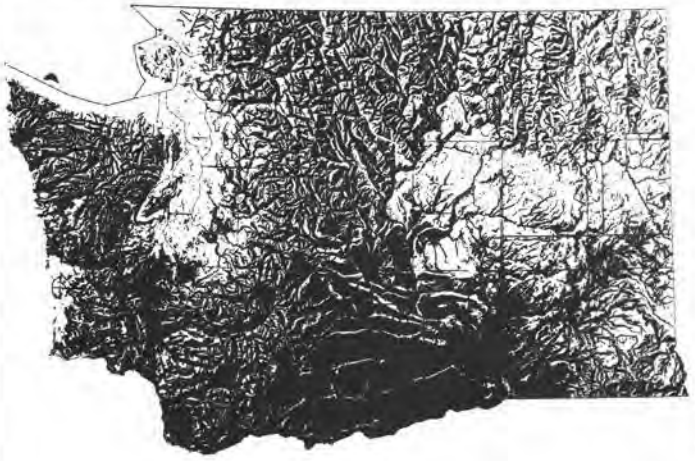

WASHINGTON GEOLOGIC NEWSLETTER

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Two new gold and silver veins were discovered this year at the Knob Hill Mine in Ferry County. The Golden Promise No. 1 and No. 2 veins are being developed from an exploration drift at the 11th level of the mine. Shown here is the No. 2 shaft, used to haul about 39,000 oz. of gold in the first 10 months of 1985.

WASHINGTON STATE DEPARTMENT OF
Natural Resources

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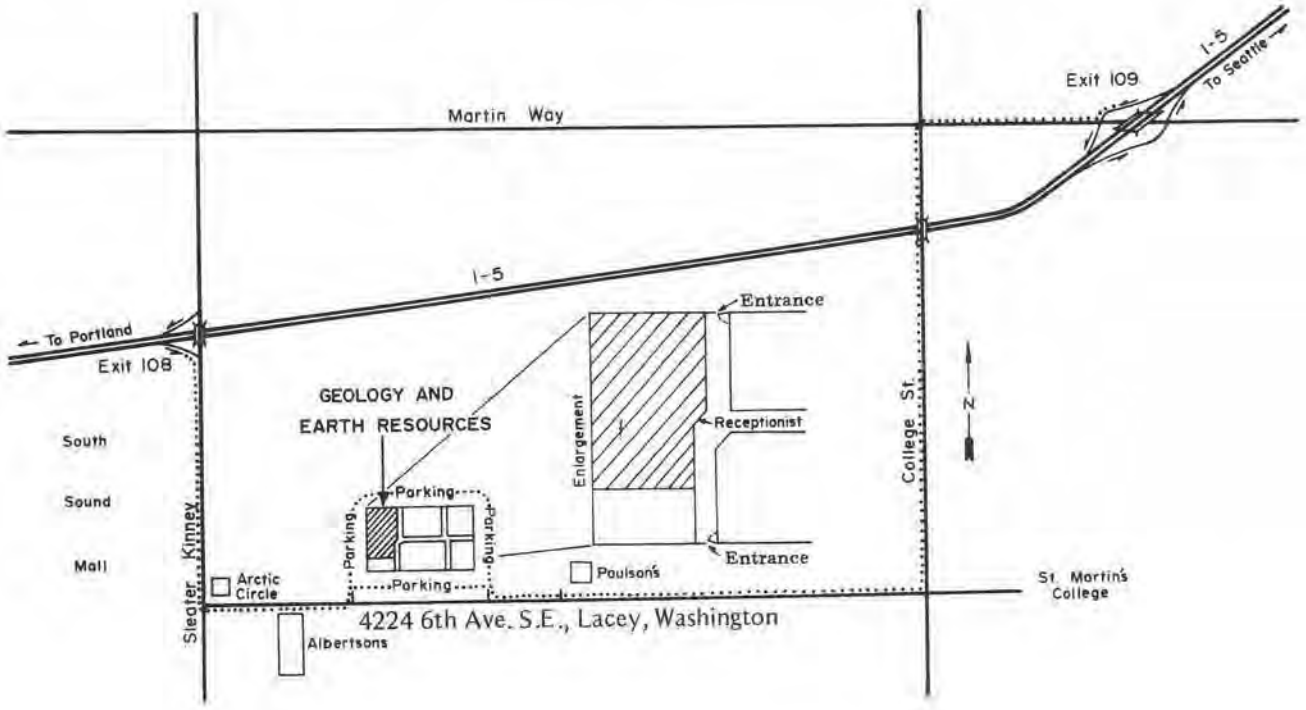

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The Washington Geologic Newsletter, a quarterly report of geologic articles, is published by the Division of Geology and Earth Resources, Department of Natural Resources. The newsletter is free upon request.

The Division also publishes bulletins, information circulars, reports of investigations, and geologic maps. A list of these publications will be sent upon request.

WASHINGTON'S MINERAL INDUSTRY, 1985

By

Nancy L. Joseph, Geologist
Division of Geology and Earth Resources

Two new mines began production in 1985, adding to the 27 active metal and industrial-mineral operations in the State of Washington. Over $30 million was spent by at least 89 companies to explore and develop mineral deposits in the state (Table 1). An additional $652,096 was added to the state trust fund through lease payments and royalties (including sand and gravel) on state-owned land.

This report on mining and exploration activity in Washington during 1985 is summarized from voluntary replies to a questionnaire sent to companies and individuals previously active in exploration and mining in the state and from published information. This report is incomplete; only 31 percent of the questionnaires were returned, and some information requested, particularly regarding expenditures and production, is confidential and not reported. However, this summary does give a good indication of the general activity for metallic and industrial-mineral deposits in the state.

Expenditures for metals exploration and development in 1985 were about $28 to $33 million. Asamera Minerals (U.S.) Inc. and Breakwater Resources, Ltd. spent $25 to $30 million of this total on development at the Cannon Mine in Chelan County. Expenditures by 62 companies reported to have explored for and developed metals in Washington were $3 million, down from $4.5 million in 1984. This reduction in outlay likely reflects the downturn in the price of metals that has slowed exploration, and the reduction (by 33) in the number of companies reported to have worked in the state in 1985. The reduction in companies reported to have worked in the state reflects the slowdown of exploration in the Wenatchee area and the consolidation of properties by the Asamera joint venture. Companies reporting work on properties in Chelan County, for example, have gone from 27 in 1984 to 11 in 1985, and two of those properties were acquired by the joint venture this past year.

Expenditures for industrial minerals increased during 1985. Over $1.3 million was reported spent in 1985, versus $386,000 reported the previous year. The figure from 1985 is more in line with the $1 million reported for 1983. Thirty-one companies reported exploring and developing industrial minerals in 1985, an increase of five over 1984.

Total revenue from prospecting, mining, and quarrying on state lands was $652,096 for the year ending June 30, 1985 (Fig. 1). This figure is sharply down from 1984, but in line with 1983 income to the state trust. The figure reflects a decrease of almost $250,000 in the revenue from sales of sand and gravel and material removed.

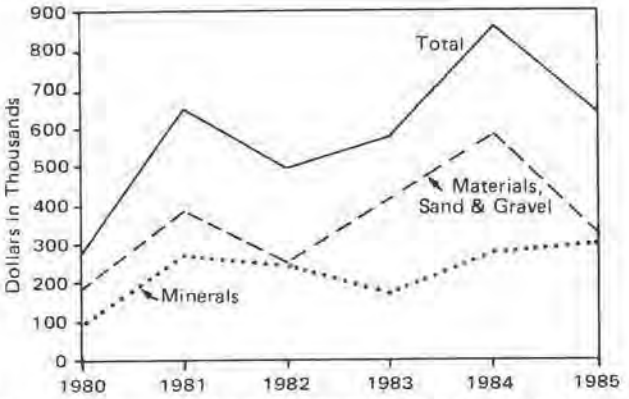

Figure 1 – Revenue from prospecting, mining, and quarrying on state lands.

METALS

Eight metal mines were active in 1985, and all but one, the Flodelle Creek Mine in Stevens County, sought gold and silver (Table 2). Generally these mines are high-grade, low-tonnage properties that can be successfully mined with low overhead.

The highlights of the year include: the initiation of production at the Cannon Mine in Chelan County, a joint venture of Asamera Minerals (U.S.) Inc. and Breakwater Resources, Ltd., and the announcement by Hecla Mining Co. that two new veins were discovered at the Knob Hill Mine in Ferry County.

Heap leaching continued at the Gold Dike Mine in Ferry County with some mining taking place on the adjacent Gold Hill property. At the Minnie Mine in Okanogan County, leaching continued on pads built in 1984. Less than 140 tons were mined by CSS Management at their Apex and Damon Mines in King County. Development work at the Wind River Mine in Skamania County, operated by Youngquist Mine Development and Consultation, Inc., is on hold while additional financial backing is secured.

No uranium was produced in Washington in 1985. The Sherwood Mine in Stevens County, operated by Western Nuclear, Inc., was on hold this year. Joy Mining Company continues to perfect their milling process for uranium from their bog deposit at Flodelle Creek in Stevens County.

Gold and silver were the targets of 70 percent of the companies exploring in the state. However, exploration for lead, zinc, molybdenum, tungsten, uranium, and tin was conducted throughout the state. Exploration for metals was concentrated in the eastern half of the state, especially in Stevens County, followed by Okanogan and Chelan Counties. On the western side of the Cascades, activity was greatest in King County, and mainly consisted of exploration for gold and silver.

Table 1. Exploration and Development in Washington, 1985*

Prospect No.	Owner/Operator	Property	Location	Commodity	Remarks
1	Amahawk Resource Corp.	Wenatchee property	Wenatchee district Chelan Co.	Au, Ag	Exploration program supervised and drilled by Asamera
2	Asamera Minerals (U.S.) Inc., Breakwater Resources, Ltd.	Cannon Mine	Sec. 16, T.22N., R.20E. Chelan County	Au, Ag	Mining and production began July 15; mill is running at 1,600 TPD (capacity of 2,000 TPD); produced 31,310 oz. gold and 46,145 oz. silver as concentrate.
3	Montana de Oro, Inc.	---	Secs. 1-3. T.22N., R.17E. Chelan County	Au	Geological and geochemical reconnaissance
4	Silver Lake Resources	Horse Lake	Secs. 24-25 T.23N., R.19E. Sec. 30 T.23N., R.20E. Chelan County	Au, Ag	Drilled property and returned to lessor
5	Sunshine Valley Minerals, Inc.	Holden Lake and 10 other properties	Secs. 17-18 T.31N., R.17E. Chelan County	Au, Cu	Mapping and sampling
6	Tenneco Minerals Co.	B-Reef, L-D Mine, Canyon No. 2	Sec. 16, T.22N., R.20E. Chelan County	Au, Ag	Drilled on B-Reef; sold property to Asamera in September
6	United Mining Corp.	B-Reef, L-D Mine Canyon No. 2	Sec. 16, T.22N., R.20E. Chelan County	Au, Ag	Sold profit interests to Asamera
7	Tillicum Gold Mining Co.	Several properties	Several sections T.22N., R.17E. Chelan County	Au	Geophysical and geochemical exploration
8	Weaco Resources, Ltd.	Wenatchee Gold	Sec. 16, T.22N., R.20E. Chelan County	Au	Planning drilling program

* see figures 2a and 2b for locations of mining properties

Table 1. Exploration and Development in Washington, 1985 – Continued

Prospect No.	Owner/Operator	Property	Location	Commodity	Remarks
9	Welcome North Mines (U.S.) Inc.	Woodworth, KP	Secs. 6-7 T.22N., R.18E. Chelan County	Au	Geological and geochemical exploration
10	Wenatchee Silica Products Inc., Asamera Minerals (U.S.) Inc.	Wenatchee silica quarry	Sec. 21 T.22N., R.20E. Chelan County	Silica	Most of production to be used at Cannon Mine
11	Ideal Basic Industries, Inc.	Twin River quarry	Secs. 22-23 T.31N., R.10W. Clallam County	Clay	Mined 120,000 tons
12	Azure Resources	Lonestar	North of Curlew Ferry County	Au, Cu	Drilled, results encouraging
13	Canorex International, Inc.	Several properties	Secs. 28-29 T.40N., R.34E. Ferry County	Au, Ag	Exploration
14	Crown Resource Corp., Sutton Resources Ltd., Gold Capital Corp.	Seattle-Flag Hill Mine	Secs. 27-28 33-34, T.37N., R.32E. Ferry County	Au, Ag	Exploration
15	Crown Resource Corp. Gold Capital Corp., Gold Texas Resources Ltd.	South Penn	Secs. 27-28 T.37N., R.32E. Ferry County	Au, Ag	Heap-leach test by Glamis Gold
16	Crown Resource Corp., Gold Capital Corp., Gold Texas Resources Ltd.	Granny	Secs. 15-16, 22, T.39N., R.33E. Ferry County	Au, Ag	Drilled 6 core holes totaling 1,874 ft. and 13 rotary holes totaling 2,546 ft.
17	Hecla Mining Co., Republic Unit	Knob Hill Mine	Sec. 27 T.37N., R.32E. Ferry County	Au	Mined 61,000 tons averaging 0.65oz/ton gold; announced discovery of two new veins
17	Hecla Mining Co., Exploration Dept.	Knob Hill Mine	Around Republic Ferry County	Au, Ag	Exploration
18	Newmont Mining Corp.	---	North of Curlew Ferry County	Au	Geological and geophysical mapping
19	Silver Bell, Inc.	ZALA-M	Sec. 30 T.38N., R.32E. Ferry County	Au, Ag	Mapping, sampling, and drilling
20	Suncoast Petroleum	Lone Ranch claims	North of Curlew Ferry County	Au	Drilling

