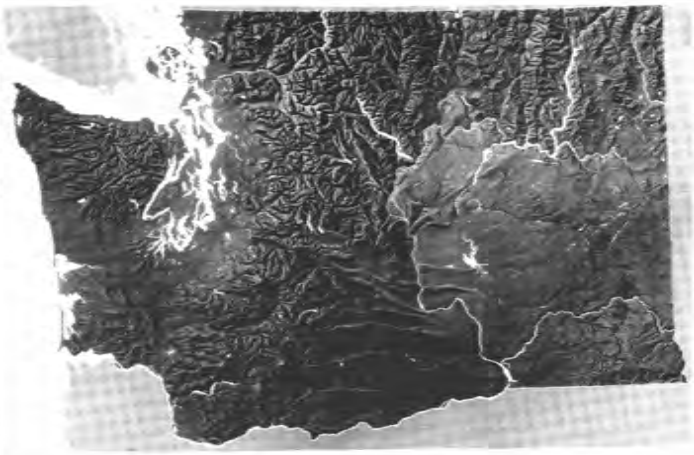

WASHINGTON GEOLOGIC NEWSLETTER

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Division of Geology and Earth Resources

Radio-controlled scoop loading gold-silver ore into truck, underground at the Cannon mine. (Photo courtesy of Asamera Minerals, Inc.)

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WASHINGTON GEOLOGIC NEWSLETTER

The Washington Geologic Newsletter is published quarterly by the Division of Geology and Earth Resources, Department of Natural Resources. The newsletter is free upon request. The Division also publishes bulletins, information circulars, reports of investigations, and geologic maps. A list of these publications will be sent upon request.

DEPARTMENT OF NATURAL RESOURCES
Brian J. Boyle
Commissioner of Public Lands
Art Stearns
Supervisor

DIVISION OF GEOLOGY AND EARTH RESOURCES
Raymond Lasmanis
State Geologist
J. Eric Schuster
Asst. State Geologist

Geologists (Olympia) Brent Barnett, Matthew J. Brunengo, Michael A. Korosec, William S. Lingley, Jr., Robert L. (Josh) Logan, Stephen P. Palmer, William M. Phillips, Weldon W. Rau, Katherine M. Reed, Henry W. Schasse, Timothy J. Walsh

Geologists (Spokane) Nancy L. Joseph, Stephanie Z. Waggoner, Keith L. Stoffel

Librarian Connie J. Manson

Library Technician Gwen F. Crain

Research Technician Arnold Bowman

Editor Katherine M. Reed

Cartographers Nancy E. Herman, Keith G. Ikerd

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Administrative Assistant Susan P. Davis

Clerical Staff Joy Fleenor, Naomi Hall, Jim Leighton

Regulatory Clerical Staff Barbara A. Preston

National Geologic Hazards Program Update

By Raymond Lasmanis and Timothy Walsh

During November 1988, the authors of this article attended two meetings sponsored by the U.S. Geological Survey (USGS) and other agencies to review national and regional federally supported programs aimed at reducing losses from geologic hazards. Lasmanis participated in the workshop on "Applications of Knowledge Produced in the National Earthquake Hazards Reduction Program: 1977-1987." Walsh attended the "Geohazards '88" symposium.

A panel format was used to review the first decade (1977-1987) of the National Earthquake Hazards Reduction Program (NEHRP). The sponsors were the USGS, the Federal Emergency Management Agency (FEMA), the National Institute of Standards and Technology (NIST, formerly the National Bureau of Standards), and the National Science Foundation (NSF).

A draft report augmented with presentations by noted authorities formed the core of the workshop. The following topics were discussed by the panels:

- Update on research application activity throughout the nation
- Overview of "Interpretative Report on Applications of Knowledge: 1977-1987"
- The future of research applications in the NEHRP: 1987-1997
- Policies and practices of the four principal agencies in NEHRP
- Improving the collaboration of knowledge producers and knowledge users
- Background on earthquake insurance
- Strengthening weak links in the research applications process of NEHRP
- Priorities, given a level budget

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MAILING ADDRESSES

Main Office:
Department of Natural Resources
Division of Geology and Earth Resources
Mail Stop PY-12
Olympia, WA 98504
Phone: (206) 459-6372

Field Office:
Department of Natural Resources
Division of Geology and Earth Resources
Spokane County Agricultural Center
N. 222 Havana
Spokane, WA 99202
Phone: (509) 456-3255

NOTE: Publications available from Olympia address only.

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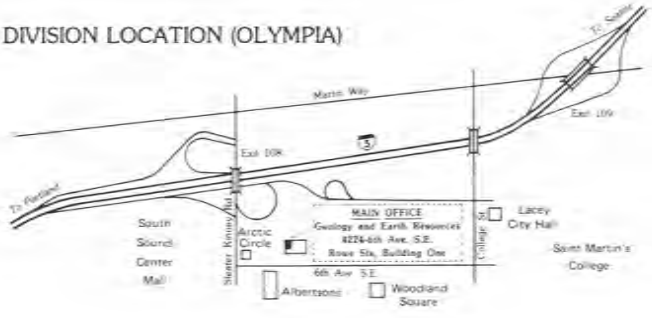

WASHINGTON'S MINERAL INDUSTRY – 1988

By Nancy L. Joseph

INTRODUCTION

According to information obtained by the Division of Geology and Earth Resources, three precious metal and one base metal mine were in operation in Washington in 1988. Seventeen companies mined and produced industrial minerals, which included limestone, dolomite, silica, olivine, clay, and diatomite (Table 1). Two companies produced portland cement, and 10 plants produced lime, calcium chloride, precipitated calcium carbonate, or ground limestone.

Preliminary information indicates that nonfuel mineral production in Washington in 1988 was valued at more than $400 million. The production of magnesium metal from dolomite, precious metal mining, and sand and gravel quarrying accounted for the bulk of this figure. The production of portland cement decreased significantly in 1988 due in part to the closure of the Columbia Northwest Cement Corp. plant in Whatcom County.

Precious metals, which now account for one-quarter of the total value of mineral production, are becoming increasingly important to Washington's mineral industry. The high levels of production from the Cannon mine and the Republic Unit, coupled with projected production at two new mines in 1990 and the increased precious metal exploration in the State should lead to significant increases in precious metal production in the future.

Total revenue from prospecting, mining, and quarrying, including sand and gravel production, on state lands was $399,695 for the fiscal year ending June 30, 1988. This figure includes payments on approximately 300 mineral leases and contracts. Revenues from prospecting increased, while revenues from sand and gravel operations decreased approximately 16 percent. (The sand and gravel industry is not discussed in this article.)

Information in this report is summarized from voluntary replies to a questionnaire sent by the Division to companies and individuals active in mineral exploration and development in the state, as well as from published information. The questionnaire is limited in scope, and, therefore, details of activities on individual properties are not always available. Not all questionnaires were returned, and some information requested, particularly regarding expenditures and production, is deemed confidential by many of those questioned and is not reported. Therefore, while this summary is a reliable indication of the mineral activity in Washington, it is incomplete and general in nature.

The locations of properties mentioned in this article are shown in Figures 1a and 1b, which cover western and eastern Washington, respectively.

METALS

Development

Gold and silver, with a combined value of more than $99 million, were the primary metals produced from the three active precious metal mines in Washington in 1988. Record amounts of more than 225,000 ounces of gold and more than 540,000 ounces of silver were produced from mines in Chelan County and Ferry County (Fig. 2, Table 2). This represents a modest increase in gold production and approximately 50 percent increase in silver production over the 1987 figures.

Lead and zinc were mined at one mine in Stevens County. This low-tonnage operation was the sole base metal producer reporting to the Division in 1988.

Chelan County

The Cannon mine, a joint venture between Asamera Minerals (U.S.) Inc. and Breakwater Resources Ltd., is the largest gold mine in the state and the second largest underground gold mine in the country. A record of 145,695 ounces of gold and approximately 250,000 ounces of silver with an average gold grade of 0.31 oz/ton was produced from the mine in 1988. The increase in gold production over the 1987 record was attributed to increased head grades and higher productivity.

Asamera Inc., which owned 92 percent of the stock in Asamera Minerals Inc., was bought out by Gulf Canada Resources Ltd. in April 1988. The new owners of the company, who reportedly acquired Asamera to obtain their overseas oil properties, have decided to put their interest in Asamera Minerals up for sale (Northern Miner, December 19, 1988).

Reserves at the Cannon mine at the end of 1987 were 4.5 million tons grading 0.260 oz/ton gold (Breakwater Resources Ltd., annual report, 1987). Underground exploration, drilling, and development continue at the mine. Drilling has delineated an ad-

Figure 1a. Location of selected mines (metallic and industrial minerals) and prospects in western Washington. Location numbers are keyed to Table 1.

Figure 1b. Location of selected mines (metallic and industrial minerals) and prospects in eastern Washington. Location numbers are keyed to Table 1.

Table 1. Mineral exploration and development in Washington, 1988. Locations given where available. See Figures 1a and 1b for property locations.

Loc. no.	County	Owner/Operator	Property	Location	Commodity	Remarks
1	Chelan	Althouse Placers, Inc.		Wenatchee Heights	Au,Ag	Leased property to Asamera Minerals
2	Chelan	Asamera Minerals (U.S.) Inc.- Exploration/ Breakwater Resources Ltd.	Wenatchee Gold	Wenatchee Heights	Au,Ag	Surface drilling
3	Chelan	Asamera Minerals (U.S.) Inc./ Breakwater Resources Ltd.	Cannon mine	sec. 16 T.22N., R.20E.	Au,Ag	Mining, surface and underground exploration and drilling
4	Chelan	Montana de Oro, Inc.	Blewett	secs.1-3 T.22N., R.17E.	Au	Mine development
5	Chelan	Raven Hill Mining	Raven group	sec. 21 T.21N., R.18E.	Au,Ag	Geologic exploration, bulk sampling
6	Chelan	Sunshine Valley Minerals, Inc.	Howe-Sound tailings	secs. 7-8 T.31N., R.17E.	Au	Exploration, processing tailings
7	Chelan	Welcome Nugget Mines	Payday group	upper Wenatchee River	Au,Ag	Dredging
8	Chelan	Welcome Nugget Mines	Welcome Nugget placer	sec. 30 T.26N., R.18E.	Au,Ag	Dug test pits
9	Clallam	Ideal Basic Industries, Inc.	Twin River quarry	secs. 22-23 T.31N., R.10W.	clay	Mining
10	Ferry	Asarco Inc.	Curlew	sec. 10 T.39N., R.33E.	Au,Ag	Drilling, geological, geochemical exploration
11	Ferry	Chemgold, Inc.	South Penn	secs. 27-28 T.37N., R.32E.	Au,Ag	Reclaiming heap-leach site
	Ferry	Crown Resource Corp./Sutton Resources Ltd./ Texas Star Resources Corp.	South Penn	secs. 27-28 T.37N., R.32E.	Au,Ag	Drilling
12	Ferry	Crown Resource Corp./Gold Texas Resources Ltd.	Queen Elizabeth	T.38N., R.33E.	Au,Ag	Drilling; geologic mapping
13	Ferry	Crown Resource Corp./Sutton Resources Ltd./Texas Star Resources Corp.	Seattle mine	secs. 33-34 T.37N., R.32E.	Au,Ag	Exploration drifting, surface drilling

Table 1. Mineral exploration and development in Washington, 1988, continued.

Loc. no.	County	Owner/Operator	Property	Location	Commodity	Remarks
14	Ferry	Cyprus Minerals Co.	Lone Ranch Creek/LDG claims	secs. 11-12, 18-19, 30 T.40N., R.35E.	Au,Ag	Exploration, claim staking
15	Ferry	N. A. Degerstrom, Inc./Inland Gold and Silver Corp./ Pegasus Gold Corp.	Leland Property	T.37-38N., R.33E.	Au,Ag	Exploration, drilling
16	Ferry	Echo Bay Mines Ltd./Crown Resource Corp./ Gold Texas Resources Ltd.	Kettle	sec. 15 T.39N., R.33E.	Au	Drifting, underground drilling; announced production plans
17	Ferry	Echo Bay Mines Ltd./Crown Resource Corp. /Gold Texas Resources Ltd.	Overlook, Key	sec. 18 T.37N., R.34E.	Au,Ag	Drilling, EIS completed; announced plans to put into production
18	Ferry	Hecla Mining Co.	Republic Unit, Golden Promise, Golden Eagle area	T.37N., R.32E.	Au,Ag	Mining,surface and underground drilling
19	Ferry	Johnson Explosives	Irish claim group	sec. 15 T.40N., R.34E.	Au	Exploration
20	Ferry	Morning Star Mines, Inc.	Morning Star mine	sec. 16 T.40N., R.34E.	Au	Rehabilitation of mine
21	Ferry	Newmont Exploration Ltd.	NHC claims	secs. 29-30, T.36N., R.33N.; west of Curlew	metals	Exploration, claim staking
22	Ferry	Tanqueray Resources Ltd./High Country Mining and Exploration	Valley mine	sec. 6 T.37N., R.33E.	Au,Ag	Surface drilling, underground development and sampling
23	Ferry	United States Borax & Chemical Corp.	Lone Star	sec. 2 T.40N., R.33E.	Au,Cu	Surface core drilling
24	Ferry	United States Borax & Chemical Corp.	Wheaton Ranch	T.39N., R.32E.	Au,Au	Drilled two core holes
25	Ferry	United States Borax & Chemical Corp./ Kettle River Resources Ltd.	Empire Creek	sec. 6 T.38N., R.33E.	Au	Optioned property

Table 1. Mineral exploration and development in Washington, 1988, continued.

Loc. no.	County	Owner/Operator	Property	Location	Commodity	Remarks
26	Ferry	United States Borax & Chemical Corp./ Vulcan Mountain, Inc./ Sundance Mining and Development Corp.	Gold Dike/Gold Hill	secs. 7-8 T.40N., R.34E.	Au,Ag,Cu	Drilling
27	Ferry	Vulcan Mountain, Inc.	Gold Dike mine	secs. 7-8, 17-18 T.40N., R.34E.	Au,Ag,Cu	Working heap leach; property optioned to U.S. Borax
	Ferry	Antilles Resources Ltd.		Republic district	Au	Geological exploration
	Ferry	Boise Cascade		Company lands		Exploration
	Ferry	Union Pacific Resources Co.			U	Reconnaissance
28	Grant	Basic Resources Corp.	Rock Top	sec. 20 T.22N., R.26E.	clay	Geological mapping, drilling
29	Grant	Witco Corp.	Sec. 17 pit	sec. 17 T.18N., R.23E.	diatomite	Hauling from stockpile
30	Grant	Witco Corp.	Sec. 7 and 8 pits	secs. 7,8 T.17N., R.24E.	diatomite	Mining
	Grant	Meridian			diatomite	Exploration
31	King	Ash Grove Cement West, Inc.	Superior quarry	sec. 1 T.19N., R.7E.	silica	Mining and screening
32	King	Cannon Minerals	El Watusi	sec. 28 T.23N., R.9E.	Au,Ag	Sampling on vein
33	King	Cannon Minerals	White River	sec. 6 T.19E., R.8E.	Au	Geologic and geochemical exploration
34	King	L-Bar Products, Inc.	Ravensdale pit	sec. 1, T.21N., R.6E.	silica	Mining and processing
35	King	Mutual Materials Co.	Elk pit	sec. 34 T.22N., R.7E.	clay	Mining
36	King	Mutual Materials Co.	Sec. 31 pit	sec. 31 T.24N., R.6E.	clay	Mining
37	King	North American Refractories Co.	Harris/Blum	sec. 32 T.24N., R.6-7E.	clay	Hauled from stockpile
38	King	Weyerhaeuser Co.	White River		Au	Exploration, drilling

Table 1. Mineral exploration and development in Washington, 1988, continued.

Loc. no.	County	Owner/Operator	Property	Location	Commodity	Remarks
39	Lincoln	Blue Silver Mining	Crystal City mine	sec. 21 T.28N., R.36E.	dolomite	Mining
40	Okanogan	L.F. Baum and Assocs.	Turtle Lake	secs. 9-10 T.36N., R.26E.	Au,Ag	Exploration, drilling
41	Okanogan	Columbia River Carbonates	Wauconda quarry	sec. 13 T.38N., R.30E.	limestone	Mining, milling
42	Okanogan	CM Silver Mines, Inc./Ciment Quebec Inc.	Reed Limestone	sec. 35 T.39N., R.26E.	limestone	Proposed building portland cement plant
43	Okanogan	Crown Resource Corp./Gold Texas Resources Ltd.	Buckhorn	T.40N., R.31N.	Au	Drilling, exploration
44	Okanogan	Crown Resource Corp./Gold Texas Resources Ltd./ Sundance Mining and Development Corp.	Ida mine	sec. 21 T.39N., R.31E.	Au,Ag	Drilled 5 reverse circulation holes
45	Okanogan	Dalton Excavating	Roxy	sec. 25 T.39N., R.25E.	Au	Drilling
46	Okanogan	ECM Inc.	Alder mine	secs. 23-26, 35-36 T.33N., R.21E.	Au	Exploration
47	Okanogan	Kerr-McGee Corp.		T.40N., R.29-30E.	Au,Ag	Dropped property
48	Okanogan	Newhawk Gold Mines Ltd. Reliant Resources, Ltd./Nord Resources Corp.	Smith Canyon	T.32N., R.21E.	Au,Ag	Trenching and drilling
49	Okanogan	OWC Inc.		secs. 26, 36 T.30N., R.22E.	Au,Ag	Claim staking
50	Okanogan	Pacific Calcium, Inc.	Tonasket Limestone quarry	sec. 26 T.26N., R.35E.	limestone	Mining and milling
51	Okanogan	Quintana Minerals Corp.	American Flag	Mazama	Au	Exploration
52	Okanogan	Say Energy Inc.	Waseco Resources	secs. 9-15 T.30N., R.22E.	Au,Ag	Exploration, drilling
53	Okanogan	Westmont Mining Inc./Crown Resource Corp.	Bodie	sec. 34 T.39N., R.31E.	Au,Ag	Geologic mapping, sampling, drilling
54	Okanogan	Sunshine Valley Minerals, Inc.	Billy Goat claims	sec. 15 T.40N., R.25E.	Au,Cu	Road work, mine development

Table 1. Mineral exploration and development in Washington, 1988, continued.

