, St. Cloud State Univ. 4131 [S. E. Lewis, collector]. **D**, Nymph of undetermined genus, 13 mm long; Paleobiology Museum of St. Cloud State Univ. AO307-237A [S. E. Lewis, collector].

Some municipalities monitor mayfly populations as indicators of water quality because the sedentary burrowing nymphs cannot tolerate toxic materials or poorly oxygenated water (Fremling and Johnson, 1990). If we can assume Eocene mayflies of these taxa had similar tolerances, we can speculate about water chemistry where the nymphs were growing.

The four Republic specimens are illustrated in Figure 2. The remarkable preservation of these fragile insects underlines the importance of collections from the Klondike Mountain Formation as windows onto Eocene life.

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Note: Fossils are a nonrenewable resource. Searching for fossils in Republic is permitted Tuesday through Saturday, 10:00 A.M. to 5:00 P.M., after May 1. Please register with the Stonerose Interpretive Center (next to the city park) before digging, and be sure to bring your specimens to the center. If you find a particularly fine or new fossil form, the center will ask you to leave it with them to assist scientists with their on-going research. Please do not dig in areas other than those open to the public. ■

Geomedia Computer System by USGS Teaches Children about Earth Science

A multimedia, interactive computer system called GeoMedia, designed to teach children (grades 4 to 6) about complex earth science processes, has been developed by the U.S. Geological Survey.

"The USGS is distributing GeoMedia digital compact disks to teachers who are willing to experiment with this new technology in the classroom," said Denise Wiltshire, chief of the project and a technical information specialist at the USGS National Center in Reston, VA.

"GeoMedia CD-ROMs contain a mix of information on earthquakes, the hydrologic cycle, topographic maps, and other earth science subjects," Wiltshire said. "Unlike traditional text books on these subjects, GeoMedia is in an interactive computerized format that allows children to plot their own personal path through the scientific information.

"The GeoMedia digital compact disk contains a wealth of facts on earth science topics, which are linked together to promote learning at the individual pace of each reader," Wiltshire said.

"For example, students may chose to learn about the forces that create earthquakes by viewing an animated sequence of images. In addition to animation, GeoMedia includes an audible narration to explain scientific concepts. The written descriptions also provide students with the opportunity to review glossary terms for unfamiliar vocabulary words.

"GeoMedia opens the doors to communicating earth science to some children who may not respond to traditional teaching methods," Wiltshire added.

Payson Steven, president of InterNetwork, Inc., a design consulting firm that collaborated with the USGS on producing GeoMedia, said "Children are more apt to comprehend a concept by interacting with the information that sparks their curiosity. Browsing through the information is dynamic and also allows many levels of focus."

GeoMedia is one of several educational products available from the USGS as part of its program to help teachers inform pre-college students about how geology, hydrology, and other earth sciences affect them, their communities, the nation, and the world. Other recent products include a series of colorful posters on water resources and a booklet on helping children learn geography.

To obtain a copy of GeoMedia, write to: Project Chief, GeoMedia; U.S. Geological Survey; 801 National Center; Reston, VA 22092. The GeoMedia CD-ROM is available at no cost to teachers and libraries while the supply lasts. ■

RI 30 WINS AWARD

Report of Investigations 30, **Paleontology and stratigraphy of Eocene rocks at Pulali Point, Jefferson County, eastern Olympic Peninsula, Washington**, received an Award of Merit in the Technical Reports category of the 1992 Art, Online, and Publications Competition sponsored by the Puget Sound Chapter of the Society of Technical Communications.

VOLCANIC ASH WORKSHOP

April 26–28 Red Lion Sea-Tac (Seattle), WA

Chairman: Dr. Tom Casadevall,
USGS Volcano Hazards Program

For more information, contact: Bill Minter, Assistant Director; Center for Professional Programs; Embry-Riddle Aeronautical University; 600 S. Clyde Morris Blvd.; Daytona Beach, FL 32114-3900; Phone: 904/226-6187; Fax: 904/226-6220.