Table 1. Exploration and Development in Washington, 1985 — Continued

Prospect No.	Owner/Operator	Property	Location	Commodity	Remarks
21	Sundance Mining & Development, Inc.	Gold Hill property	North of Curlew Ferry County	Au, Ag	Sampling and geological mapping; excavation and crushing
22	Vulcan Mountain, Inc.	Gold Dike Mine	Secs. 7-8 T.40N., R.34E. Ferry County	Au, Ag	Heap leaching in progress
23	Witco Chemical Corp.	Grant County pits	T.18N., R.23E., T.17N., R.24E. Grant County	Diatomite	Mined and milled 60,000 tons
24	Ocean Farms Inc.	Ocean Farms	Sec. 13 T.18N., R.12W. Grays Harbor Co.	Peat moss	Mined 10,000 cubic yards
25	CSS Management Corp.	Apex & Damon Mines	Secs. 33-34 T.26N., R.10E. King County	Au, Ag	Mined and milled 125 tons
26	Industrial Mineral Products, Inc.	Ravensdale sand pit	Sec. 36 T.22N., R.6E. King County	Silica, Clay	Mining and milling
27	Mariposa Resources, Inc.	Cleopatra Mine	Sec. 24 T.25N., R.10E. King County	Ag	Announced joint-venture agreement
28	Mutual Materials Co.	Cougar pit	Sec. 31 T.24N., R.6E. King County	Clay	Mining
29	Mutual Materials Co.	Elk pit	Sec. 34 T.22N., R.7E. King County	Clay	Mining
30	North American Refractories Co.	Blum	Sec. 31 T.21N., R.7E. King County	Clay	Mining; exploration
31	Terra Alta Mining Co.	Coney Basin group	Sec. 19 T.24N., R.11E. King County	Au, Ag	Exploration
32	South Fork Ltd. Partnership	Lower Taneum, Lucky Gulch claims	Sec. 25 T.19N., R.15E. Kittitas County	Au, Ag	Exploration
33	Taneum Investors Group	South Fork claims	Sec. 24 T.19N., R.15E. Kittitas County	Au, Ag	Exploration

Table 1. Exploration and Development in Washington, 1985 – Continued

Prospect No.	Owner/Operator	Property	Location	Commodity	Remarks
34	Rexcon, Inc.	Junction Reef Gold	T.24-25N., R.38-40E. Lincoln County	Au, Ag	Geological, geochemical, geophysical exploration
35	Charles M. Shaw	Crystal Mine	Sec. 21 T.28N., R.36E. Lincoln County	Ag, Pb, W, marble	Geological reconnaissance
36	Agro Minerals, Inc.	Poison Lake Mine	Sec. 5 T.38N., R.27E. Okanogan Co.	Gypsum	Mining
37	Columbia River Carbonates, Genstar Stone Products Co.	Wauconda Whitestone	Sec. 13 T.38N., R.30E. Okanogan Co.	Limestone	Drilling and geochemical sampling; quarrying and crushing of 40,000 tons began in September
38	Cordilleran Development, Inc.	Minnie Mine	Sec. 23 T.32N., R.22E. Okanogan Co.	Au, Ag, Cu	Continued heap leaching; geologic mapping
39	Crown Resource Corporation, Gold Capital Corp., Sutton Resources Ltd., Deep South Petroleum Ltd., Gold Texas Resources Ltd.	Key	Sec. 31 T.36N., R.25E. Okanogan Co.	Au, Ag	Drilled 14 vertical rotary holes totaling 1,938 ft. on 100-ft. centers
40	Keystone Gold, Inc.	Grey Eagle area	Sec. 16 T.40N., R.30E. Okanogan Co.	Au, Ag	Geological and geochemical exploration
41	Keystone Gold, Inc.	Crystal Butte	Sec. 35 T.40N., R.30E. Okanogan Co.	Au, Ag	Geological and geochemical exploration
42	Northwest Kaolin	Red Shirt Mine	Sec. 18 T.33N., R.25E. Okanogan Co.	Au	Geological and geochemical reconnaissance
43	Silver Bell, Inc.	Silver Bell Mine	Sec. 25 T.38N., R.31E. Okanogan Co.	Ag, Au	Drilling; geological and geophysical reconnaissance
44	Sundance Mining Development Inc.	Ida Mine	Secs. 21, 28 T.39N., R.31E. Okanogan Co.	Au	Acquired property
45	Sunshine Valley Minerals, Inc.	Billy Goat	Sec. 15 T.38N., R.20E. Okanogan Co.	Au, Ag	Exploration

Table 1. Exploration and Development in Washington, 1985 – Continued

Prospect No.	Owner/Operator	Property	Location	Commodity	Remarks
46	Western Land & Resources Inc.	Bodie Mine	Sec. 3 T.38N., R.31E. Okanogan Co.	Au, Ag	Exploration
47	Lehigh Portland Cement Co.	Troyer	Sec. 20 T.39N., R.43E. Pend Oreille Co.	Silica	Mined 23,804 tons
48	Lehigh Portland Cement Co.	Champane Placer	Sec. 27 T.39N., R.43E. Pend Oreille Co.	Limestone	Mined 238,195 tons
49	Pintlar Corp.	Pend Oreille Mine	Secs. 15-16, 21-22 T.39N., R.43E. Pend Oreille Co.	Pb, Zn	Mine remains on standby
50	Mutual Materials Co.	Clay City pit	Sec. 25 T.17N., R.4E. Pierce Co.	Clay	Mining
51	IMC Olivine– Imcore Division	Twin Sisters	Secs. 3-4, 8-9, 16 T.36N., R.7E. Skagit Co.	Olivine	Production from stockpile
52	International Minerals & Chemical Corp.	Several properties	Mount Baker mining district Skagit Co.	Olivine	Geological exploration
53	Plexus, Inc.	Silver Star	Sec. 4 T.3N., R.5E. Skamania Co.	Au, Cu, Mo	Drilling
54	Youngquist Mine Development & Consultation, Inc.	Wind River Mine	Sec. 9 T.5N., R.7E. Skamania Co.	Au, Ag	Development drifting
55	Interpace Industries, Inc.	Mica Mine & plant	Secs. 14, 23 T.24N., R.44E. Spokane Co.	Clay	Mined 36,000 tons
56	Billiton Exploration USA Inc.	Aspend Hill, Deep Lake, Cedar Creek	Northern Stevens County	Au, Ag	Geological, geochemical reconnaissance; drilling
57	Canorex International, Inc.	Several properties	Sec. 9 T.37N., R.39E. Stevens Co.	Ag, Pb, Zn	Exploration
58	Challin-Ore Mining	Just Time	Secs. 17-20 T.39N., R.42E. Stevens Co.	Ag, Pb, Zn	No production due to market conditions

Table 1. Exploration and Development in Washington, 1985— Continued

Prospect No.	Owner/Operator	Property	Location	Commodity	Remarks
59	Challin-Ore Mining	Electric Point	Sec. 15 T.40N., R.42E. Stevens Co.	Ag, Pb, Zn	No production due to market conditions
60	Chewelah Eagle Mining Co.	Chewelah Eagle Mine	Sec. 5 T.32N., R.41E. Stevens Co.	Dolomite	Mined 300 tons
61	Joy Mining Co. (WashTex)	Flodelle Creek Mine	Sec. 5 T.35N., R.42E. Stevens Co.	U	Perfecting milling process
62	Lane Mountain Silica Co.	Lane Mountain claims	Secs. 22, 34, T.31N., R.39E. Stevens Co.	Silica	Mined 152,000 tons
63	Leadpoint Consolidated Mines Co.	Leadpoint Consolidated properties	Secs. 12-13, 23 T.39N., R.41E., Secs. 7, 12-13, 17-18, T.39N., R.42E., Stevens Co.	Ag, Pb, Zn	Exploration
64	Mines Management, Inc.	Iroquois	Secs. 19-20, 29-30, T.40N., R.42E., Stevens Co.	Pb, Zn	Exploration
65	Mines Management, Inc.	Advance, H-C	Sec. 18 T.39N., R.41E. Stevens Co.	Pb, Zn	Exploration
66	Mine Tech Corp.	Silver Star Dolomite Mine	Sec. 22 T.29N., R.37E. Stevens Co.	Ag, barite, dolomite	Geological exploration
67	Minexco Inc.	Huckleberry Mountain	Several Secs. T.29-30N., R.38E. Stevens Co.	Au, Ag	Geological and geochemical exploration
68	North American Refractories Co.	Harris	Sec. 34 T.30N., R.42E. Stevens Co.	Clay	Mining
69	Northwest Alloys, Inc.	Blue Creek quarry	Sec. 29 T.33N., R.40E. Stevens Co.	Silica	Mining
70	Northwest Alloys, Inc.	West Dolomite Mine	Sec. 12 T.33N., R.39E. Stevens Co.	Dolomite	Mining

Table 1. Exploration and Development in Washington, 1985 — Continued

Prospect No.	Owner/Operator	Property	Location	Commodity	Remarks
71	Rochester Minerals, Inc.	First Thought	Sec. 18 T.39N., R.37E. Stevens Co.	Au	Drilled 8 holes, total 3,700 ft.
72	Syracuse Minerals, Ltd.	Old Dominion Mine	Sec. 9 T.35N., R.40E. Stevens Co.	Au, Ag	Exploration, drilling
73	Terra Alta Mining Co.	Lake View	Sec. 19 T.40N., R.42E. Stevens Co.	Silica	Reconnaissance
74	Van Horn-Watson Mining Co.	Gold Nugget claims	Sec. 20 T.40N., R.37E. Stevens Co.	Au, Ag	Exploration
75	Washington Resources Partnership	Calhoun Mine	Secs. 2-4, 9-11 T.39N., R.41E. Stevens Co.	Limestone	Drilling
76	Western Nuclear, Inc.	Sherwood Project	Sec. 1,2, 34-36 T.28N., R.37E. Stevens Co.	U	Mine on hold
77	Western Land & Resources Inc.	McNally	Sec. 33, 34 T.40N., R.37E. Stevens Co.	Au, Ag	Exploration
78	Jones Quarry	Jones quarry	Sec. 29 T.18N., R.2W. Thurston Co.	Basalt	Mined 140,000 tons
79	Mutual Materials Company	Bucoda pit	Secs. 10, 14 T.15N., R.2W. Thurston County	Clay	Mining
80	Columbia North-west Cement Corp.	Kendall quarry	Sec. 14 T.40N., R.5E. Whatcom Co.	Limestone	Mined 850,000 tons, produced 600,000 tons limestone for cement
81	Olivine Corp.	Swen Larsen quarry	Sec. 34 T.38N., R.6E. Whatcom Co.	Olivine	Mining and milling
82	Seattle-St. Louis Mining Co.	Minnesota Mine	Sec. 2 T.37N., R.16E. Whatcom Co.	Au, Ag	Surface trenching; reopening of old workings
83	Western Gold Mining, Inc.	New Light Mine	Sec. 27 T.38N., R.17E. Whatcom Co.	Au	Surface and underground geologic mapping

Table 2. Active Metal Mines, 1985

County	Property	Operator/Owner	Commodity	Production & Development Data
Chelan	Cannon Mine	Asamera Minerals (U.S.) Inc., Breakwater Resources, Ltd.	Au, Ag	Produced 31,310 oz. gold and 46,145 oz. silver as concentrate, July-Dec. 1985
Ferry	Gold Dike Mine	Vulcan Mountain, Inc.	Au, Ag	Continued leaching 50,000 tons
	Gold Hill Mine	Sundance Mining & Development, Inc.	Au, Ag	2,500 tons mined by Vulcan Mountain, Inc.
	Knob Hill Mine	Hecla Mining Co.	Au, Ag	Mined 61,000 tons averaging 0.65oz/ton Au; continued exploration
King	Apex & Damon Mines	CSS Management Corp.	Au, Ag	Mined 125 tons
Okanogan	Minnie Mine	Cordilleran Development, Inc.	Au, Ag, Cu	Leaching continued
Skamania	Wind River Mine	Youngquist Mine Development & Consultation, Inc.	Au, Ag	1,025 ft. of drift completed; plans are to start up when refinancing is completed
Stevens	Flodelle Creek Mine	Joy Mining Co. (WashTex)	U	Working to perfect milling process

Chelan County

The flurry of exploration activity in the Wenatchee area has resulted in the opening of the Cannon Mine, jointly held by Asamera Minerals (U.S.) Inc. (51%) and Breakwater Resources, Ltd. (49%). After completion of the mill installation, the 4,000-ton/day underground crusher, and the 350-foot-high tailings dam across Dry Gulch, production began on July 15, 1985. From July through December the mine produced 31,310 ounces of gold and 46,145 ounces of silver in concentrate form. Asamera reportedly spent $25 to $30 million for mine development in 1985.

The 2,000-ton/day mill at the property began producing at 1,600 tons per day, processing material from the development-drifting stockpile. The concentrate is expected to run between 5 and 6.5 oz/ton gold and 0.5 and 2 oz/ton silver. Recoveries of 86 to 91 percent are expected. The concentrates are shipped via Vancouver, Washington, to either a West German or Japanese smelter. Reported proven and probable reserves are 5.3 million tons of 0.214-oz/ton gold from the B, B west, and B north orebodies.

With mine development came the consolidation of mining properties in the Wenatchee District. United Mining Corp. sold their interest in the central B-reef to Tenneco Minerals Co. in 1984, then sold their profit interests on the property to Asamera Minerals (U.S.) Inc. in 1985. Tenneco, after drilling out a

Cannon mine - rotary dryer. Concentrates which contain 5-6 oz. per ton gold and 40% SiO_2 are dried before shipping, so that the 4,000-ton loads carried by freighter overseas to be refined will not shift in transit.

reported 300,000 to 400,000 ounces of gold in the central B-reef, sold the property to Asamera. Asamera also bought Wenatchee Silica Products Inc., Production from the quarry will be used mainly at the Cannon Mine, although limited production will be sold.

The exploration division of Asamera spent $1 million in the Wenatchee area in 1985. This included exploration on the 5,000 acres that the joint venture holds in the state. According to Engineering and Mining Journal (April, 1985), supervision and drilling of the Amahawk Resource Corp. property southeast of the Cannon Mine was also done by Asamera.

