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THE ORE BIN

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DEPARTMENT OF GEOLOGY AND MINERAL INDUSTRIES

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OREGON'S MINERAL AND METALLURGICAL INDUSTRY IN 1976

Ralph S. Mason, Deputy State Geologist
Oregon Department of Geology and Mineral Industries

Oregon's mineral and metallurgical industries almost exactly equalled the 9-year record production established in 1975. Preliminary figures for 1976 show a total of $106,122,000, which compares with $106,004,000 for the previous year. The current year's production may be low and subject to upward revision, as indicated by the final figures for last year, which were nearly 20 percent more than the preliminary estimate. The U.S. Bureau of Mines makes the annual canvass of mineral producers largely by mail. Slowness in response plus other difficulties account for the adjustment of the preliminary figures.

Little change was noted in the amount of production for the various commodities compared to last year. The value represented by the production which cannot be disclosed increased ccnsiderably, however, to a total of $33.6 million. This category includes cement, copper, diatomite, emery, gold, lead, silver, talc, and nickel.

Not included in the State total shown above is an additional $500 million worth of Oregon metallurgical products such as ferroalloys, carbide, reactive metals, ferro-silicon, ceramic ware, and aluminum.

Industrial Minerals

Production of both sand and gravel and crushed stone declined slightly over the previous year, responding to the continuing low level of heavy construction and road building. Interest in future supplies of these vital commodities took a sharp upward turn during the year as more and more county and city governments requested assistance from the State Department of Geology and Mineral Industries. Cooperative studies with several counties were underway during the year, and more are scheduled for 1977.

Sand and gravel and stone accounted for 62.5 percent of the State's mineral production in 1976, but the importance of these commodities to community development far outweighs the dollar value. No substitute exists for most of the uses to which the products are put; and when local supplies are exhausted, transportation assumes a major role in the laid-down cost.

Operation of the Empire Lite-Rock expansible shale quarry and plant in Washington County was assumed by GATX Leasing Corporation. The plant was forced to suspend operations during the year since it could not meet emission standards set by the Department of Environmental Quality. The plant had been in almost continuous operation since 1944, producing lightweight aggregate and pozzolan.

Skeletons of highly ornamented, tiny aquatic plants were mined, processed, and sold for pet litter by American Fossil, Incorporated at its diatomite operation in Christmas Valley in northern Lake County.

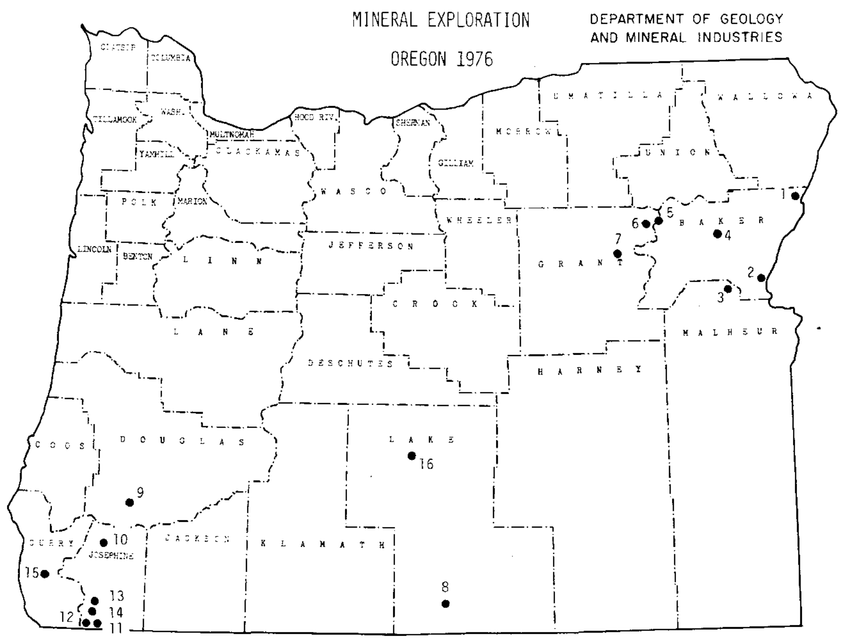
Table 1. Some of Oregon's minerals at a glance

Minerals	1975	1976*
Clays	$ 214,000	$ 263,000
Gem stones	500,000	500,000
Lime	3,281,000	2,727,000
Nickel	W	W
Pumice	3,937,000	4,014,000
Sand and gravel	29,596,000	24,850,000
Stone	40,321,000	40,142,000
Value of items not disclosed: cement, copper, diatomite, emery, gold, lead, silver, talc, nickel.	28,155,000	33,621,000
TOTAL	$106,004,000	$106,122,000

*Preliminary data provided by U.S. Bureau of Mines

EXPLORATION PROGRAMS

Numerous exploration programs were underway in Oregon during 1976. Considerable interest was directed to old mining districts having a history of gold, silver, or copper production. The search for geothermal energy intensified with both State and private industry conducting drilling campaigns and temperature gradient studies. Interest in uranium and chromite was revived. Two companies fielded crews searching for low-grade nickel deposits, and the Oregon Department of Geology and Mineral Industries entered into an agreement with the U.S. Bureau of Mines to study nickel resources.



1. IRON DYKE CU-AU	5. MEADOW LAKE CU	9. SILVER PEAK CU-ZN-AG	13. EIGHT DOLLAR MTN. NI
2. BAYHORSE AG	6. NEW YORK AU	10. ALMEDA AG-CU	14. WOODCOCK MTN. NI
3. BASIN CREEK PLACER	7. DIXIE MEADOW AU	11. QUEEN OF BRONZE CU-AU	15. RED FLAT NI
4. VIRTUE AU	8. WHITE KING U	12. TURNER ALBRIGHT CU	16. AMERICAN FOSSIL, INC.

The Iron Dyke copper mine on the Snake River in eastern Baker County was explored by Texasgulf. The Iron Dyke has a history extending back to the discovery of the deposit in 1897. The mine and mill were active during the first two decades of this century. In recent years there has been sporadic activity but no real production.

The Cougar and New York mines, Granite district, eastern Grant County, were investigated by W. A. Bowes and Associates of Steamboat Springs, Colorado. Both properties have a history of gold and silver production but have been idle in recent years. Plans to heap-leach the ore with sodium cyanide starting in the spring of 1977 were announced.

An intensive program of exploration and development was carried out by Dixie Meadows Gold Mines Ltd. at the old Dixie Meadows mine in the Quartzburg district of Grant County.

Johns-Manville continued exploration drilling at their Meadow Lake copper property near the crest of Elkhorn Ridge in Baker County. The company began investigating the area in 1971 with a soil sampling program, followed by diamond drilling. Due to environmental considerations the surface has been disturbed little. Drilling equipment has been transported either on all-terrain vehicles or by backpack.

Ibex Minerals,Inc. rehabilitated the main haulage level of the long-idle Bayhorse silver mine near Huntington on the Snake

River. The mine, which has a record of 286,000 ounces of silver produced prior to 1920, is being diamond drilled to determine the extent of the mineralized horizon.

The Big Yank Lode, a mineralized zone extending from the Almeda mine on the Rogue River northward for 35 miles to the Silver Peak mine in Douglas County, was the center of attention for Chevron, American Selco, Canadian Superior, Texasgulf, and Utah International. A total of $350,000 in copper, gold, and silver was produced from the various mines scattered along the lode early in the century. Cominco was also active in the area, focusing attention on the portion of the mineralized zone extending southward from the Almeda mine.

In the Takilma area of southern Josephine County, Canadian Superior reopened the Queen of Bronze mine, which supported a smelter in the early 1900's and has a history of production of about 35,000 tons. The deposit of small, irregular-shaped, somewhat lenticular bodies of massive sulphides was discovered in 1862.

The lateritic nickel deposits of southwestern Oregon were investigated by Inspiration at the Rough and Ready group, Inter-American Nickel Co. at Eight Dollar Mountain in Josephine County, and Hanna Nickel at Woodcock Mountain, several miles to the south. Hanna also continued its investigation at Red Flat in Curry County. The Oregon Department of Geology and Mineral Industries completed an evaluation of nickel resources in southwestern Oregon under a contract with the U.S. Bureau of Mines. The Department plans to pursue the study in the northeastern part of the State in 1977. The Bureau of Mines Albany Metallurgical Research Center conducted a series of metallurgical extraction tests on nickel laterites during the year.

American Selco explored the Turner-Albright copper-gold mine in southern Josephine County. Masses of highly silicified gossan enclosed in greenstone contain both pyrite and chalcopyrite.

At the Virtue gold mine near Baker, Tony Brandenthaler tested some of the old dumps to determine if they could be heap-leached. The Virtue, located in 1862, produced $2,200,000 in the period ending in 1907.

Western Nuclear did some exploratory drilling at the White King uranium mine in Lake County. The company has maintained ownership of both the White King and the adjacent Lucky Lass mines for many years. The properties are the only ones with records of uranium production in the State. Exxon and Utah International have established land positions in the same general area, and both conducted some drilling during 1976.

The Metals

Oregon retained the distinction of being the only state in the Union with a producing nickel mine. Hanna Mining Co. operated its Nickel Mountain mine and smelter at Riddle, Douglas County throughout the year, producing an estimated 19,847 short tons of nickel. The mine and smelter have been in continuous operation since 1954.

Production of gold continued at a very low level during the year. Basin Creek Mines, Inc. continued its placering on Basin Creek in the Mormon Basin district of northern Malheur County. Water for the operation must be pumped, settled, and recycled. Production during the operating season, June through September, totaled about 1,000 ounces.

Growing concern over the continued availability of metallurgical grade chromite from foreign sources prompted a renewed interest in southwestern Oregon chromite deposits. Oregon chrome mines contributed substantial quantities of high-grade lump ore and concentrates during World War II and the succeeding stockpile program.

Although Oregon is not a major metal mining state, the mineral processing industry's nine plants produced aluminum, ferroalloys, steel, zirconium, and titanium valued at more than $520 million from out-of-state ores and recycled materials. A total of 21 nonferrous and 15 iron and steel foundries in the State shipped products valued at an estimated $1 billion.

* * * * *

MINED LAND RECLAMATION IN 1976

Standley L. Ausmus, Administrator, Mined Land Reclamation
Oregon Dept. of Geology and Mineral Industries

During 1976, completed mined-land reclamation projects totalled 31. Typical projects for converting mined land to beneficial use were: Reforestation; restoration of range land; development of recreation sites; reclamation of solid-waste landfills for home, industrial, and commercial building sites; and restoration of mined land to agricultural use. Some lands having no immediate beneficial use were contoured and landscaped to blend as imperceptibly as possible with the surrounding terrain.