National Natural Landmarks Program in the Pacific Northwest Region

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The National Natural Landmarks Program was established in 1962 by Secretary of the Interior Stewart Udall under the authority of the Historic Sites, Buildings, and Antiquities Act of 1935. National Natural Landmarks (NNL) are nationally significant areas that have been so designated by the Secretary of the Interior. To be nationally significant, a site must be one of the best examples of a type of biotic community or geologic feature in its physiographic province. Examples include terrestrial and aquatic ecosystems, as well as features, exposures, and landforms that record active geologic processes and fossil evidence of biological evolution.

The goal of the NNL Program is to identify, recognize, and encourage protection of sites containing outstanding examples of geological and ecological components of the nation's landscape. The landmarks have been designated on both public and private land; the program is designed to obtain concurrence of the owner or administrator for the landmark's status.

Selection Criteria

The determination that a site is one of the best examples of a particular feature in a natural region or physiographic province is based primarily on how well it illustrates the feature and the condition of the specific feature; secondary criteria are its rarity, diversity, and values for science and education.

Studies of the 33 physiographic provinces of the United States and its territories have produced an inventory of potential sites for further evaluation. These sites have a variety of ecological and geological themes. Sites can be added to this inventory through an initial recommendation by outside groups or private citizens. Recommendations quite often come from state natural heritage program inventories or other groups, including The Nature Conservancy.

Designation Process

The National Park Service must receive prior approval from the landowner to conduct an on-site evaluation of areas that are highly ranked either in the theme studies or by outside recommendations. The National Park Service contracts with scientists to conduct on-site evaluations. The evaluations gather additional information and compare the site against other similar sites, guided by the national significance criteria.

Completed on-site evaluations are peer-reviewed by other scientists and then by the National Park Service. If a site is deemed to fulfill the requirements for NNL status, and if landowners have indicated their consent for designation, the Director of the National Park Service then nominates the site to the Secretary of the Interior for designation. During the designation process, the National Park Service solicits comments from landowners, from local, State, and Federal government officials, and from other interested groups and individuals. Once designated, the area is listed on the National Registry of Natural Landmarks.

The NNL Program recognizes and encourages voluntary, long-term commitment of public and private owners to protect an area's outstanding values. Owners who voluntarily agree to help protect their landmark property are eligible to receive a certificate and plaque for display at the site.

As of January 1993, 587 NNL sites have been designated. Thirty-four of these sites are in the Pacific Northwest Region: 11 in Idaho, 6 in Oregon, and 17 in Washington. Figure 1 shows the location of the Washington sites.

To date, 16 of the 587 sites originally designated as NNLs have been become part of the National Park system. The three landmarks in the Pacific Northwest Region are Cassia Silent City of Rocks (City of Rocks National Reserve) and Hagerman Fauna Sites (Hagerman Fossil Beds National Monument) in Idaho and Point of Arches (Olympic National Park) in Washington.

National Natural Landmark Moratorium

On November 28, 1989, the Director of the National Park Service placed a moratorium on the NNL Program, specifically postponing activities related to evaluation, nomination, and designation of new sites for NNL status. The purpose of the moratorium was to allow sufficient time to conduct a thorough review of the program, including regulations and procedures. Attention was also focused on ensuring adequate provisions for landowner notification, rights and consent. The moratorium is still in effect.

Status of the NNL Program

The Washington, D.C., office of the NNL Program has promulgated five initiatives as a result of recent audits:

(1) A proposed rule revising the regulations (36 CFR Part 62) for the NNL Program was published in November 1991. Provisions require landowner consent before conducting an evaluation of property as part of the landmark designation process. Publication of the final rule is pending; former President Bush placed a freeze on regulatory actions.

(2) A program handbook is being developed to ensure that applicable standards and quality-control procedures for all aspects of the landmark evaluation, nomination, designation, and monitoring process are complete.

(3) A contract to identify and corroborate the names and addresses of all private NNL landowners is nearing completion.

(4) A user-needs analysis of the Natural Landmarks System database was completed, and an update of the database will be completed by April 30, 1993.