Cannon mine — 350-foot-high tailings impoundment structure across Dry Gulch.

Other reported activity in the Wenatchee area included sampling and geophysical exploration by Wenatchee Resources Ltd. on their Jack's Family claims. Weaco Resources Ltd. of Vancouver, B.C., planned a drilling program on their property. Silver Lake Resources drilled at the Horse Lake property, then returned the property to the lessor.

In the Blewett district, three companies have reported exploration for vein gold within the Ingalls ophiolite complex. Tillicum Gold Mining Company reported that geophysical and geochemical surveys were done on their property. Welcome North Mines (U.S.), Inc. prospected their KP and Woodworth properties with geology and geochemistry. Montana de Oro, Inc. also explored their claims with geochemistry and geology.

Sunshine Valley Minerals, Inc. reported that geological and geochemical prospecting was done on their Holden property in the northern part of the county.

Ferry County

Hecla Mining Co. announced the discovery of two new veins at the Knob Hill Mine, which may extend the life of the mine. The Golden Promise No. 1 assayed 0.3oz/ton gold over 5.7 feet; the Golden Promise No. 2 assayed 2.4oz/ton gold and 12oz/ton silver across 12.7 feet. The Golden Promise No. 2 was followed for 185 feet, and was found to be faulted off at both ends. More drilling is being done to test the vein at higher levels. The mine yielded 61,000 tons of ore averaging 0.65oz/ton gold, mostly from the Bailey vein, discovered in 1983.

The Coeur d'Alene-based exploration department of Hecla Mining Co. reported exploring near Republic through geology, geochemistry, and drilling.

Crown Resource Corp., in joint venture with Gold Capital Corp., and Gold Texas Resources Ltd., have explored their Granny and South Penn properties. The Granny property, 14 miles north of Republic, contains disseminated gold and silver mineralization in Eocene volcanic rocks. The North American Gold Mining Industry News (Oct. 25, 1985), reports that, in 1985, six core holes totaling 1,874 feet and 13 rotary holes totaling 2,546 feet were drilled in addition to the 234 holes previously drilled on the property. Metallurgical testing was also in progress. At the South Penn property, controlled by the Crown Resource joint venture, Glamis Gold continued heap-leach testing.

Exploration continued at the Seattle-Flag Hill Mine, a joint venture of Crown Resource Corp. and Sutton Resources Ltd.

Geochemical and geological exploration and drilling for epithermal deposits in the Republic graben is being conducted by Canorex International, Inc., on several properties in Ferry County.

Heap leaching continued at the Gold Dike Mine, owned by Vulcan Mountain, Inc. The company has built a new office, laboratory, and plant facility and has been working to perfect their gold-extraction techniques. The ore zone at the Gold Dike Mine extends to the north onto the Gold Hill property, owned by Sundance Mining and Development, Inc. The mineralized zone is reported to be 2,000 feet in length and 65 to 75 feet wide. Prospectors Advertising Service (June-July, 1985) reports that the Gold Hill deposit contains 100,000 to 900,000 tons of minable reserves averaging 0.07oz/ton gold, with silver credits.

Vulcan Mountain, Inc., who will mine and extract the gold from the Gold Hill property, had mined approximately 2,500 tons and crushed half of that for leaching before work was stopped for the winter. According to The Wallace Miner (Nov. 21, 1985), Sundance will receive 9 percent net smelter return from gold recovered from the Gold Hill property.

Drilling at Azure Resources' Lone Star property intercepted 0.2oz/ton gold and 4.5 percent copper over 30 feet, according to The Northern Miner (Nov. 4, 1985). The property, which is near the Canadian border, is reported to be a massive sulfide at the flat-lying contact of

volcanics and footwall serpentinites. Newmont Mining Corp. is reported to have acquired ground south and east of the property, and has done geophysical and geologic mapping in the area.

King County

CSS Management Corp., operators of the Apex and Damon properties near Skykomish, Washington, reported mining and milling 125 tons of rock with gold and silver mineralization. According to Western Mining News (Aug. 23, 1985), Mariposa Resources, Inc., will participate in a joint venture for a 25 percent interest in the Cleopatra Mine. The Cleopatra Mine was reported to have been worked in 1984 by CSS Management Corp.

Reconnaissance exploration on the Coney Basin group was done by Terra Alta Mining Co. The company is exploring 1- to 14-foot-wide quartz-sulfide veins within the Snoqualmie Granodiorite.

Kittitas County

A geologic evaluation was conducted by South Fork Limited Partnership on their Lower Taneum and Lucky Gulch claim groups. Taneum Investors Group also did a geological evaluation of their gold and silver prospect in the county.

Lincoln County

Rexcon, Inc., explored their Junction Reef gold property with geology, geochemistry, and geophysics. The gold and silver epithermal vein system outcrops in a steptoe of Precambrian Belt Supergroup rocks surrounded by the Columbia River basalts.

Geological reconnaissance was done at the Crystal Mine property of Charles M. Shaw. Silver, lead, tungsten, and marble are reported to be commodities of interest in the skarn deposit.

Okanogan County

Heap-leach operations continued at the Minnie Mine on the pad started in 1984. Geologic mapping and sampling was done on the property operated by Cordilleran Development, Inc.

Exploration drilling at the Key property, operated by Crown Resource Corp., was done by Gold Texas Resources Ltd. Fourteen vertical rotary holes totaling 1,938 feet were drilled on the Key West orebody. North American Gold Mining Industry News (Oct. 25, 1985) reported that reserves are estimated at 350,000 tons of potentially open-pit-minable material grading 0.16oz/ton gold, based on the 1985 drilling and four holes drilled in 1983. The mineralized zone is reported to be 30 feet thick and potential mineralization is untested to the north and east.

Several properties within the Toroda Creek graben were prospected for gold and silver. Silver Bell, Inc., reported that geochemical and geological surveys and drilling were done at their Silver Bell Mine. No production was reported. Sundance Mining & Development, Inc., acquired the Ida Mine. Geology, geophysics, and geochemistry were conducted by Western Land & Resources Inc., at the Bodie Mine.

Northwest Kaolin undertook geological and geochemical reconnaissance at the Red Shirt Mine. It is reported that the epithermal gold mineralization occurs along a fault zone in carbonitized Cretaceous Red Shirt gabbro.

Sunshine Valley Minerals, Inc., explored their Billy Goat property for gold and silver. Keystone Gold, Inc., used geology and geochemistry to prospect their Crystal Butte and Grey Eagle properties.

Callahan Mining Corp. explored for gold and silver. Epithermal gold was the target of geologic, geochemical, and geophysical exploration by Nord Resources Corp.

Pend Oreille County

The Pend Oreille Mine in northern Pend Oreille County remains on standby; mine maintenance and pumping continues. The lead-zinc mine, owned by Pintlar Corp., a subsidiary of Gulf Resources and Chemical Corp., was under option earlier in 1985 to a group of Canadian investors; however, that deal has been terminated.

Skamania County

Development drifting continued at the Wind River Mine near Carson, where 1,025 feet of drift was completed and 50,000 tons of 0.5oz/ton gold ore was delineated. The gold, which occurs in narrow, wispy quartz veins and stringers, cuts the andesitic volcaniclastics of the Ohanapecosh Formation. The mine, owned by Youngquist Mine Development and Consultation, Inc., is currently on hold until additional financial backing is acquired.

Plexus, Inc., examined their Silver Star property by exploration drilling. A feasibility study on the property has been completed, and the company is now waiting for a recovery in the price of copper.

Stevens County

Stevens County was the most active county for base and precious minerals exploration during 1985. However, no metal production was reported.

Rochester Minerals, Inc., reported that eight diamond drill holes, for a total of 3,700 feet, were drilled at the First Thought Mine near Orient. The North American Gold Mining Industry News (Oct. 11,

Figure 2a – Locations of active mining properties in western Washington, 1985. See Table 1 for further information. (Note: Prospect numbers are keyed to Table 1.)

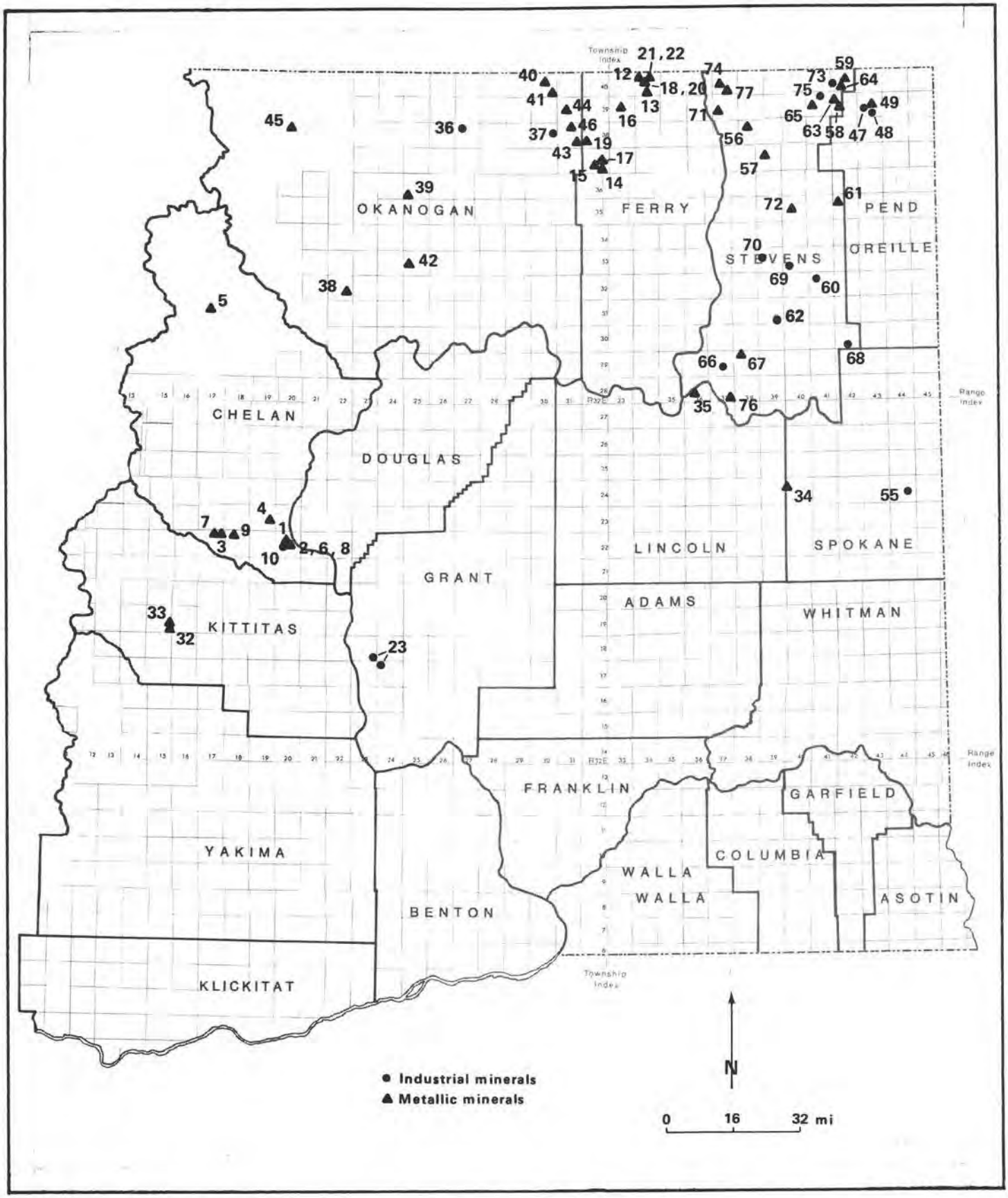

Figure 2b – Locations of active mining properties in eastern Washington, 1985. See Table 1 for further information. (Note: Prospect numbers are keyed to Table 1.)

1985) reported that Rockmaster Resources, Ltd., entered into an option agreement to acquire a 100 percent interest in the property.

Western Land & Resources Inc., did reconnaissance exploration for gold and silver on their McNally property in the Rossland volcanics. Gold and silver mineralization was also the target of geological and geochemical exploration pursued by Minexco Inc., on their Huckleberry Mountain property.

Van Horn-Watson Mining Company explored for gold and silver in the Rossland volcanics on their Gold Nugget claims.

Lead-zinc-silver mineralization in lower Paleozoic rocks was the target of several companies in Stevens County. Canorex International, Inc., explored for stratabound deposits in the lower Paleozoic shale belt. Leadpoint Consolidated Mines Company reported limited exploration on their properties. Challin-Ore Mining of Chewelah conducted exploration on their properties in the Northport mining district. Reconnaissance exploration and drilling was performed at the Old Dominion Mine by Syracuse Minerals, Ltd. Exploration was done at the Advance, Iroquois, and H-C Mines by Mines Management, Inc.

Billiton Exploration USA Inc., reported that geological and geochemical reconnaissance was done in the search for gold, silver, lead, and zinc in the northern part of the county. Targets were sedimentary exhalative deposits in Devonian argillites and Ordovician slates.

Boise Cascade Corp. explored for base and precious metals, and industrial minerals on corporate timberlands. Geological, geochemical and geophysical techniques were utilized to explore for vein, massive-sulfide, and disseminated deposits.

Terra Alta Mining Company explored the potential of the Lake View property. The Lake View contains a 2- to 4-foot massive quartz vein with silver sulfides in argillites and graphitic phyllites.

Callahan Mining Corp. and Nicor Mineral Ventures explored for gold and silver.

The Sherwood Mine, operated by Western Nuclear, Inc., is on hold; production ceased in August of 1984. The mine, on the Spokane Indian Reservation, is a past producer of uranium.

The milling process for uranium at the Flodelle Creek Mine operated by Joy Mining Co. (WashTex) is being perfected on the stockpile of uranium ore. This is the first surficial uranium deposit to be mined in the United States.

Whatcom County

Western Gold Mining, Inc., of Colville, reported that RD Resources, Ltd., of Vancouver, B.C., did surface and underground geologic mapping at the New Light Mine.