The sizes of these sites range from 1 or 2 acres up to 40 or 50 acres, with an average of 8 to 10 acres of disturbed land reclaimed at each. Continuing at this rate, we will be reclaiming 30 to 40 acres of mined land per month. Reclamation costs average $150 per acre. Offsetting this expense are increased land values, protection and preservation of natural resources, and improved quality of the immediate environment. Although some of these benefits are not measurable in dollars, the overall balance is tipped in favor of reclamation.

As of January 1, 1977 there were 206 active surface mining permits in effect, with approved reclamation plans on file. Active sites with "grandfather" certificates (limited exemptions) totalled 312. An additional 461 surface-mining sites are registered but are

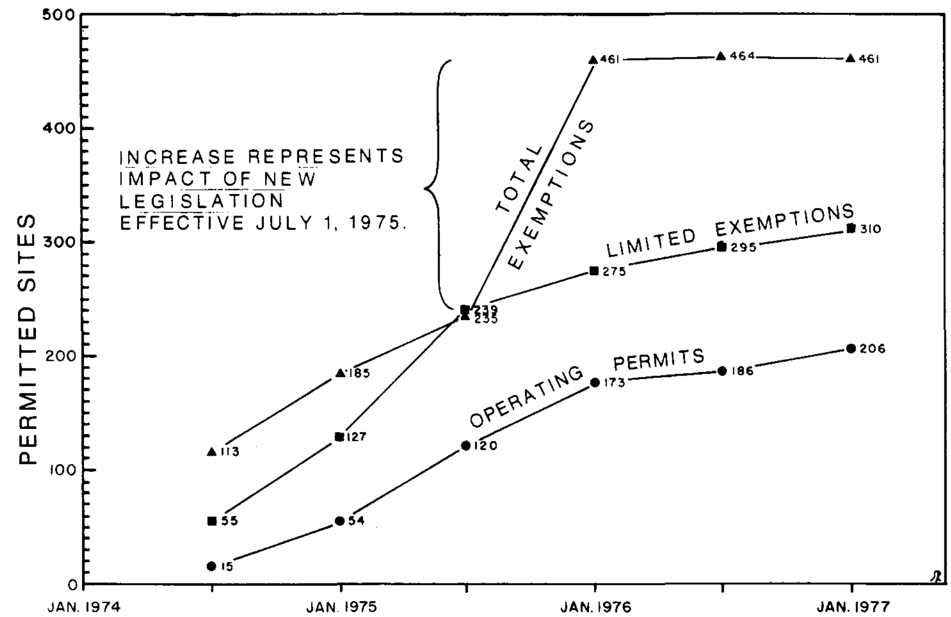


Figure 1. Mined land reclamation growth since 1974.

either inactive or too small to require permits at the time of registration. The status of each of these totally exempt sites is reviewed annually.

Total site registration as of January 1, 1977 was 1,314. Of these, 335 sites have been completed, abandoned, or determined to be under the jurisdiction of either the State Board of Forestry or the Division of State Lands.

New mining permits, with approved reclamation plans, are issued at an average of 5 per month, and another 10 permits are renewed each month. New limited exemptions are registered at the rate of 5 per month, and 18 are renewed.

Growth in mined land reclamation since January 1974 is shown in Figure 1.

* * * * *

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GEOTHERMAL ACTIVITY IN 1976

Donald A. Hull* and V.C. Newton, Jr.**

Government agencies and university researchers conducted more geothermal research in Oregon in 1976 than in 1975. Exploration by industry groups decreased, however, and no major discoveries were reported. One deep-test well was drilled and a second one, begun late in 1975, was finished. The major part of the exploration effort involved drilling shallow gradient holes to depths generally less than 500 feet. The Department issued six permits for deep wells and nine permits for prospect (thermal gradient) well projects in 1976.

Industry Activity

The majority of exploration programs were conducted east of the Cascade Range in the Basin and Range geologic province. Thermal Power Co. drilled a production test to a depth of 5,842 feet, south of Klamath Falls (see Figure 1); but caving and loss of tools forced the company to abandon the hole.

Chevron Oil Co. drilled temperature gradient holes in the Bully Creek area west of Vale in Malheur County, in the Alvord Desert near Fields, and in the Warner Valley south of Adel. AMAX Exploration, Inc. is currently engaged in a gradient drilling project in the Bully Creek area. Phillips Petroleum Co. drilled gradient holes near Newberry Volcano and Glass Buttes during the summer. Weyerhaeuser Co. and Pacific Power and Light Co. drilled a 2,000-foot hole west of Klamath Falls to test for geothermal gradient. (See Figure 2.)

Temperature gradient holes drilled by private companies are designed to locate and outline areas of abnormally high subsurface temperature, and in some cases subsequent deep drilling may be warranted.

The modest level of exploration by private companies in 1976 compared to 1975 was due to several factors, including: (1) The continued delay in leasing of key Federal lands in the Western Cascades and at Glass Buttes, (2) the lack of suitable Federal tax incentives for high-risk geothermal explorations, and (3) discouraging results in early drilling ventures. (Tables 1, 2, and 3.)

Research

Basic and applied geothermal studies are being conducted in the State by university researchers, the U.S. Geological Survey,

* Geothermal Researcher, Oregon Dept. of Geol. and Mineral Indus.
** Petroleum Engineer, Oregon Dept. of Geol. and Mineral Indus.

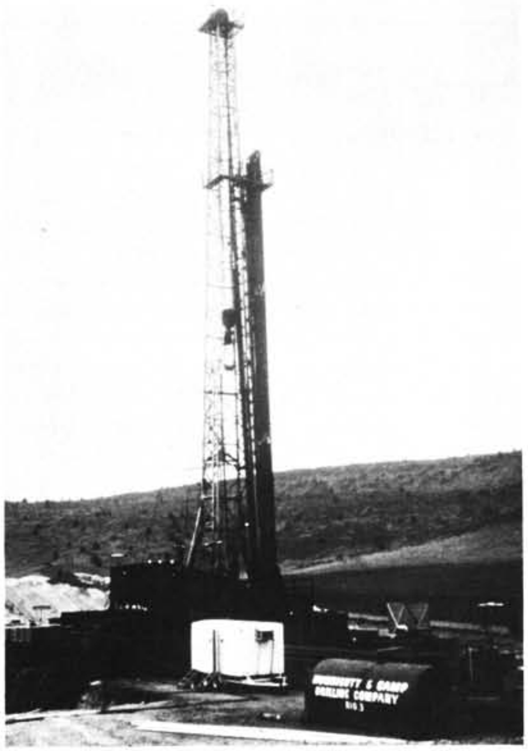

Figure 1.

Thermal Power Company deep geothermal test drilling (5,842 feet) about 18 miles south of Klamath Falls.

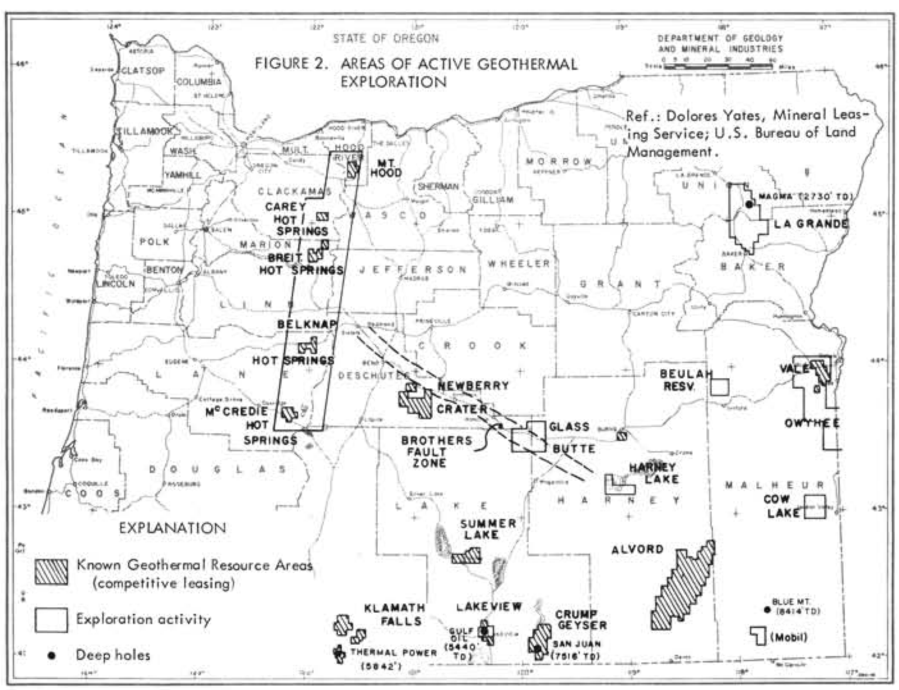

FIGURE 2. AREAS OF ACTIVE GEOTHERMAL EXPLORATION

Table 1. Geothermal deep well permits, 1976

Permit Number	Date Issued	Company	Location	Status
8	10/30/75	Weyerhaeuser - Pac. Power and Light	NE1/4NW1/4 sec. 15, T. 37 S., R. 7 E., Klamath Co.	Drilled 2,006'. Completed as temperature monitoring hole. Cased to total depth. Hole spudded in 1975 and drilling completed in 1976.
9	6/11/76	Thermal Power Co.	SW1/4 sec. 35, T. 40 S., R. 9 E., Klamath Co.	Drilled 5,842'. Pipe stuck at 2,400', backed off drill pipe and plugged hole. Abandonment in process.
10	8/28/76	Dept. of Geol. and Mineral Ind.	Proj. sec. 15, T. 2 S., R. 8 E., Clackamas Co.	Proposed to drill to 2,000'. Project postponed because of withdrawal of access to the Bull Run Reserve.
11	8/30/76	Dept. of Geol. and Mineral Ind.	Proj. sec. 19, T. 2 S., R. 8 E., Clackamas Co.	Proposed to drill to 2,000'. Project postponed because of withdrawal of access to the Bull Run Reserve.
12	10/15/76	Dept. of Geol. and Mineral Ind.	SE1/4 sec. 21, T. 4 S., R. 28 E., Morrow Co.	Proposed to drill to 1,000'. Mechanical difficulties encountered. Completed as monitor hole with total depth of 850'.
13	10/19/76	Republic Geothermal, Inc.	SE1/4 sec. 28, T. 18 S., R. 45 E., Malheur Co.	Proposed to drill to 1,500'. Project postponed.
14	10/19/76	Republic Geothermal, Inc.	SE1/4 sec. 28, T. 18 S., R. 45 E., Malheur Co.	Proposed to drill to 8,000'. Project postponed.