(5) A management control system will be operational within 6 months after adoption of the NNL regulations.

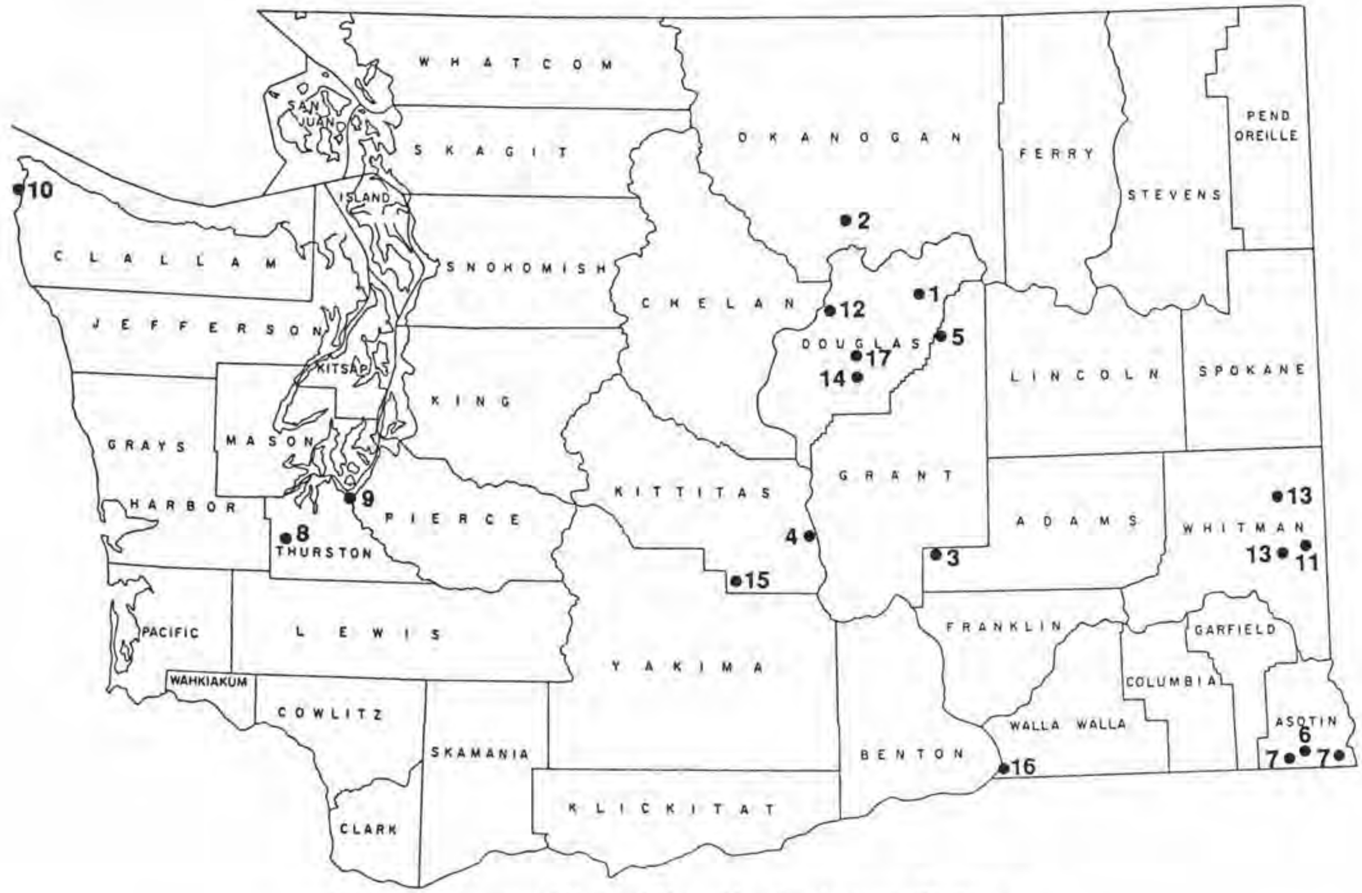

Figure 1. Location of National Natural Landmark sites in Washington.