Surface trenching and reopening and sampling of old adits were done by Seattle-St. Louis Mining Co. at the Minnesota Mine.

Statewide

Exploration was done statewide by several companies. U.S. Borax & Chemical Company explored for gold, silver, and industrial minerals through geological and geochemical reconnaissance. Kennecott Exploration and Rio Algom Exploration Inc., conducted property examinations of several gold properties. Noranda Exploration, Inc., and Asarco Inc., explored for gold and silver. Cominco American Inc., explored statewide for base and precious metals and industrial minerals. Minatome Corp. searched for uranium in northeastern Washington.

INDUSTRIAL MINERALS

Fifteen companies controlled 21 mines for industrial minerals in Washington during 1985 (Table 3). Over 330,000 tons of silica were mined throughout the state by four companies. Clay was mined from seven pits by four companies. Limestone and dolomite were mined by four companies in the northeastern portion of the state and by one company in western Washington. Basalt, gypsum, diatomite, and peat moss were also produced.

Production began at the new Wauconda Whitestone Mine in Okanogan County, operated by Genstar Stone Products Co. and Columbia River Carbonates. The mine, which began production in September, has already mined and crushed 40,000 tons of marble to be used for white paper coating.

Exploration for industrial minerals was reported by eighteen companies. Limestone, silica, and clay were the most sought-after minerals, followed by barite, olivine, and diatomite.

Chelan County

Asamera Minerals (U.S.) Inc., purchased Wenatchee Silica Products Inc., in 1984. Most of the production will be used at the new Cannon Mine; some additional product will be sold to outside buyers.

Clallam County

Ideal Basic Industries, Inc., mined 120,000 tons of clay from their Twin River quarry. The clay is used in the manufacturing of cement.

Grant County

Witco Chemical Corp. mined 60,000 tons of

diatomite from their Grant County pits. Drilling was also done on the property.

Meridian Minerals explored for industrial minerals.

Grays Harbor County

Ocean Farms, Inc., mined 10,000 cubic yards of peat moss from their Grays Harbor County operation.

King County

Mutual Minerals Co. of Bellevue reported mining clay from shales at their Elk and Cougar pits. The company mined 100,000 cubic yards of clay in 1985 from four western Washington operations.

Silica and minor clay were produced by Industrial Mineral Products, Inc., from their Ravensdale sand pit. Production is from nearly vertically dipping nonmarine sandstones of the Eocene Puget Group.

Meridian Minerals explored for industrial minerals.

Okanogan County

Quarrying and crushing of 40,000 tons of limestone were done at the new Wauconda Whitestone Mine, a joint venture of Columbia River Carbonates and Genstar Stone Products Co. The deposit was discovered in December 1984; geological mapping, geochemical testing, and core drilling delineated the deposit in 1985. The marble consists of podiform calcite-marble lenses within the calc-silicate schists, phyllites, and amphibolites of the Permian Spectacle Formation. The marble will be stockpiled for milling by Columbia River Carbonates at their Woodland, Washington, processing facility, currently under construction. The carbonates will be used for white paper coating.

Production remained steady at the Poison Lake mine, operated by Agro Minerals, Inc., of Oroville, Washington. The gypsum is mined for use in agriculture. The hot-spring-fed deposit essentially replenishes itself and has been worked since the late 1800's.

Pend Oreille County

Lehigh Portland Cement Co. produced limestone and silica from their properties at Metaline Falls. The Champane Placer property produced 238,195 tons of limestone and the Troyer property produced almost 24,000 tons of silica.

Pierce County

Clay was mined from the Clay City pit owned by Mutual Materials Co.

Excavation beginning at new Wauconda Whitestone deposit.

Skagit County

International Minerals and Chemical Corp. did geological exploration on several properties in their pursuit of olivine. At the Twin Sisters property, operated by IMC Olivine-Imcore Division, production was again from the plant stockpile.

Spokane County

Interpace Industries, Inc., had the only reported mining activity in Spokane County. The Mica mine and plant produced 36,000 tons of clay, which represents a more than three-fold increase over their reported 1984 production.

Stevens County

Dolomite was produced by Northwest Alloys, Inc. from their West Dolomite pit. Production increased from 1984. Chewelah-Eagle Mining Company processed 300 tons of dolomite for industrial use through a lessee.

Washington Resources Partnership drilled the Metaline Formation at the Calhoun Mine. Preliminary investigation of the commercial feasibility for production of limestone is under way.

Geological reconnaissance was undertaken at the Silver Star Dolomite Mine in the search for silver, barite,

Table 3. Active Industrial-Mineral Mines, 1985

County	Property	Operator/Owner	Commodity	Production & Development Data
Clallam	Twin River quarry	Ideal Basic Industries, Inc.	Clay	Mined 120,000 tons
Grant	Grant County pits	Witco Chemical Corp.	Diatomite	Mined and milled 60,000 tons
Grays Harbor	Ocean Farms	Ocean Farms Inc.	Peat moss	Mined 10,000 cubic yards
King	Ravensdale sand pit	Industrial Mineral Products, Inc.	Silica, clay	Increased silica production
	Cougar pit	Mutual Materials Co.	Clay	Mined
	Elk pit	Mutual Materials Co.	Clay	Mined
Okanogan	Poison Lake Mine	Agro Minerals, Inc.	Gypsum	Production steady
	Wauconda Whitestone	Columbia River Carbonates, Genstar Stone Products Co.	Limestone	Production began in September; 40,000 tons quarried and crushed
Pend Oreille	Champane Placer	Lehigh Portland Cement	Limestone	Mined 238,195 tons
	Troyer	Lehigh Portland Cement	Silica	Mined 23,804 tons
Pierce	Clay City pit	Mutual Materials Co.	Clay	Mined
Skagit	Twin Sisters	IMC Olivine—Imcore Division	Olivine	All production from plant stockpile
Spokane	Mica Mine	Interpace Industries, Inc.	Clay	Mined 36,000 tons
Stevens	Chewelah Eagle Mine	Chewelah Eagle Mining Co.	Dolomite	Mined 300 tons
	Lane Mountain	Lane Mountain Silica Co.	Silica	Mined 152,000 tons
	West Dolomite pit	Northwest Alloys, Inc.	Dolomite	Production increased
	Blue Creek quarry	Northwest Alloys, Inc.	Silica	Mined
Thurston	Jones quarry	Jones Quarry	Basalt	Mined 140,000 tons
	Bucoda pit	Mutual Materials Co.	Clay	Mined
Whatcom	Kendall quarry	Columbia Northwest Cement Corp.	Limestone	Mined 850,000 tons; produced 600,000 tons limestone for cement
	Swen Larsen quarry	Olivine Corp.	Olivine	Mined and milled

and dolomite. Mine Tech Corp. expects to increase exploration efforts at the mine in 1986.

Lane Mountain Silica Co. was the largest producer of silica in Washington in 1985, although production was slightly behind output for 1984. The deposit is in a friable section of Cambrian Addy Quartzite. Silica was also produced by Northwest Alloys, Inc. from their Blue Creek quarry.

Thurston County

Jones Quarry mined 140,000 tons of basalt from their quarry.

Whatcom County

Olivine was mined and milled by Olivine Corp. at the Swen Larsen quarry.

Limestone for use in cement was mined from the Kendall quarry, operated by Columbia Northwest Cement Corp. A total of 850,000 tons were mined, producing 600,000 tons of limestone.

Statewide

Meridian Minerals Co. explored throughout the state for industrial minerals. Clay, diatomite, limestone, silica, stone, and sand and gravel were pursued with geological exploration and drilling.

TIN, TUNGSTEN, AND MOLYBDENUM GEOCHEMISTRY OF PARTS OF STEVENS AND SPOKANE COUNTIES, WASHINGTON

By

Bonnie B. Bunning, Geologist

Division of Geology and Earth Resources

"Tin, Tungsten, and Molybdenum Geochemistry of Parts of Stevens and Spokane Counties, Washington," by Bonnie B. Bunning, is a new publication (Report of Investigations 28) of the Division of Geology and Earth Resources.

Twelve of the 51 mines and prospects sampled for this study carried anomalously high values of tin. The highest values were taken at the Young America and Daisy and Tempest mines. Four samples from the Daisy and Tempest mines assayed greater than 100 ppm tin. High values from the Young America mine ran greater than 1000 ppm tin. A newly discovered occurrence of scheelite, molybdenite, and chalcopyrite substantially increases the known area of tungsten mineralization in the Chewelah district. Two former tungsten districts, the Germania and Blue Grouse Mountain, were found to have high potential as porphyry molybdenum targets. Eight areas are recommended for follow-up work: Freeman clay pit, the Young America mine, Daisy and Tempest mines, USFS sample G-6/25 11R (tin); Regal Serpentine Quarry (tungsten); and Germania and Germania Consolidated mines, Blue Grouse Mountain, and the Silver Summit mine (molybdenum).

The results are taken from 131 rock samples collected from 51 mines and prospects in Stevens and Spokane Counties and analyzed for tin, tungsten, and molybdenum. Pulps from an additional 21 rock samples and 13 stream-sediment samples taken by the U.S. Forest Service were analyzed for tin.

High-grade mine samples were taken from prospects that (1) reportedly contain tin, tungsten, molybdenum, or copper; (2) are found near the reported occurrences; or (3) are geologically favorable for tin, tungsten, or molybdenum deposits. Sites identified as anomalously high by 1981 field work were revisited in 1983, and additional samples were taken to trace the source of the anomaly.

COAL ACTIVITY IN WASHINGTON - 1985

by

Henry W. Schasse, Geologist
Division of Geology and Earth Resources

Coal activity in Washington was at its lowest for the past five years. Exploration activity was low due to the continued depressed state of the coal market.

Two companies remained as the only producers of coal in Washington. They include the Washington Irrigation and Development Co. (WIDCO), operator of the Centralia Mine in Lewis County, and Palmer Coking Coal Co., which operates a small open-pit mine in southwestern King County.

WIDCO continues to supply its sole customer, the Centralia Steam Plant, from its Centralia open-pit operation. Production for 1985 amounted to 4,425,474 tons, or about 0.5 million tons more than last year's production, slightly less than its average annual production of 4.5 million tons over the past 11 years. The company also continued confirmation drilling of its mineral holdings at Centralia.

Underground coal gasification (UCG) research, started in 1980 at the WIDCO Centralia Mine, was terminated in 1985 by the partners involved. Empire Energy Co. (a subsidiary company of WIDCO) was coordinating the UCG efforts in Washington with partners which included the U.S. Department of Energy, the Gas Research Institute, WIDCO, Amoco Production Co., Washington State Energy Office, and the Weyerhaeuser Co. Unresolved liability considerations in the event of an out-of-control UCG burn led to the project's termination. There are still plans to excavate the burn cavity resulting from the 30-day test performed in 1983 in order to study the burn geometry. The excavation will probably take place sometime this spring.

Palmer Coking Coal Co. produced 17,125 tons of bituminous coal from its McKay Section 12 Mine east of Black Diamond. Most of its coal is sold to public institutions, and a very small percentage is sold for residential heating. This year's production exceeded last year's production by about 8,000 tons.

One of the more significant coal exploration efforts in Washington came to a halt in 1985. Royal Land Co., a subsidiary of Old Ben Coal Co., closed its office in Chehalis in November of last year. Poor market conditions were given as the reason for terminating their Curtis-Vader coal project. Royal Land Co. still holds a land position with its partner, International Paper Co., and other private leases.

Meridian Minerals Co. continued a low-key coal-exploration effort on its southern King County holdings. During 1985 it drilled a reported six exploratory holes in the Green River coal district. Meridian plans to continue exploratory drilling on a similarly modest scale during 1986.

Pacific Coast Coal Co. (PCCC) continues to get closer to opening its John Henry No. 1 open-pit mine northeast of Black Diamond. It received its mining permit from the Federal Office of Surface Mining (OSM) in 1985. PCCC is awaiting approval of its grading permit from King County. The company expects to break ground as soon as it receives the county permits, which it anticipates will be this spring.

The Council of Energy Resource Tribes completed its report last year on exploration drilling for coalbed methane on the Muckleshoot Indian Reservation. Drilling was completed in early 1984. One of the two test holes which were drilled intersected coal seams of the Kummer and Franklin coal groups. Methane was encountered in that hole; it probably came from the deeper, higher-rank seams of the Franklin coal group. Saltwater was also produced by that test hole, which was sealed to prevent possible environmental damage. The second hole did not intersect coal-bearing rocks of the Puget Group. A reference copy of the report can be seen at the Division library.

WILLIAM LINGLEY, JR. JOINS DIVISION

William Lingley, Jr. joined our staff on January 2 as a Geologist IV. He will be responsible for statewide administration of the following acts: Surface Mined Land Reclamation Act, Oil and Gas Conservation Act, and the Geothermal Resources Act.

Bill has a B. A. and M. S. (1973) in Geology from Western Washington University. His strength is the more than 11 years experience in all phases of oil and gas exploration from initial outcrop mapping to well site geology, log interpretation, drill project supervision and management. He has specialized working knowledge of northern Rocky Mountains, Indonesia, United Arab Emirates, Papua New Guinea and Australia. He comes to us from Chevron Overseas Petroleum, Inc., where he was an exploration coordinator. He has some experience in base metal exploration.

OIL AND GAS ACTIVITY IN WASHINGTON STATE - 1985

by

Raymond Lasmanis, State Geologist
Division of Geology and Earth Resources

The year started with the drilling of two new field wildcats in Oregon and Washington by Amoco Production Co. as part of their program on land leased from Weyerhaeuser Co. Amoco Weyerhaeuser 1-29 in Grays Harbor County was drilled with great difficulty to 12,293 feet, and then plugged and abandoned on January 29, 1985. Amoco's hole C-1 in Mason County was drilled to 2,500 feet, and then plugged and abandoned on May 28, 1985. It has been reported that the lease with Weyerhaeuser has been terminated, leaving two wildcats and six stratigraphic tests undrilled. Well data for 1-29 will become public on March 27, 1986, and the data for C-1 will become public on August 2, 1986.