Table 2. Geothermal prospect well permits (thermal gradient holes), 1976

Permit No.	Date Issued	Company	Location	No. Holes - Status
16	5/19/76	Dept. of Geol. and Mineral Ind.	Glass Buttes area, Lake and Deschutes Counties	11 gradient holes, depth not to exceed 500'. Holes still being monitored.
17	6/4/76	Chevron Oil Co.	Southern Warner Valley, Lake Co.	21 gradient holes, depth not to exceed 500'. Holes still being monitored.
18	6/4/76	Chevron Oil Co.	West of Vale, Malheur Co.	18 gradient holes, depth not to exceed 500'. Holes still being monitored.
19	6/4/76	Chevron Oil Co.	Alvord Valley, Harney Co.	13 gradient holes, depth not to exceed 500'. Holes still being monitored.
20	6/10/76	Dept. of Geol. and Mineral Ind.	Western Cascades	10 gradient holes, depth not to exceed 500'. Includes one hole near Timberline Lodge. Holes still being monitored.
21	-	Dept. of Geol. and Mineral Ind.	Old Maid Flat, Mount Hood area	Changed to a deep well permit after decision to drill below 500'.
22	-	Republic Geothermal, Inc.	Vale area, Malheur Co.	Changed to a deep well permit after firm decided to drill deeper than 500'
23	10/19/76	Dept. of Geol. and Mineral Ind.	Succor Creek, Malheur Co.	5 gradient holes, depth not to exceed 500'. Holes still being monitored.
24	10/26/76	Dept. of Geol. and Mineral Ind.	Western Cascades (project extended)	5 gradient holes, depth not to exceed 500'. Includes a hole near Snow Bunny, Mount Hood. Holes still being monitored.
25	11/10/76	Dept. of Geol. and Mineral Ind.	Brothers fault zone, Malheur Co. (project extended)	4 gradient holes, depth not to exceed 500'. Project cancelled.
26	11/25/76	AMAX Explor., Inc.	Bully Creek area, Malheur Co.	44 gradient holes, depth not to exceed 500'. Drilling is in progress.

and the Oregon Department of Geology and Mineral Industries. (See list of reports below.)

Gunnar Bodvarsson at Oregon State University (OSU) is studying forced geo-heat extraction and modeling of thermophysical processes. At Oregon Institute of Technology (OIT) John Lund is investigating corrosion associated with geothermal fluids.

The Eastern Oregon Community Development Council at La Grande is investigating the feasibility of district space heating in Baker and Union Counties under the direction of Rich Huggins. The Geo-Heat Institute at OIT, the Oregon Department of Economic Development, and the Oregon Department of Geology and Mineral Industries are jointly studying applications of geothermal energy in food processing in the Klamath Falls and Vale-Ontario areas, with funds provided by the U.S. Energy Research and Development Administration. Brian Baker at the University of Oregon and Richard Couch at OSU are directing gravity and aeromagnetic surveys in the High Cascades and in the Vale area in Malheur County. At OIT John Lund is studying hydrological and geochemical aspects of the geothermal reservoir in the Klamath Falls urban area. Gene G. Culver, from OIT, and Gordon M. Reistad, from OSU, are investigating downhole heat exchanger designs. Paul J. Lienau, director of the Geo-Heat Institute at OIT, is studying the feasibility of district heating in Klamath Falls. Don J. Karr and W.C. Johnson are studying greenhouse and aquaculture applications, respectively.

The Oregon Department of Geology and Mineral Industries is continuing statewide heat-flow studies, under the direction of Donald Hull, with funding provided in part by the U.S. Geological Survey. Emphasis in 1976 was in the Western Cascade Range and the Brothers fault zone.

Norman Peterson, of the Department, and Walter Youngquist, consultant, completed a geologic reconnaissance of geothermal areas in the Western Cascades, financed jointly by the Eugene Water and Electric Board and the Department. Paul Hammond continued geologic studies on geothermal potential of the Western Cascades for a research project sponsored jointly by Portland General Electric Co. and the Department. The Department also contributed to studies of geothermal potential in the Old Maid Flat area near Mount Hood. The project objective was development of a hot water supply for the Portland area. Consulting geologist John Hook was the principal researcher, and Northwest Natural Gas Company assisted in funding the investigation and made a feasibility estimate for transmission facilities.

Richard Bowen, consulting geologist, prepared estimates for use of geothermal water to heat the Timberline Lodge at Mount Hood. This work, financed by the Department as part of its study of heat flow in the Cascades, included drilling a hole near the lodge to measure the geothermal gradient.

Ed Sammel and John Sass, of the U.S. Geological Survey, have recently completed a detailed study, including heat-flow data, of hydrology in the Klamath Falls basin.

Table 3. Federal geothermal exploration permits

Company	Date	Area	Type Survey
Hunt Oil Co.	3/24/76	Owyhee, Malheur Co.	Electrical resistivity
Chevron Oil Co.	5/4/76	Vale area, Malheur Co.	Electrical resistivity
Chevron Oil Co.	4/28/76	Warner Valley, Lake Co.	Electrical resistivity
Geonomics, Inc.	10/6/76	Alvord Desert, Harney Co.	Electrical resistivity, magnetotelluric
So. Union Prod.	12/1/76	Summer Lake, Lake Co.	Suite of geologic and geophysical surveys

Leasing

More than 2,000,000 acres are either applied for or under lease in Oregon for geothermal rights. A total of 78,136 acres of noncompetitive leases and 53,226 acres of competitive leases were in effect on Federal lands in Oregon at the beginning of the year. Another 1,200,000 acres of noncompetitive leases are now pending. The U.S. Bureau of Land Management held three lease sales in 1976, selling production rights on approximately 20,000 acres of KGRA lands (Tables 4 and 5).

The U.S. Bureau of Land Management processing of environmental reviews has advanced so well that the backlog of lease filings should be considerably reduced by this time next year. Applications for geothermal leases were filed during the year in the following areas:

Mount Hood area	Portland Gen'l. Electric Co.
Sisters area	PGE
Glass Buttes area	Phillips Petroleum Co.
Carey (Austin) Hot Springs area	Alaska Pacific Lumber
Carey H.S. area	Charlotte Hook
Carey H.S. area	Laura Spangler
Carey H.S. area	Sun Oil Co.
Warner Valley	Chevron Oil Co.

Table 4. Federal geothermal lease sales, 1976[1]

KGRA	Date	Tract No.	Bidder	Acres	Total Bid	Bid per Acre
Klamath Falls	5/13/76	1	Thermal Power Co.	280.00	$1416.80	$ 5.06
Klamath Falls	5/13/76	2-10	no bids	-	-	-
Klamath Falls	5/13/76	11	Thermal Power Co.	628.40	6353.13	10.11
Klamath Falls	5/13/76	12	Thermal Power Co.	600.00	6066.00	10.11
Klamath Falls	5/13/76	13	Thermal Power Co.	160.00	499.20	3.12
Klamath Falls	5/13/76	14	Thermal Power Co.	118.85	1201.58	10.11
Summer Lake	9/23/76	1	So. Union Prod. Co.	2391.70	9351.55	3.91
Summer Lake	9/23/76	2	Chevron Oil Co.	2281.85	4041.00	1.77
Summer Lake	9/23/76	3-4	no bids	-	-	-

[1]Area Geothermal Office, U.S. Geological Survey, Palo Alto, California

Table 5. Reoffering of Federal leases

KGRA	Date	Tract No.	Bidder	Acres	Total Bid	Bid per Acre
Vale H.S.	12/9/76	1	Union Oil Co.	1280	$27,021	$21.11
Vale H.S.	12/9/76	2	Union Oil Co.	2245	47,393	21.11
Vale H.S.	12/9/76	3	AMAX Explor.	2003	2,323	1.16
Crump Geyser	12/9/76	4-10	no bids	-	-	-
Crump Geyser	12/9/76	11	Chevron Oil Co.	1920	6,029	3.14
Crump Geyser	12/9/76	12	no bids	-	-	-
Crump Geyser	12/9/76	13	Chevron Oil Co.	1600	13,091	8.18
Crump Geyser	12/9/76	14	Chevron Oil Co.	1360	7,018	5.16
Crump Geyser	12/9/76	15-17	no bids	-	-	-
Klamath Falls	12/9/76	18-26	no bids	-	-	-
Klamath Falls	12/9/76	27	So. Union Prod.	1688	3,932	2.33
Klamath Falls	12/9/76	28	So. Union Prod.	1160	2,703	2.33

Indications are that economic conditions will continue to be favorable, and with continued effort geothermal energy can become one of the State's important resources.

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Peterson, D.L., and Meyer, R.F., 1976, Principal facts for a gravity survey of Summer Lake Known Geothermal Resource Area, Oregon: U.S. Geol. Survey open-file report 76-702A, 4 p.

Sass, J.H., Galanis, S.P., Jr., Munroe, R.J., and Urban, I.C., 1976, Heat-flow data from southeastern Oregon: U.S. Geol. Survey open-file report 76-217, 52 p.

Senterfit, R.M., and Bedinger, G.M., 1976, Audio-magnetotelluric data log and station location map for the Klamath Falls Known Geothermal Resource Area, U.S. Geol. Survey open-file report 73-320, 6 p.

Senterfit, R.M., and Dansereau, D.A., 1976, Station location map and audio-magnetotelluric data log for Summer Lake Known Geothermal Resource Area, Oregon: U.S. Geol. Survey open-file report 76-514, 6 p.

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OREGON ACADEMY OF SCIENCE TO MEET IN FEBRUARY

The 1977 meeting of the Oregon Academy of Science will be held in the Erb Memorial Union, University of Oregon, Saturday, February 26. William Loy, Department of Geography, is in charge of arrangements. Registration will start at 8:30 and a fee of $1.00 will be charged. Meetings will begin at 9:00 a.m. and continue the full day at the eight concurrent sections. Co-chairmen for the Geology Section are Robert Lawrence, Oregon State University, and Ansel Johnson, Portland State University.

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OIL AND GAS EXPLORATION IN 1976

V. C. Newton, Jr.
Petroleum Engineer, Oregon Dept. of Geology and Mineral Industries

Onshore

The Department issued drilling permits to Reichhold Energy Corporation and Texas independent, Michel T. Halbouty, in 1976. Reichhold reportedly was delayed by a partnership arrangement, so drilling did not begin this year. Halbouty postponed drilling until Federal leases are issued in the area of interest. There was no exploration boom in Oregon, but more oil companies are asking, "Why not oil in the Beaver State?" The number of deep exploration holes per square mile of prospective sedimentary basin is lower in Oregon than almost anywhere else in the United States.