Program Initiatives for 1993

The Pacific Northwest Regional NNL Program initiated a cooperative agreement with The Nature Conservancy and state natural heritage programs to refine ecological or geological theme studies and develop methodology for comparing and evaluating potential landmark sites throughout the region when the current program moratorium ends. The new study will specifically address potential NNL sites for two of the five remaining themes for the Columbia Plateau Natural Region: Douglas fir forests, and riparian woodlands.

Washington Landmark Sites

Locations of sites described below are shown on Figure 1; numbers in the list are keyed to these locations on the map.

(1) **Boulder Park and McNeil Canyon Haystack Rocks**—These two adjacent sites contain the greatest concentration and best examples of glacial erratics on the Columbia Plateau, possibly in the entire United States. The boulders provide important evidence for glacial erosion and transport, as well as the direction of movement and distribution of glaciers on the Columbia Plateau during the last glaciation.

(2) **Davis Canyon**—The site is one of the least disturbed and most extensive examples of antelope bitterbrush (*Purshia tridentata*)/Idaho fescue (*Festuca idahoensis*) shrub steppe remaining on the Columbia Plateau.

(3) **Drumheller Channels**—The site is a spectacular tract of butte-and-basin scabland and provides excellent geomorphic evidence for late Pleistocene catastrophic floods on the Columbia Plateau.

(4) **Ginkgo Petrified Forest**—Two features make this petrified forest distinctive: the large number of genera and species represented, and the unusual preservation of fossils in lava flows.

(5) **Grand Coulee**—Grand Coulee is the largest coulee in the Columbia Plateau and is probably the world's finest example of a recessional cataract gorge.

(6) **Grande Ronde Feeder Dikes**—The feeder dikes are known at only a few places. The best exposures are in this area along the north side of the Grande Ronde River. The dikes fed the voluminous Miocene lava flows of the Columbia Plateau of southeastern Washington and northeastern Oregon.

(7) **Grande Ronde Goosenecks**—The lower course of the Grande Ronde River has many excellent examples of entrenched meanders or goosenecks. These features record regional uplift and forced entrenchment of a stream in its pre-uplift meandering pattern. Two localities along the Grande Ronde make up the landmark.

(8) **Mima Mounds**—This landmark contains superb examples of mound topography in the North Pacific Border natural region.

(9) **Nisqually Delta**—The delta supports one of the five best known examples of the Washington–Oregon Salt Marsh Subtheme of the Temperate Coastal Salt Marsh Theme in the North Pacific Border Region. It is a major resting area for migratory waterfowl in the southern Puget Sound region.

(10) **Point of Arches**—The landmark contains spectacular examples of the results of shoreline erosion (Fig. 2). It also has a nearly pristine environmental spectrum ranging from rocky tideland to climax upland vegetation.

(11) **Rose Creek Preserve**—The preserve constitutes the best remaining example of the aspen (*Populus tremuloides*) phase of the hawthorn (*Crataegus douglasii*)/ cow parsnip (*Heracleum lanatum*) habitat type.

(12) **Sims Corner Eskers and Kames**—This site contains the best examples of Pleistocene ice stagnation landforms in the Columbia Plateau and western United States. Although the Great Lakes region and New England contain similar features, those at Sims Corner are well preserved thanks to the arid climate.

(13) **Steptoe and Kamiak Buttes**—Steptoe Butte is the type example of a steptoe, an isolated hill or mountain surrounded by lava flows. Kamiak Butte is an excellent place from which to view the Palouse country and loess.

(14) **The Great Gravel Bar of Moses Coulee**—This is perhaps the largest example of bars created by outburst floods on the channeled scabland. The bars are well preserved and have only sparse vegetative cover.

(15) **Umtanum Ridge Water Gap**—Water gaps have been cut through several anticlinal ridges between Ellensburg and Yakima by the antecedent Yakima River. State Route 821 passes through the gap, where folded rocks illustrate results of tectonic stress and stream cutting.