Loc. no.	County	Owner/Operator	Property	Location	Commodity	Remarks
	Okanogan	Orvana Resources Corp.				
55	Pend Oreille	Lehigh Portland Cement Co.	Champane Placer	sec. 27 T.39N., R.43E.	limestone	Mining
56	Pend Oreille	RFC Resource Finance Corp./ Pintlar Corp.	Pend Oreille mine	sec. 15 T.39N., R.43E.	zinc	Optioned property; drilling
57	Pend Oreille	Raven Hill Mining	Peacock claims	sec. 2 T.31 N., R.45E	Au,Ag	Exploration and mine development
58	Pend Oreille	United Catalyst Inc./First Miss Gold Inc.	Totem Talc	sec. 23 T.39N., R.44E.	talc	Drilling, bulk sampling
59	Skagit	Applied Industrial Materials Corp.	AIMCOR Olivine	secs. 3-4, 8-9, 16-17 T.36N., R.7E.	olivine	Milling, reclamation
	Snohomish	Island Arc Exploration		Sultan basin	Au,Ag	Exploration
	Snohomish	Jeannie Ring		Sultan basin	Au,Ag	Exploration
60	Spokane	Interpace Industries Inc.	Mica mine, plant, and Pottratz Pit	sec. 14 T.24N., R.44E.	clay	Mining
	Spokane	Union Pacific Resources Co.			U	Reconnaissance
61	Stevens	A. Ambrose	Ambrose Mining	sec. 16 T.40N., R.39E.	Au	Dredging
62	Stevens	Blue Silver Mining	H and B mine	sec. 15 T.29N., R.37E.	Au,Ag	Mining
63	Stevens	Boise Cascade Corp.	Fifteenmile Creek	sec. 19 T.39N., R.38E.	Au	Exploration
64	Stevens	Chewelah Eagle Mining Co.	Chewelah Eagle group	sec. 5 T.32N., R.41E.	Ag	Drilling, road building
65	Stevens	Clemets/Powers/ Duval	Partner/Double Eagle group	T.40N., R.37E.	Au	Geological exploration, drilling
66	Stevens	Cortez International Ltd.	Turk mine area/Deer Trail mine	sec. 1 T.29N., R.37E.	Ag, magnesite	Auctioned assets of Deer Trail mine
67	Stevens	Lane Mountain Silica Co.(subsidiary of Hemphill Brothers, Inc.)	Lane Mountain Silica	sec. 27 T.31N., R.39E.	silica	Mining

Table 1. Mineral exploration and development in Washington, 1988, continued.

Loc. no.	County	Owner/Operator	Property	Location	Commodity	Remarks
68	Stevens	Leadpoint Consolidated Mines Co.	Leadpoint Consolidated properties	secs. 12-13 T.39N., R.41E. secs. 7-8, 17-18 T.39N., R.42E.	Ag, Pb, Zn	Surface sampling
69	Stevens	Nanome Aggregates, Inc.	Several quarries		dolomite	Mining and processing
70	Stevens	Northport Limestone Co.(subsidiary of Hemphill Brothers, Inc.)	Northport Limestone	sec. 8 T.39N., R.40E.	limestone	Mining and screening
71	Stevens	Northwest Alloys, Inc.	Blue Creek mine	sec. 29 T.33N., R.40E.	silica	Mining
72	Stevens	Northwest Alloys, Inc.	Addy dolomite quarry	secs. 13-14 T.33N., R.39E.	dolomite	Mining, production of magnesium metal
73	Stevens	Orient Mining Co. (Boise Cascade Corp.)/Pathfinder Gold Corp.	First Thought mine	T.39N., R.37E.	Au,Ag	Drilling
74	Stevens	United Copper Mines		secs. 29, 31-32 T.33N., R.41E.	Au,Ag	Assessment work
75	Stevens	Vanhorn and Watson Mining Co.	Copper Penny	sec. 29 T.40N., R.37E.	Au,Ag	Geological mapping, sampling
76	Stevens	Vanhorn and Watson Mining Co.	Gold Nugget	sec. 20 T.40N., R.37E.	Au,Ag	Geological mapping, sampling
77	Stevens	Western Land and Resources	McNally-Freedom claims	T.40N., R.37E.	Au,Ag	Exploration
	Stevens	Boise Cascade Corp.	Corporate lands		Au,Ag	Exploration
	Stevens	Meridian Minerals Co.			limestone	Exploration
	Stevens	United States Borax & Chemical Corp.			Au	Exploration
	Stevens	Union Pacific Resources Co.			U	Exploration
78	Whatcom	Clauson Lime Co.	Bear Mountain pit	near Maple Falls	limestone	Mining
79	Whatcom	Olivine Corp.	Swen Larsen quarry	sec. 34 T.38N., R.6E.	olivine	Mining

Table 1. Mineral exploration and development in Washington, 1988, continued.

Loc. no.	County	Owner/Operator	Property	Location	Commodity	Remarks
80	Whatcom	Seattle-St. Louis Mining Co.	Minnesota mine	sec. 2 T.37N., R.16E.	Au,Ag	Exploration
81	Whatcom	Steelhead Resources Ltd.	Excelsior mine	secs. 5-6 T.39N., R.8E.	Au,Ag	Announced reserves
82	Whatcom	Western Gold Mining, Inc.	New Light mine	sec. 27 T.38N., R.17E.	Au,Ag	Surface and underground sampling
		CoCa Mines Inc.			metals	Property exams
		American Copper and Nickel Company, Inc.			Au	Property exams
		M. D. Regan and Assocs.			Au	Property exams
		Newmont Exploration, Ltd.			metals	Exploration
		Noranda Exploration, Inc.			Au	Reconnaissance
		Pegasus Gold Corp.			Au	Property evaluation
		Phelps Dodge Corp.			Au	Exploration

ditional 250,000 tons of reserves with an average grade of 0.335 oz/ton gold in the B-neath zone, below the 200-foot level, and 75,000 tons of reserves averaging 0.310 oz/ton gold from an extension of the zone to the west. Exploration drilling in the B-4 zone has indicated anomalous mineralization to both the east and the west (Asamera Minerals, Inc., second quarter report, 1988).

Mining methods employed at the underground trackless mine include mining by sublevel blast hole stoping, with backfilling of each sublevel as soon as the ore is removed. A 15 foot x 15 foot decline from the surface at a 15 percent slope provides access to the mine; ore is hoisted in two skips in an 18-foot-diameter vertical shaft (Argall, 1988). The mine employs 205 people; their "operating cash cost" is $172 per ounce of gold.

Ferry County

Hecla Mining Co. continued high levels of production at the Republic Unit in Republic. The company produced 80,000 ounces of gold and nearly 290,000 ounces of silver from the Golden Promise veins, with an average gold grade of 0.96 oz/ton. Production was 14 percent more than in 1987. The underground mine produces gold for $135 per ounce (including all costs), which makes it one of the lowest cost gold producers in the nation.

During the first quarter of 1988 the company announced that the Golden Promise area contained 1.2 million tons of reserves and mineralized rock averaging 0.5 oz/ton gold. These reserves should extend the life of the mine for at least 7 years. The company has continued the exploration drilling program in the mine to further increase reserves.

Seven veins have been discovered in the Golden Promise area where production began in 1986. The northeast-striking, southeast-dipping banded chalcedony epithermal veins are in the Eocene Sanpoil Volcanics near the contact with the Klondike Mountain Formation. The veins are a few feet to 20 feet thick and have a vertical range of at least 800 feet. Gold occurs as electrum, native gold, sulfosalts, and

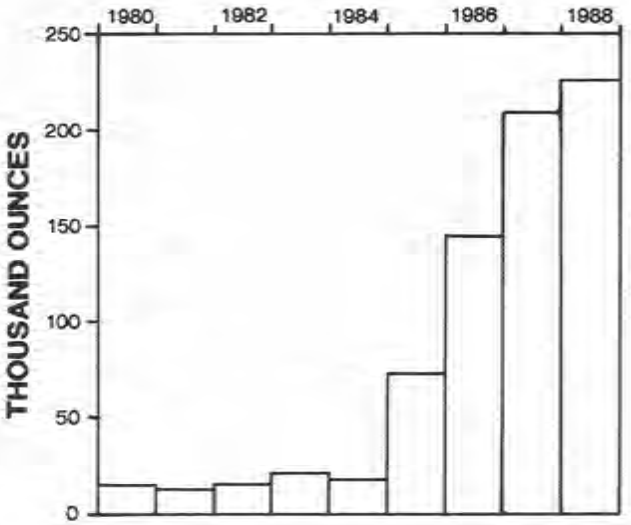

Figure 2. Estimated gold production in Washington. The production estimate for 1988 reflects record production from the two major gold mines in the state. Production increased dramatically beginning in 1985 as a result of the opening of the Cannon mine and increased production at the Republic Unit.

selenides; silver occurs as naumannite and electrum (Republic Unit Staff and Dayton, 1988).

At the Gold Dike mine, owned by Vulcan Mountain, Inc., heap-leach processing continued during part of the year. U.S. Borax & Chemical Corp. has had an option on the Gold Dike and the adjacent Gold Hill property that is owned by Sundance Mining and Development Co. since late 1987. United States Borax & Chemical Corp. drilled more than 6,000 feet of core at the properties to determine reserves. Gold mineralization is reported to occur as disseminated auriferous pyrite and as quartz-pyrite veinlets in alkalic intrusive rocks of the Shasket Creek alkalic complex (Herdrick and Bunning, 1984).

Exploration

Sixty-two companies reported exploring for metals in Washington in 1988, and with few exceptions, they were exploring for precious metals. Exploration dollars spent for metals in the state increased significantly. A value estimated from the voluntary replies to the questionnaires sent to operators of mineral properties in Washington indicates that a minimum of $13 million was spent for metal exploration in 1988 as compared to a minimum of $3.5 million reported in 1986. These figures can only be used for comparison because not all expenditures for exploration and development are reported on the returned questionnaires.

Chelan County

Asamera Minerals (U.S) Inc. and Breakwater Resources Ltd. announced the discovery of gold mineralization at the Wenatchee Gold property in the Wenatchee Heights area, 2 miles southeast of the Cannon mine. The discovery was the result of drilling more than 60 drill holes at the property during the last 2 years. Three separate target areas have been identified by the widely spaced drilling along a zone 9,000 feet in length. Reported values from each of the target areas range from 0.025 oz/ton gold to more than 0.25 oz/ton gold. Environmental studies are being conducted at the site in anticipation of a possible 6,000-foot exploration adit that is being contemplated by the companies. Drilling continued throughout 1988 to further test the property.

Althouse Placers Inc. and Summit Silver Inc. as well as several local residents have signed leases with the joint venture partners in the Wenatchee Heights area. These leases were part of the approximately 1,200 acres of new leases that were acquired during the third quarter, adding to the large land holdings near Wenatchee that have been obtained by the joint venture partners.

Table 2. Properties producing base and precious metals, 1988.

Property	Owner and/or operator	County	Production and development
Cannon mine	Asamera Minerals (U.S.) Inc.; Breakwater Resources Ltd.	Chelan	Produced 146,695 oz of gold and 250,000 oz of silver
H and B mine	Blue Silver Mining	Stevens	Mined 6,000 tons of rock containing lead, zinc, silver, and gold
Republic Unit	Hecla Mining Co.	Ferry	Produced 70,000 oz of gold and nearly 290,000 oz of silver
Gold Dike mine	Vulcan Mountain, Inc.	Ferry	Processed gold heap leach operation for part of the year

At the old Lovitt mine, 2 miles south of the Cannon mine, a surface and underground drilling program was conducted by the joint venture partners to evaluate the Wenatchee D reef as an open-pit heap-leach target (Asamera Minerals, Inc., first quarter report, 1988).

Montana de Oro, Inc. removed overburden, opened old mine adits, and drove 300 feet of new drifts at their property in the Blewett Mining District. The property consists of quartz-calcite-talc-sulfide veins in serpentinized ultrabasic rock.

Raven Hill Mining conducted geological exploration and sampling at their lode and placer deposits in the Chiwaukum graben.

Sunshine Valley Minerals, Inc. continued separation of slime and sand at the Howe-Sound tailing piles from the old Holden mine. The U.S. Forest Service is planning to reclaim the tailings pile because of the possible threat of sedimentation to Lake Chelan during a major flood.

Welcome Nugget Mines continues to explore their placer claims on the upper Wenatchee and Little Wenatchee Rivers.

Ferry County

Ferry County was the area in which a large part of the state's exploration activity took place in 1988. Most of the exploration was centered around the

Nearly 1 million ounces of gold were produced from the Lovitt mine (Golden King mine) between 1949 and 1967. The Cannon mine is located to the northwest of the Lovitt mine, on the opposite side of the ridge. The view is to the northwest from Wenatchee Heights; Rooster Comb is to the right. (Photo by Roger Gill, Asamera Minerals [U.S.] Inc. Exploration.)

Aerial view of the Cannon mine surface facilities from the south. The trackless underground mine has been in operation since mid-1985 and has produced more than 400,000 ounces of gold. The city of Wenatchee is in the background in the upper right. (Photo courtesy of Asamera Minerals, Inc.)

Republic graben. The number of claims located in the county has more than doubled in the past 2 years; the present total is approximately 3,000 claims (Doug Sauer, Ferry County Planning Dept., oral commun., 1989). Most of these claims are located in the northern part of the county, north of the Colville Indian Reservation. A majority of the 23 companies that reported working in the area explored for gold in epithermal veins in the Eocene Sanpoil Volcanics and for replacement deposits in Paleozoic sedimentary rocks (Fig. 3).

Echo Bay Mines Ltd. announced in November that they will put two underground mines into production in early 1990. The Kettle and the Overlook mines are a joint venture with Crown Resource Corp. and Gold Texas Resources Ltd., each of whom own 15 percent. More than $13 million have been spent on the two properties to date, and an additional $47 million will be spent to put the mines into production (Echo Bay Mines Ltd., third quarter report, 1988).

Reserves for the two properties have been estimated at 3.9 million tons of ore averaging 0.189 oz/ton gold; however, the deposits have not yet been fully delineated. Consultants to Echo Bay estimate that the two mines will produce 729,000 ounces of gold. Production is expected to be 110,000 ounces of gold per year the first 2 years, with annual production of 85,000 ounces thereafter at a cost of $200 per ounce. Employment is projected to be between 105 and 130 workers.

The Kettle mine is located a mile west of Curlew. The 3,500-foot spiral decline begun in 1987 has been completed, and underground drilling was undertaken in 1988 to further define the banded and brecciated epithermal Lucy and Brutus veins. Echo Bay estimated that production from the mine will be 300 to 500 tons per day. The ore will be processed at the Key mill near the Overlook deposit 8 miles northeast of Republic.

The Overlook mine will be an underground mine at which production is estimated to be 1,000 to 1,500 tons per day. The mine, beneath Cooke Mountain, will be accessed by a 2,700-foot adit. An upper 1,250-foot adit will access the uppermost part of the deposit, provide ventilation, and serve as an escape way. The deposit is a magnetite replacement deposit in Paleozoic limestones and a stockwork deposit in the overlying clastic sedimentary rocks, all of which are intruded by an Eocene dike. The Overlook deposit has the highest ore grade of the three deposits tested by Echo Bay near Cooke Mountain; the other two deposits are the Key East and Key West deposits (Fig. 4).

Ore from the Kettle and Overlook mines will be processed at the Key mill (Fig. 4). The conventional mill will be designed to process 1,500 to 2,000 tons per day and will use tank cyanidation. Tailings will

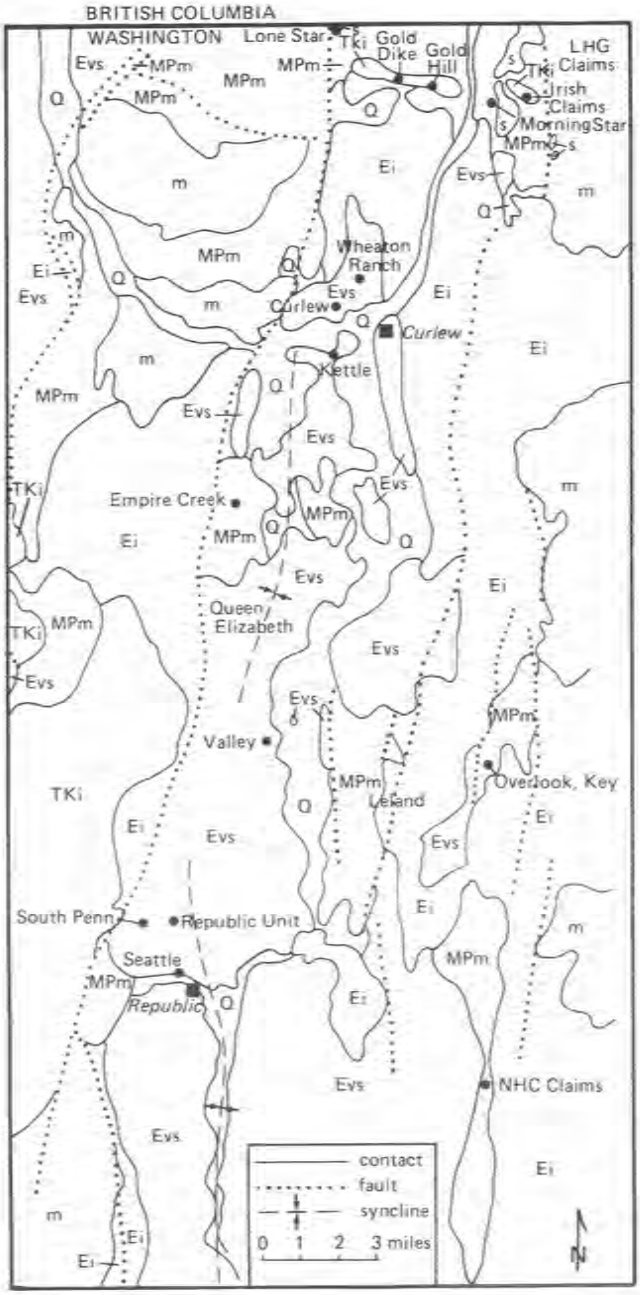

Figure 3. Areas of active exploration in northwestern Ferry County, (T 36-40 N, R 32-33 E). Most of the exploration activity was for gold and silver in Eocene volcanic rocks (Evs), Paleozoic and Mesozoic metasedimentary and metavolcanic rocks (MPm), and serpentinite (s). Q, Quaternary sediments; Evs, Eocene volcanic rocks and sediments; Ei, Eocene intrusive rocks; TKi, Tertiary/Cretaceous intrusive rocks; m, metamorphic rocks. (From Keith Stoffel, DGER, unpublished mapping).

be pumped to tailings embankments adjacent to the mill site.