Drilling Permits

Company	Permit	Well	Location	Projected Depth	Status
Reichhold Energy Corp.	#69	Columbia County #1	NW 1/4 sec. 11 T 6 N, R 5 W Columbia Co.	4,000'	Drilling pending
Michel T. Halbouty	#70	Federal #1-10	NE 1/4 sec. 10 T 23 S, R 29 E Harney Co.	8,500'	Drilling pending

Leasing

Leasing for oil and gas minerals continued at an active pace in 1976. Two new companies, Champlin Petroleum and Gas Producing Enterprises, both of Denver, Colorado, entered the competition. Champlin is reported to have applied for more than 100,000 acres of Federal leases in the Juntura-Harper area of Malheur County in 1976. Gas Producing Enterprises, Incorporated, began a leasing program in eastern Coos County in October 1976. Mobil Oil Company continued adding to its 700,000-acre lease holdings in southwestern Oregon; Texaco, Incorporated, added to its acreage in central Oregon; and Standard Oil of California enlarged its lease blocks in eastern Oregon during the year. Independents Ericc Von Tech, Farnham Chemical Company, and Reichhold Energy Corporation continued to build lease positions during the year. This current onshore activity may surpass all earlier exploration surges in Oregon. Large onshore exploration programs were undertaken here in 1945-46, 1952-57, and 1960-63. The offshore area was examined during the 1961-69 period when oil companies spent more than $60 million to test promising shelf structures. No commercial discoveries of oil or gas have been made in Oregon to date.

Estimates of oil and gas lease holdings or applications for leases in the State are listed here by lessees; the major portion of leases are on Federally owned lands. (See Figure 1.)

Batts, John	Billings, Mont.	60,000 acres
Champlin Petroleum Co.	Englewood, Colo.	100,000
Far West Oil Co.	Portland, Ore.	10,000
Farnham Chemical Co.	Portland, Ore.	15,000
Gas Producing Enterprises	Denver, Colo.	15,000
R.F. Harrison	Seattle, Wash.	5,000
Mobil Oil Co.	Denver, Colo.	700,000
Reichhold Energy Corp.	Tacoma, Wash.	30,000
Standard Oil of Calif.	San Francisco, Calif.	200,000
Texaco, Inc.	Los Angeles, Calif.	200,000
Tri-Tex	Sidney, Neb.	5,000
Ericc Von Tech	Coos Bay, Ore.	15,000

Between 1964 and 1967 seven deep holes were drilled off the Oregon coast,and an eighth hole was redrilled because of mechanical problems. These drillings revealed no discoveries, but shows of hydrocarbons appeared. Data from deep drilling and geophysical surveys indicate that prospective marine sedimentary rocks extend to a depth of 20,000 feet below the ocean floor at some locations. The main discouraging factor encountered was the lack of sand strata which could serve as a reservoir for fluid hydrocarbons.

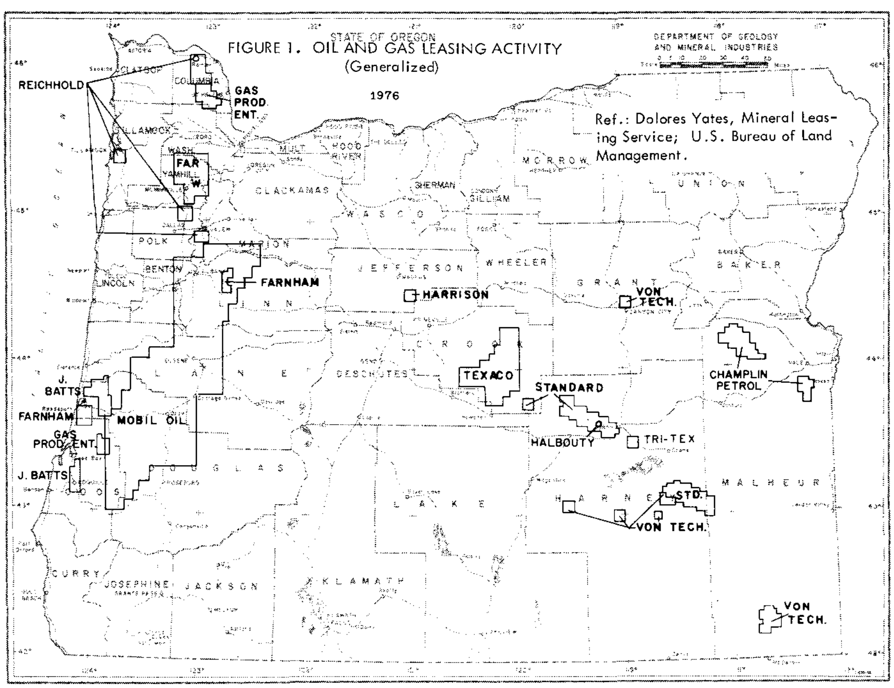


FIGURE 1. OIL AND GAS LEASING ACTIVITY
(Generalized)
1976

OCS Geophysical Permits, 1976

Company	Address	Permit No.	Expiration Date
Aero Service	Houston, Tex.	OCS 75-29	10/20/76
BBN Geomarine Services	Oxnard, Calif.	OCS 75-30	12/01/76
Shell Oil Co.	Los Angeles, Calif.	OSC 75-27	09/30/76
Texaco, Inc.	Los Angeles, Calif.	OCS 64-13	11/06/76
Western Geophysical	Englewood, Colo.	OCS 75-24	09/23/76

Research Triangle Institute, North Carolina, under contract with the U.S. Bureau of Land Management, held a regional workshop at the Portland Hilton Hotel December 15-17, 1976 to discuss necessary studies preliminary to leasing Pacific Coast shelf lands for oil and gas development. The USBLM contemplates calling for nominations in January 1977. If industry expresses interest in the Pacific Coast, certain areas will be offered for lease late in 1978. Estimate of lag time to possible production from the date of offering is from 6 to 8 years. The delay will be due to environmental review and to the physical means of finding petroleum. It will be 1985 at the earliest before any possible commercial production reaches the Oregon shore. Such additional oil and gas would come at a time when the U.S. is importing more than one-half of the petroleum products it will be using.

* * * * *

GEOLOGIC QUADRANGLE MAPS PUBLISHED

Three geologic maps covering a block of six quadrangles in Lincoln and adjacent counties have been published by the U.S. Geological Survey as part of its Miscellaneous Investigations Series. Authors are P.D. Snavely, Jr., N.S. MacLeod, H.C. Wagner, and Weldon Rau. Their work represents considerable refinement in stratigraphic interpretation over the maps of this series published in 1949 under the Survey's Oil and Gas Investigations series (OM 88 and 97). The three multicolor maps include cross sections and descriptions of units. The scale is 1:62,500. Each map is for sale for $1.00 by the U.S. Geological Survey, Box 25286, Federal Center, Denver, CO 80225.

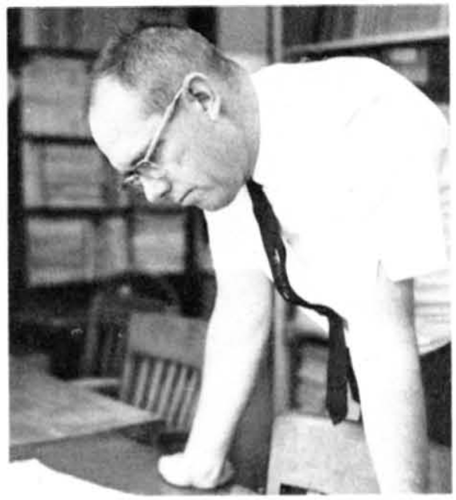
Map I-866. Geologic map of the Waldport and Tidewater quadrangles, Lincoln, Lane, and Benton Counties, Oregon.

Map I-867. Geologic map of the Yaquina and Toledo quadrangles, Lincoln County, Oregon.

Map I-868. Geologic map of the Cape Foulweather and Euchre Mountain quadrangles, Lincoln County, Oregon.

* * * * *

CHANGE OF HORSES IN MIDWINTER



R.E. (Andy) Corcoran

On February 1 Raymond E. Corcoran, State Geologist for Oregon since 1969, became Special Assistant for Environmental Assessment under the U.S. Bureau of Mines' Associate Director of Mineral and Materials Research and Development in Washington, D.C.

Corcoran, known as "Andy," had been with the Oregon Department of Geology and Mineral Industries since 1953, except for a 4-year period (1957-60) working on bauxite deposits for Harvey Aluminum Co. After rejoining the Department he began a program of coordinating and furthering the State Geologic Map Program for the eastern half of Oregon.

In 1969 Corcoran was appointed State Geologist, succeeding Hollis Dole. Under Corcoran's direction the Department has broadened its services to the State and has added new field offices in Albany and Corvallis. Significant research to promote use of geothermal heat as an alternate energy source was initiated during his administration. The Department's contributions to the State during Andy's tenure are symbolized by more than 50 informative bulletins, maps, and other published materials.

Ralph S. Mason now fills the position of State Geologist. Mason joined the Department as mining engineer in 1943 and continued in that position until 1971, when he was made Deputy State Geologist to assist Corcoran in carrying out the Department's rapidly expanding responsibilities. Ralph is well known to hundreds of Oregonians and others who have attended his geology classes, listened to his lectures and TV talks, and obtained his patient and friendly advice on all aspects of mining and prospecting.

Ralph S. Mason

As director of the Oregon Department of Geology and Mineral Industries, Ralph will carry on the Department's main objectives to conduct studies and publish reports involving the search for energy resources, the location and conservation of mineral resources, and the mapping of geologically hazardous conditions as a basis for land use planning.

CORRECTION: DESCHUTES VALLEY EARTHQUAKE REPORT

Please correct the coordinates for two stations listed on Table 1, page 155, October 1976 ORE BIN to read as follows:

OMW Omak, WA 48.480 N. lat., 119.561 w. long.
GMW Gold Mt., WA 47.548 N. lat., 122.786 w. long.

* * * * *

EAGLE CAP WILDERNESS GETS MINERAL SURVEY

Geological Survey Bulletin 1385-E describes a mineral survey of the Eagle Cap Wilderness, Oregon, proposed additions, and adjoining areas. The report states that 1,500 mining claims have been located in the wilderness area, although the only production is of gold from the Cornucopia district. More than $15 million in gold, silver, and copper have been produced from this district. However, the workings are now inaccessible. According to the bulletin, existing maps and records suggest that significant resources of gold may still be present.