There is considerable interest in viewing all of the information pertaining to Shell Oil Co.'s well BN 1-9 drilled on Saddle Mountain in Sec. 9, T.15N., R.25E., Grant County. The data will become public on April 13, 1986.

The Spring of 1985 brought excitement and optimism that the coalbed-methane potential of Pierce County would be tested by Wilexco Inc. and L. B. Petroleum, Inc. The accompanying map (Fig. 1) shows the distribution and status of coalbed-methane wells. In order to accommodate the relatively new technology for extracting methane directly from coalbeds, the Oil and Gas Conservation Committee in a meeting April 18, 1985, established the temporary "Carbonado Coal Pool". A 160-acre temporary development unit and multiple completions were authorized. These rulings are effective for two years.

L.B. Petroleum, Inc., drilled well Kerryn BN 34-11 to a final depth of 4,886 feet. It is located in Sec. 34, T.19N., R.6E., Pierce County. Although the well was designed to test Tertiary sandstone reservoirs, considerable coal was encountered; therefore, the operator worked with the Department of Ecology to convert the well to a coalbed-methane test well. The hole was plugged and abandoned on Feb. 5, 1986 after encountering minor amounts of methane.

MTA Resources, Inc., Dahl No. 1, one mile east of Birch Bay, Whatcom County, is presently suspended at 255 feet. Dahl No. 1 well is a shallow coalbed-methane test well on an anticline which has been tested by six previous operators. During 1982, diamond drilling for coal by Utah International Inc. on the structure encountered a significant gas show.

Although drilling has moderated, shot-hole seismic activity is at an all-time high. During 1984 the oil and gas supervisor issued nine permits. During 1985 a total of 35 permits have been issued. In all cases these permits are in conjunction with Vibroseis surveys. Shell has applied for 24 permits, Arco Exploration Co. 10 and Northern Geophysical of America one. Activity is concentrated in Adams, Grant, Kittitas, and Franklin Counties, with eight to ten surveys in each county. Other lines are proposed for Yakima, Klickitat, Lincoln, Benton, Walla Walla, Chelan, and Grays Harbor Counties. Particular centers of attention are Badger Pocket southeast of Ellensburg, Sentinal Gap area near Mattawa, the Connell area in Franklin County, and Columbia Hills in Klickitat County. There is optimism that such a high level of shot-hole seismic activity is leading to drill-target delineation.

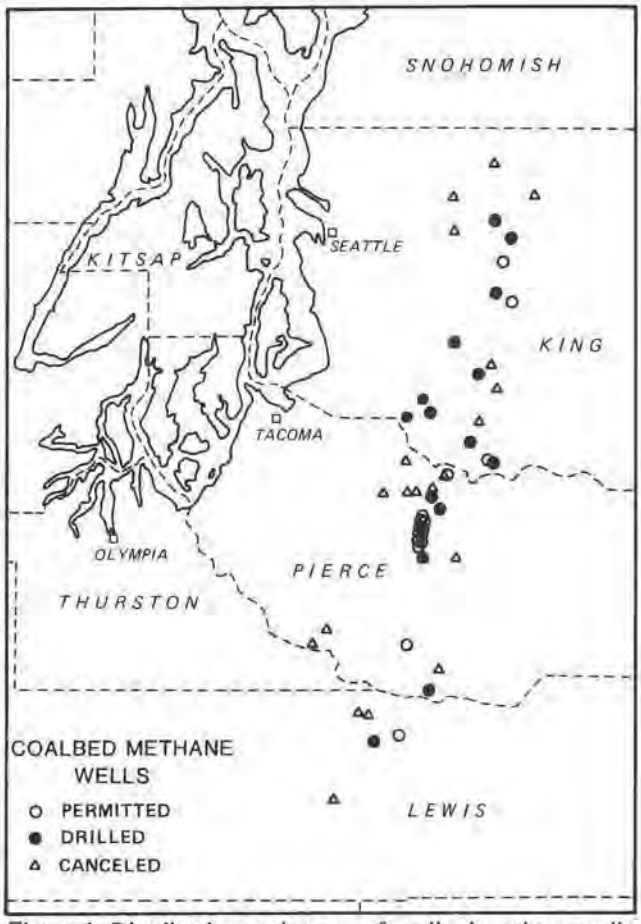

Figure 1. Distribution and status of coalbed-methane wells

To sum up, 1986 should see a renewal of drilling applications, and there is optimism that the coalbed-methane potential of Washington State will be adequately tested.

STATUS OF OIL AND GAS DRILLING PERMITS

Well	Permit No.	Total depth (ft)	Status
AMOCO Production Company Enumclaw 1-34	354	—	Cancelled
AMOCO Production Company WC-83-7	355	—	Cancelled
AMOCO Production Company WC-83-3	356	—	Cancelled
AMOCO Production Company WC-83-9	362	—	Cancelled
AMOCO Production Company WC-83-8	363	—	Cancelled
AMOCO Production Company WC-83-4	364	—	Cancelled
Weyerhaeuser D-No. 1	395	—	Cancelled
Weyerhaeuser C-No. 2	397	—	Cancelled
Wilexco Inc. Wilexco-Carbonado 1-17	404	1,367 K.B.	Drilling suspended

Correction:
AMOCO Production Company WC-83-21 (Permit No. 378) was plugged and abandoned 4-1-84, not 4-10-84 as previously reported.

MINERALS FORECAST REPORT AVAILABLE FROM BLM

A five-year mineral resource development forecast is available from Bureau of Land Management offices in Oregon and Washington, according to William G. Leavell, BLM Oregon-Washington state director.

The 56-page report describes important Pacific Northwest minerals, their location, their present status, and BLM forecasts for the agency's five-year plans.

Leavell said, "BLM is responsible for administering mineral and energy resources on approximately 53 million acres of public lands in Oregon and Washington. We are also minerals trustee for more than three million acres of Native American lands in the two states."

The report made some specific forecasts:

OIL AND GAS — There will be at least one new oil or natural gas commercial discovery in BLM's Spokane or Salem district by 1990.

GEOTHERMAL — There will be no unusual new demand for geothermal leasing. Emphasis will shift from leasing to exploration, probably on the flanks of the Cascades.

COAL — Exploration will continue west of the Cascades.

SAND AND GRAVEL — Demand for BLM mineral material will remain relatively static for the next five years.

GOLD — Gold prices will rise with consequent rising activity in mining claims.

NON-ENERGY LEASABLE MINERALS — Demand will remain about the same for potassium, sodium, and phosphates.

URANIUM — The market is depressed and likely will remain so for some time.

Patrick Geehan, BLM deputy state director for mineral resources, said this is the first forecast of its type for Oregon and Washington. "We welcome public comments to enhance both the description of mineral terrains and interpretation of future BLM needs to carry out an effective minerals management program on federal and tribal lands in Oregon and Washington."

For more information contact Bill Keil, United States Department of the Interior, Bureau of Land Management, Oregon state office, P.O. Box 2965 (825 NE Multnomah Street), Portland, OR 97208, telephone (503) - 231-6276, and refer to release number 86-15.

Drilling the Spud Hill geothermal test hole in northern Skamania County. Seven holes were drilled during the 1985 project, using two drill rigs and requiring two and a half months to complete.

GEOTHERMAL EXPLORATORY DRILLING BY THE STATE OF WASHINGTON IN 1985

By

Brent Barnett, Geologist
and
Michael A. Korosec, Geologist
Division of Geology and Earth Resources

INTRODUCTION

As part of an ongoing program for the past ten years, the Washington State Division of Geology and Earth Resources has been engaged in test hole drilling for geothermal gradient and heat flow assessment throughout the Washington Cascade Mountains. The results of this program up through 1983 are summarized in the Division Open-File Report 84-2 (Korosec, 1984b).

During the Summer and Fall of 1985, the Division drilled seven new geothermal gradient test holes in the southern Washington Cascades. This year's drilling was funded primarily by the U.S. Department of Energy, with subordinate cost sharing by the State of Washington.

The 1985 project area is located within the Gifford Pinchot National Forest in Skamania County and adjoining areas of Yakima and Klickitat Counties (Fig. 1). The test holes were sited with two main objectives in mind: (1) to more accurately define the general extent of potential geothermal resources and high heat flow associated with the Cascade volcanic arc; and (2) to pinpoint and evaluate specific targets that are geologically favorable for geothermal resources. The pursuit of these objectives leads to a greater understanding of the structural, tectonic, and volcanic character of the Washington Cascades.

DRILL SITE GEOLOGIC SETTINGS

One of the main criteria for siting the holes

specifically where they were drilled was the structural and geologic favorability of the areas. Recent studies on ages and volumes of Quaternary volcanism in the southern Washington Cascades (Hammond, 1980; Hammond and Korosec, 1983) suggest the existence of more or less discrete belts or zones of concentrated Late Cenozoic volcanic activity. Figure 1 shows the approximate inferred boundaries of three of these zones, informally referred to as the Mount St. Helens, Indian Heaven, and Mount Adams zones. In addition to the large andesitic-dacitic stratocones that are found within the Mount St. Helens and Mount Adams zones, these volcanic fields consist of basalt and basaltic andesite cinder cones and shield volcanoes from fissure-type eruptions.

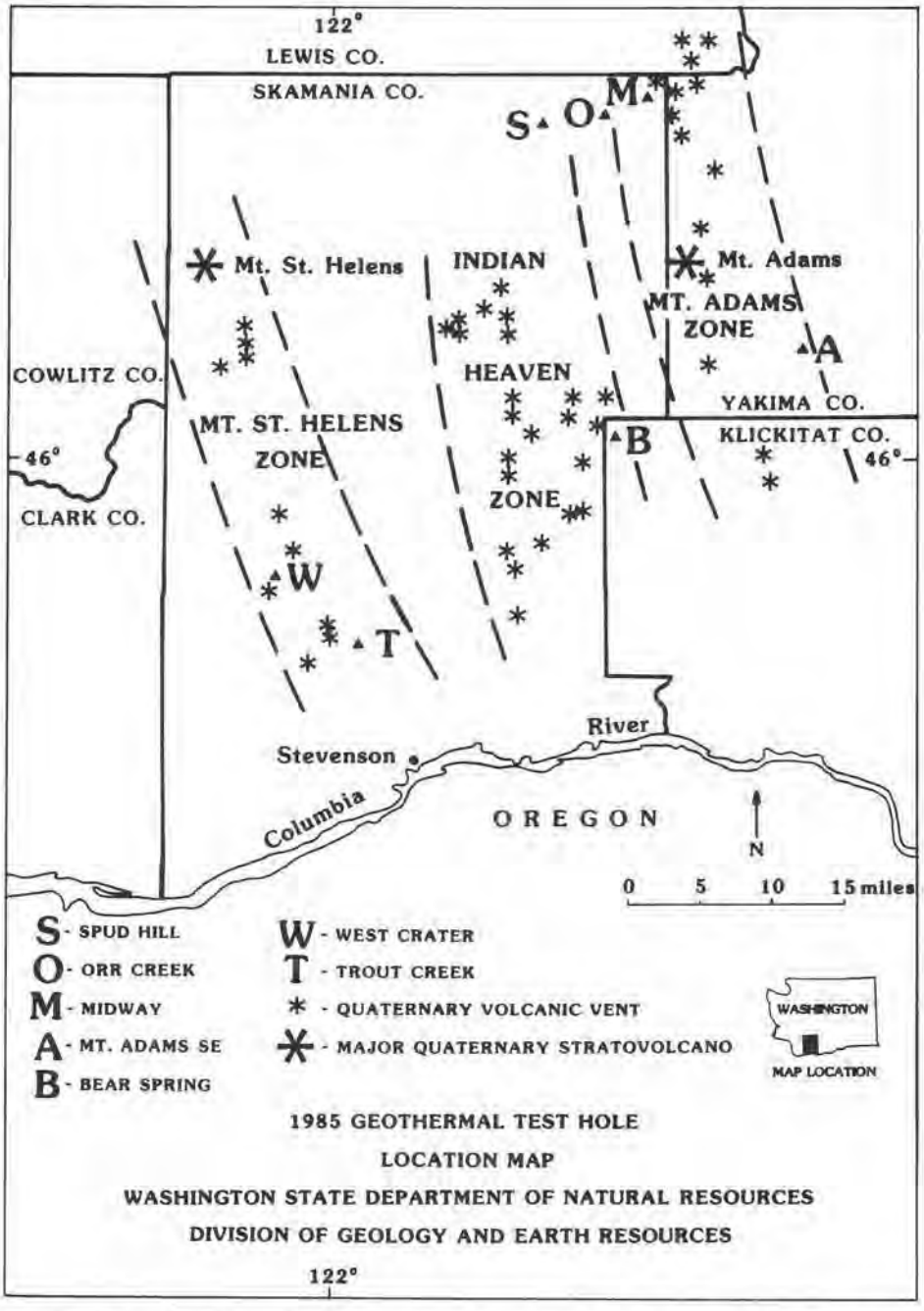

Figure 1. Locations of geothermal gradient test holes drilled during 1985 by Division of Geology and Earth Resources showing the volcanic zones of Mount St. Helens, Indian Heaven and Mount Adams (see text for discussion). Asterisks representing Quaternary volcanic vents show the approximate location of individual volcanoes, or the averaged position of a cluster of vents (zone boundaries adapted after Hammond and Korosec, 1983).

Carbon 14 age-dating of wood debris associated with flows (excluding the Mount St. Helens volcano) indicates that eruptive activity may be as young as 5,000 to 7,000 years, for vents in the West Crater area of the Mount St. Helens zone (Hammond, personal communication). Potassium-argon dating suggests that most of the flows in all zones are no older than about 700,000 years (Korosec and Hammond, 1983). Because these relatively young volcanic zones may represent deep-seated structures controlling the path of magma and hydrothermal fluids to the surface, they are especially attractive as potential geothermal resource targets. In the past, drilling within the Mount St. Helens and Indian Heaven zones has shown that local areas of elevated heat flow and geothermal gradients do indeed exist, but their regional extent is indeterminate (Schuster and others, 1978; Korosec, 1983).