Hecla Mining Co. has expanded their exploration program in the Republic area, where the company has a land position consisting of more than 5 square miles. Drilling has been concentrated in the

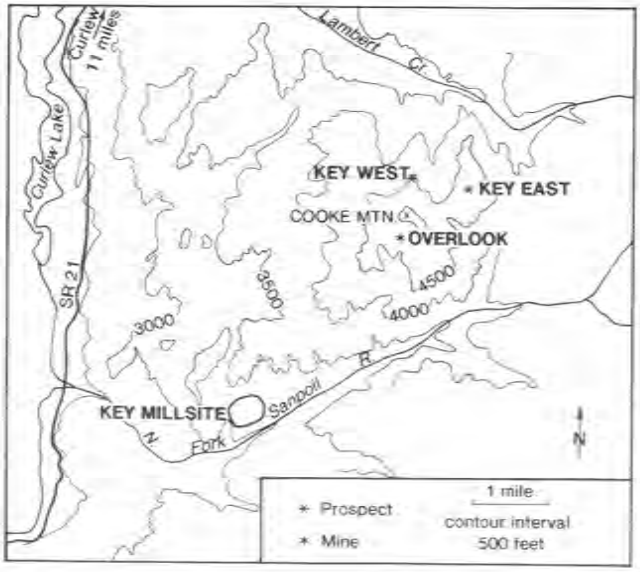

Figure 4. Location of the Overlook mine and Key mill in T. 37 N., R. 33-34 E. The mine and mill will be put into production by Echo Bay Mines Ltd. in 1990. Ore from the Kettle mine, 1 mile west of Curlew, will be processed at the Key mill.

Golden Eagle area adjacent to the Republic Unit and north of the mine area.

Republic Gold Corp., a wholly owned subsidiary of Hecla Mining Company, has signed two 35-year leases with Ferry County to explore on county-owned lands within the limits of the town of Republic. Under the terms of the lease, Republic Gold will pay the county $4,000 the first year in fees, the amount escalating by $2,000 each year until a maximum of $12,000 per year is reached. If mining does take place, the county would receive a percentage of the net profits (Spokesman Review, Oct. 26, 1988).

Tanqueray Resources Ltd. conducted exploration at the Valley mine under an option agreement with High Country Mining and Exploration. Exploration included at least 10 surface core holes, underground development, and sampling. The vein was encountered in eight of these holes; however, minable gold grades were not intercepted (Tanqueray Resources Ltd., first quarter report, 1988). The vein of banded chalcedonic quartz and calcite in the Sanpoil Volcanics strikes northeast and dips approximately 35 degrees to the east. The mine was last active in mid-1987.

Crown Resource Corp., in joint venture with Sutton Resources Ltd. and Texas Star Resources Corp., conducted delineation drilling at the South Penn property. Twenty-one reverse-circulation and three core holes for a total of 5,700 feet were drilled at the epithermal gold and silver deposit in the Sanpoil Volcanics. The drill program has enlarged the area of previously defined mineralization and discovered new areas of high-grade mineralization at depth (Mining Record, Nov. 30, 1988). Chemgold, Inc. reclaimed a small heap-leach operation at the deposit that they worked in 1987.

Crown Resource Corp., in joint venture with Sutton Resources, Inc. and Texas Star Resources Ltd., completed more than 14 surface core holes and 3 underground long holes for a total of more than 2,700 feet at the Seattle mine. The mine, which produced limited tonnage in 1983 and 1984, contains narrow high-grade veins in sediments and tuffaceous rocks of the lower Sanpoil Volcanics.

Crown Resource Corp. in joint venture with Gold Texas Resources Ltd. conducted reconnaissance drilling, geological mapping, and geochemical sampling at their Queen Elizabeth property. Epithermal gold-bearing quartz veins in the Sanpoil Volcanics are the exploration target.

North of the Kettle mine, Asarco Inc. drilled 1,500 feet of core and conducted soil geochemistry work and geophysical surveys at their Curlew project. To the north on an adjacent property, United States Borax & Chemical Corp. drilled two holes at their Wheaton Ranch property. Both prospects are in the Sanpoil Volcanics.

Morning Star Mines, Inc., worked to rehabilitate the Morning Star mine and began bulk sampling in the area of previous mining. The gold and copper mine has been idle since World War II.

N. A. Degerstrom, Inc., in joint venture with Inland Gold and Silver Corp. and Pegasus Gold Corp., continued exploration on the Leland property, directly west of the Overlook and Key properties of Echo Bay. Geologic mapping and magnetic surveys were conducted; diamond drilling was undertaken to test magnetic anomalies. The 8-square-mile property consists of mining claims and private land.

United States Borax & Chemical Corp. drilled more than 2,000 feet of core at the Lone Star mine, a former copper and gold producer. The deposit, which straddles the international border, is reported to be in metamorphosed rocks of probable volcanic origin at the contact with a serpentine body. According to the Inventory of Washington Minerals (Huntting, 1956, p. 54), the deposit was last mined in 1917, and 250,000 tons of rock averaging 1.94 percent copper, 0.047 oz/ton gold, and 0.2 oz/ton silver were left in the ground. The company has also optioned the Empire Creek property, 12 miles north of Republic, from Kettle River Resources Ltd.

Cyprus Minerals Co. drilled in the Lone Ranch Creek area, east of Danville. Other claims were also added to their holdings in the high-grade metamorphic rocks.

Newmont Exploration Ltd. explored for precious metals in the county. The company located a claim block on the South Fork of O'Brien Creek.

Johnson Explosives conducted geological and geochemical exploration seeking gold in an alkalic dike on the Irish claim group.

Other companies exploring in the county include Antilles Resources Ltd. which explored for gold. Boise Cascade Corp. engaged in reconnaissance exploration for gold on company lands in the county. Union Pacific Resources Co. explored for uranium.

King County

Weyerhaeuser Co. completed a third season of reconnaissance drilling and mapping at their White River property. The company is seeking gold and copper in quartz-alunite-altered Miocene volcanic rock. Mineralization is structurally, temporally, and genetically related to the margin of a Miocene caldera (McCulla, 1986).

Cannon Minerals explored for gold-bearing veins in intrusive rocks at the El Watusi property near North Bend. Precious metals in Miocene volcanic rocks with quartz-alunite alteration were targeted by the company at their White River property.

Mark Wagner continued exploration on claims near Coney Basin near Skykomish.

Okanogan County

Exploration has increased in Okanogan County as those seeking precious metals have "moved west" from the Republic graben area into areas with similar geology.

Crown Resource Corp. in joint venture with Gold Texas Resources Ltd. announced the discovery of significant mineralization at their Buckhorn project in the Myers Creek Mining District in the northeastern part of the county. The company drilled 13 reverse-circulation holes into the gold-bearing skarn for a total of more than 5,200 feet. Crown Resource reported significant mineralization in four of the five areas tested, including one 75-foot-thick zone that contained 0.319 oz/ton gold.

The Crown Resource Corp. and Gold Texas Resources Ltd. joint venture drilled 5 reverse-circulation holes totaling more than 2,300 feet at the Ida mine. The work was done under a lease agreement with Sundance Mining and Development Corp. Geological and geophysical exploration was also undertaken at the property in the search for gold-bearing epithermal veins in Eocene volcanic rocks in the Toroda Creek graben.

Westmont Mining Inc. in joint venture with Crown Resource Corp. drilled 3,000 feet and conducted geological mapping and soil and rock sampling at the Bodie mine. The property, which was last mined in 1944 (Moen, 1980), is located in the Toroda Creek graben and is in Eocene volcanic rocks.

Several companies explored for precious metals west of the Okanogan River. Newhawk Gold Mines Ltd. in joint venture with Reliant Resources, Ltd., and Nord Resources Corp. did limited trenching, drilling, and geochemical sampling at their Smith Canyon property. Newhawk Gold reported that although the results from their work were mildly encouraging, the property was returned to the Reliant Resources/Nord Resources joint venture (Newhawk Gold Mines Ltd., second quarter report, 1988).

ECM Inc. conducted geological, geochemical, and geophysical exploration at the Alder mine. The gold-silver-copper property 5 miles southwest of Twisp is in the Lower Cretaceous Buck Mountain Formation.

Quintana Minerals Corp. continued exploration at their American Flag property near Mazama.

L. F. Baum and Associates continued exploration at the Turtle Lake property that included reverse-circulation drilling, and geological and geophysical work. The company is seeking precious metals and copper in a sedimentary-rock-hosted deposit.

Say Energy Inc. and OWC Inc., who hold large claim blocks in the southeast part of the county, explored their claims for gold, silver, and copper.

Other groups exploring in Okanogan County include Dalton Excavating, who drilled at their Roxy property. Sunshine Valley Minerals, Inc., continued precious metal exploration on their Billy Goat claims; activities included work on roads and geological and geochemical exploration.

Pend Oreille County

Resource Finance Corp. (RFC) has entered into an option purchase agreement with Pintlar Corp., a wholly owned subsidiary of Gulf Resources and Chemical Corp., to acquire the assets of the Pend Oreille mine. The new Canadian company can exercise its option to acquire 100 percent of the underground mine for $1.25 million. Prior to beginning underground development, dewatering of the mine will be necessary. Surface drilling has begun at the mine; RFC estimates that it will cost $1 million to evaluate the mine. The mine, which has been closed since 1977, was the largest zinc mine in the state.

Raven Hill Mining explored for base and precious metals on their Peacock claims group near Cooks Mountain.

Pierce County

Mark Wagner explored for gold and copper mineralization in the Miocene Carbon River stock north of Mount Rainier.

Spokane County

Union Pacific Resources Co. explored for uranium in the county. Exploration included geological mapping and sampling.

Snohomish County

Several companies and individuals explored for precious metals in the Sultan River drainage, including Island Arc Mining Corp. and Jeanne Ring. Recreational placer mining has been popular in the county.

Stevens County

Boise Cascade Corp., in joint venture with Pathfinder Gold Co., continued to explore for gold and silver at the First Thought mine. Drilling continued at this epithermal vein deposit in the Sanpoil Volcanics near the contact with the Klondike Mountain Formation.

These joint venture partners have also been exploring the McNally-Freedom claims held by Western Land and Resources, where geologic mapping, soil geochemistry, and a geophysical survey were conducted.

Boise Cascade Corp. also continued exploration at their Fifteenmile Creek property. The prospect contains gold-bearing massive sulfide veins in the Jurassic Rossland Volcanic Group. The company also continues to explore for metals on other corporate lands in the county.

Vanhorn and Watson Mining Co. conducted geological mapping and core drilling at their Copper Penny property. Mapping and sampling were accomplished at their Gold Nugget property. Both of the prospects, which are under lease to Blaine Exploration Co., are in the Rossland Volcanic Group.

Chewelah Eagle Mining Co. continued exploration for base metals and silver on their claims near Chewelah Mountain.

United Copper Mines engaged in minor work on their claims in the Chewelah Mining District. Leadpoint Consolidated Mines Co. explored their lead-zinc-silver properties in the Metaline Formation in the Northport Mining District.

At the H and B mine Blue Silver Mining removed 25,000 tons of overburden and mined 6,000 tons of material. The precious and base metal veins at the property are in Precambrian metasedimentary rocks.

The capital assets of the Deer Trail mine, owned by Cortez International Ltd., were liquidated to satisfy debts owed by the company. The Deer Trail mine was in operation in from 1981 to 1984. The company holds state mineral leases in the area to explore the potential of the Turk magnesite deposit.

Union Pacific Resources Co. explored for uranium in the county.

Whatcom County

Steelhead Gold, a wholly owned subsidiary of Steelhead Resources Ltd., continued to explore the Excelsior mine east of Glacier. The company announced reserves of 4.1 million tons grading 0.042 oz/ton gold and 2.6 oz/ton silver after an extensive drilling program in 1987. Sampling done in 1988 examined possible extensions of the mineralization to the west and north. The deposit, which was previously drilled by United States Borax & Chemical Corp., is hosted by volcanic and sedimentary rocks of the Jurassic Wells Formation.

In the Slate Creek Mining District, Western Gold Mining, Inc., did surface and underground sampling at the New Light mine. Seattle-St. Louis Mining Co. continued small-scale exploration on the quartz vein at the Minnesota mine.

Statewide

Several companies explored for precious metals throughout the state, including American Copper and Nickel Company, Inc., Noranda Exploration, Inc., Orvana Resources Corp., Pegasus Gold Corp., Phelps Dodge Corporation, Newmont Exploration Ltd., CoCa Mines Inc., and M. D. Regan and Associates.

INDUSTRIAL MINERALS

Development and Exploration

Seventeen companies produced industrial minerals from 21 sites during 1988 (Table 3). Value-added processing increased the value of the state's industrial minerals. Northwest Alloys, Inc., mine and plant in Stevens County was the highest-value industrial mineral operation in the state because of the value added to dolomite through the production of magnesium metal. Limestone was generally used in the manufacture of portland cement. Silica was produced by four operations for uses that included plate glass, colored glass bottles, and cement. Two companies produced portland cement, while a third company continued to explore the possibility of building a new portland cement plant in Okanogan County. Clay was produced by four companies for use in cement and structural bricks. Diatomite was produced by one company, and two companies made products from olivine mined in the state.

Clallam County

Ideal Basic Industries, Inc., produced 100,000 tons of clay from the Twin River quarry. The clay is barged to their Seattle plant, where it is used in the manufacturing of portland cement. The clay is mined from weathered mudstone in the Twin River Group of Oligocene age.

Grant County

Witco Corp. continues to be the sole producer of diatomite in the state. Production in 1988 increased significantly over that in 1987 with the bulk of the production from the pit in section 8. The com-

Table 3. Properties producing industrial minerals, 1988.

Commodity	Property	Owner and/or Operator	County	Production and development
Clay	Twin River quarry	Ideal Basic Industries, Inc.	Clallam	Mined 100,000 tons
Clay	Mica mine, plant and Pottratz pit	Interpace Industries Inc.	Spokane	Mining
Clay	Elk pit	Mutual Materials Co.	King	Mined 28,500 tons
Clay	Sec. 31 pit	Mutual Materials Co.	King	Mined 85,000 tons
Clay	Harris/Blum	North American Refractories Co.	King	Hauled from stock pile
Diatomite	Sec. 7 and 8 pits	Witco Corp.	Grant	Mined 350,000 tons
Diatomite	Sec. 17 pit	Witco Corp.	Grant	Mined 30,000 tons
Dolomite	Crystal City mine	Blue Silver Mining	Lincoln	Mined 30,000 tons
Dolomite	Several quarries	Nanome Aggregates, Inc.	Stevens	Mining from several pits
Dolomite	Addy Dolomite quarry	Northwest Alloys, Inc.	Stevens	Mined 760,000 tons
Limestone	Bear Mountain pit	Clauson Lime Co.	Whatcom	Mining
Limestone	Wauconda quarry	Columbia River Carbonates	Okanogan	Mined 35,000 tons
Limestone	Champane Placer	Lehigh Portland Cement Co.	Pend Oreille	Mined 241,860 tons
Limestone	Northport Limestone	Northport Limestone Co. (Hemphill Brothers, Inc.)	Stevens	Mined 45,000 tons
Limestone	Tonasket Limestone quarry	Pacific Calcium, Inc.	Okanogan	Mining and milling
Olivine	Aimcor Olivine	Applied Industrial Materials Corp.	Skagit	Crushing and screening
Olivine	Swen Larsen quarry	Olivine Corp.	Whatcom	Mining
Silica	Superior quarry	Ash Grove Cement West, Inc.	King	Mined 45,000 tons
Silica	Ravensdale pit	L-Bar Products, Inc.	King	Mining
Silica	Lane Mountain Silica	Lane Mountain Silica Co. (Hemphill Brothers, Inc.)	Stevens	Mined 300,000 tons
Silica	Blue Creek mine	Northwest Alloys, Inc.	Stevens	Mined 20,000 tons

pany sought permits for a new diatomite pit in the Frenchman Hills. The diatomite is mined from lake bed deposits interstratified with flows of the Columbia River Basalt Group.

Basic Resources Corp. conducted geological mapping, sampling, and drilling at their Rock Top claim group. The deposit contains non-swelling bentonite that is present in sedimentary layers between flows of Columbia River basalt. The clay is reported to be suitable for many uses, including absorbants, oil and gas drilling muds, and filters.

King County

L-Bar Products, Inc., continued mining silica at their Ravensdale pit. The sand is mined, washed, screened, and dried to produce silica for making colored bottles and cement. The sand is mined from the Eocene Puget Group.

Ash Grove Cement West, Inc. mined, crushed, screened, and stockpiled 45,000 tons of silica at their Superior quarry. The mine, which began operation in 1987, supplies silica primarily for the production of portland cement; however, other uses include aggregate, decorative stone, sand-blast sand, and roofing granules. The low-alkaline, microcrystalline quartz deposit consists of altered and silicified Miocene volcanic rock.

Mutual Materials Co. was the largest clay producer in the state. The company mined shale from two pits in the county.

Lincoln County

Dolomite was mined by Blue Silver Mining from the Crystal City mine. The white rock is reported to contain 31.5 percent CaO and 21 percent MgO.

Okanogan County

Ciment Quebec Inc. has proposed building the dry-process, state-of-the-art $80 million Interstate Portland Cement, Inc. plant near Ellisforde. The company has signed an option for the high-calcium Reed Limestone property on the west side of the Okanogan River with CM Silver Mines, Inc., a wholly owned subsidiary of Lucky Three Mining Co. The company plans to move the limestone from "White Rock Mountain" by conveyor to the portland cement plant on the east side of the river. The project is on standby while a new permitting and financing strategy is developed by the company.

Columbia River Carbonates, a limited partnership of Bleek Management, Inc. and Genstar Carbonates Inc. mined and crushed 35,000 tons of high-calcium-carbonate rock at their Wauconda quarry. The white marble is sent by rail to the Columbia River Carbonates plant at Woodland, near Vancouver, where it is ground to fine and ultrafine powder and slurry.

Pacific Calcium, Inc. continues to mine limestone and dolomite from the Tonasket Limestone quarry. The carbonate is crushed in Tonasket and sold for poultry feed and soil amendment and as a lawn-care product.

Pend Oreille County

Lehigh Portland Cement Co. produced 241,860 tons of limestone from the Champane Placer. The limestone is mined from the Cambrian-Ordovician Metaline Formation for use in the production of portland cement. Lehigh is the only company in the state to produce portland cement from limestone that is mined in Washington.

United Catalysts Inc. in joint venture with First Miss Gold Inc. continued exploration at their Totem talc property in the northeasternmost part of the county. Drilling and bulk sampling was done at the property in a shear zone in the Late Proterozoic Monk Formation.

Skagit County

Applied Industrial Materials Corp. (AIMCOR) crushed and screened olivine purchased from an outside source. The company produces olivine flour for use as foundry and blast sands.

AIMCOR was honored by the Pacific Northwest Region of the U.S. Forest Service for "exceptional environmental stewardship" of public lands exhibited in their reclamation project at the Twin Sisters quarry in the Mt. Baker-Snoqualmie National Forest (Joseph, 1988).