The report points out that silver and lead occur in a quartz vein just beyond the north boundary of the area. The vein is estimated to contain 68,000 tons of material with 0.03 ounces of gold per ton, 0.71 ounces silver per ton, and 2.90 percent lead. Significant concentrations of copper may occur in certain parts of the area, according to the report.

* * * * *

OIL AND GAS LEASES ISSUED BY BLM IN EASTERN OREGON

Twelve oil and gas leases covering 26,818 acres in northwestern Harney County, Oregon have been issued to Standard Oil Co. of California by the Bureau of Land Management.

Murl W. Storms, BLM's Oregon state director, has announced that these leases, effective December 1, 1976, are the first of their kind issued in eastern Oregon since enactment of the National Environmental Policy Act (NEPA) in 1970

The area that Michel T. Halbouty, a Texas independent, plans to drill, under a "farm-out" agreement with Standard, is believed to be included in theleased land.

* * * * *

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* * * * *

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The ORE BIN
Volume 39, No. 2
February, 1977

NO MOSS ON OUR STONES

Ralph S. Mason

There are no simple solutions to many of today's problems, and supplying intelligent choices seems to be getting more difficult. Providing acceptable options for making decisions dealing with land use is steadily becoming one of the Department's most important functions. State, Federal, and local governments are becoming increasingly aware of the need for basic, factual data on the limitations and potentials of the surface and subsurface lands under their jurisdiction. For the past 10 years the Department has been providing just this type of information on a cooperative basis upon request. Dr. John Beaulieu, environmental geologist with the Department staff, describes some of our activities in this very important field in the article which follows.

Forty years ago the Department made its first study of the State's energy resources, publishing a report on Coos Bay coal in 1938. Since then, much effort and concern have gone into studies of the potential for oil, gas, uranium, and geothermal energy. To date no oil or gas has been found and only modest amounts of uranium have been produced. Oregon has a history of widespread, recent volcanism, with over 170 known thermal springs. In addition, results of heat-flow studies in shallow wells suggest an excellent chance of finding sufficient geothermal energy for commercial development. Dr. Donald Hull, staff geothermal specialist, enlarges on this newest source of energy and the potential for it here in the State in an accompanying article.

Concern for the quality of the environment finds its greatest champions here in Oregon. Directly as a result of this deep-rooted feeling, the Legislature created the Mined Land Reclamation Act in 1971 and designated the Department as administrator. Since that time, a small, largely fee-supported program has attempted to bring all subject surface-mining operations under the act. The principal thrust of the law is to assure that abandoned pits be cleaned up and the land reclaimed for some subsequent beneficial use. The history of one of these operations appears below as an example of complete cooperation between the landowner, operator, and the State. Jerry Gray, one of the authors, was the first staff member to work under the act and was the entire crew for 15 months until additional reserves came on board.

Geology used to be a subject of interest to geologists only. Nowadays children are interested in a wide variety of geologic phenomena; many college students take courses in geology just to learn more about the world they live in; and adults are becoming increasingly concerned about the environment, energy, mineral resources, and the part that geology plays in land planning at the local level. Their concerns reach the Department in many ways, and trying to respond to all of them poses problems. Many requests can be satisfied by means of existing publications printed over the past 40 years. Others require some personal attention by the staff, who either rummage through their files or search memories of their own past experiences for answers. Fortunately, we have access to many years of cumulative staff experiences which enable us to answer the wide variety of questions we are asked.

Environmental Geology

John D. Beaulieu

Accomodation of orderly land development while insuring public health, safety, and welfare is difficult and complex. The complexity is greatly reduced, however, if plans for land use are made with a full understanding of the natural characteristics of the land, the processes that shape it, and local geologic hazards. Geologic hazards of concern to the planner include mass movement, slope erosion, stream flooding, stream erosion and deposition, earthquake potential, and volcanic potential.

Average annual dollar losses caused by geologic hazards in Oregon are difficult to determine, owing to incomplete and scattered data. Indications are that landslide losses may total between $4 million and $40 million per year. As many as nine persons have been killed by a single landslide in Oregon in recent years. Losses through coastal retreat have totaled millions of dollars, because large parts of major communities have been destroyed. Flood losses alone will total $36 million per year by the year 2000.

In view of these losses, the Department's environmental geology program in recent years has emphasized land use geology. Projects have been completed in coastal Tillamook and Clatsop Counties, inland Tillamook and Clatsop Counties, Lincoln County, coastal Lane County, coastal Douglas County, western Coos County, and western Linn County. During the present biennium, work has been conducted in western Curry County, northern Hood River, Wasco, and Sherman Counties, and central Jackson County (see map, p. 25). The projects are briefly described below.

Land use geology of Curry County

The objective of this investigation was to provide county personnel with needed geologic information to assist them in

Slumping of roadway by undercutting of fill material is a common geologic hazard along western Oregon streams.

Floods are a frequent geologic hazard for coastal lowlands in Oregon.

planning for future growth. Major concerns are mass movement, coastal retreat, earthquake potential, flooding, and minerals as they relate to planning. Funding was provided by Curry County, LCDC, and the Department.

Curry County has undergone at least six major periods of geologic deformation. Shear zones associated with the last period offset rocks as young as Pliocene at Cape Blanco and may still be active. Currently available information is not adequate to give a final word on the seismic potential of the coastal parts of the county.

Results of the investigation of western Curry County are available in Bulletin 90, "Land Use Geology of Western Curry County, Oregon."

Geologic hazards of northern Hood River, Wasco, and Sherman Counties, Oregon

The objective of this current study is to provide county personnel with needed geologic information to assist them in planning for future growth. Unlike the Curry County study, this study emphasizes geologic hazards, with a minimum of attention paid to engineering properties of geologic units and none to mineral resources. Funding was provided by LCDC and the Department.

Massive, deep bedrock landslides have been identified along major faults and joints in Columbia River Basalt as well as in tuffaceous rock units in the overlying Dalles Formation and underlying Eagle Creek Formation. At The Dalles several factors combine to produce serious landslide problems within the urbanized area of the community. These include gentle northerly dips, tuffaceous interbeds, ground-water accumulation and discharge along the contact of the Dalles Formation and the underlying Columbia River Basalt, and changing land use. More detailed information must now be developed to guide the community toward responsible handling of these problems.

Results of the investigation will be published as Bulletin 91 in the late spring or summer.

Land use geology of central Jackson County

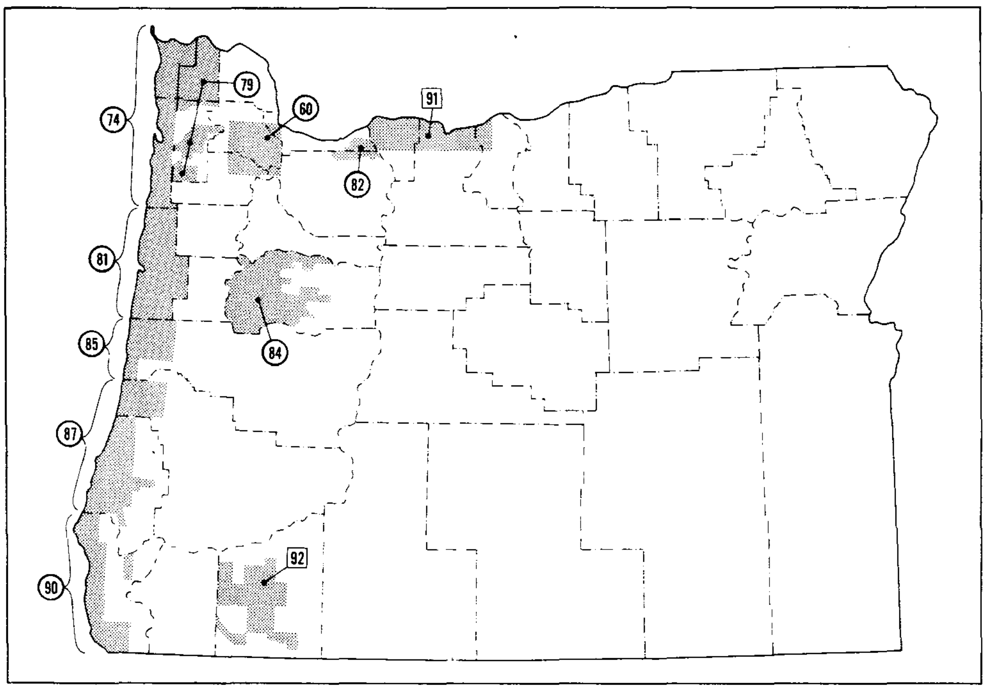
The objective of this study is to provide a broad base of geologic information for planning purposes with special attention to hazardous ground-water conditions, stream-bank erosion as it relates to gravel management, and mass movement. The study is being funded jointly by the Department, LCDC, and Jackson County.

Of particular concern are the geological problems associated with the flat terrain of the Bear Creek valley. Waters debouching from the surrounding mountains feed Bear Creek and deliver sediment to the valley. The alluvial fill of the valley is relatively thin and overlies bedrock which for the most part is impermeable and does not readily accept infiltrating water. In addition, much of the deposited material is rich in clay. The net result is a valley floor with low gradients, clay-rich soils, and poor drainage. High ground water and ponding plague the valley during the wet winter months; high ground water in the summer is a result of irrigation and unfavorable geology.

Results of this investigation will be published as a bulletin later this year.

Summary

The great variety of geologic settings and hazards encountered in the Department's environmental geology projects underscores the need for a broad base of geologic expertise in evaluating the geology of a region as it relates to land use. In addition, the ongoing program of environmental geology is making significant contributions to selected aspects of environmental protection, land management, and research.