Waters from hot springs and mineral springs, mostly occurring along fault trends or major lineaments in the southern Washington Cascades, have been extensively sampled and chemically analyzed (Korosec and Hammond, 1983; Korosec, 1984a). The equilibrium reservoir temperatures at depth, predicted by applying various geothermometers to the results of the chemical analyses, suggest that many of these hydrothermal systems are hot enough for the generation of electrical energy. In order to test the hydrology, geothermal gradients, and heat flow associated with these systems, earlier drilling projects by the Division have concentrated, in part, on constructing shallow test holes (152 m) near thermal and mineral springs. Results of these projects are presented in Korosec and others (1983).

Each of the holes drilled in 1985 was sited within or near one of the volcanic zones described above. Orr Creek (DNR85-1C) was spudded just outside the western boundary of the Mount Adams zone and approximately 1/8 mile south of the Orr Creek warm springs. Water from the spring was analyzed in 1979 and indicated equilibrium reservoir temperatures ranging from from 78°C to as high as 231°C, depending on which geothermometer is considered. The Spud Hill hole (DNR85-2) was drilled ½ mile east of two Quaternary cinder cones near what is believed to be a northern extension of the Indian Heaven zone.

The Midway hole (DNR85-3) lies within the Mount Adams zone and near Potato Hill, a basaltic andesite vent probably younger than 100,000 years. The Mount Adams SE hole (DNR85-4) was drilled within the Mount Adams fissure zone just ½ mile north of a Quaternary basalt vent. Bear Spring (DNR85-5) lies barely within the interpreted eastern boundary of the Indian Heaven zone, about ¾ mile south of Flattop Mountain, another Quaternary basalt vent.

The final two holes of the 1985 project, West Crater (DNR85-6) and Trout Creek (DNR85-7C), were drilled within the southern part of Mount St. Helens zone along a more restricted NW-SE lineament called the Wind River zone (Berri and Korosec, 1983). As shown in Figure 2, this structure is roughly demarcated by the course of the Wind River, a line of Tertiary intrusives, Quaternary volcanic vents, and by the occurrence of mineral springs and hot springs along its length. The intersection of the Wind River zone with the Little Wind River fault is the site of hot springs with surface temperatures of up to 53°C (Berri and Korosec, 1983). Drilling by the Division in 1981 near the Carson and Shipherds Hot Springs showed what is believed to be a very localized gradient of 366°C/km (Korosec and others, 1983). The 1985 Trout Creek hole, located 10 miles NNW of the hot springs, is a deeper twin to a 152 m hole drilled at the same location by the Division in 1981. The main reason for drilling deeper was to see if the high gradient of 84°C/km would persist with depth.

The West Crater hole is situated amid a concentration of Quaternary eruptive centers ranging in composition from high alumina basalt to andesite of

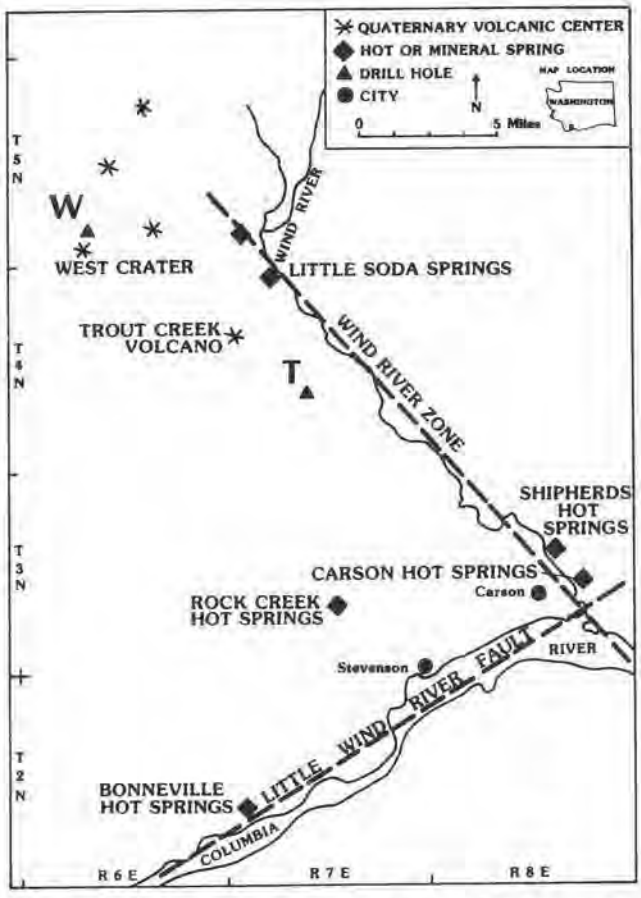

Figure 2. Major structural and volcanic features in the vicinity of the West Crater (W) and Trout Creek (T) drill holes. The map area is within the southern extent of the Mount St. Helens fissure zone (see Fig. 1). Positions of the Wind River zone and Little Wind River fault are from Berri and Korosec (1983).

the West Crater volcano. Hammond (personal communication) has suggested that at least 3 of the vents in the area are of Holocene age, with West Crater flows being as young as 5,000 years.

DRILL HOLE LITHOLOGIES

Drill hole lithologies are dominated by Tertiary volcaniclastic and pyroclastic rocks of Oligocene to Miocene age in all but two of the holes. These rocks consist of alternating layers of laharic agglomerates, tuffs, tuff breccias, and volcanically-derived sediments, now mildly metamorphosed and zeolitized. Owing to a ubiquitous clayey matrix, inherent permeability is usually very low in these rocks. Fractures are normally the only means by which water may migrate into or out of the formations. Consequently, hole problems were encountered only in the most severely fractured intervals within this rock type.

The two holes which did not encounter the Tertiary volcaniclastics were the Orr Creek (DNR85-1C) and Mount Adams SE (DNR85-4) holes. The Orr Creek hole was drilled entirely within a Tertiary quartz diorite plug of probable Miocene age. Permeability within this rock is also limited to fracture zones, but even these are often clogged with zeolite or clay filling. Lost circulation was a problem only in the largest of these fractured intervals.

The Mount Adams SE hole (DNR85-4) penetrated Miocene Grande Ronde Basalt of the Columbia River Basalt Group and associated interbeds for its entire extent. Fractured basalt intervals and sand-rich interbeds serve as aquifers or thief zones at this location. The hole was stopped somewhat short of the target depth (152 m) due to extreme caving within a basalt flow top or interbed. Table 1 summarizes drill hole lithologies and project data.

DRILLING AND HOLE COMPLETION

Two depth categories of holes were selected to be drilled; Orr Creek (DNR85-1C) and Trout Creek (DNR85-7C) were planned for 400 m (1,300 ft) depths, and the remaining five holes were to be drilled to 152 m (500 ft) each. In some cases, however, the actual completed depths were less as a result of drilling problems and budget constraints. Two different drilling methods were employed during the project. Orr Creek and Trout Creek were slim holes, drilled with a wireline diamond drill. These two deep holes were both spudded using an HQ-size coring assembly and later reduced to NX at around the 152 m level in each hole. The five shallow holes were drilled with a 6-inch pneumatic down-hole hammer. Diamond Drill Contracting Company of Spokane was the prime contractor for the project.

Immediately after drilling, each hole was completed in the manner schematically diagrammed in Figure 3. The main component of the test well is the 1½-inch black iron threaded pipe which was lowered into the finished hole, and filled with water. This water-filled conduit serves as a conductive corridor for use of a down-hole temperature probe in determining the local geothermal gradient. Where detected, all aquifers or permeable zones were cemented during pipe installation to prevent vertical water movement in the annulus, since that condition would tend to obscure the geothermal gradient in the affected portions of the hole.

GEOTHERMAL GRADIENTS AND TEMPERATURE–DEPTH CURVES

Following completion, each hole was given several weeks to equilibrate with the ambient formation temperatures, and was then logged with a down-hole temperature-sensing probe to obtain the local geothermal gradient.

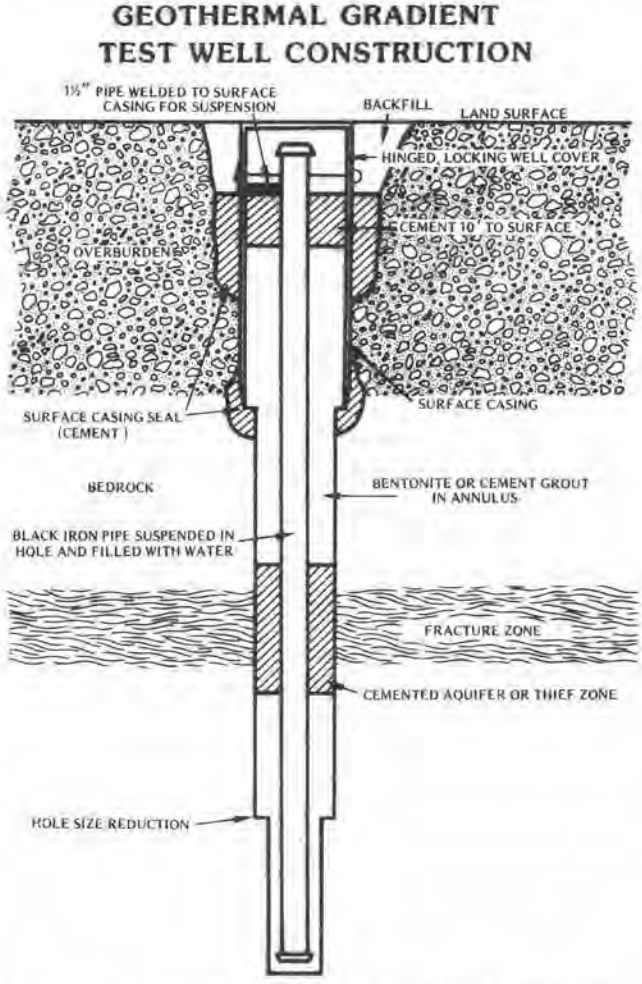

Figure 3. Schematic diagram of a completed geothermal gradient test hole as constructed for the Division's 1985 project. Hole size reduction applies only to the two deep core holes, Orr Creek and Trout Creek. The 1½-inch pipe is suspended by welds in order to eliminate tight bends that may hinder probe passage.

Table 1. — Summary of parameters for 1985 geothermal gradient test holes

Hole Name	Location Sec/T/R	Date Completed	Total Depth Drilled	Lithologic Summary	Date of Temperature Logging	Gradient °C/km / Interval of Measurement (meters)	Bottom-Hole Temperature °C
Orr Creek (DNR85-1C)	SW ¼, NE ¼ Sec. 19 T. 10N., R. 10E.	9-10-85	1000 ft. (305 m)	0-2 m, soil/colluvium, 2-31 m Tertiary quartz diorite porphyry; 31-41 m, fractured quartz diorite and fault breccia; 41-150 m, quartz diorite porphyry; 150-173 m, brecciated quartz diorite; 173 m-T.D., quartz diorite porphyry.	10-3-85	42 / 25-305	17.7
Spud Hill (DNR85-2)	NE ¼, SW ¼ Sec. 21 T. 10N., R. 9E.	8-18-85	500 ft. (152 m)	0-18 m, colluvium and landslide debris; 18 m-T.D., Tertiary pyroclastic rocks.	10-24-85	72 / 25-149	16.3
Midway (DNR85-3)	NW ¼, SW ¼ Sec. 15 T. 10N., R. 10E.	8-20-85	360 ft. (110 m)	0-55 m, glacial drift and intercalated basalt flow-flow breccia; 55 m - T.D., Tertiary pyroclastic rocks.	10-24-85	33 / 15-109	7.1
Mount Adams SE (DNR85-4)	SW ¼, SW ¼ Sec. 9 T. 7N., R. 12E.	8-23-85	473 ft. (144 m)	0-2 m, colluvium/soil; 2-37 m, basalt; 37-107 m, sand, gravel and clay interbeds in basalt; 107-137 m, basalt (aphyric); 137 m-T.D., scoriaceous basalt and sediments.	10-23-85	45 / 30-142	12.5
Bear Spring (DNR85-5)	SW ¼, NE ¼ Sec. 7 T. 6N., R. 10E.	8-26-85	500 ft. (152 m)	0-6 m, basaltic colluvium; 6-24 m, basalt, basalt flow breccia; 24 m-T.D., Tertiary pyroclastic rocks.	10-23-85	21 / 60-150	7.5
West Crater (DNR85-6)	SE ¼, SE ¼ Sec. 29 T. 5N., R. 6E.	9-6-85	500 ft. (152 m)	0-2 m, soil/colluvium; 2-15 m, basaltic flow breccia, tuff and tuff breccia; 15 m-T.D., Tertiary pyroclastic rocks.	10-23-85	-4 / 35-152	3.0
Trout Creek (DNR85-7C)	SE ¼, SW ¼ Sec. 21 T. 4N., R. 7E.	10-1-85	1169 ft. (357 m)	0-29 m, glacial drift and outwash sediments; 29-40 m, basaltic andesite flow; 40 m-T.D., Tertiary pyroclastic rocks.	10-22-85	87 / 50-330	36.3

The logging system consists of a thermistor probe on a 2000-ft. sheathed cable connected to a digital multimeter on the surface. The multimeter directly registers resistance values in ohms as the probe is lowered. Readings in ohms are recorded at 5-meter intervals until hole bottom is reached, then the bottom hole resistance is taken and the probe is withdrawn from the hole. The resistance readings are converted to temperatures in °C by means of conversion tables provided with the system. These data may then be plotted as a temperature-depth curve to illustrate the local geothermal gradient in °C/km, as shown in Figures 4 and 5.