Spokane County

Interpace Industries Inc. continued production of clay from the Mica and Pottratz pits near Mica. Structural bricks produced at the plant, including popular light-colored bricks, are sold nationwide.

Stevens County

Northwest Alloys, Inc., a wholly owned subsidiary of Aluminum Co. of America, mined 760,000 tons of dolomite from the Addy Dolomite quarry. North-west Alloys' mine and plant at Addy is now the highest value mineral operation in the state because of its high volume of production and the value added to the dolomite by the production of magnesium metal at the plant. The company is one of only three producers of magnesium metal in the United States and can produce 15 to 20 percent of the world plant capacity for the metal. The company employed more than 460 workers in 1986 and continues as the largest employer in Stevens County (TEAM WASHINGTON, 1986).

In April, Northwest Alloys resumed the production of 75 percent ferrosilicon at their Addy plant. Ferrosilicon is used in the silicothermic process (whereby magnesia in calcined dolomite is reduced by silicon) employed at the magnesium plant. The company had been purchasing ferrosilicon since the furnaces were shut down in 1985, but the company resumed production because of the increases in price due to increased demand from the steel industry (Gerety, 1988). Mining of silica resumed at the Blue Creek quarry near Addy in order to supply the ferrosilicon plant. The quarry produced 20,000 tons of quartzite from the Addy Quartzite.

L-Bar Products Inc. continued to produce fertilizer from magnesium sludge from the Northwest Alloys plant. The fertilizer is marketed as "Ag Mag K".

Hemphill Brothers, Inc. operated two industrial mineral properties in the county. Lane Mountain Silica Co., the largest silica producer in the state, produced 230,000 tons of high-purity silica from a

friable area of Addy Quartzite. Northport Limestone Co. crushed and screened 45,000 tons of limestone from the Metaline Formation at their quarry east of the Columbia River near Northport.

White and colored dolomite was mined and processed by several companies, including Nanome Aggregates, Inc.

Whatcom County

Olivine Corp. continues to mine olivine from the Swen Larsen quarry. The company pioneered the development of a waste incinerator using modular olivine refractory slabs.

Clauson Lime Co. continues to mine high-calcium limestone from their Bear Mountain pit near Maple Falls.

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The **Pegasus Gold Corporation** of Spokane is the first recipient of the Northern Regional Forester's Excellence Award in what the U.S. Forest Service hopes to continue as an annual presentation.

The initial award is based on the Pegasus mining operation in the Deer Lodge National Forest of western Montana, near Butte.

Hecla Sees Diversification as Key to Comeback

Hecla Mining Company's economic rebound in the last five or six years is attributed to diversification of its interests.

Arthur Brown of Coeur d'Alene, Idaho, Hecla's president, adds belt-tightening policies and new mechanization methods as other major reasons for a "substantial increase" in profits in recent years.

The company's Lucky Friday mine, an 80-year-old silver producer at Wallace, Idaho, no longer is Hecla's flagship operation, Brown said during the Northwest Mining Association's 94th annual convention in Spokane.

Other factors in Hecla's healthier fiscal position, according to Brown:

- Exploration in the Northwest Territories of Canada for beryllium, a metal lighter than aluminum;
- Exploration for gold in British Columbia and Nova Scotia;
- A search for industrial metals in six southwest states.
- Ownership of gold property, the old Knob Hill mine near Republic, which Hecla acquired eight years or so ago and where additional ore has been discovered.
- A 25-percent reduction in costs at the Lucky Friday mine.

Hecla reduced its costs for mining silver by $2 an ounce, to about $5, according to Brown. He also said the industry cost for mining gold is about $250 per ounce, but that Hecla has its cost down to about $150 an ounce.

Lower operating costs at the Lucky Friday mine, according to Brown, resulted from increased mechanization and the development of improved methods for hard-rock underground mining. Another item in lowering costs, said Brown, is an agreement with employees to reduce the labor force from 240 to 175 by mid-1989. In exchange, Brown said, Hecla has provided employees with a profit-sharing arrangement.

Gold is Hecla's major income item, according to Brown, followed by industrial metals, then silver. He said the price of silver in recent years has been a "wild roller coaster. If we were involved only in silver, our company would be hurting. We had to diversify."

Petroleum Geology of the Washington Continental Margin

By Stephen P. Palmer and William S. Lingley, Jr.

[Modified from Palmer and Lingley, 1989]

INTRODUCTION

The western Olympic Peninsula and adjacent offshore areas of Washington have a history of oil and gas exploration dating from 1901, when a wildcat well was drilled near Copalis Beach. Subsequently, 116 wildcats have been drilled in this general region including several wells on the beach and four in deep-water offshore. Many of these wells had significant shows of oil and/or gas, but profitable production has not been established (McFarland, 1983). The most recent phase of exploration in the area ceased when the Sunburst No. 1 well in Jefferson County was abandoned during 1982.

The Minerals Management Service (MMS), Department of the Interior, has begun preparation for an auction of oil and gas leases on the Washington and Oregon outer continental shelf (OCS), designated Sale 132. Sale 132 would be scheduled during 1992 if industry interest, as indicated in a formal notification process, is sufficient to assure that the auction will be successful and if environmental issues are satisfactorily resolved. The location of the Washington portion of proposed Sale 132 is shown on Figure 1. State territorial waters, encompassing the area within 3 miles of the coast, are not included in the sale.

The purpose of this study was to provide a geological and geophysical assessment of the petroleum potential of the Washington OCS for the benefit of the public. The area of our assessment includes State territorial waters and all federal waters north of Oregon from the 3-mile limit westward to the boundary of Sale 132. A secondary objective of this project was to collect and archive geological and geophysical data in the public domain that are relevant to petroleum assessment in the Washington OCS. These data, which will be available to the public through the Division of Geology and Earth Resources, are also useful for regional geological studies and hazard assessment.

PETROLEUM GEOLOGY OF THE WASHINGTON CONTINENTAL MARGIN

Petroleum assessments are based on the study of sedimentary rocks that have potential to generate and store commercial quantities of oil and/or gas. Sedimentary rocks buried in the Earth's crust commonly contain fossil wood, leaves, algae, and other organic debris that are source materials for gas and oil. Heating source rocks to near the boiling point of water activates chemical reactions that convert the organic debris to petroleum [thermal maturation*]. Low-density petroleum produced by these reactions migrates toward the surface from its source through water-filled pores and faults. Stratified sedimentary rocks are commonly folded and/or faulted into domes (anticlinal structures in which strata dip away from the fold culmination in every direction) which can stop or trap the upward-migrating petroleum. Porous strata that have the capacity to store large volumes of oil and gas [reservoir rocks] must be present within the trap. In addition, these reservoir rocks must be overlain by impermeable rocks [seals] that inhibit continued upward migration of the petroleum. Oil and gas fields are large traps which reflect the rare situation in which all of the conditions described above occur in proper sequence (that is, deposition of source, reservoir, and sealing rocks, followed by development of a trap, and then maturation and migration of the petroleum into the trap). A petroleum assessment is simply a quantitative analysis of each of these factors based on geologic study of an area.

[1] This article is a summary of an assessment of the oil and gas potential of the Washington outer continental shelf conducted by the Division of Geology and Earth Resources and the Washington Sea Grant Program (Palmer and Lingley, 1989). This study and the publication of the complete report were supported by an appropriation from the Washington State Legislature, under ESSB No. 5533, Laws of 1987, to the Washington Sea Grant Program at the University of Washington. Additional support was provided by grant NA86AA-D-SG044 from the National Oceanic and Atmospheric Administration to the Washington Sea Grant Program, projects R/MS-33 and A/PC-5. The writers express their appreciation to Parke Snavely of the U.S. Geological Survey and to W. W. Rau of Washington Division of Geology and Earth Resources for numerous contributions to this report and for reviewing the text. We thank Trish Peyton and Glenn Ledbetter of the Ocean Resources Assessment Project, Washington Sea Grant Program, for their kind assistance.

* In this summary terms commonly used in the petroleum industry are bracketed.

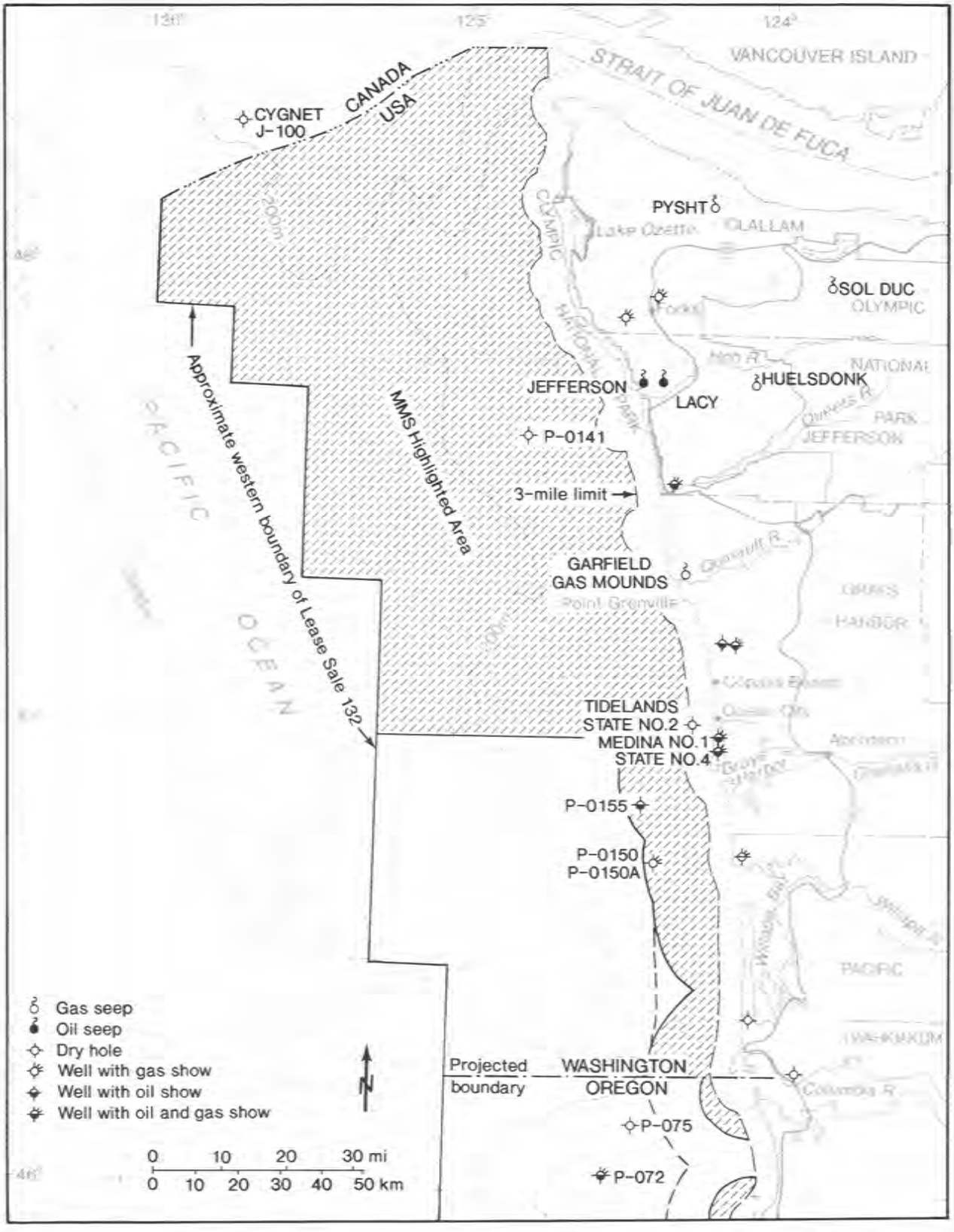

Figure 1. Location of oil and gas seeps and some significant wells on the western Olympic Peninsula and adjacent offshore regions, the area of the proposed OCS Lease Sale 132, and the area highlighted by the Minerals Management Service (MMS).

The geologic history relevant to petroleum accumulation in coastal Washington began with deposition of the area's oldest unaltered sedimentary rocks, the Ozette melange (Snavely and others, 1986) and the Hoh rock assemblage (Rau, 1973). The Ozette and Hoh sequences are composed mainly of sandstones, siltstones, and claystones deposited in deep water on the Pacific oceanic floor between approximately 50 and 15 million years ago (Snavely, 1987). These sediments were probably scraped off the Pacific floor and accreted to the North American continent as the oceanic floor was subducted beneath the continent. During the accretion process, intense faulting and folding created a chaotic mixture of Hoh and Ozette rock types known as melange. Melange is generally not prospective for oil and gas accumulation. Between about 12 and 2 million years ago, accreted Hoh and Ozette sequences were covered by the Montesano and Quinault Formations, which are also composed of sandstones, claystones, and siltstones. During and after deposition, the Montesano and Quinault Formations were deformed, but much less severely than the underlying Ozette and Hoh melanges. This period of deformation created numerous faults and anticlines in the Montesano and Quinault stratigraphic intervals. A small number of these anticlines are probably domes and consequently could serve as *potential* traps for the accumulation of oil and gas.

Source Rocks, Maturation, and Migration

Despite the lack of oil or gas production in Washington, the western Olympic Peninsula is a remarkably petroliferous terrane. Oil and gas seep to the surface at several locations on the western Olympic Peninsula, and numerous exploratory wells drilled onshore and offshore encountered significant oil and gas shows. Very dark gray clay layers in Ozette and Hoh sequences exposed along sea cliffs in Olympic National Park and adjacent beaches seep traces of oil into the Pacific Ocean. Early inhabitants of the peninsula referred to these clay layers as "smell muds". The Medina No. 1 well, drilled on the beach at Ocean Shores (near Ocean City), sold small amounts of oil to a Tacoma refinery between 1958 and 1962 (McFarland, 1983). A nearby well, the State No. 4, produced a small quantity of gas that was sold to the Ocean Shores real estate development. These observations indicate that petroleum has been generated and has migrated to the surface along the coastal zone adjacent to the Sale 132 area.

Paradoxically, laboratory studies by the U.S. Geological Survey (Snavely and Kvenvolden, 1988) and our own work have failed to delineate specific source rock horizons that generated these oil seeps and shows.

Reservoir Rocks and Seals

Reservoirs for oil, gas, and underground drinking water commonly consist of small gaps or voids [pores] between grains of sand in sandstones. The storage capacity of a sandstone reservoir is determined by the percentage of the rock that is composed of pores [porosity]. Permeability is the measurement of the ease with which fluids can flow through a reservoir. A reservoir will not yield profitable amounts of petroleum unless fluid can flow from porous rock into the well bore. Porosity and permeability in offshore reservoirs must be especially high in order for the well to produce petroleum at volumes and rates sufficient to recoup the expenses of building a production platform and transportation facilities. Permeability commonly decreases with decreasing grain size; consequently, sandstones generally are considered as potentially commercial reservoirs, whereas few siltstones or claystones produce oil or gas at commercial rates.

Porosity and permeability data obtained from exploratory wells on the Olympic Peninsula indicate that the Hoh and Ozette sequences typically have insufficient permeability to support commercial offshore production rates (Fig. 2a). Most of the pores in these rocks have been filled with mineral cements, thus reducing both the storage capacity and permeability (Galloway, 1974). Furthermore, intense folding, faulting, and fracturing of the Hoh and Ozette sequences that occurred during accretion may limit the lateral extent of individual Hoh or Ozette sandstone reservoirs (Rau, 1975, 1979; Snavely and others, 1986).

The porosity and permeability of sandstone sequences within the Montesano and Quinault Formations compare favorably to those of producing reservoirs in some of the world's largest oil fields (Fig. 2b). Wells drilled in the Ocean City area encountered a continuously porous sandstone unit in the Montesano Formation that is more than 600 feet thick (informally named the Ocean City sand), and in which nearly one-third of the total sandstone volume is composed of void space (porosity equals 33%). This exceptional sandstone reservoir has been drilled only in the Ocean City area (Bergen and Bird, 1972) and in one offshore well, the P-0155 (The Shell Oil Co., 1967). Our work suggests that equivalents of this sandstone may be locally present elsewhere on the continental margin, but prediction of the distribution of these sandstones, which is critical to successful exploration, will be difficult. Nonetheless, these Montesano sandstone reservoirs present an attractive petroleum exploration target.

Seals are generally composed of impermeable claystone or siltstone layers that inhibit migration of oil and/or gas from the reservoir. Oil and gas seeps occur where seals are not present or are breached by faulting or erosion, and as a result the petroleum migrates to the surface. In some places faults may seal traps.