LAND-USE GEOLOGY STUDIES

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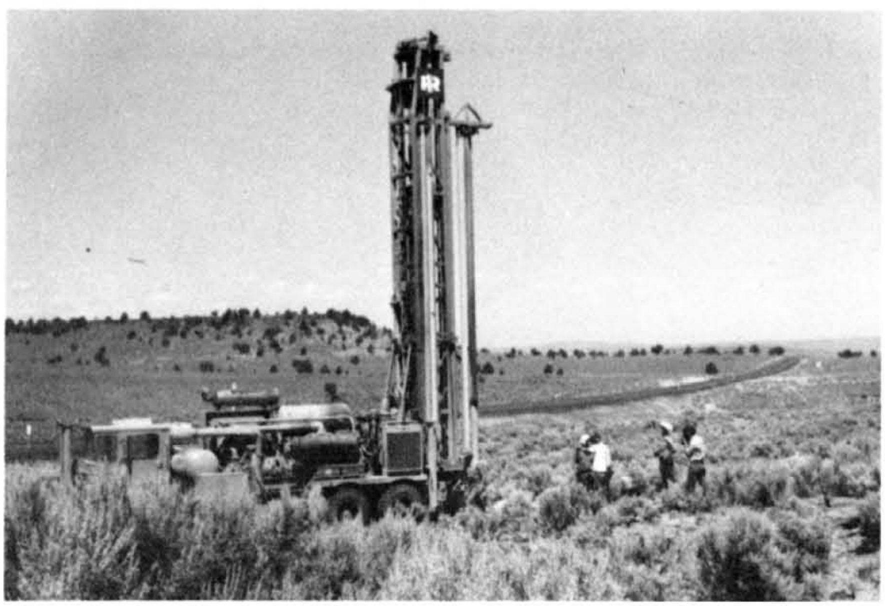
79. Inland Tillamook-Clatsop Cos.
81. Lincoln County
84. Western Linn County
85. Coastal Lane County
87. Western Coos-Douglas Cos.
90. Curry County
91. N. Hood R., Wasco, Sherman Cos.
92. Parts of Jackson Co.

Geothermal Assessment

Donald A. Hull

During the 1975-1977 biennium, our geothermal research was directed toward regional assessment of potential resources throughout Oregon and more detailed evaluation of favorable areas. These studies were financed mainly with Federal grants from the U.S. Geological Survey, the Energy Research and Development Administration, and the U.S. Bureau of Mines. The assessment techniques included geological mapping, heat-flow drilling, electrical resistivity surveying, and geochemical sampling of hot springs.

The products of these studies consist of a heat-flow map of the State, a library of geochemical analyses of geothermal fluids, and a variety of maps and reports describing promising geothermal resource areas in detail. These data will be of value to both public and private groups engaged in land use planning and exploration for geothermal resources. In addition, we anticipate that the results of our geothermal work during the 1975-1977 biennium will serve as a basis for environmental monitoring during future development of Oregon's geothermal resources.



Department's drilling project to measure heat flow along the Brothers fault zone in Harney County, central Oregon. Measurement of heat flow patterns in this area of young volcanic rocks assists in regional evaluation of potential geothermal energy resources.

Oil and Gas

Vernon C. Newton

The biennial period 1975-1977 was a time of renewed oil and gas activity for Oregon. The Department issued six oil and gas drilling permits during the biennium (five in western Oregon and one in central Oregon). The "energy crisis" and large increases in the price of petroleum products brought a surge of interest in the potential of frontier areas such as Oregon. This activity extended to all of the State's 27,000 square miles of sedimentary basins.

The Department's staff provided basic geologic data for Reichhold Energy and Northwest Natural Gas companies' joint venture in western Oregon to explore for natural gas. The State Geologist gave testimony at a Public Utility Commission hearing in favor of allowing Northwest Natural Gas to take part in the search for gas deposits. The two companies drilled four deep test holes in the summer of 1975 but were not successful in making a discovery. The drilling did, however, lend encouragement; and the companies have planned additional test drilling in western Oregon.

A study was undertaken and completed by the Department during the biennium to determine the prospects for commercial natural gas deposits in the upper Nehalem basin of northwestern Oregon. The investigation was also directed toward finding a gas storage structure if discovery of natural gas did not appear likely. Three companies now hold oil and gas leases in the area: Reichhold Energy, Northwest Natural Gas Company, and Gas Producing Enterprises.

A moratorium covering oil and gas leasing of Federal lands in Oregon has existed for the past 5 years; but starting late in 1976, the U.S. Bureau of Land Management began issuing leases again. The leases are being issued on an area-by-area basis, following environmental assessments. The Department has given the USBLM assistance by supplying geologic and exploration data for the preparation of its environmental reports.

Department representatives attended three conferences on oil and gas leasing of the Federal outer continental shelf lands in the two-year period. All of the sessions were conducted by the U.S. Bureau of Land Management with the purpose of keeping the various states informed of progress. A tentative Pacific Coast sale date has been set by the USBLM for late in 1978. A call for nominations of prospective areas by industry was issued in January 1977. Environmental studies will take approximately 2 years, during which time the Department will be asked for input related to geology, drilling, and development.

Farming Mined Farm Land

Ralph S. Mason and Jerry J. Gray

This is a story about a farm that was improved by mining. It is a success story with a cast of only three - a landowner, a mine operator, and the State Mined Land Reclamation Division. Of the three, the landowner and the operator are by far the most important. The State played a minor, but legally necessary, role by helping out from time to time. Great credit must go to the landowners, Jack and Mary Chapin of Salem, who insisted that the utility and livability of their farm should not be permanently lessened by the mining operation. Much credit is also due to Gordon H. Ball, Inc. of Danville, California, the firm responsible for the entire mining and reclamation program. The firm worked closely with the Chapins and the State, exceeding the requirements of the contract with the owners and the reclamation plan submitted to the State.

The locale is gently rolling farm land in the Willamette Valley 9 miles north of Salem, the State Capitol. Figures 1-A and 1-B show how the Chapin farm looked before the Gordon H. Ball company started its work. At that time, an old gravel pit, scattered mining refuse, and an adjacent swampy area made quite a bit of the land useless for farming. Here are the highlights of the story:

1. Prior to July 1, 1972: As 7 acres of the Chapin farm had been mined for sand and gravel prior to enactment of the Mined Land Reclamation Act, they were not covered by the Act and, therefore, had not been reclaimed.
2. April 1973: Gordon H. Ball, Inc., successful bidder for improving Interstate Highway I-5 between Salem and Woodburn, submits application for a provisional operating permit from the State Mined Land Reclamation Division.
3. May 1973: Mining contract is signed between the Chapins and Gordon H. Ball, Inc. for 50 acres, including the old gravel pit.
4. July 1973: Marion County issues conditional use permit for mining sand and gravel on the Chapin property.
5. July 1974: A performance bond of $25,000 is received by the Chapins from the Gordon H. Ball company.
6. August 1974: Reclamation plan is submitted to the Mined Land Reclamation Division.
7. November 1974: Reclamation Division is made co-holder of performance bond with the landowners.
8. December 1974: Surface Mining Permit is issued to Gordon H. Ball, Inc. by Reclamation Division.
9. October 1976: Mining and reclamation of the site is completed and operator is released from bond by landowners and the Reclamation Division.

And now for the program notes. You have already had a bird's-eye view of the mining site before it was opened up by the Gordon

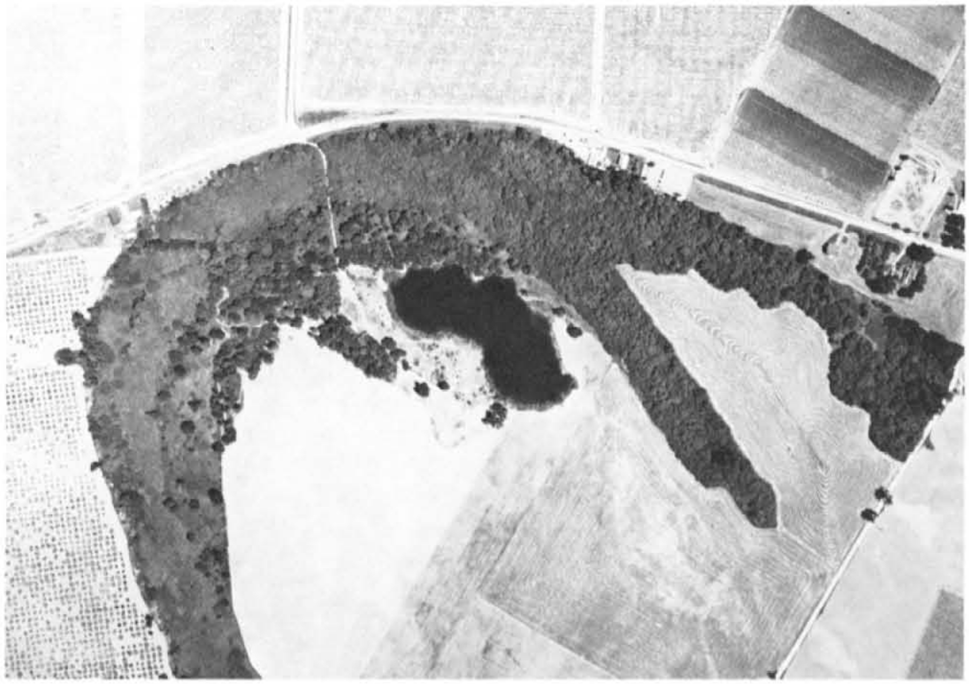


Figure 1-A. Farm before mining began under a reclamation plan.

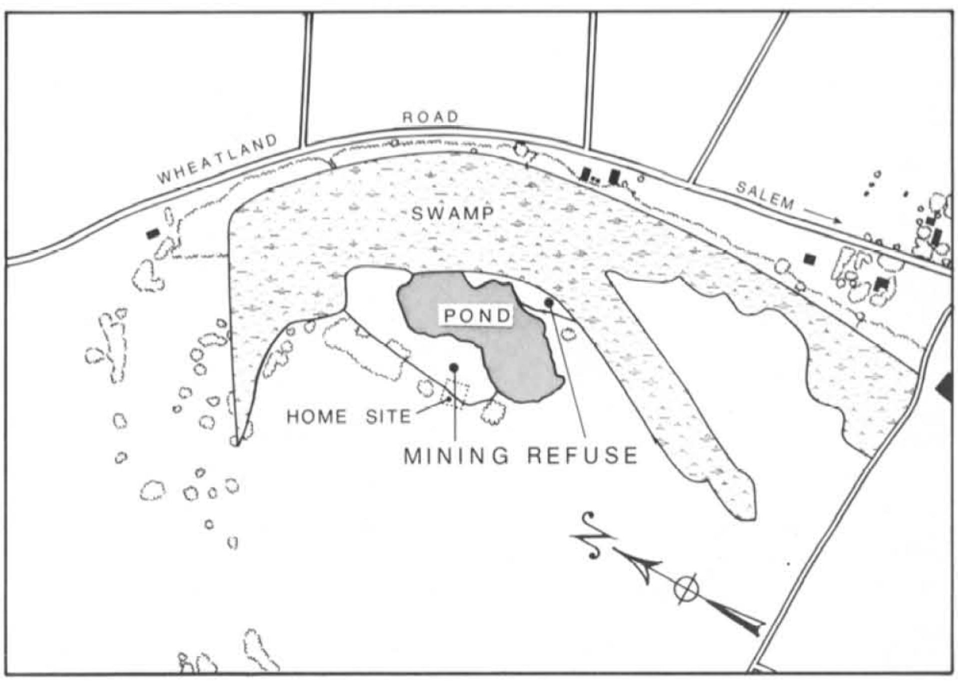


Figure 1-B. Sketch map identifying details of above photo.