(16) **Wallula Gap**—Glacial-outburst waters that crossed the Channeled Scablands during the Spokane floods were channeled through Wallula Gap. For several weeks, as much as 200 mi^3 of water per day were delivered to a gap that could discharge less than 40 mi^3 per day. Ponded water filled the Pasco Basin and the Yakima and Touchet valleys to form temporary Lake Lewis.

(17) **Withrow Moraine and Jameson Lake Drumlin Field**—Withrow Moraine is the only Ice Age terminal moraine in the Columbia Plateau natural region. The drumlin field is the best example of those features within the natural region. Together they provide dramatic evidence of depositional and erosional processes that accompany continental glaciation. ■

Figure 2. Point of Arches, between Cape Flattery and Cape Alava on the west shore of the Olympic Peninsula, is part of the Olympic National Park. The sea stacks are more resistant to erosion than the rocks that surround them. Photo courtesy of S. T. Gibbons.

Proposed Seismic Zone Changes in Western Washington *(Continued from p. 2.)*

(Zone 3 requires a 50 percent increase over zone 2B in the assignment of the base shear, or the resistance to lateral forces, to be used in building design, as well as some additional requirements for ductility.)

The Oregon Seismic Safety Advisory Policy Commission recommended that western Oregon also be upgraded from zone 2B to 3.

In July of 1992, the Washington Department of Natural Resources, the Structural Engineers Association of Washington, the Structural Engineers Association of Oregon, and the Oregon Department of Geology and Mineral Industries submitted a request to implement the recommendations to the International Conference of Building Officials (ICBO), the governing body for the UBC. This code change and all the other code changes that were referred to ICBO's Lateral Design Code Development Committee were published in *Building Standards* in November/December 1992. On February 4, 1993, the Committee unanimously approved the proposed code change and referred it to the full membership of ICBO for approval at their annual meeting in September. Any challenges to proposed changes must be filed with ICBO before June 1, 1993.

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Tacoma Smelter Stack Demolished

by Raymond Lasmanis

On January 17, 1993, the Tacoma Smelter stack (Fig. 1), a landmark on Commencement Bay since 1917, was demolished by explosives into a pile of 2.5 million bricks. The Tacoma Smelter had a history pre-dating statehood.

The initial smelter was built on the Swansea site in the 1880s by Tacoma Smelting and Refining Company and was the largest in the state at that time. Mr. W. N. Rust was the general manager, and Swansea was later renamed Ruston in his honor. The first smelter had a capacity of 240 tons of ore per day and had a brick stack 80 ft high. In 1890, the smelter was operated by 60 men, with a total monthly payroll of $5,500.

Other smelters in the state at the turn of the century were the Everett Smelter, operated by the Puget Sound Reduction Company; the Northport Smelter operated by Northport Smelting and Refining Company, Ltd.; the Colville Smelter, operated by the Mutual Smelting and Mining Company of Washington, which initiated operations in 1887; and the Spokane Smelter, operated by the North Pacific Reduction Company.

With its advantageous position with respect to water transportation, the Tacoma Smelter continued to expand itsoperation. By 1901, capacity had been increased to 400 tons of ore per day.

In May of 1902, a copper blast furnace was added. Ore was processed at the rate of 1,500 tons per day, and the refinery was producing 180 million pounds of copper per year. Ores and concentrates from Washington, Oregon, Montana, Alaska, and the Coeur d'Alene mining district in Idaho, as well as Mexico, Central America, Chile, Peru, Korea, Japan, and the Phillipines, were being processed.

Figure 1. The Tacoma Smelter stack as it appeared in November of 1992.

In 1917, to meet the demands of World War I and a rapidly industrializing nation, the origial smelter facilities were rebuilt, including the construction of the landmark stack to a height of 572 ft 10 in.

Even by 1921, the stack was still promoted as being the tallest in the world.

Over time, Washington state smelters closed one by one. The Tacoma Smelter, operated by ASARCO, was the last to meet this fate. Despite $100 million in capital improvements spent by ASARCO since 1968 to comply with environmental regulations, the only U.S. tidewater smelter was forced to close permanently in March of 1985.