Most sedimentary sequences in the western Olympic Peninsula contain impermeable siltstones

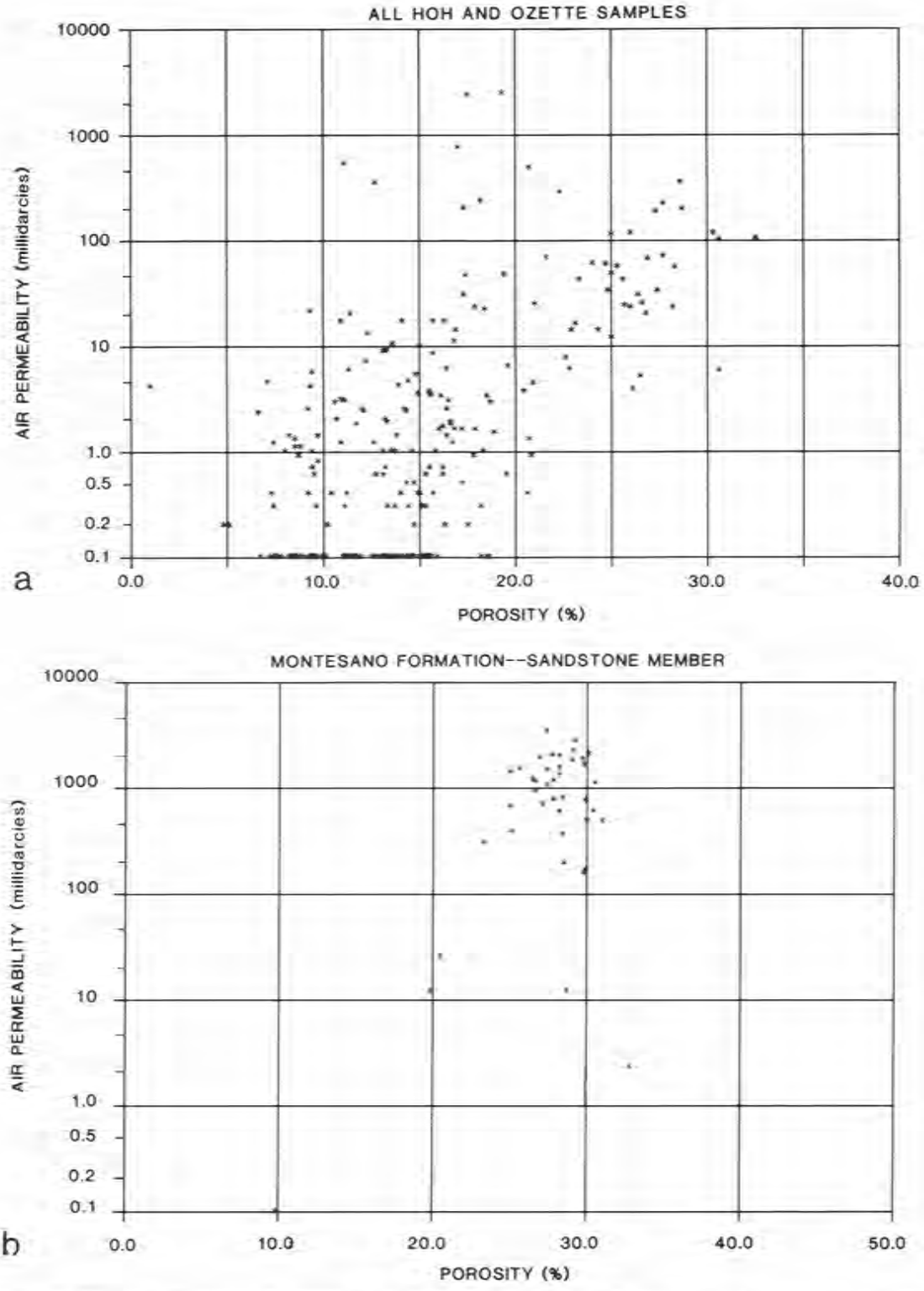

Figure 2. Plots of porosity and permeability data obtained from analysis of cores from numerous onshore wells. (a) Data from the Hoh and Ozette rocks show that most samples have permeabilities less than 50 millidarcies (md) and porosities less than 25%. For commercial offshore production, permeability must exceed 50 md to permit adequate flow rates. The high clay content of Hoh and Ozette sandstones reduces the effective porosity below the measured porosity values shown in this figure. (b) Porosity-permeability data for the sandstone member of the Montesano Formation, a 600-ft-thick massive sandstone drilled in the Ocean City area. Permeabilities of this sandstone generally range from 500 to 2,500 md, and porosities range from 25 to 32%. These porosities and permeabilities compare favorably with those of sandstone reservoirs in many of the world's major oil fields; this thick sandstone presents an attractive petroleum exploration target.

and claystones suitable for sealing underlying sandstone reservoir horizons. Minor shows recorded in the thick Montesano sandstone unit encountered in the Ocean City area indicate that gas, and possibly oil, have migrated into this sandstone at some time in the past. However, our work suggests that the overlying siltstone seal was breached by erosion approximately 5 million years ago, and, consequently, oil and gas that may have accumulated in the sandstone escaped.

Traps

Anticlinal folds in stratified rocks having potential to trap petroleum are generally located using seismic reflection surveying. This geophysical technique involves reflecting sound waves off buried strata in the same fashion that sonar locates submarines. The reflection data are used to map the geometry and approximate depth of anticlinal folds (Fig. 3). The seismic reflection data are generally acquired along shotlines laid out as an intersecting grid.

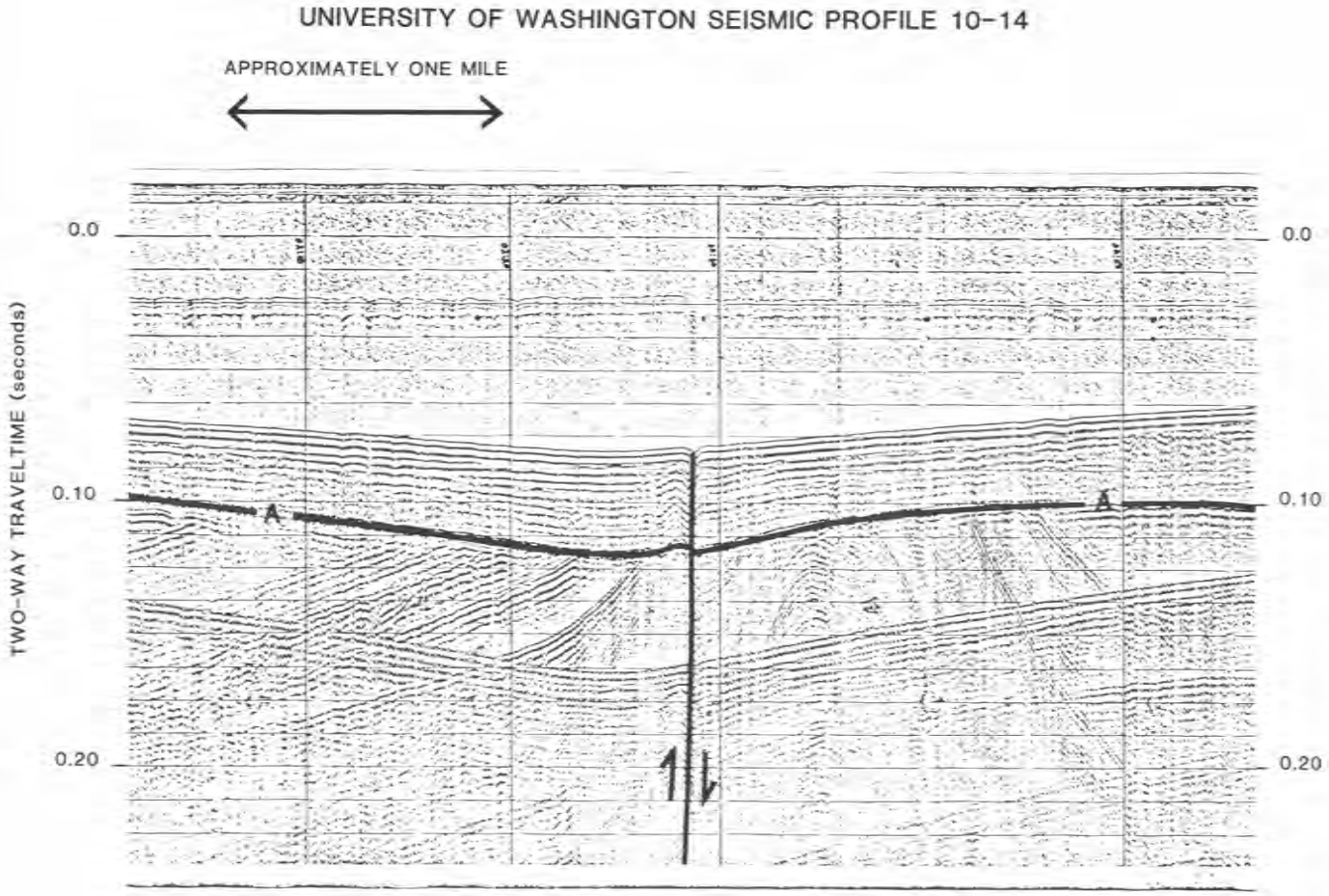

Figure 3. A seismic reflection profile acquired in 1967 approximately 10 miles offshore from the mouth of the Queets River during Cruise 10 of the University of Washington RV *Oceaneer*. The ocean surface is at 0.0 seconds two-way travel time (TWT), and the sea floor is at approximately 0.075 seconds TWT, which corresponds to a water depth of 190 feet. The series of laterally continuous black and white horizons recorded below the sea floor corresponds to reflections from discrete sedimentary strata and are termed events. This profile shows steeply dipping strata on the flanks of an anticline that have been truncated by erosion along event A. Nearly horizontal sediments have been deposited above horizon A; these strata have been displaced by a fault, indicated by the heavy vertical line near the center of the profile. This fault disrupts the sea-floor topography, indicating that fault movement is recent. The horizontal events recorded below 0.125 seconds TWT are multiple echoes of the strata lying between the sea floor and event A. The events reflecting from the strata on the flanks of the anticline continue through this spurious "sea-floor multiple". This seismic reflection profile images sedimentary strata approximately 500 feet below the sea floor; other seismic profiles presented in Palmer and Lingley (1989) image strata to approximately 10,000 feet below the sea floor.

We have used seismic reflection data acquired by the U.S. Geological Survey (Mann and Snavely, 1984; McClellan and Snavely, 1987, 1988), the Scripps Institution of Oceanography (Silver, 1972), and the University of Washington (Bennett and others, 1969a,b; Bennett and Henry, 1969) to evaluate possible domes on the Washington OCS that may act as oil and/or gas traps. The grid spacing of public-record seismic profiles is greater than the size of typical traps; therefore, it is probable that we have been unable to identify many potential traps. Similarly, the wide spacing of seismic profiles prevents accurate mapping of all dimensions of potential traps as well as limiting the ability to demonstrate that the identifiable anticlines have domal configurations. However, we can demonstrate that many folded structures exist in the offshore region, and we anticipate that some of these may act as traps.

Results of Previous Offshore Drilling

Four oil and gas exploratory wells have been drilled offshore of Washington. The State of Washington leased oil and gas rights in its territorial waters during the period from 1960 to 1964. The Union Oil Company drilled the first deep offshore exploratory well, the Tidelands State No. 2, in 1962, but no shows or reservoir rocks were encountered. In 1964, an offshore oil and gas lease sale was conducted by the Department of the Interior on the Washington and Oregon OCS (Webster, 1985). Three Washington OCS exploratory wells (the Shell P-0150/150A and P-0155, and the Pan American P-0141) were drilled on leases purchased during this sale at prices ranging from $5 to $310 per acre (Webster, 1985). Small flows of gas were tested in the P-0150A and traces of oil were logged in the P-0155. Montesano Formation sandstone reservoirs were not present in two of the OCS wells. In the P-0155, where a thick Montesano sandstone was present, the seal was inadequate. All four offshore exploratory wells were abandoned as dry holes. These results, however, do not condemn the area; many major oil- and gas-producing areas worldwide have had more than 25 dry holes drilled prior to the initial discovery.

OIL AND GAS POTENTIAL OF THE WASHINGTON OCS

Petroleum exploration is an intermittent process that is controlled by data availability, technical knowledge, results of previous exploration, and economic conditions. Offshore exploration ceased in the late 1960s because of the lack of encouraging results from the four offshore wells. Since that time, geologic and seismic data have improved significantly in both quality and quantity, and technical knowledge has increased substantially. Increased exploration interest in the Washington continental margin is foreseeable because of these factors, and because most areas favorable for easy discovery of large oil or gas accumulations worldwide have been thoroughly assessed by drilling.

The combination of possible traps, numerous oil shows, and an exceptional quality (if unpredictably distributed) Montesano sandstone reservoir suggests potential for a major energy resource on the Washington continental shelf. The motivating force for future exploration of offshore Washington would be the potential for discovery of a giant field (500 million barrels of oil or equivalent gas). Giant fields contain more than 70 percent of the world's recoverable oil. We regard the overall potential for discovery of a giant field on the Washington continental margin as 2 on a worldwide scale of 10. However, the best remaining unexplored basins, such as the Arctic National Wildlife Refuge, are 7 or 8 on this same scale, while most unexplored basins worldwide are rated 5 or less.

On the continental shelf, the potential for petroleum generation and for the occurrence of Montesano sandstone reservoirs is greatest near the coastline. The region within 12 miles of the coast and north of 47° latitude (the MMS highlighted area in Fig. 1) encompasses approximately 75 percent of the area on the Washington OCS which we regard as favorable for significant petroleum accumulations. We regard the potential for petroleum accumulations seaward of the continental shelf, on the continental slope and Pacific Ocean abyssal plain, as poor.

TECHNICAL SUMMARY

This section provides technical details that support some conclusions given in the preceding summary.

(1) The following is a brief history of some geologic events that affected the Washington continental margin. It has been prepared using work by Bergen and Bird (1972), Grady (1985), Rau (1970, 1973, 1975, 1979, 1980), Rau and McFarland (1982), Rau and Grocock, 1974), Rector (1958), Snavely (1987), Snavely and Kvenvolden (1988), Snavely and others (1986), Stewart (1970), Tabor (1972,1975), Tabor and Cady (1978), Walsh and others (1987), and Wagner and others (1986).

(a) *50 Ma*: Subsidence in the area of the present Olympic Mountains and partial topographic isolation of this area by development of thrusted (or constructional-volcanic?) highlands north of the Crescent thrust, south and east of the Southern Fault Zone, and on the east side of Willapa Bay. These highlands were composed of lower Eocene Crescent Formation basalts.

(b) 48 to 27 Ma: Deposition of turbidites of the Ozette melange in the area of the present Olympic Mountains and Washington continental shelf (approximately 48 to 35 Ma). A widespread depositional hiatus may have occurred during much of the Oligocene (35 to 27 Ma). The nature of the basement under these turbidites is unknown.

(c) *27 to 14 Ma*: Continued thrusting in the northwestern Olympic Peninsula parallel with the Crescent thrust. Deposition of the Hoh rock assemblage in areas now on the western Olympic Peninsula and Washington continental shelf.

(d) 17 to 12 (?) Ma: Regional uplift and erosion(?) of the Hoh and uplift of the Olympic Mountains.

(e) *12 to 8 (?) Ma*: Foundering of eroded Hoh and Ozette sequences in the area of the present shelf and subsequent deposition of hemipelagic sediments of the Montesano claystone member and equivalent units.

(f) *8 (?) to 5 Ma*: Development of the present continental shelf and continuous deposition of upper Montesano Formation and equivalent sediments including the Ocean City sand. Uplift was accompanied by strike-slip faulting and intermittent diapiric intrusion.

(g) *5 Ma to present*: Deposition of the Quinault and Quillayute Formations and Quaternary sediments. Intermittent diapiric intrusion and possible strike-slip faulting.

(2) Anticlines are common on the continental margin. Simple anticlines range from 0.5 to 7 miles in profile (as measured from the troughs of adjacent synclines). Diapiric uplifts are commonly greater than 2.5 miles in profile. The orientations and dimensions of these folds and diapirs cannot be mapped with the existing public-record seismic data set. It is not possible to map closure on any of these anticlines from these data.

(3) Porosity in the Hoh rock assemblage and Ozette melange sandstones mostly ranges from 5 to 30% (Fig. 2a), and thickness of sandstone units in 14 selected wells averages 34 feet. Permeability in the Hoh and Ozette is low due to high clay volumes and secondary mineralization. On the basis of well data, it is not possible to distinguish prospective Hoh and Ozette broken formations from nonprospective chaotic turbidites or melange fabrics in sandstones. House-sized sandstone olistoliths crop out as sea stacks along the coast.

(4) Porosity of the Montesano Formation sandstone member ranges from 25 to 32% (Fig. 2b), and sandstone unit thickness averages 40 feet. The Montesano sandstone member (Ocean City sand and equivalents) was drilled in the Ocean City area and in the P-0155 wildcat, where wireline log, sidewall core, and seismic data indicate that more than 600 feet of porous sandstone are locally present. Permeability in the Montesano sandstone member is typically greater than 500 millidarcies. This sandstone is not sealed in the Ocean City area or in the P-0155 well. Similar sandstones crop out on the east side of Aberdeen and directly north of Point Grenville. We regard these sandstones as the primary exploration target on the Washington continental margin.

(5) The Quinault and Quillayute Formations and equivalent strata are probably not buried to sufficient depths to be considered as conventional petroleum plays.

(6) Significant oil and gas shows were tested in the Ocean City, Hoh River, and Forks areas, and oil shows were logged in the P-0155 offshore wildcat. Numerous coastal outcrops of very dark gray mudstone and siltstone presently seep oil. Two tests of the P-0150A yielded 10 and 26 thousand cubic feet of gas per day from a zone in the Hoh rock assemblage (The Shell Oil Co., 1966), and several gas seeps have been located onshore.

(7) Rocks from the continental margin and western Olympic Peninsula analyzed to date have fair potential to generate natural gas (Kvenvolden and others, 1988b). Although some rocks in the Ozette melange near Forks have two rare biomarkers also found in oil samples from coastal wells and seeps (Kvenvolden and others, 1988a), no oil-prone source rocks have been identified in the study area.

(8) Geohistory analysis, thermal alteration indices, vitrinite reflectance, and T_{max} determinations indicate that the sections penetrated offshore are generally immature for petroleum generation (Brown and Ruth, 1982a-e used with permission of EXLOG, Inc.; Grady, 1985). Onshore, seeps and significant shows are concentrated between the coast and a parallel line roughly 20 miles to the east.

(9) The primary exploration play will probably be for the sweet, paraffinic oils rather than for gas.

(10) Structures dissected (or formed?) by strike-slip faults could facilitate migration between the Montesano reservoir sequences and underlying source rocks. These structures may also control deposition and/or distribution of sandstone sequences within the Montesano and Quinault

Formations. Similarly, marginal faulting along diapirs could facilitate migration between the Montesano reservoir sequences and underlying source rocks. A gas seep is present on the margin of a structure interpreted as a diapir by Rau and Grocock (1974), which is located onshore near Cape Elizabeth. Domes and stratigraphic truncations adjacent to cores of diapiric intrusions are potential petroleum traps.

(11) We speculate that a single, hypothetical Ozette or Hoh oil pool might contain 10 million barrels of recoverable oil. However, risked reserves for the Ozette and Hoh would be only a small fraction of this volume owing to discontinuous reservoir strata and to the difficulty of defining traps with seismic data.

(12) Speculative reserves for a single, hypothetical Montesano oil pool, assuming that the reservoir has the average porosity and thickness of those penetrated to date, are 20 million barrels. A 300-foot-thick Montesano sandstone reservoir, 50 percent full to spill, could contain 250 million barrels of recoverable oil.

(13) The entire shelf may have potential to contain gas and/or oil accumulations within the Ozette, Hoh, and Montesano sections. Areas directly adjacent to the coast are closer to the Montesano provenance and, consequently, are considered as more prospective with regard to sandstone reservoir development than areas farther west. Furthermore, the coastal area is adjacent to the zone of common seeps and shows. The potential of the continental slope and Pacific abyssal plain is considered poor.

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The topic for the **5th annual symposium of the Northwest Petroleum Association**, to be held May 18-20, 1989, will be the hydrocarbon potential of the Columbia Basin, Oregon and Washington. Emphasis will be on potentially productive Eocene and Oligocene sediments underlying the Columbia River basalts. A day of technical presentations and two days of field trips are scheduled. For more information, contact: Phil Brogan, 1426 NW Harmon Blvd., Bend, OR 97701; (503) 382-0650

COAL ACTIVITY IN WASHINGTON—1988

By Henry W. Schasse

Coal exploration activity in Washington continued at a low level because the coal market remains soft. Only one company explored for coal (in Whatcom County) during 1988.