Ball company. Figure 2 shows what it looked like during the peak production period. If you are confused by all the changes, keep your eye on the trees at lower left of the pond. They are part of the reclamation plan and are on stage in all three scenes. The scene is reminiscent of an Army proving ground when viewed from this angle, but please note that a dense line of trees along Wheatland Road forms a most effective visual barrier. Only the tip of the tall boom on the dragline by the edge of the pond was ever visible from the road.

The Chapin property was underlain by more than 40 feet of excellent sand and gravel, and the mining contract was written to encourage the operator to excavate as deeply as possible in order to gain the maximum amount of gravel per acre mined and to leave a viable lake. Since the aggregate processing would disturb good farm land and since the reclamation plan required restoring that land, the Chapins required that the topsoil in all areas to be disturbed had to be stockpiled and subsequently replaced and smoothed. In addition to restoring the disturbed areas, the operator had to grade the beach area around the lake to a slope not greater than 2:1. A strip in front of the home site was leveled with a 4:1 slope to form a bathing beach.

Figure 3 shows things all tidied up. Where once there were useless odd-shaped pieces of farm land, there are now usable areas. The brushy, swampy land has been filled in and replanted. A gently undulating heavy-duty access road leads to the home site. The Chapins' new home will command a view across a 24-acre lake fringed by tall trees. The lake is an esthetically pleasing private recreational facility, a fishing hole, and a handy source for water during the dry season. Furthermore, the beaches have a slope of 3:1 and 5:1 - better than the contract called for.

Finances are often a painful subject, especially for artistic productions like this one. Not here. The Chapin property happened to be 2.4 miles closer to the center of the I-5 highway project than an existing commercial pit nearby. Approximately 700,000 cubic yards of gravel were delivered to the highway project, with a royalty of 21.8 cents per cubic yard paid to the Chapins. At a cost of 10 cents per cubic yard per mile of haul, the 2.4-mile saving amounted to $168,000 for Gordon H. Ball, Inc. The reclamation work is estimated to have been worth about $50,000 to the Chapins; but since it was accomplished on a rolling basis as the work progressed, the actual expense to Ball was considerably less. A total of about 1,000,000 cubic yards of gravel was involved in the total project.

In a program such as this, the tax man cometh sooner or later. In this instance, he was ever present; and the following figures for the assessed valuation of the Chapin farm are of interest. In 1973 the Chapins' farm land was assessed at $24,470. During the first year of the Gordon H. Ball operation, the value climbed to $76,610, declining to $69,130 the next year. In 1976, after the mining was completed and the farm reclaimed, the assessed valuation was placed at $57,550. In other words, the farm land in-

Figure 2. Land use during mining and aggregate processing.

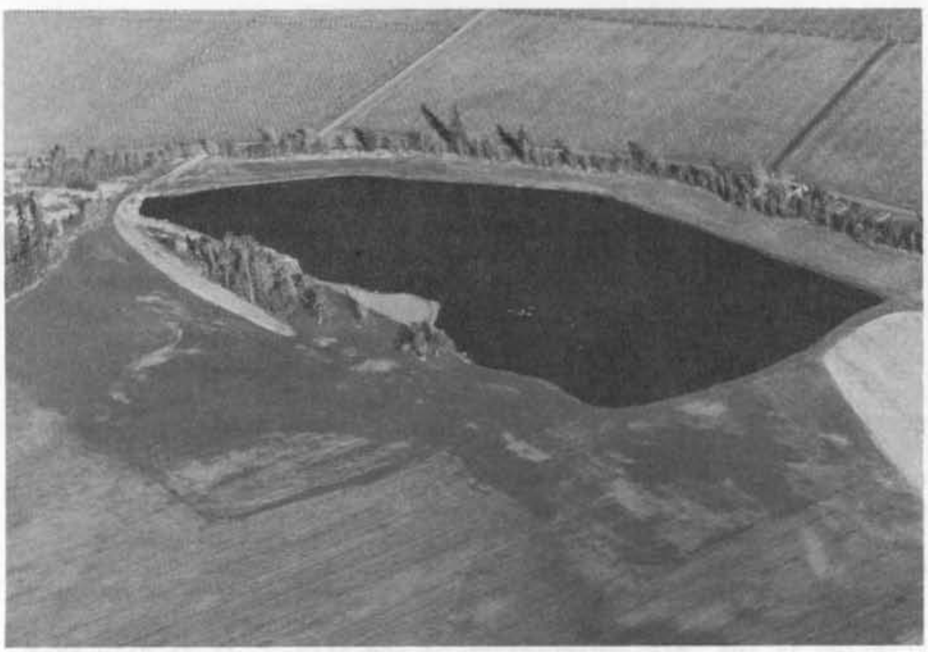


Figure 3. Land use after mined land reclamation completed.

creased in value over the 3-year period by $33,080, which amounts to 135 percent.

Ironically, a July 1973 letter written to the Marion County Planning Commission regarding the operations at the Chapin farm asked, "When will the raping of good farm land for mineral extraction stop?" This is a classic example of the way uninformed observers misinterpret what they see.

As we stated at the beginning, the Mined Land Reclamation Division played a small part in this entire program. If any credit is to be given to the agency, it would be for its role in making periodic inspections, assisting both the landowner and the operator from time to time, and, more importantly, recognizing that here was an excellent example of how good farm land underlain by valuable sand and gravel can be treated so that the farmer not only enjoys an economic advantage but ends up with a greatly improved farm, with a higher value and increased productive capacity.

If you are interested in learning just what the Mined Land Reclamation Act is all about, please write the Mined Land Reclamation Division, P.O. Box 1028, Albany, Oregon 97321, c/o Mr. Stan Ausmus, Administrator. Basically, the act applies to mining operations that disturb more than one acre of land annually or that produce more than 2,500 cubic yards annually; however, the Division's expertise is available for any reclamation problem.

If you reclaim what you disturb, we'll not disturb while you're reclaiming.

Department Publications

As the final step in many of its activities, the Department publishes results of its findings. The nature and complexity of the study determines the type of publication, distribution, and press run, ranging from limited numbers of open-file reports to several thousand copies of some environmental geology studies issued as bulletins complete with numerous multi-color maps. All formal publications are routinely distributed to repository libraries for dispersal of the information and preservation of the record. Additional copies are supplied to the cooperating agencies or local governments, and the rest are available for purchase.

Over the years much attention has been given to the problem of how much to charge for Department publications. Our basic philosophy currently revolves around two main considerations - first is to set sales prices at a level that will assure availability to those for whom the publication was intended; second is to try to recapture direct printing, handling, and mailing costs, plus a little more to provide for future publications. Printing is the "art preservative of the arts." It is also very expensive and, coupled with soaring postal rates, has closed the "freebies" window, perhaps forever.

Publications: 1975-1976

Bulletins

Bull. 87 - Environmental Geology of Western Coos and Douglas Counties, Oregon (1975)
Bull. 88 - Geology and Mineral Resources of the Upper Chetco Drainage including the Kalmiopsis Wilderness and Big Craggies Botanical Areas, Oregon (1975)
Bull. 89 - Geology and Mineral Resources of Deschutes County, Oregon (1976)
Bull. 90 - Land Use Geology of Western Curry County, Oregon (1976)

Oil and Gas Investigations

Inv. 5 - Prospects for Natural Gas Production and Underground Storage of Pipeline Gas in the Upper Nehalem River Basin, Columbia-Clatsop Counties, Oregon (1976)

Miscellaneous Papers and Publications

Index to the ORE BIN - 1950 to 1974 (1975)
Thermal Springs and Wells in Oregon (rev. 1975)
Proceedings of Citizens' Forum on Potential Future Sources of Energy (1975)
Fifth Gold and Money Session and Gold Technical Session Proceedings (1975)
Short Paper 25 - Petrology of the Rattlesnake Formation (1976)
Open-file - Bauxite (DOGAMI-USBM) (1976)
Open-file - Stream Sediment Sampling (1976)

Manuscripts in progress

Geologic Map Series 7 - The Baker 1° by 2° Quadrangle
Geothermal Report 1 - Geothermal Exploration Studies in Oregon
Bulletin 91 - Geologic Hazards of Parts of Northern Hood River, Wasco, and Sherman Counties, Oregon
Rock Material Resources of Umatilla County, Oregon
Fossil Reprints from The ORE BIN

The ORE BIN

Our monthly periodical, The ORE BIN, now in its 39th year, continues in good health with a paid subscription list of 2,205 (as of December 1976), plus copies for libraries and over-the-counter sale. Copies go to every county in the State, every State in the U.S., and to 14 foreign countries as well.

* * * * *

NATURAL GAS STUDY PUBLISHED

The Department recently published Oil and Gas Investigation No. 5, "Prospects for Natural Gas Production and Underground Storage of Pipeline Gas in the Upper Nehalem River Basin, Columbia-Clatsop Counties." Authors are Vernon C. Newton and Robert O. Van Atta.

The report discusses the stratigraphy of the area, the findings in two deep Texaco test holes, and petrographic descriptions of sedimentary units. Also included in the publication is a description of the Jackson Prairie gas-storage field near Chehalis, Washington. A geologic map showing interpreted fold and fault structures accompanies the report. Price of the publication is $5.00.

* * * * *

FEDERAL OIL AND GAS LEASE FEES RISE

Certain fees on non-competitive Federal oil and gas leases increased February 1, under new regulations announced by the U.S. Department of the Interior. The annual rental for leases awarded non-competitively, including the "simultaneous" leases, is now one dollar per acre, rather than 50 cents; but leases that were already in force are not affected.

* * * * *

M'DERMITT CALDERA REPORT ON OPEN FILE

"Volcanic Rocks of the McDermitt Caldera, Nevada-Oregon," by Robert C. Greene, has been issued as Open-file Report 76-753 by the U. S. Geological Survey. The report describes the sequence of Miocene volcanic rocks centering around the McDermitt Caldera, the probable source of an alkali rhyolite covering an area of about 60,000 square miles in Oregon and Nevada. A copy of the report is available for inspection at the Department's library in Portland.