Of the five shallow holes represented in Figure 4, Midway, Bear Spring, and Spud Hill all show reasonably constant increases in temperature with depth. The Midway hole was stopped 42 m short of the target depth due to caving in the hole. While the overall gradient at Midway is 33°C/km, the temperature-depth curve shows a slight warming trend near the bottom. Bear Spring is the lowest positive gradient recorded this year. The 21°C/km value may reflect a cold groundwater system at depth partially masking the true local geothermal gradient. Below the depth of seasonal disturbance, Spud Hill yields a relatively high gradient of 72°C/km. A small vertical section of the Spud Hill curve around 120 m probably represents very limited downward flow of water in this portion of the hole.

The Mount Adams SE and West Crater curves show some profound irregularities that require explanation. Between the 70-m and 80-m levels in the Mount Adams SE hole, the temperature jumps from about 9°C to over 12°C, and then remains nearly isothermal below the 80-m level. The probable reason for this sudden increase is that 12°C water was encountered in a permeable layer near the bottom of the hole and is flowing upward under artesian pressure to about the 70-m level. Around 70-80 m, the water is probably exiting the hole into a thief zone. Thus, water in the measuring pipe from 80 m to total depth assumes the thermal characteristics of the aquifer encountered near the hole bottom.

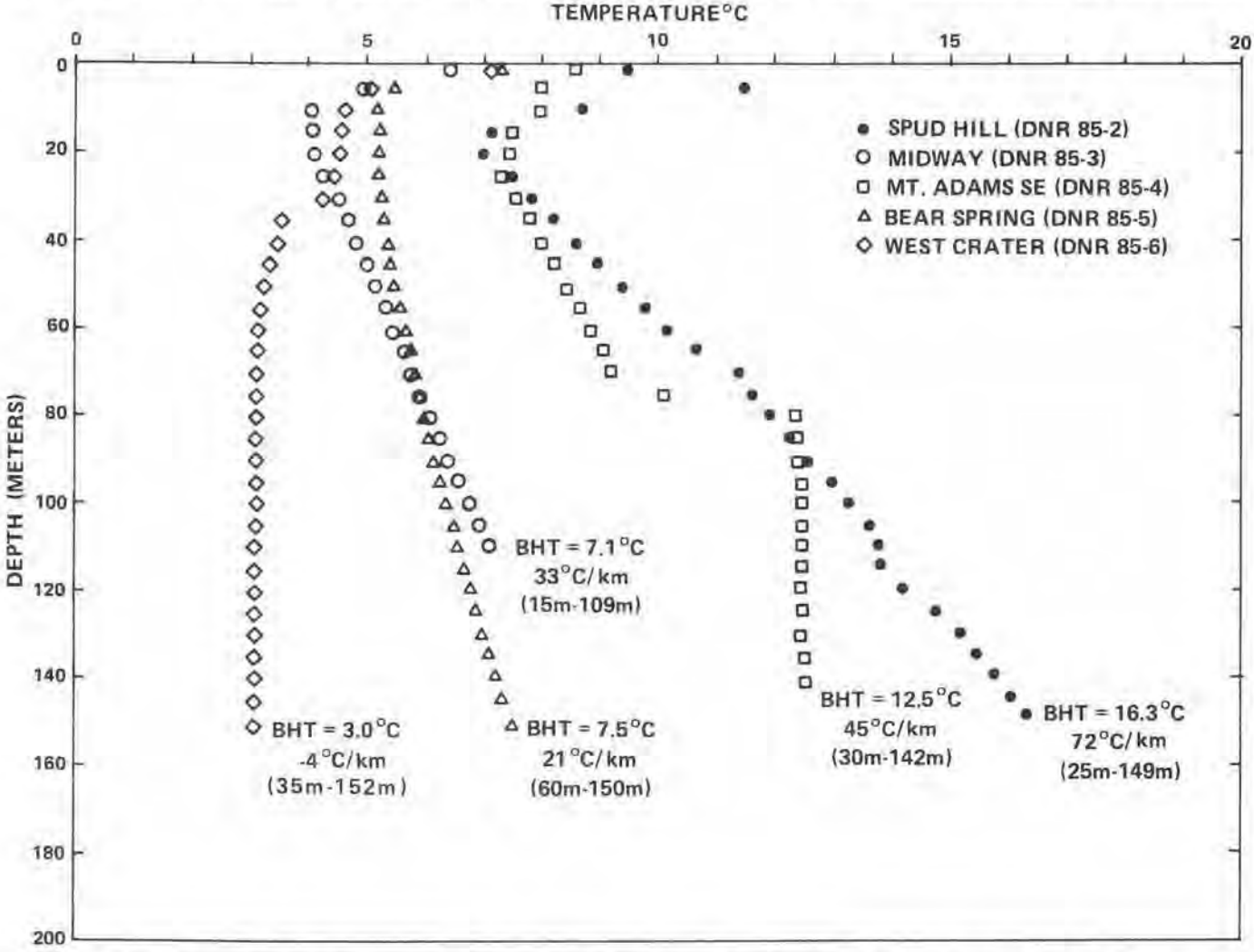

Figure 4. Temperature-depth curves for the five shallow test holes drilled by the Division in 1985 (see Fig. 1 for hole locations). Symbols represent temperature readings at 5-meter intervals. Bottom-hole temperature, gradient, and the interval over which the gradient was calculated are given at the endpoint of each curve.

If this is the problem, and if sealing of the annulus had been more successful, this condition would have been eliminated, and the entire curve below 30 m would appear as a projection of the interval between 30 m and 70 m.

The West Crater curve may be the result of drilling into rocks pervaded by extremely cold (3°C) groundwater to considerable depth. The large Quaternary cinder cones and scoriaceous volcanic edifices in the immediate vicinity of the hole serve as tremendous cold water recharge areas. Although the West Crater hole was drilled into relatively "tight" Tertiary rocks, the circulation of the cold water into fracture systems could impart a low temperature to rocks outside of and below the Quaternary pile.

The temperature-depth curve for the Orr Creek (DNR85-1C) hole (Fig. 5), may be viewed as representing two separate gradients. A large fault zone between 150 m and 173 m containing flowing water may be serving to thermally isolate the upper 155 m of the hole from that portion below the zone. From 25 m to 155 m, the gradient is approximately 27°C/km, whereas below the fault zone, the gradient abruptly increases to 56°C/km and remains relatively constant to the bottom. The average gradient from 25 m to 305 m is 42°C/km. If the lower gradient is the true regional gradient, then heat is probably being removed laterally along the fault.

The highest gradient and bottom hole temperature observed during the 1985 project were at Trout Creek (DNR85-7C). The gradient of 87°C/km from 50 m to 330 m, is 3°C/km more than the gradient recorded in 1981 from a 152 m hole 15 m away (DNR-7).

The last 20-30 m of the 1985 Trout Creek temperature-depth curve shows a slight deflection toward a lower gradient. The reasons for this are problematic, but an increase in permeability, mostly due to fracturing, or

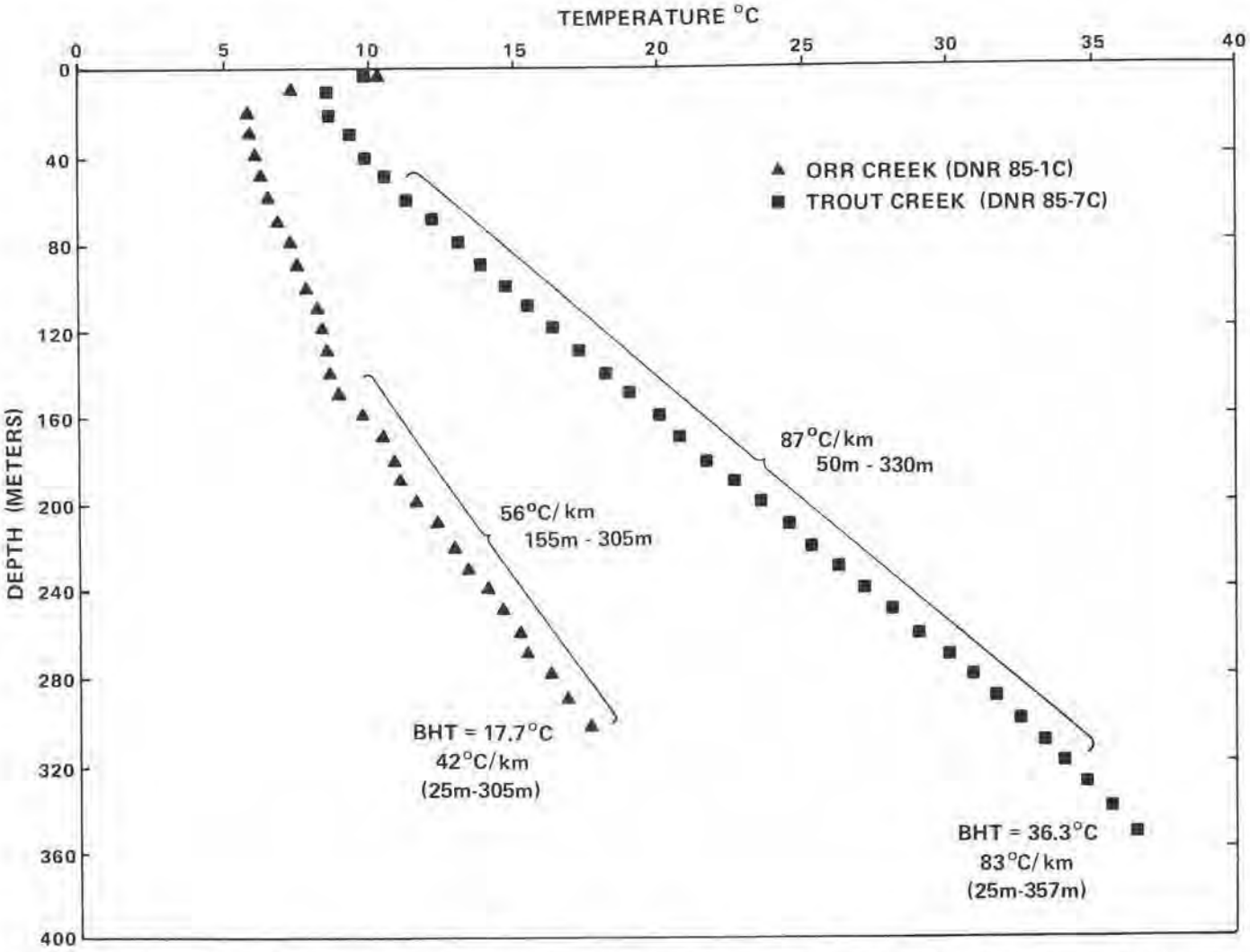

Figure 5. Temperature-depth curves for Orr Creek and Trout Creek, the two deep holes drilled by the Division in 1985 (see Fig. 1 for locations). Symbols represent temperature readings at 10-meter intervals. Bottom-hole temperature, overall gradient, and the interval for which the gradient is calculated are given at the endpoint of each curve. Bracketed intervals show higher gradients, which are possibly most representative of the true gradient at the corresponding site.

increased thermal conductivity of the rock could cause the observed change. An increase in fracture density is recorded from core near hole bottom, so that increased water circulation at this level is possible.

CONCLUSIONS

Of the seven holes drilled in 1985, Trout Creek (DNR85-7C) and Spud Hill (DNR85-2) have the highest geothermal gradients; 87°C/km and 72°C/km, respectively. Both holes are situated near or upon structural zones that apparently hosted recurrent volcanic and intrusive activity. In the Wind River area, where the Trout Creek hole is located, Quaternary volcanoes and present-day thermal and mineral springs roughly define a trend also occupied by Miocene intrusives (Berri and Korosec, 1983). Near the Spud Hill hole, Quaternary eruptive centers overlie Miocene silicic lavas and intrusives that are astride a fault and fracture zone possibly extending from the Cowlitz River (south of Mount Rainier) to the Indian Heaven area. These features may represent deep-seated, reactivated structures which serve not only as feeder systems for magma, but as conduits for hydrothermal fluids which may, in turn, supply near-surface aquifers. However, as exemplified by the temperature conditions in holes such as West Crater and Bear Spring, cold water recharge in some areas may mask or dilute the effects of upflowing hydrothermal fluids to significant depths. Geothermal exploration targets in the south Cascades should include sites near the structures discussed above, especially where they intersect other large faults or shear zones. As shown by the Trout Creek drill holes, results from shallow (150 m) drill holes may be successful in determining local geothermal gradients. But, as shown by holes like West Crater, extra care must be exercised in the siting of these shallow holes.

Since 1975, the Division has completed five geothermal drilling projects and a total of 39 temperature-gradient test holes, sited throughout the Washington Cascades. Evidence gathered to date indicates that there are many potential direct-use sites for geothermal energy in Washington (Korosec, 1984a), mostly associated with warm water aquifers of the Columbia Plateau and the thermal springs along the Columbia River. The potential and nature of the high-temperature resources capable of electrical generation are still only poorly understood, and will remain so until a more urgent need to develop alternative energy sources arises. At that time, efforts by private industry will need to include the prediction and testing of fracturing and lithologic character at depth. This exploration must be aimed at selecting sites which will produce not only high temperatures, but good permeability and an abundance of hydrothermal fluids.

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HIGH - CALCIUM LIMESTONE

By

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Division of Geology and Earth Resources

Calcium carbonate—limestone and marble—is used in some form in nearly every industrial process and in the manufacturing of thousands of products. The largest uses of limestone are for cement and road aggregate. Crushed high-calcium limestone (95% $CaCO_3$, or greater) is used as a flux in the smelting of aluminum and steel, as a soil amendment, and as a feed additive in agriculture. Ground high-calcium limestone is used as fillers and whiteners in paint, paper, white paste products, roof tiles, and glass.

The calcined limestone (lime, CaO) market is predicted to grow at a rate of three percent per year (Pressler and Pelham, 1985). An eight-percent growth rate is predicted for ground calcium carbonate products. An even higher rate of market growth for ground $CaCO_3$ products can be expected in the Northwest if calcium carbonate is substituted for kaolin as a paper filler. One new plant is under construction at Woodland, Washington to produce fine-grind calcium carbonate for fillers and coatings, but to date no paper manufacturers in the Northwest have announced plans for plant conversions to utilize calcium carbonate fillers.