The two Washington coal mines that operated during 1987 continued to produce coal during 1988. The Centralia Mine, operated by Washington Irrigation and Development Company (WIDCO), located 5 miles northeast of Centralia, Lewis County, in the Centralia-Chehalis Coal District, continued to be the state's largest coal producer. Pacific Coast Coal Co. (PCCC) continued to increase its production at its 2-year-old John Henry No. 1 Mine, located approximately 2 miles northeast of Black Diamond, King County, in the Green River Coal District.

WIDCO produced 5,034,935 clean short tons of subbituminous coal during 1988; this is approximately 639,000 tons more than it produced during 1987. The Centralia mine has produced an average of 4.1 million tons per year since it began production in 1971. The mine supplies the steam power plant located approximately a mile from the mine. Coal mined at Centralia comes largely from five coal seams that are stratigraphically near the middle of the Skookumchuck Formation, an upper member of the Eocene Puget Group. Coal production for 1988 was principally from two of those seams, the Smith and Big Dirty coal seams.

PCCC completed its second full year of production at its John Henry No. 1 mine, producing 110,157 short tons of bituminous coal. This represents an increase of 61,000 tons over its 1987 production. A large share of its 1988 production went to WIDCO to blend with coal mined at Centralia in order to maintain sulfur dioxide emissions within state and federal environmental limits at the Centralia steam plant. PCCC also supplied coal to state institutions at Monroe and Shelton and to the U.S. Navy submarine facility at Bangor for their heating plants. In addition, some coal was sold to the Ideal Cement Company.

PCCC mined the Franklin Nos. 7, 8, 9, and 10 coal seams during 1988. (Figure 1). These coal seams, which have a high-volatile B bituminous rank, occur stratigraphically near the base of the Eocene Puget Group sediments in the Green River Coal District (Schasse, 1987). PCCC continues to truck its coal to a wash plant operated by Palmer Coking Coal Co. at Black Diamond. Its plans for a new beneficiation plant at the mine remain on hold until it has acquired sufficient long-term contracts from industrial customers to justify the necessary capital outlay. The John Henry No. 1 mine has a design capacity of 250,000 tons per year. It currently mines its coal at an overall recovery of 75 percent.

Cravat Coal Company of Cadiz, Ohio, drilled 10 to 20 shallow exploratory holes on the No. 1 (Discovery) coal seam in the Glacier coal field in north-central Whatcom County from June through August 1988 (Schasse, 1988). On the basis of reportedly disappointing results from their drilling, Cravat Coal Co. elected to drop its lease with the A. Firchau es-

Figure 1. View east toward the west highwall in Pit No. 1 of John Henry No. 1 open-pit coal mine, 2 miles northeast of Black Diamond, August 1988. The highwall exposes the Franklin nos. 7, 8, and 9 coal seams in a faulted anticline; these are highlighted by several thin, light-colored, volcanic ash beds.

tate, which leases the Glacier coal field from the land owner, the Glacier Land Co. Representatives of the Firchau estate have elected to keep details of the past summer's exploratory drilling proprietary at this time.

References Cited

Schasse, H. W., 1987, Coal activity in Washington–1986: Washington Geologic Newsletter, v. 15, no. 1, p. 21-23.

Schasse, H. W., 1988, Coal exploration in Whatcom County: Washington Geologic Newsletter, v. 16, no. 3, p. 11.

Geologic Hazards Program—Continued

It was the consensus of the participants that during the next decade the NEHRP effort should shift resources from pure research to applied research, data translation, and application of knowledge by state and local governments. It was also recommended that an oversight commission be established to advise the four federal agencies that are responsible for carrying out NEHRP under the auspices of the Earthquake Hazards Reduction Act. A more effective hazards reduction program should result. The report will be released by the USGS as Open-File Report 88-13B.

A portion of the NEHRP review workshop was devoted to receiving information about the International Decade for Natural Hazard Reduction. The initial proposal at the United Nations was sponsored by 94 countries. As it was not supported by the U.S., the proposal failed. A substitute U.S. program under the auspices of UNESCO was adopted, its committee consisting of 24 nations, each having one representative and the U.S. having two members. The committee met in Geneva, Switzerland, in July, then in New York during October. Two final meetings during January and March 1989 will be held in Morocco and Japan, respectively. The first U.S. meeting of the corresponding U.S. Decade for Natural Disaster Reduction took place in mid-October. It was agreed that the program decade would start January 1, 1990; that the national effot would be headed by a U.S. committee with an academic chairperson; and the National Academy of Sciences (NAS) would act in an advisory capacity and direct the new administration's transition team by February 1, 1989. Serving on the U.S. committee will be a federal secretariat with representation from USGS, National Oceanic and Atmospheric Administration and the U.S. Forest Service. Funding will be provided by the USGS and NAS.

A consortium of state and local governments, academic institutions, professional associations, and others will implement the program objectives. Rapid onset hazards highlighted for study and information transfer are earthquakes, volcanic eruptions, tsunamis, landslides, wind storms, and wildfires; also to be considered is drought. Several national demonstration projects have been suggested, including one for the Pacific Northwest. More is to come on this subject during 1989 as concepts are formalized by the U.S. Committee for Natural Hazard Reduction.

The Geohazards '88 symposium was held at the western Regional headquarters of the USGS in Menlo Park, Calif., and was a collaboration of knowledge producers and knowledge users. Attendance was about evenly divided between geologists, seismologists, and hydrologists on the one hand, and urban planners, emergency management specialists, and elected officials on the other. The conference consisted of four sessions highlighting current USGS research on the identification and mitigation of geologic hazards, particularly in western states.

USGS and California Division of Mines and Geology (CDMG) seismologists described their efforts at predicting the probabilities and effects of earthquakes along the San Andreas Fault, principally in the Los Angeles and San Francisco areas. USGS geologists discussed landslide hazards and volcanic hazards. The discussion of landslides focused on efforts to describe, catalog, and predict landslides in the San Francisco Bay region. Volcanic hazards in the Cascade Range were described, and attempts to predict future volcanic activities in eastern California were discussed. USGS hydrologists discussed water pollution both in San Francisco Bay and in the San Joaquin Valley. Most of the talks were also presented as poster sessions.

Following the formal sessions there was a lively panel discussion of the pitfalls of disseminating scientific information about geologic hazards to local officials charged with implementing appropriate measures. Of particular interest was the effect of a volcanic eruption warning on the affected community. Considerable distrust was generated because the warning appeared in the press before the official announcement. It was alleged that the ensuing hysteria depressed property values in a popular resort area, underscoring the need for carefully timed and planned communications.

The Division has available 30 copies of the December 1939 Monthly Bulletin of the State College of Washington, v. 22, no. 7, part 1, which includes the following articles:

McGivern, J. G., Directional properties of worked magnesium alloys.

Culver, H. E., Some geologic aspects of the magnesite deposits of Washington.

Send your request to Ray Lasmanis, State Geologist (see address on p. 2 of this Newsletter).

Geothermal Drilling by the State of Washington in 1988

By Brent Barnett

From September to early November of 1988, the Washington Division of Geology and Earth Resources successfully completed the drilling of eight geothermal gradient test holes in the Cascade Range of southern Washington. Funding for the project was provided by a grant from the U.S. Department of Energy, with subordinate State matching funds. Drill site selection and project supervision were done by Brent Barnett and Michael Korosec of the Division staff.

The holes are located in the Gifford Pinchot National Forest along a line extending roughly south from Mount Rainier to near the Columbia River (Figure 1). This region was selected because of favorable results from earlier projects (Barnett and Korosec, 1986; Korosec, 1984; Schuster and others, 1978), and it was designed to fill gaps remaining in the areal distribution of temperature-gradient and heat flow data points. Young volcanic features, prominent faults, and other inferred structures were used as more specific criteria for selecting individual sites. Each of the eight holes was drilled to approximately 152 meters depth.

The results of down-hole temperature measurements from each hole are shown diagrammatically in Figure 2. Preliminary gradient values in °C/km (not corrected for terrain effect) are:

Carlton Creek (DNR 88-1), 52;

Chambers Creek (DNR 88-3), 58;

Table Mountain (DNR 88-4), 56;

Pin Creek (DNR 88-6), 50;

Quartz Creek (DNR 88-7), 34;

Shingle Mountain (DNR 88-8), 34.

Both the Snyder Mountain (DNR 88-2) and Babyshoe Ridge (DNR 88-5) holes appear to be isothermal down to 152 m, and thermally decoupled from regional crustal heat flow. These preliminary results confirm the existence of a widespread zone of high heat flow and temperature gradients, and have further delineated the extent of this significant geothermal energy target.

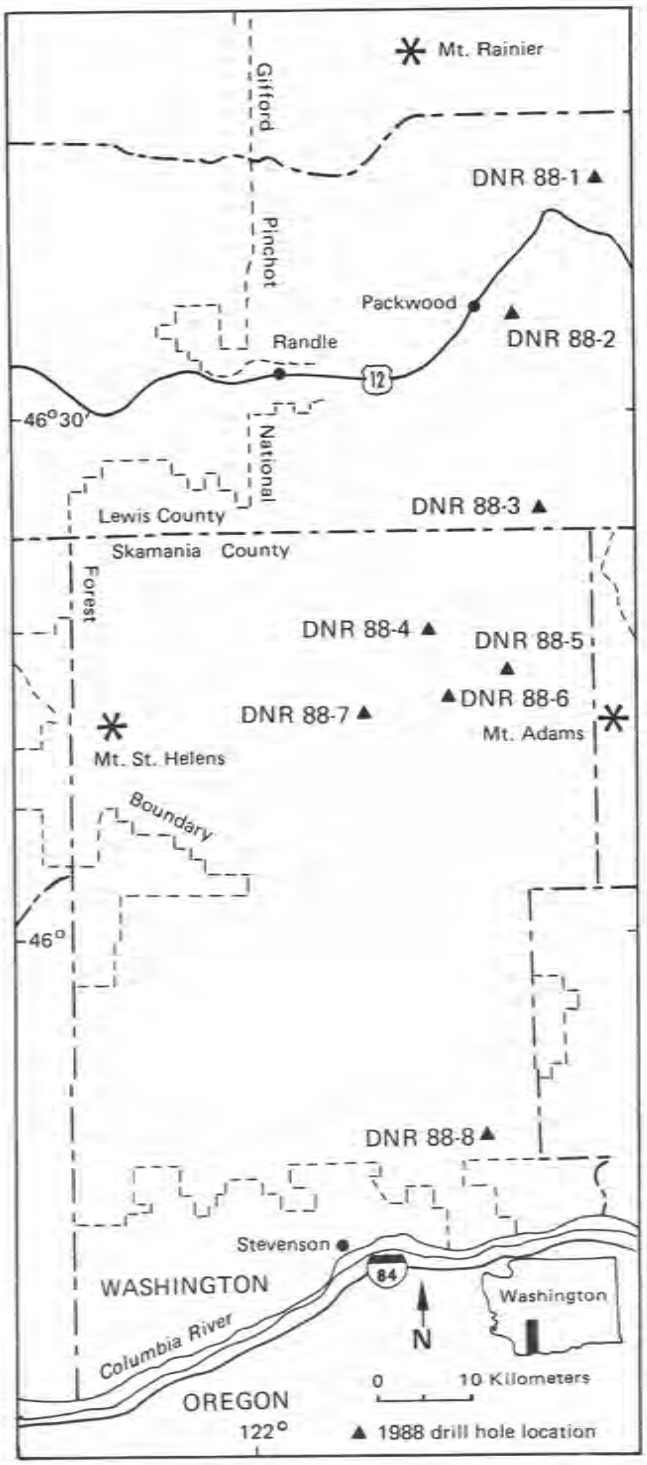

Figure 1. Locations of the geothermal gradient test holes drilled by the Division of Geology and Earth Resources in 1988.

References Cited

Barnett, Brent; Korosec, M. A., 1986, Geothermal exploratory drilling by the State of Washington in 1985: Washington Geologic Newsletter, vol. 14, no. 1-2, p. 21-28.

Korosec, M. A., 1984, Summary of geothermal exploration activity in the State of Washington from 1978 to 1983: National Technical Information Service DOE/ET/27014-T19 (DE84014863). [Also released as DGER Open File Report 84-2.]

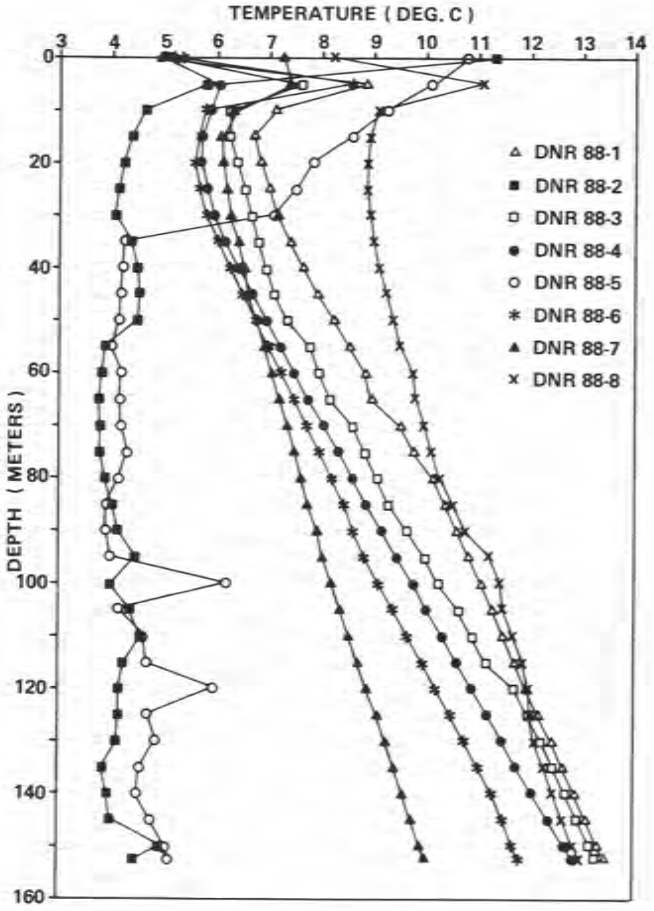

Figure 2. Temperature-depth curves for the 1988 geothermal gradient test holes. Readings were taken at 5-meter intervals in each hole. Large deflections on the curve of DNR 88-5 are due to the exothermic reaction of curing cement which was used in sealing the hole. The gradients of both DNR 88-5 and DNR 88-8 had not yet stabilized by the time of the last logging of the holes.

Schuster, J. E.; Blackwell, D. D.; Hammond, P. E.; Hunting, M. T., 1978, Heat flow studies in the Steamboat Mountain-Lemei Rock Area, Skamania County, Washington: Washington Division of Geology and Earth Resources Information Circular 62, 56 p.

Drilling operations at the Quartz Creek (DNR88-7) site, one of eight geothermal gradient test holes drilled by the Division in 1988.

Final Interior Rulesmaking Increases Mining Law Fees in 1989

The Bureau of Land Management (BLM) has issued final rules that would facilitate greater cost recovery under its mining law administration program by revising certain existing fees and establishing new fees. The rules became effective Jan. 3, 1989.

According to BLM Director Robert F. Burford, the fee changes are being implemented under Title V of the Independent Offices Appropriation Act of 1952. Title V provides that federal agencies should recover costs of program administration for services that provide special benefits to identifiable non-federal recipients above and beyond those accruing to the public at large.

"In Fiscal Year 1987, we recorded more than 147,000 new mining claims and processed about 654,000 filings of affidavits for assessment work," Burford said. "We also recorded and processed many other mining claim-related documents. This rulemaking allows us to recover more of the costs of administering this program."

In Oregon and Washington, there were 11,700 new mining claims recorded in FY 1987. More than 32,300 affidavits were filed for assessment work.

Burford indicated that the increased fees would generate nearly $4.5 million in additional annual revenues that, when combined with current revenues from existing fees, would make available approximately $5.2 million to be appropriated to BLM for the mining law program.

Burford emphasized that BLM has been sensitive to the impact this rulemaking might have on the min-

ing community, and has worked to develop fees that would be equitable to all segments of that community.

"Last spring, I personally engaged in 'pulse taking' discussions on the proposal with many groups, individuals, and Members of Congress," Burford said. "Then, when we issued the proposed rulemaking June 23, I told my staff to take the unprecedented step of sending 60,000 postcards to notify mining claimants that the rulemaking was available for comment. We wanted to ensure that the people most likely to be affected by the rulemaking would have ample opportunity to review it.

"In addition, we have delayed issuing the final regulations until December so that they will become effective early next year, rather than becoming effective right at the end of this year. We didn't believe it would be fair to require peopled filing affidavits of assessment work in late December to pay a $5-per-claim fee when people who file in November or early December could file without paying a fee. Plus, this will give mining claimants about nine months to plan for this new fee."

Mining claimants are required by the Mining Law of 1872 to do at least $100 worth of assessment work per claim per year. Most claimants file their affidavits of assessment work with BLM in the late fall or early winter each year. The $5-per-claim per-year filing fee would increase the federally imposed component of the cost of maintaining each claim by not more than 5 percent per year.

According to BLM records, approximately 85 percent of federal mining claimants hold 20 or fewer mining claims. The new $5 fee would amount to no more than $100 per year for these claimants. Because many claimants seeking to make discoveries on their claims are doing more than the minimum $100 annual labor, the impact on their total costs would be much less than 5 percent. An analysis of the processing costs for BLM in Fiscal Year 1987 indicates that each claim for which an affidavit of assessment work (or notice of intent to hold) was filed required an expenditure of $7.42 by BLM.

BLM administers the mineral estate underlying approximately 600 million acres of federal lands, primarily in the West; approximately half of this acreage is prospectively subject to the Mining Law of 1872. Under the Mining Law, a U.S. citizen is entitled to locate a claim on federal lands that are not otherwise withdrawn from mineral entry. The claimant may then explore for minerals and develop any valuable deposits that are discovered. Any activity disturbing more than 5 acres requires submission and approval of a plan of operations.

To obtain these benefits, a claimant must properly maintain the claim by, among other things, complying with the Federal Land Policy and Management Act of 1976. This Act requires recordation of each claim initially, followed by an annual filing of an affidavit that the required amount of assessment work has been done, or a notice that the owner intends to hold the claim.

[Source: BLM Oregon State Office, Portland, December 9, 1988]

Denver Consultant Elected in NW Mining Change

The Northwest Mining Association, generally headed by an operator or an explorationist, has gone to a consultant as its new president.

T. M. Li of Denver took over January 1. Li, vice president and general manager for Behre Dolbear-Riverside, Inc., considered one of the top consulting mining engineering groups in the U.S., takes over from Bill Booth of Hecla Mining Company of Coeur d'Alene, Idaho.