The demolition of the Tacoma Smelter stack wrote the final chapter for the base metal smelting industry in Washington State.

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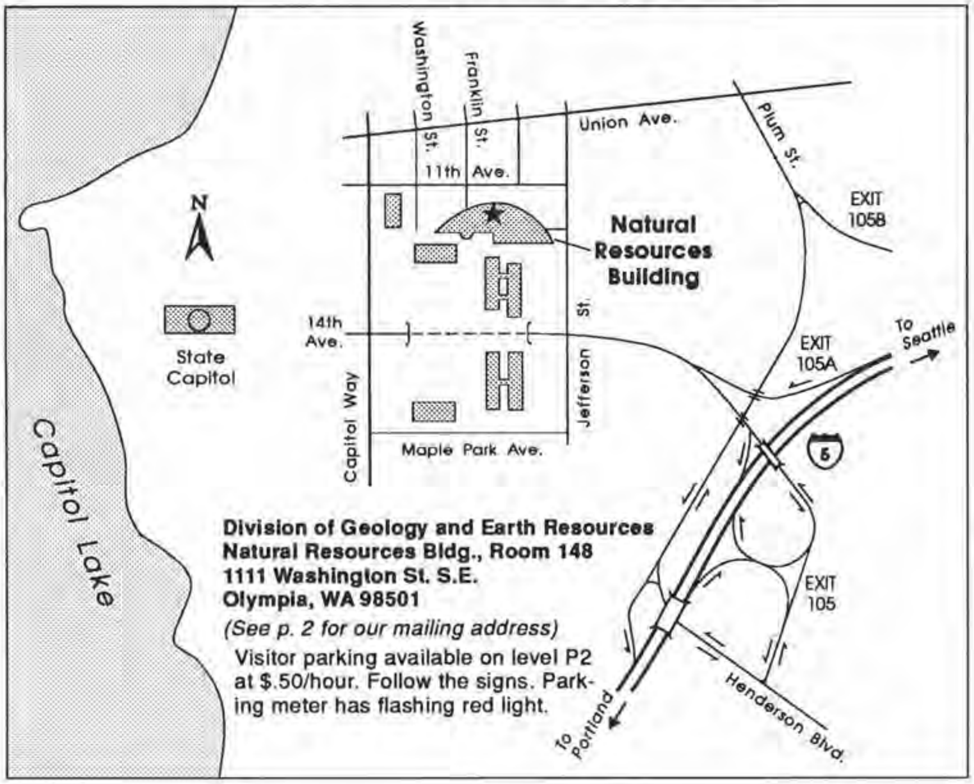

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NORTHWEST GEOLOGICAL SOCIETY

For professionals, students, and other interested persons, the society provides a forum for the presentation and discussion of geologic topics, emphasizing those of the Pacific Northwest or of fundamental scientific interest. Meetings are the second Tuesday of the month, October to May, at University Plaza Hotel, NE 45th St., in Seattle. A no-host bar and dinner are followed by a speaker and discussion. Anyone may attend the meetings.

Speakers for upcoming coming monthly meetings are:

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Field trips (members only): June and September. 1993 membership dues $20/yr (professional); $5/yr (student). Address inquiries to Donn Charnley; 19344 11th Ave. NW; Seattle, WA 98177.

Division Publications

New Release

Geologic and geophysical mapping of Washington, 1984 through 1992, and, Theses on the geology of Washington, 1986 through 1992, Open File Report 93-1, compiled by Connie J. Manson. The report consists of 37 pages (including 8 plates). *This report supersedes the previous version, Open File Report 92-1.* The price is $4.63 + .37 tax (for Washington residents only) = $5.00.

Out of Print

Handbook for Gold Prospectors in Washington, Information Circular 57, is close to being out of print. There are fewer than 100 copies remaining. We do expect to reprint later this spring, but if you definitely need a copy this summer, we suggest you order now. The price of this popular 90-page book is $1.85 + .15 tax (for Washington residents only) = $2.00.

Antimony occurences of Washington, Bulletin 39, is out of print.

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