EXPLORATION

Exploration for high-calcium limestones in Washington has recently increased in an effort to find deposits to meet possible future demand. The northern half of the state contains numerous deposits of high-calcium limestones and marbles of Precambrian, Paleozoic, and Triassic ages (Mills, 1962; Danner, 1966). The highest potential for exploration in the eastern part of the state is in both the Cambrian Metaline Limestone and Permian Spectacle Formation, host of the newly developed Wauconda Whitestone deposit in Okanogan County. In the western part of the state, limestone bodies occur in Devonian through Permian rocks. Pennsylvanian and Permian high-calcium limestones within eugeosynclinal assemblages have historically been the most productive. While deposits of high enough grade and sufficient tonnage may yet be found in Washington, they will prove to be economic to mine only if they are easily accessible or close to processing plants (Mills, 1962; Danner, 1966).

Deposit size, grade, purity, and proximity to market are the most important factors to the viability of a limestone deposit. Limestone grades of greater than 95 percent $CaCO_3$ are essential for use as high-calcium limestone, and the limestone must also be free of impurities such as silica, magnesium, iron and phosphorus. A high brightness value is also critical for use in industries where the whiteness of the stone is an important characteristic. The chemical consistency of the limestone is also important. Non-limestone, impure beds, or pinching and swelling units can decrease the quality of the limestone and increase mining costs. Transportation and processing costs must be kept low so that calcium carbonate can compete with other products with similar uses. For this reason many producers of limestone products develop their own quarries which are located near both the processing plant and sites of industrial use.

SOME USES OF LIMESTONE AND MARBLE

High-calcium limestone and marble-rock with 95 percent or more $CaCO_3$ can be utilized in industry in several forms: as lime (a product of calcination), as a precipitate, or as a crushed or ground product.

Calcined Limestone

Calcination is the thermal decomposition of calcium carbonate into lime (CaO) and evolved carbon dioxide (CO_2). When calcium carbonate is heated to 2000°F, quicklime is produced, and at 3000°F dead-burned lime is produced. Production of lime utilizes 20 percent of the production of high-calcium limestone.

Quicklime in some form is used in almost every industrial operation, either during manufacturing or in neutralizing industrial effluent. In metallurgy and steel manufacturing, lime is important as a flux. Lime is also important in water purification, in neutralizing acid waters, in treatment of sewage sludge, and as a disinfectant. Dead-burned lime is a dense, nonreactive substance that is generally used as a refractory in steel production.

A high $CaCO_3$ content of 98 percent or more with low percentages of impurities such as silica, magnesium, phosphorous, and iron is required for lime. Limestone decreases in solid volume and weight on ignition, so that the relative percentages of impurities increase during calcination. Because of the shrinkage factor, nearly two tons of limestone are required to produce one ton of lime. Limestone sells for $4 to $14 per ton. Energy consumption in the production of

quicklime is 6.7-million Btu per ton (Pressler and Pelham, 1985). The value of quicklime averaged $47 per ton in 1983. Clearly, the cost of quarrying, energy, and transportation are critical to profitability. Most lime production in Washington is concentrated around Puget Sound, near the quarries and industrial users.

Precipitated Calcium Carbonate

Precipitated calcium carbonate (PCC) is an ultrafine product formed by chemical dissolution of a high-calcium limestone or by ion exchange. Most PCC is recovered as a by-product from paper and pulp mills or from municipal water-softening plants. A pilot plant to manufacture PCC has just started production in Tacoma.

Precipitated calcium carbonate is preferred by the paper industry, especially for coating for white paper, and by other industries that require an ultrafine product of consistent particle size, chemical purity, and high brightness. The product can be ground if submicron-sized particles are required.

Ground and Crushed High-Calcium Limestone

Limestone and marble can be ground or crushed for numerous uses. New technology in crushing has expanded the markets for limestone products, particularly as fillers, extenders, and whiting agents.

Rock is designated as fine-grind when it is ground to 44 microns (325 mesh) or less, and ultra-fine-grind when the average particle size is less than 3 microns. The rock is ground in a dry or wet process; however, a wet grind is preferred for most ultra-fine products, because the slurry can be directly added to the manufacturing process.

In Seattle, one manufacturer produces ground-limestone products ranging from 200 mesh to 4 microns. A new plant is under construction in Woodland, near Vancouver, Washington, to produce an ultra-fine-grind product for use in whiting.

Ground limestone products sell from $98 to $260 per ton, depending on the average particle size; it is an energy-intensive product that utilizes 20 to 200 kwh to produce one ton of a 1-micron product.

Coarse-Grind

In the Northwest, glass manufacturing is an important market for producers of ground-limestone products. Limestone is used as a fluxing agent to form a chemically fused calcium silicate glass phase. The CaO of the limestone increases the insolubility of the glass, improves strength, reduces brittleness, and imparts a desired luster to the finished product.

Glass manufacturers require purity and consistency in chemistry and particle-size distribution. A $CaCO_3$ content of 98 percent or greater is generally required. The iron content for most glass products should be less than 0.05 percent, with less than one percent each of organic matter and insoluble substances, including silica.

Mineral fillers and resins are utilized in the production of white paper to fill voids between fine, intermeshed cellulose material, and as whiting to coat the paper to give it reflectance. Traditionally, the paper industry uses an acid process with kaolin as a mineral filler. Calcium carbonate is used in the process to digest the pulp and neutralize the effluent and precipitated calcium carbonate can be used as a coating. An alkaline process has been used in Europe by most white paper manufacturers for the last 15 years, using calcium carbonate as the mineral filler. Paper plants in the eastern United States are slowly converting to this process, which produces a whiter, stronger, more-permanent paper, at lower production costs. However, no plants on the West Coast have done so and most still use the acid process.

Requirements for processed calcium carbonate in the manufacturing of white paper are stringent: high calcium carbonate content, with a low percentage of impurities, especially grits, silicates, or material which may decrease the whiteness upon fine grinding. A "GE Brightness" of 92 or better is required. Properties such as crystal structure, rheology, and plasticity are important because the industry requires an ultra-fine water-ground product. The top grind size generally used for filler is 8 microns with 50 percent of particles in the range 2.2 to 1.5 microns, and the top size for coating is 4 to 5 microns with 50 percent of particles in the range 0.8 to 1 micron.

Compatibility of the size of the crushed-limestone particles with the silica sand is required to allow total homogeneity throughout the process. For float glass, for example, a consistent 3-mm size is sufficient, whereas a dominantly 75-micron (200-mesh) limestone is used for the production of fiberglass.

Ground limestone has several applications in agriculture. The main function of calcium carbonate is to reduce soil acidity. The additive also increases the effectiveness of certain fertilizers. A high-purity limestone, with minimal silica, iron, aluminum, magnesium, and heavy minerals, is also used as a mineral supplement in animal feed. The limestone is generally ground to 4 to 0.5 mm, and for some larger animals it is then made into pellets.

Fine- and Ultra-Fine-Grind

One of the largest uses of high-calcium limestone is in the manufacturing of paint, where it is used both to extend pigment and to control the gloss of the paint. A high-gloss paint uses an ultra-fine-grind of 3 microns

or finer, whereas a flat wall paint utilizes a fine-grind of 4 to 7 microns. Generally, less of the more expensive pigments are required when calcium carbonate filler is used. Calcium carbonate has an advantage over other mineral fillers in that it is hydrophilic and can be used in water-based paints.

Requirements of calcium carbonate for use in paints are similar to those for use in paper. A high-purity carbonate (96% to 98% $CaCO_3$) with high whiteness is necessary.

Calcium carbonate is the most widely used mineral filler in the plastics industry. Polyvinyl chloride products contain 20 to 30 percent ultra-fine limestone filler. Consistency of color and high brightness are important characteristics for limestone products used in non-black plastics.

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HIGH - CALCIUM LIMESTONES TESTED FOR BRIGHTNESS

By

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In 1981 the Division of Geology and Earth Resources sampled sixteen high-calcium limestone occurrences in eastern Washington for brightness testing. Sample sites were selected from those listed in *High-calcium limestones of eastern Washington* (Mills, 1962). Only limestones meeting the minimum purity standards of 95% $CaCO_3$, 3% $MgCO_3$, 1.5% SiO_2, 0.4% Al_2O_3, and 0.1% Fe_2O_3 were sampled. Twenty five-pound chip samples of unweathered limestone were collected for analysis.

Brightness is a numerical value for the reflectance of a sample in filtered light. The measurement of brightness generally used in the United States is called "GE Brightness," in reference to the specific photoelectric-cell instrument adopted by the Technical Association of Pulp and Paper Industries (TAPPI). GE Brightness is measured by focusing a light source of known wavelength (457nm) onto a paper or a pressed powder sample at an angle of 45 degrees. Brightness is read at 90 degrees to the sample by a photoelectric cell. In general, a GE Brightness of at least 92 on a scale of 100 is required for most whiting agents.

Samples collected for brightness testing were prepared in the Division's Olympia laboratory. The sample was crushed in a jaw crusher. Twenty-five grams of the crushed material were ground for 30 minutes in an agate mortar and pestle, wet-screened through a 200 mesh screen, and dried. The sample was reground using a mortar and pestle and pressed into a 3 centimeter "spec-cap" disk.

Relative brightness of the prepared disks was measured in sunlight with a photometer calibrated to manganese oxide samples of standard, measured brightness. The results are summarized in Table 1.

Table 1. — Sample Location, Comparative Brightness, and Estimated Reserves

Sample No.	Deposit Name	Location	DGER Brightness	Estimated Reserves (tons)[1]
L-81-9B	Pingston Creek (south reef)	SE ¼, Sec. 34, T.37N., R.38E., Stevens County	< 60	1,900,000
*L-81-10B	U.S. Gypsum (lower quarry)	NE¼ NE¼ Sec. 16, T.37N., R.38E., Stevens County	89.25	+1,000,000

[1] Reserve estimates taken from Mills, J. W., 1962, High-calcium limestones of eastern Washington: Washington Division of Mines and Geology Bulletin 48, 268 p.
*also tested for GE Brightness; see Table 2.

Table 1. – Sample Location, Comparative Brightness, and Estimated Reserves – Continued

Sample No.	Deposit Name	Location	DGER Brightness	Estimated Reserves (tons)[1]
*L-81-11B	U.S. Gypsum (upper quarry)	SW¼ Sec. 10, T.37N., R.38E., Stevens Co.	89.25	+3,000,000
L-81-12B	Bossburg East	NE¼, Sec. 33, T.38N., R.38E., Stevens Co.	< 60	46,000,000
*L-81-13B	Bossburg East	E½, Sec. 33, T.38N., R.38E., Stevens Co.	92.0	13,750,000
L-81-14B	Onion Creek	SW¼, SW¼, Sec. 25, T.39N., R.39E., Stevens County	89.25	800,000
L-81-15B	J. & E. Sherve	SE¼, NW¼, Sec. 8., T.39N., R.40E., Stevens County	81.5	11,000,000
*L-81-16B	Aladdin	S½ Sec. 29, T.38N., R. 41 E., Stevens Co.	86.0	5,000,000
*L-81-17B	Cedar Lake	SE¼ Sec. 35, T.40N., R. 41E., Stevens Co.	89.25	25,000,000
L-81-18B	Jumpoff Joe Lake SW	W ½, Sec. 1, T.30N., R.40E., Stevens Co.	81.5	
L-81-19B	Jumpoff Joe Lake SW	SW¼ Sec. 1, T.30N., R.40E., Stevens Co.	68.0	400,000
L-81-20B	Jumpoff Joe Lake SW	SW¼ Sec. 36, T.31N., R.40E., Stevens Co.	86.0	
L-81-21B	Hoage Lake	SW¼ NE¼ Sec. 22, T.40N., R.43E., Pend Oreille Co.	75.5	175,000,000
L-81-22B	Toroda Creek	NW¼ Sec. 25, T.38N., R.30E., Okanogan Co.	92.0	15,000,000
L-81-23B	Toroda Creek	NW¼ Sec. 25, T.38N., R.30E., Okanogan Co.	84.0	
L-81-24B	Cayuse Mtn.	Ctr. Sec. 25, T.38N., R.26E., Okanogan Co.	< 60	10,560,000
L-81-25B	Bunch-Wildermuth	Sec. 20, T.39N., R.29E., Okanogan Co.	71.5	5,000,000
L-81-26B	Buckhorn Mtn.	SE¼ Sec. 28, T.40N., R.30E., Okanogan Co.	< 60	15,000,000
L-81-54B	Pingston Creek (north reef)	SE¼ Sec. 34, T.37N., R.38E., Stevens Co.	67.5	2,450,000
L-81-55B	Brooks	NE¼ Sec. 22, T.37N., R.38E., Stevens Co.	75.5	4,500,000
L-81-56B	Aladdin	S½ Sec. 29, T.38N., R.41E., Stevens Co.	81.5	5,000,000

Five of the seven brightest samples were sent to Thompson, Weinman and Company in Cartersville, Georgia, for GE Brightness testing. The five samples were ground ultrafine (less than 12 microns) and tested. Tint (the difference between GE Brightness measured in blue and amber light) was also measured. Material with a tint value greater than 2 is unsuitable as a whiting agent. The GE Brightness, tint and size data are tabulated below (Table 2).

Table 2: GE Brightness of Selected Samples

Sample No.	GE Brightness	Tint	Insolubles	Particle Size -12 μ	Particle Size -3 μ
L-81-10B	91.46	1.76	0.7%	95.5%	53.0%
L-81-11B	89.84	1.74	2.0	95.5	49.0
L-81-13B	77.42	.83	1.0	94.0	48.9
L-81-16B	90.76	3.15	0.3	96.0	52.0
L-81-17B	89.52	5.25	8.7	93.0	47.0

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