Mark Anderson, general manager of ASAMERA of Wenatchee, was elected first vice president of the Spokane-based organization of 2,200 members from the mineral industry throughout North America.

Other new officers are David A. Holmes, exploration manager for Meridian Minerals Co. in Englewood, Colo., second vice president, and David M. Menard, vice president of Washington Trust Bank in Spokane, treasurer.

John L. Neff, a Spokane attorney, was re-elected secretary. Bill Mote of Spokane, the association's executive director, is a standing vice president.

T. M. Li

Geological Society of America Sectional Meetings

The Cordilleran and Rocky Mountain Sections of the Geological Society of America will hold their annual meetings from May 8 to 11, 1989, in conjunction with the Rocky Mountain and Pacific Sections of the Paleontological Society, the Pacific Northwest Section of the National Association of Geology Teachers, and the Association for Women Geoscientists. The meetings, scheduled for the Spokane, Washington, Convention Center, are cosponsored by the Department of Geology of Eastern Washington University and the Department of Geology and Geological Engineering, University of Idaho. The meeting is also hosted by the Spokane office of the Geologic Division, U.S. Geological Survey; the Western Field Operations Center, U.S. Bureau of Mines; the Northwest Mining Association; the Division of Geology and Earth Resources, Washington Department of Natural Resources; and the Idaho Geological Survey.

PROGRAM

Nearly 650 papers covering a wide spectrum of the geology of western North America will be presented in symposia, technical sessions, and poster sessions. Twenty-five field trips will be led into the diverse geologic landscape of the Northern Rocky Mountains, Okanogan Highlands, Blue Mountains, Cascade Mountains, Columbia Basin, and Snake River Plain.

Symposia

1. **Geophysical Framework of the Cordillera**; Christopher J. Potter and Walter D. Mooney, Presiding
2. **Evolution of the Proterozoic Rocks of the Northern Cordillera**

   Part I: Sedimentation and Tectonics; James W. Whipple, Presiding

   Part II: Economic Geology; John C. Balla, Presiding
3. **Synoptic Paleozoic Biogeography of Selected Tectonic Fragments, Western North America**; J. Thomas Dutro, Jr., Presiding
4. **Upper Paleozoic Biostratigraphy and Stratigraphy of the Northern Rocky Mountains**; Bruce R. Wardlaw and Ernest H. Gilmour, Presiding
5. **Upper Paleozoic Orogenies of Western North America**; Linda B. McCollum and Nancy L. Joseph, Presiding.
6. **Late Paleozoic and Early Mesozoic Paleogeographic Relations: Klamath Mountains, Sierra Nevada, and Related Rocks**; M. Meghan Miller and David S. Harwood, Presiding
7. **Western Edge of the North American Continent: Mesozoic Tectonic Evolution**; Karen Lund and Mel A. Kuntz, Presiding
8. **Deformational History of the Coast Mountains and North Cascades, Washington, British Columbia, and Southeast Alaska**

   Part I: North Cascades; Darrel S. Cowan, Robert B. Miller, and Paul J. Umhoefer, Presiding

   Part II: Coast Mountains; Margaret Rusmore, George E. Gehrels, and Glenn J. Woodsworth, Presiding
9. **Tectonic Evolution of the Brooks Range, Alaska**; Wesley K. Wallace, Presiding
10. **Paleogene Sedimentation, Volcanism, and Tectonics of the Western United States**; Thomas D. Fouch and Alan R. Niem, Presiding
11. **Paleocene-Eocene Crustal Extension and Associated Dome Formation, Volcanism, Plutonism, and Sedimentation in Northeast Washington and Adjacent Areas**; Kenneth F. Fox, Jr. and A. John Watkinson, Presiding
12. **Tectonic Setting of Volcanic-Hosted Ore Deposits in the Pacific Northwest**; Byron R. Berger, Presiding
13. **Neogene Volcanism in the Western United States**

    Part I: Magmatism and Tectonism in and Adjacent to the Cascade Province; Donald A. Swanson and Richard M. Conrey, Presiding

    Part II: Magmatism and Tectonism in the Cordilleran Continental Interior; William P. Leeman and William K. Hart, Presiding
14. **Neotectonics of the Cascadia Subduction Zone**; Robert S. Yeats and Brian F. Atwater, Presiding
15. **Earthquake-Induced Landslides**; Robert L. Schuster and Gerald W. Thorsen, Presiding
16. **Quaternary Catastrophic Floods Generated by Failure of Natural Dams in the Western United States**; John P. Buchanan and Keith L. Stoffel, Presiding
17. **Use of Soils for Correlation and Interpretation of Quaternary Geologic Events**; Eric V. McDonald and Alan J. Busacca, Presiding
18. **Hydrogeologic and Hydrogeochemical Investigations for Waste Management**; Barbara Cooke Williams, Presiding
19. **Radon in the Natural Environment**; Raymond Tekverk and Jan E. Fay, Presiding
20. **Earth Science Education**; Kurt L. Othberg, Presiding

FIELD TRIPS

The Washington Division of Geology and Earth Resources and the Idaho Geological Survey will be publishing field trip guidebooks for the Cordilleran and Rocky Mountain sections, respectively. The guidebooks can be purchased at the meeting.

Pre-Meeting

1. **The Priest River Complex and the Newport Fault Zone**; Brady R. Rhodes, Tekla A. Harms, and Donald W. Hyndman, Leaders

2. **Volcanism, Plutonism, and Sedimentation Associated with Core Complex and Graben Development in the Central Okanogan Highlands, Washington**; R. Wade Holder, Grace A. McCarley Holder, David R. Gaylord, and Kenneth F. Fox, Jr., Leaders
3. **Paleogene Strike-Slip Sedimentary Basins of Central Washington**; James E. Evans and Samuel Y. Johnson, Leaders
4. **Structure of the Yakima Fold Belt, Central Washington**; Stephen Reidel and Newell P. Campbell, Leaders
5. **Cambrian of Northern Idaho and Northwestern Montana**; John Bush, Leader
6. **Geology, Alteration, and Mineralogy of the Alkaline Gem Stocks, Northern Idaho**; D. Kate Schalck, Leader
7. **The Miocene Clarkia Fossil Beds of Northern Idaho**; Jack Smiley, Leader
8. **Transect through the Baker-Wallowa-Seven Devils Terranes: A Forearc to Island Arc Transition in Northeastern Oregon?**; M. Allan Kays and Ellen M. Bishop, Leaders

Concurrent with Meeting

9. **The Northern Columbia Plateau from the Air**; Dale F. Stradling and Eugene P. Kiver, Leaders
10. **Geologic Factors Influencing Residential Radon**; Raymond Tekverk and Jan E. Fay, Leaders
11. **Geologic Controls of Groundwater Movement in the Spokane Aquifer**; George E. Maddox, Leader

Post-Meeting

12. **The Deer Trail Group: Is it of the Belt Supergroup?**; Fred K. Miller and James W. Whipple, Leaders
13. **Paleozoic and Lower Triassic Biostratigraphy and Paleogeography of Northeastern Washington**; J. Thomas Dutro, Jr. and Ernest H. Gilmour, Leaders
14. **Mineralization and Tectonics in the Southern Kootenay Arc and Purcell Anticline**; Richard Lambert and Trygve Höy, Leaders
15. **Elements of the Cascades 'Collisional' Orogen: A Transect from the Methow Basin to the San Juan Islands, Washington**; Michael F. McGroder, Robert B. Miller, Mark T. Brandon, and Ralph Haugerud, Presiding
16. **Geology of Eocene Mineral Deposits, Ferry County, Washington**; Richard Tschauder, Leader
17. **Sources for the Columbia River Basalt Group**; Peter R. Hooper and Stephen Reidel, Leaders
18. **Lake Missoula Floods and Channeled Scablands**

    Part I: Evidence for the Late Wisconsin Ice Dam and Floods in the Purcell Trench; Roy M. Breckenridge, Leader

    Part II: Glacial and Multiple Flood History of the Northern Borderlands; Eugene P. Kiver and Dale F. Stradling, Leaders

    Part III: Record of Pre-Late Wisconsin Floods and Late Wisconsin Flood Features; Alan J. Busacca and Eric V. McDonald, Leaders
19. **Geologic Engineering and Landslide Mitigation at Grand Coulee Dam**; Greg W. Behrens and Phil J. Hansen, Leaders
20. **Synplutonic Mafic Dikes and Granite Intrusion Migmatites of the Idaho Batholith and Mylonite of the Western Idaho Suture Zone**; Donald W. Hyndman, Leader
21. **Subaqueous Basalt Eruptions into Pliocene Lake Idaho, Snake River Plain, Idaho**; Margaret D. Jenks and Bill Bonnichsen, Leaders
22. **Hydrogeology of Mine Tailings, Coeur d'Alene Mining District, Northern Idaho**; Dale Ralston and John Riley, Leaders
23. **Geology of Hells Canyon from a Raft**; Rolland Reid and Roy E. Williams, Leaders
24. **A Structural Section Through a 25-Kilometer-Thick Thrust System in West-Central Montana: Paradise to Garrison**; Jim Sears and Christopher P. Weiss, Leaders
25. **History and Geology of the Coeur d'Alene Mining District, Northern Idaho**; Peter L. Siems, James Constantopoulos, and Earl H. Bennett, Leaders

EXHIBITS

Exhibits will be displayed in the main hall of the Convention Center, adjacent to the poster sessions and meeting rooms. The cost of booths will be $100 for educational and non-profit institutions and $250 for commercial exhibitors.

SPECIAL EVENTS

Don't miss Bloomsday, the largest timed road race in America, with more than 59,000 participants! The 12-kilometer (7.46-mile) race starts at 9 a.m. on Sunday, May 7. All official participants who cross the finish line are awarded T-shirts, and special prizes will be awarded to winners of GSA competition.

A dinner/dance/scenic cruise on beautiful Lake Coeur d'Alene in northern Idaho is planned for Tuesday night, May 9. Bus transportation will be provided.

INFORMATION

For registration information, contact Margie Wallace, Conference Coordinator, Regional University Conferences, M.S. 11, Eastern Washington University, Cheney, WA 99004, (509) 359-2406.

For program information, contact John P. Buchanan, Program Chairman, Department of Geology, M.S. 70, Eastern Washington University, Cheney, WA 99004, (509) 359-7493.

For exhibit information, contact Russell Boggs, Exhibits Coordinator, Department of Geology, M.S. 70, Eastern Washington University, Cheney, WA 99004, (509) 359-7497.

Defense Waste Cleanup: A Proposal for a National Solution

Governor Booth Gardner *and* Governor Neil Goldschmidt
State of Washington State of Oregon

November 30, 1988

I. Introduction

Over the past 45 years, the United States has developed, produced and tested nuclear weapons at sites in thirteen states. During this period, massive quantities of radioactive and chemical wastes have been allowed to accumulate at these sites, including Washington's Hanford Reservation. Some past disposal practices were inadequate. Aging "temporary" storage facilities have failed. As a result, these wastes now threaten the environment and the public health and safety.

As the Governors of Oregon and Washington, we have joined forces to stave off that threat. We are pursuing the retrieval, safe cleanup and permanent disposal of Hanford's radioactive and chemical wastes. Our goal is to achieve this cleanup within 30 years.

The defense waste problem is more than an important Northwest issue. It is a national problem. It involves U.S. Department of Energy (USDOE) defense facilities in twelve other states. We strongly believe that the long-term answer to Hanford's problems ultimately lies in a national effort to clean up all USDOE defense facilities.

Accordingly, we are calling for prompt and decisive action by Congress to enact legislation which will create an effective, long-term cleanup program. It must cover the cleanup and permanent disposal of radioactive and chemical wastes at Hanford and other USDOE defense facilities.

II. The Need for a National Cleanup program

Recent reports by USDOE and the General Accounting Office (GAO) document serious waste and contamination problems at virtually every USDOE defense facility. Cases of extensive soil and groundwater contamination are common. In some cases, groundwater contamination is thousands of times above federal drinking water standards. At two installations, soil contamination levels hundreds to thousands of times that of background levels have been reported. Further, the full extent of contamination at USDOE facilities remains unknown. New problems continue to come to light.

In July 1988, USDOE told Congress that defense waste cleanup could cost as much as $110 billion over the next 50 years. The GAO feels the cost may be as high as $130 billion. Despite these cost estimates, only about $975 million was appropriated in FY 1989. And, the major portion of these funds is for continued management of waste in temporary storage—and not for cleanup and permanent disposal.

USDOE has made progress in starting cleanup at a number of facilities, including Hanford. But, it remains uncertain whether this work will be completed before serious and permanent harm is done. There is no firm federal commitment to the cleanup. Schedules have slipped repeatedly. USDOE has no milestones or deadlines for completing cleanup work. Funding is far less than needed. Application and enforcement of federal and state laws and regulations are uncertain. The role of affected states and tribes is not clear. Public confidence in the ability to handle these wastes safely has seriously eroded.

The longer cleanup is delayed, the more costly and dangerous it will be. Hundreds of millions of dollars will continue to be spent on temporary storage. Aging storage facilities will continue to fail. Waste forms now stable may not remain so. Wastes will continue to spread through the environment, contaminating more soil and water.

The time has come for the federal government to solve the waste problem at Hanford and the other USDOE sites. It is time for a firm and substantive federal commitment. These wastes have been produced as part of the nation's defense programs. Their cleanup and disposal are a national obligation.

The magnitude of waste cleanup and disposal problems dictates the need for a national effort to clean up all USDOE sites. A credible cleanup program must ensure that radioactive and chemical wastes are kept away from people for as long as the wastes are dangerous. The program must include:

1. A detailed schedule;
2. Sufficient funding;
3. An effective regulatory structure;
4. The means to build and maintain public confidence; and
5. The development of advanced technologies to ensure safe, thorough and cost effective waste cleanup and disposal.

III. Key Elements of a National Program

Congress must take action now to ensure the safe and expeditious cleanup of radioactive hazardous and mixed wastes at all USDOE facilities. The program must address these points:

A. Schedule for Cleanup

There must be a firm commitment to complete the cleanup and disposal within a reasonable and specific period of time. In 1983, USDOE proposed the cleanup of radioactive wastes at Hanford, the Savannah River plant and the Idaho National Engineering Laboratory within 30 years. Now USDOE hints it will take 50 to 60 years to complete the cleanup.

Without a firm schedule, there is no assurance that the critical cleanup work will be completed in a timely manner—if at all. Without a schedule, there is no means by which to rank priorities, measure performance, determine funding needs or allocate resources.

The program must set milestones and deadlines to complete the cleanup. Federal environmental laws provide a precedent for setting a compliance deadline. We feel that a commitment to clean up all USDOE facilities within 30 years is both essential and achievable.

The program must also include a national priority system. That system must ensure that the wastes that pose the greatest public and environmental risks are handled first. In must ensure the prompt elimination of immediate threats. It must also ensure the cleanup and disposal of any other wastes before the public is put at risk. The system must consider people at risk, environmental factors, and the nature and volume of wastes. It must also take

An agreement between the federal government and the State of Washington signed 2/27/89 states that Washington will receive

into account the complexities of cleanup and the costs of deferring action.

The program must provide for the schedule adjustments needed to deal with unforeseen problems. USDOE must work with federal and state regulatory agencies to prepare and implement detailed work plans. The plans must be consistent with national priorities and deadlines. USDOE should have the flexibility to adjust schedules and reallocate resources, so long as such action will not extend cleanup work beyond the deadline. USDOE should keep Congress fully apprised of its progress and any major changes in work schedules and plans.

B. Funding

The program must be able to assure adequate and long-term funding for waste cleanup and disposal. An effective cleanup program will require a Congressional commitment to substantially increase funding levels for cleanup.

A trust fund to finance cleanup and disposal work should be considered. Direct appropriations to the fund should be sufficient to ensure the cleanup of existing wastes by the deadlines set by Congress. The proper handling, storage and disposal of wastes generated in the future should be on a "pay-as-you-go" basis. Agencies responsible for the wastes should be required to make annual payments to the trust fund.

Payments to the fund must be sufficient to cover USDOE cleanup costs. The payments must also cover costs incurred by the U.S. Environmental Protection Agency (EPA) and the affected states and Indian tribes. The distribution of trust funds must be based on national cleanup priorities and on work schedules for completing cleanup activities by the established deadline.

C. Compliance with Federal, State Regulations

For over 40 years, waste handling, storage and disposal has been largely exempt from any independent oversight. In a number of instances, poor waste management and disposal practices have knowingly been tolerated. These practices have contributed significantly to the waste cleanup and contamination problems. USDOE has acknowledged these past practices. It has stated that it will comply with state and federal regulations in the future. But, the situation remains uncertain.

The federal government has attempted to block the application and enforcement of state Resource Conservation and Recovery Act (RCRA) programs at Colorado's Rocky Mountain Arsenal and USDOE facilities. These actions make state regulatory authority questionable. USDOE also continues to challenge EPA's authority to enforce federal regulations and standards. These challenges raise grave doubts that the federal government will effectively regulate itself.

The program must set up a clear regulatory framework for the cleanup. State and federal regulatory programs are key to an effective and credible cleanup process. These regulatory programs provide the independent authority needed to ensure that waste problems are fully evaluated and that corrective actions are both timely and appropriate.

The program must direct that all cleanup and disposal work strictly comply with applicable federal and state laws and regulations. EPA must have the clear authority to issue orders and enforce compliance with approved cleanup plans and schedules.

The role of state regulators must also be reaffirmed. This is especially true where a state has authority to implement federal laws such as RCRA. The implementation of the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) at USDOE facilities should not supersede or replace the implementation of RCRA for active hazardous and mixed waste sites. Likewise, the program must uphold a state's delegated authority to implement and enforce other federal environmental regulations.

Finally, since federal and state regulatory programs are critical parts of the cleanup process, the program must ensure that both EPA and the states have adequate funding for regulatory functions.

D. Public Confidence

The magnitude, history and nature of the nuclear weapons waste problems make public confidence and acceptance crucial to cleanup success. The public must be fully aware of the problems. People must be convinced that cleanup solutions will ensure a safe and healthy environment.

To win public confidence, the decision-making and review processes must be open to the public. People must have the opportunity to understand the issues. They must have the chance to influence decisions relating to cleanup, transportation and disposal of wastes.

In this effort, the affected states and Indian tribes should play a key role in public involvement and education programs. The cleanup program must provide for and fund state and tribal activities such as:

1. Technical review of cleanup plans and methods;
2. Transportation planning and emergency response;
3. Environmental monitoring of waste sites and cleanup activities; and
4. Public information and involvement programs.

E. Development of Cleanup Technology

The diversity of environmental conditions coupled with the variety of waste forms, types and volumes found at USDOE sites present a formidable challenge to an effective cleanup program. We need to ensure the safest, most thorough and cost efficient cleanup and disposal effort possible. We must not limit our options solely to technology currently available. The program must provide for the continuing research and development of advanced cleanup and disposal technology.

IV. Conclusion

For decades, radioactive and hazardous chemical wastes have been allowed to accumulate at USDOE defense facilities across the nation, including Washington's Hanford Reservation. Today, as the result of inadequate past disposal practices and failing temporary storage facilities, these wastes pose a serious threat to the public safety and the environment.

While USDOE has begun to acknowledge and correct the problems posed by the wastes, the future is uncertain. The cleanup and disposal of wastes will cost billions of dollars and require decades to complete. Yet, no firm schedule exists and funding lags far behind requirements for an effective cleanup effort.

If we are to ensure a safe and healthy environment for the citizens of the Northwest and the nation, decisive action is essential. It is time for the federal government to fulfill its obligation to ensure the safe and permanent disposal of these wastes. I urge Congress to act quickly in establishing an effective and credible cleanup program for USDOE facilities.

$2.9 million between now and mid-1991 to clean up Hanford waste. Future funding must be appropriated by Congress.

Selected Additions to the Division of Geology and Earth Resources Library

October, 1988 though January, 1989

THESES

Adams, Benjamin Nickolas, 1988, Depositional environment, petrography, and tectonic implications of informally named middle to late Eocene Marine strata, western Olympic Peninsula, Washington: Western Washington University Master of Science thesis, 163 p.

Bottomley, Richard J., 1975, Argon-40/Argon-39 dating of basalts from the Columbia River plateau: University of Toronto Master of Science thesis, 103 p.

Carkin, Brad A., 1988, The geology and petrology of the Fifes Peak Formation in the Cliffdell area, central Cascades, Washington: Western Washington University Master of Science thesis, 157 p., 2 plates.

Denny, Stuart, 1988, Crustal structure of the Juan de Fuca Ridge as determined from deep towed seismic reflection profiles: University of Washington Master of Science thesis, 95 p.

Evans, J. E., 1988, Depositional environments, basin evolution and tectonic significance of the Eocene Chumstick Formation, Cascade Range, Washington: University of Washington Doctor of Philosophy thesis, 325 p.

Fuller, B. N., 1987, Seismic reflection data acquisition problems in the Columbia River Plateau and Snake River Plain: University of Wyoming Master of Science thesis, 87 p.

Ma, Li, 1988, Regional tectonic stress in western Washington from focal mechanisms of crustal and subcrustal earthquakes: University of Washington Master of Science thesis, 84 p.

Maloy, John A., 1988, Changes in grain-size distribution in a gravel-bed stream due to a point-source influx of fine sediment: Western Washington University Master of Science thesis, 50 p.

Margolis, Jacob, 1987, Structure and hydrothermal alteration associated with epithermal Au-Ag mineralization, Wenatchee Heights, Washington: University of Washington Master of Science thesis, 90 p.

McKiness, J. P., 1988, The Quaternary system of the eastern Spokane Valley and the lower, northern slopes of the Mica Peak uplands, eastern Washington and northern Idaho: University of Idaho Master of Science thesis, 100 p., 1 plate.

Moody, Ula Laura, 1987, Late Quaternary stratigraphy of the channeled scabland and adjacent areas: University of Idaho Doctor of Philosophy thesis, 419 p.

Owen, Claudia, 1988, The petrogenesis of blueschist facies ironstones in the Shuksan and Easton Schists, north Cascades, Washington: University of Washington Doctor of Philosophy thesis, 290 p.

Wood, T. R., 1987, The hydrogeology of the Wanapum basalt, Creston study area, Lincoln County, Washington: Washington State University Master of Science thesis, 166 p.

U.S. GEOLOGICAL SURVEY

Published reports

Evans, James G., 1988, Deformation in the Stensgar Mountain quadrangle, Stevens County, Washington: U.S. Geological Survey Bulletin 1820, 30 p., 1 plate.

Moody, D. W.; Carr, Jerry; Chase, E. B.; Paulson, R. W., compilers, 1988, National water summary 1986–Hydrologic events and ground-water quality: U.S. Geological Survey Water-Supply Paper 2325, 560 p.

Open-File Reports

Dion, N. P.; Olsen, T. D.; Payne, K. L., 1988, Preliminary evaluation of the ground-water resources of Bainbridge Island, Kitsap County, Washington, with a section on Geohydrologic units, by M. A. Jones: U.S. Geological Survey Water-Resources Investigations Report 87-4237, 82 p.

Embrey, S. S.; Dion, N. P., 1988, Effects of the 1980 eruption of Mount St. Helens on the limnological characteristics of selected lakes in western Washington: U.S. Geological Survey Water-Resources Investigations Report 87-4263.

Hays, W. W., editor, Workshop on "Evaluation of earthquake hazards and risk in the Puget Sound and Portland Areas,"; Proceedings of conference XLII: U.S. Geological Survey Open-File Report 88-541, 1 v.

Heaton, T. H.; Hartzell, S. H., 1986, Estimation of strong ground motions from hypothetical earthquakes on the Cascadia subduction zone, Pacific Northwest: U.S. Geological Survey Open-File Report 86-328, 1 sheet microfiche [69 p.].

Meyer, D. F.; Dodge, J. E., 1988, Post-eruption changes in channel geometry of streams in the Toutle River Drainage basin, 1983-85, Mount St. Helens, Washington: U.S. Geological Survey Open-File Report 87-549, 226 p.

Packard, F. A.; Skinner, E. L.; Fuste, L. A., 1988, Effects of coal mine drainage on the water quality of small receiving streams in Washington, 1975-77: U.S. Geological Survey Water-Resources Investigations Report 85-4274, 65 p.

Sabol, M. A.; Turney, G. L.; Ryals, G. N., 1988, Evaluation of available data on the geohydrology, soil chemistry, and ground-water chemistry of Gas Works Park and surrounding region, Seattle, Washington: U.S. Geological Survey Water-Resources Investigations Report 87-4045, 49 p., 1 plate.

Shearer, C. F., editor, 1988, Minutes of the National Earthquake Prediction Evaluation Council, April 2 and 3, 1987: U.S. Geological Survey Open-File Report 88-37, 332 p.

Snavely, P. D., Jr.; Gower, H. D.; Yount, J. C.; Tagg, A. R.; Lee, J. W.; Lander, D. L., 1977, High resolution seismic profiles in Hood Canal and southern Puget Sound, Washington: U.S. Geological Survey Open-File Report 77-195, 1 p., 1 roll microfilm.

WASHINGTON STATE AGENCY REPORTS

Garland, Dave; Safioles, Sally, 1988, Seasonal variation of chloride in ground water at southern Camano Island, Island County, Washington, 1985-87: Washington Dept. of Ecology Technical Report 87-15, 35 p.

Juul, S. T. J., 1988, A study of the water quality of Curlew Lake, Washington: Washington Water Research Center Report 70, 358 p.

Noson, L. L.; Martens, Carole, 1987, Washington State school earthquake emergency planning: University of Washington Geophysics Program, 15 p.

University of Washington Geophysics Program, 1988, Quarterly network report 88-C on seismicity of Washington and northern Oregon, July 1 through September 30, 1988: University of Washington Geophysics Program, 24 p.

GEOLOGY OF WASHINGTON—General

Brandon, M. T.; Cowan, D. S.; Vance, J. A., 1988, The Late Cretaceous San Juan thrust system, San Juan Islands, Washington: Geological Society of America Special Paper 221, 81 p., 1 plate. Charles, M. T.; Kim, J. C. K., editors, 1988, Crisis management–A casebook: Charles C. Thomas Publisher [Springfield, Ill.], 286 p.

Easterbrook, D. J., editor, 1988, Dating Quaternary sediments: Geological Society of America Special Paper 227, 165 p.

Harris, S. L., 1988, Fire mountains of the west–The Cascade and Mono Lake volcanoes: Mountain Press Publishing Company [Missoula, Mont.], 379 p.

Kingsbury, G. L.; Ray, R. M., 1986, Reclamation and redevelopment of contaminated land–Volume I, U.S. case studies: U.S. Environmental Protection Agency EPA/600/2-86/066, 3 sheets microfiche [186 p.].

Malins, D. C.; McCain, B. B.; Brown, D. W.; and others, 1982, Chemical contaminants and abnormalities in fish and invertebrates from Puget Sound: U.S. National Oceanic and Atmospheric Administration Technical Memorandum OMPA-19, 168 p.

Nance, J. J., 1988, On shaky ground: William Morrow and Company [New York, N.Y.], 416 p.

Northwest Mining Association, 1988, 1988-89 service directory: Northwest Mining Association, 245 p.

Socolow, A. A., 1988, The state geological surveys–A history: Association of American State Geologists, 499 p.

Tynni, Risto, 1986, Observations of diatoms on the coast of the state of Washington: Finland Geological Survey Report of Investigations 75, 25 p., 32 photo plates.

U.S. Department of Energy, 1988, Consultation draft site characterization plan, reference repository location, Hanford Site, Washington: U.S. Department of Energy DOE/RW-0164, 9 v.

U.S. Forest Service, 1988, Supplement to the draft environmental impact statement, proposed land and resource management plan, Wenatchee National Forest: U.S. Forest Service, 1 v.

OTHER REPORTS OF INTEREST

California Seismic Safety Commission, 1988, California at risk–Reducing earthquake hazards 1987-1992: California Seismic Safety Commission, 189 p. ("Advance copy")

Das, Shamita; Boatwright, John; Scholz, C. H., 1986, Earthquake source mechanics: American Geophysical Union Geophysical Monograph 37 (Maurice Ewing Volume 6), 341 p.

Engdahl, E. R., compiler; Reinhart, W. A., preparer, 1988, Seismicity map of North America: Geological Society of America DNAG Continent-Scale Map 004, 4 sheets, scale 1:5,000,000.

Hershman, M. J.; Fluharty, D. L.; Powell, S. L.; and others, 1988, State and local influence over offshore oil decisions: Washington Sea Grant Program, Washington State and Offshore Oil and Gas, 297 p.

Link, P. K.; Hackett, W. R., editors, 1988, Guidebook to the geology of central and southern Idaho: Idaho Geological Survey Bulletin 27, 319 p.

Ludwig, W. J.; Houtz, R. E., 1979, Isopach map of sediments in the Pacific Ocean basin and marginal sea basins: American Association of Petroleum Geologists, 2 sheets, scale 1:14,000,000.

Oregon Ocean Resources Management Task Force, 1988, Managing Oregon's ocean resources: Oregon Ocean Resources Management Task Force, 2 v.

Reinhardt, Juergen; Sigleo, W. R., editors, 1988, Paleosols and weathering through geologic time–Principles and applications: Geological Society of America Special Paper 216, 181 p.

Simpson, D. W.; Richards, P. G., editors, 1981, Earthquake prediction–An international review: American Geophysical Union Maurice Ewing Series 4, 680 p.

Sloss, L. L., editor, 1988, Sedimentary cover–North American craton: Geological Society of America DNAG Geology of North America, v. D-2, 506 p., 8 plates (in accompanying folder).

Stark, M. M., 1988, Mining and mineral industries–An information sourcebook: Oryx Press [Phoenix, Ariz.], 124 p.

Tempelman-Kluit, Dirk, editor, 1985, Field guides to geology and mineral deposits in the southern Canadian Cordillera: Geological Association of Canada, 1 v.

U.S. Minerals Management Service, 1988, Pacific OCS Region, Environmental studies plan, fiscal year 1989: U.S. Minerals Management Service OCS Report MMS 88-0024, 104 p.

Note: The DGER library has also received numerous reports from Rockwell Hanford Operations (pertaining to the geology and hydrology of the Hanford area), from various consulting firms (relating to the geology and seismic hazards of western Washington and adjacent areas), and all available U.S. Federal Emergency Management Agency reports in their Earthquake Hazards Reduction Series. These items are too voluminous to list here, but are available for examination in the DGER library in Olympia.

Status of Radon Efforts in Washington: December 1988

More than 19,000 homes have been tested so far by individual Washington homeowners and public agencies.

Testing statewide is broken down something like this:

- In 3 percent of the homes, values of more than 4 picoCuries/liter (pCi/L) of air were recorded.
- Test results average less than 1 pCi/L.
- The highest test result was 201 pCi/L.

Testing in Spokane County:

- In 50 percent of the homes tested, values of more than 4 pCi/L were recorded.
- Test results average 8 pCi/L.
- The highest test result was 92 pCi/L.

The federal government has recommended a guideline of 4 piC/L (annual average measurement) for homes.

The Task Force has started a public information campaign. The radon speakers bureau is in great demand. The Office of Radiation Protection of the Department of Social and Health Services has available a toll-free radon hot line (dial 1-800-323-9727).

[Source: Washington State Radon Task Force, December 21, 1988.]

Geology of Industrial Minerals Forum Booked for Portland

The Forum on the Geology of Industrial Minerals, an annual gathering at different sites throughout the United States, will be held in the Northwest for the first time. The 25th Forum is scheduled for the Portland Center Red Lion Inn April 30 through May 2, 1989.

Topics to be addressed during the day and a half of paper presentations will include Oregon perlite, emery, talc, limestone, and bentonite; Washington olivine; Idaho garnet and perlite; Northwest diatomite, zeolite, and pozzolan; playa resources; and state and provincial summaries, including Oregon, Washington, Idaho, Montana, and British Columbia.

Following the sessions in Portland, a three-day field trip by bus has been planned to showcase the industrial resources of Oregon. Overnight stops are planned at Baker, Ontario, and Bend.

Additional information on the Forum may be obtained from Ron Geitgey, Oregon Department of Geology and Mineral Industries, 910 State Office Building, 1400 S.W. 5th Ave., Portland, OR 97201, phone (503) 229-5580.

Meetings

Pacific Northwest Chapter, Friends of Mineralogy

Annual spring symposium, "Minerals of the Inland Northwest"

May 26-28, 1989
Holiday Inn
Coeur d'Alene, Idaho

Darko Sturman, associate curator of the Royal Ontario Museum, will be the principal speaker. His topic will be minerals of the Yukon Terrtory and the Yukon iron deposit. Other speakers will include Joe Nagel, curator of the University of British Columbia Geology Museum, and Mel Dyck of Laramie, WY.

For further information, write:

Lanny Ream
Mineral News
P. O. Box 2043
Coeur d'Alene, Idaho 83814

1989 Workshop on Earthquake Hazards in the Puget Sound/Portland area

March 28-29, 1989
Portland Marriott
Portland, OR

Sponsored by the Oregon Department of Geology and Industries, the Oregon Department of Emergency Management, the Washington Department of Natural Resources, the Washington Department of Community Development, the Federal Emergency Management Agency, and the U.S. Geological Survey.

For additional information, contact:

Timothy Walsh (206) 459-6372
Ian Madin (503) 229-5580
Linda Noson (206) 481-4694

Staff Notes

Robert L. "Josh" Logan was promoted January 3 from Geologist 2 to Geologist 3 in the Environmental Geology section. In his new position, Josh will be the lead geologist for Quaternary geology studies in the state geologic map program. He also will head up efforts at slope stability studies in the Puget Sound area.

Stephen P. Palmer was hired February 13 to conduct studies of earthquake hazards in the Puget Sound area. His appointment is made possible by a grant from the National Earthquake Hazards Reduction Program (NEHRP). His duties will focus on the behavior of sediments during earthquake shaking.

Steve earned a B.S. in Geology, and an M.S. and Ph.D. in Engineering Science, all from the University of California, Berkeley. He has worked for Gulf Oil Company, Schlumberger Well Services and Westinghouse Hanford Company. Most recently, he has completed (with Bill Lingley) an assessment of the petroleum potential of the Washington outer continental shelf for the Washington Sea Grant Program.

This volcanic pipe in Ferry County is locally known as **Corkscrew Mountain**. Its peculiar twisted structure gave rise to its name—it looks like a bolt with a left-handed thread.

According to R. C. Pearson of the U.S. Geological Survey, "The pipe is oblong in plan (120x300m), and its south side is exposed for a vertical distance of about 100 m on the slope north of the valley of Toroda Creek, 4 km above its confluence with Kettle River. It cuts bedded tuffaceous deposits of the Eocene Klondike Mountain Formation. From a distance, the pipe appears to consist of a series of curving parallel dikes about 0.6-3 m thick and about 5-8 m apart. The thin "dikes" stand out in relief and...resemble threads of a giant screw. But...the thin sheets are actually older than the thicker sheets between, as determined by thin dikelets from the one penetrating the other. The thin sheets are dacitic in composition, whereas the thicker sheets are lithoidal.

"The helical structure is explained as the result of cooling of uniform magma. As the moving magma gradually slowed and cooled, it became more and more viscous until it sheared or fractured along equally spaced shear surfaces or joints. These surfaces were curved in three dimensions because of the torsional stress. The resulting loss of pressure along the shear surfaces caused the adjacent magma to freeze, producing the vitric sheets. The remaining magma...cooled more slowly to form the lithoidal rock."

(From Pearson, R. C., Geological Society of America Abstracts with Programs, 1988, v. 20, no. 6, p. 462.)

New Division Releases

Open File Report 88-5: Structural geology along the northwestern Columbia River basalt margin, Washington, by N. P. Campbell. The 108-page report includes 8 plates. The price is $9.28 + .72 (tax) = $10.00.

Open File Report 89-1: Geologic and Geophysical Mapping of Washington, 1984-1988 and Theses on the Geology of Washington, 1986 -1988, compiled by Connie J. Manson. The first part of this work is the cumulated update to the Division of Geology and Earth Resources Information Circular 77, "Index to geologic and geophysical mapping of Washington, 1899-1983." The second part is the cumulated update to the Division's Information Circular 80, "Theses on Washington Geology, 1901-1925." The 26-page report includes 7 plates. The price is $0.93 + .07 (tax) = $1.00.

Geologic Map GM-35: Bluelight 15-minute Quadrangle, Washington; Geologic Map GM-36: Poisel Butte 15-minute Quadrangle, Washington; Geologic Map GM-37: Logy Creek 15-minute Quadrangle, Washington, by R. D. Bentley, N. P. Campbell, and John E. Powell. Each of the three maps has a brief description of geologic units, a diagram of map unit correlation, a cross section, a table of major element geochemical analyses, and a three-color map at 1:48,000 on one sheet. The price is $1.85 + .15 (tax) = $2.00 each.

Geologic Map GM-38: Map of the Saddle Mountains, Washington, by S. P. Reidel. This publication consists of three 3-color maps at 1:48,000, cross sections, and isopach maps of selected Columbia River basalt flows. The plates are accompanied by a 28-page text that includes results of geochemical analyses. The price is $6.03 + .47 (tax) = $6.50.

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Natural Resources

Division of Geology and Earth Resources
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