* * * * *

GRAVITY SURVEY DATA ON OPEN FILE

The U.S. Geological Survey has issued Open-file Report 76-702A, "Principle facts for a gravity survey of Summer Lake Known Geothermal Resource Area, Oregon," by D.L. Peterson and R.F. Meyer. A reproducible copy of the three-page report is on file in the Department library.

* * * * *

DEPARTMENT RECEIVES WALTERS FOSSIL COLLECTION

The fossil collection of the late George and Jennie Walters of Portland, Oregon was recently donated to the Department by their son, Glen Walters. The collection is made up of a wide diversity of beautifully preserved fossils, identified and labeled, which won for the Walterses numerous awards in Mineralogical Society shows. The fossils are on display in the museum at the Department's Portland office.

* * * * *

FISH AND WILDLIFE DEPARTMENT ISSUES PLACER MINING GUIDELINES

The Oregon Department of Fish and Wildlife has issued a leaflet, "Oregon Guidelines for Timing of In-Water Work to Protect Fish and Wildlife Resources," which lists "preferred work periods" in Oregon streams. The DFW suggests that placer miners, particularly those using suction dredges larger than 4 inches, restrict their activities to the periods listed. Failure to do so might subject operators to penalties provided in Oregon Revised Statutes 498.006 and 509.040. Chapter 498 prohibits "chasing wildlife" and Chapter 509 prohibits "molesting spawning salmon."

Since the time required for the eggs to hatch and the fry to emerge varies among fish species at various water temperatures, and since weather conditions and stream flows vary considerably from year to year, the dates set forth in the Guidelines could be altered by the Department of Fish and Wildlife to assure optimum protection for the spawning fish. To avoid uncertainty and the threat of punishment, check before commencing placering operations. Write to the Department of Fish and Wildlife, 506 S.W. Mill Street, Portland, OR 97208; or call 229-5408.

* * * * *

NATIONAL PARK AREAS CLOSED TO MINERAL DEVELOPMENT

Six areas in the National Park system which had remained open to mineral entry under the general Mining Laws are now closed to new mining exploration and development by Public Law 94-429, recently enacted. The areas affected are: Death Valley National Monument, Glacier Bay National Monument, Crater Lake National Park, Organ Pipe Cactus National Monument, Mount McKinley National Park, and Coronado National Memorial.

Under the new law, existing mining claims within any of the six areas will be presumed to be abandoned unless recorded with the Secretary of the Interior by September 28, 1977. This procedure will enable the agency to determine valid mineral rights.

* * * * *

QUARTZVILLE AREA REPORT ON OPEN FILE

"Geology and mineral deposits of the Quartzville mining district, central Western Cascades, Oregon," by Steven R. Munts, is on open file in the Department library in Portland. The 150-page report is preliminary and subject to revisions and additions. The Department plans to publish the work upon its completion by the author.

* * * * *

SPOKANE OFFICE FURNISHES U.S. GEOLOGICAL SURVEY BOOKS

The Spokane branch of the U.S. Geological Survey is now the closest source for USGS bulletins, professional papers, water-supply papers, and miscellaneous leaflets on areas in Western states.

Order from: Public Inquiries Office, USGS; Room 678 U.S. Court-House Bldg.; West 920 Riverside Avenue; Spokane, WA 99201.

Make checks payable to U.S. Geological Survey.

Please note that the Spokane Branch of the Survey does not handle maps. To order maps of the Western states, write to: Branch of Distribution, USGS; Box 25286, Federal Center; Denver, CO 80225.

* * * * *

ALSEA FORMATION BOOKLET PUBLISHED BY SURVEY

"Alsea Formation, an Oligocene marine sedimentary sequence in the Oregon Coast Range," by P.D. Snavely, Jr., N.S. MacLeod, W.W. Rau, W.O. Addicott, and J. E. Pearl, has been issued as U.S. Geological Survey Bulletin 1395-F. The 21-page publication is illustrated and is for sale by U.S. Geological Survey, Public Inquiries Office, Room 678, U.S. Court House Building, West 290 Riverside Avenue, Spokane, Washington 99201. The price is 65 cents.

The Alsea Formation crops out in an arcuate belt in Lincoln County, contains abundant molluscan and foraminiferal faunas of early Oligocene age, and dips westward beneath the upper Oligocene-lower Miocene Yaquina Formation. Formerly designated as the upper part of the Toledo Formation, the Alsea has been given formational rank. Because the lower part of the Toledo is now considered to consist of Eocene Yamhill and Nestucca Formations, the name "Toledo Formation" has been abandoned by the Survey.

* * * * *

TIME TO RENEW? Note your ORE BIN expiration date on the back cover of the October issue. Renew in time to avoid "losing" an issue.

AVAILABLE PUBLICATIONS

(Please include remittance with order; postage free. All sales are final - no returns. A complete list of Department publications, including out-of-print, mailed on request.)

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26. Soil: Its origin, destruction, and preservation, 1944: Twenhofel	$ .45
33. Bibliography (1st suppl.) geology and mineral resources of Oregon, 1947: Allen	1.00
35. Geology of Dallas and Valsetz quadrangles, Oregon, rev. 1964: Baldwin . .	3.00
36. Papers on Tertiary foraminifera: Cushman, Stewart and Stewart, 1949: v. 2, . .	1.25
39. Geol. and mineralization of Morning mine region, 1948: Allen and Thayer . .	1.00
44. Bibliog. (2nd suppl.) geology and mineral resources of Oregon, 1953: Steere.	2.00
46. Ferruginous bauxite deposits, Salem Hills, 1956: Corcoran and Libbey	1.25
49. Lode mines, Granite mining district, Grant County, Oregon, 1959: Koch . .	1.00
52. Chromite in southwestern Oregon, 1961: Ramp	5.00
53. Bibliog. (3rd suppl.) geology and mineral resources of Oregon, 1962: Steere, Owen	3.00
57. Lunar Geological Field Conf. guidebook, 1965: Peterson and Groh, editors .	3.50
60. Engineering geology of Tualatin Valley region, 1967: Schlicker and Deacon .	7.50
61. Gold and silver in Oregon, 1968: Brooks and Ramp	7.50
62. Andesite Conference guidebook, 1968: Dole	3.50
63. Sixteenth biennial report of the Department, 1966-1968	1.00
64. Mineral and water resources of Oregon, 1969: USGS with Department. . . .	3.00
65. Proceedings of Andesite Conference, 1969: [copies]	10.00
66. Geol. and mineral resources of Klamath and Lake Counties, 1970	6.50
67. Bibliog. (4th suppl.) geology and mineral resources of Oregon, 1970: Roberts	3.00
68. Seventeenth biennial report of the Department, 1968-1970	1.00
69. Geology of southwestern Oregon coast, 1971: Dott	4.00
71. Geology of selected lava tubes in Bend area, Oregon, 1971: Greeley . . .	2.50
72. Geology of Mitchell quadrangle, Wheeler County, 1971: Oles and Enlows . .	3.00
75. Geology and mineral resources of Douglas County, 1972: Ramp	3.00
76. Eighteenth biennial report of the Department, 1970-1972	1.00
77. Geologic field trips in northern Oregon and southern Washington, 1973 . .	5.00
78. Bibliog. (5th suppl.) geology and mineral resources of Oregon, 1973: Roberts	3.00
79. Environmental geology inland Tillamook and Clatsop Counties, 1973: Beaulieu .	7.00
80. Geology and mineral resources of Coos County, 1973: Baldwin and others . .	6.00
81. Environmental geology of Lincoln County, 1973: Schlicker and others . . .	9.00
82. Geol. hazards of Bull Run Watershed, Mult., Clackamas Counties, 1974: Beaulieu	6.50
83. Eocene stratigraphy of southwestern Oregon, 1974: Baldwin	4.00
84. Environmental geology of western Linn County, 1974: Beaulieu and others . .	9.00
85. Environmental geology of coastal Lane County, 1974: Schlicker and others .	9.00
86. Nineteenth biennial report of the Department, 1972-1974	1.00
87. Environmental geology of western Coos and Douglas Counties, 1975	9.00
88. Geology and mineral resources of upper Chetco River drainage, 1975: Ramp .	4.00
89. Geology and mineral resources of Deschutes County, 1976	6.50
90. Land use geology of western Curry County, 1976: Beaulieu	9.00

GEOLOGIC MAPS	
Geologic map of Galice quadrangle, Oregon, 1953	1.50
Geologic map of Albany quadrangle, Oregon, 1953	1.00
Reconnaissance geologic map of Lebanon quadrangle, 1956	1.50
Geologic map of Bend quadrangle and portion of High Cascade Mtns., 1957 . . .	1.50
Geologic map of Oregon west of 121st meridian, 1961 . . . . [Over the counter]	2.00
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Geologic map of Oregon (9 x 12 inches), 1969	.25
GMS-2: Geologic map of Mitchell Butte quadrangle, Oregon, 1962	2.00
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GMS-6: Prelim. report on geology of part of Snake River Canyon, 1974	6.50
GMS-7: Geology of the Oregon part of the Baker quadrangle, Oregon, 1976 . . .	in press

GEOTHERMAL REPORTS	
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5. Prospects for natural gas prod. or underground storage of pipeline gas		in press
SHORT PAPERS		
18. Radioactive minerals prospectors should know, 1976: White, Schafer, Peterson.		.75
19. Brick and tile industry in Oregon, 1949: Allen and Mason		.20
21. Lightweight aggregate industry in Oregon, 1951: Mason		.25
24. The Almeda mine, Josephine County, Oregon, 1967: Libbey		3.00
25. Petrography, type Rattlesnake Fm., central Oregon, 1976: Enlows		2.00
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2. Oregon mineral deposits map (22 x 34 inches) and key (reprinted 1973):		1.00
4. Regulations for conservation of oil and natural gas (2nd rev., 1962):		1.00
5. Oregon's gold placers (reprints), 1954		.50
6. Oil and gas exploration in Oregon, rev. 1965: Stewart and Newton		3.00
7. Bibliography of theses on Oregon geology, 1959: Schlicker		.50
Supplement, 1959-1965: Roberts		.50
8. Available well records of oil and gas exploration in Oregon, rev. 1973: Newton		1.00
11. Collection of articles on meteorites, 1968 (reprints from The ORE BIN)		1.50
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13. Index to The ORE Bin, 1950-1974		1.50
14. Thermal springs and wells, 1970: Bowen and Peterson (with 1975 suppl.)		1.50
15. Quicksilver deposits in Oregon, 1971: Brooks		1.50
16. Mosaic of Oregon from ERTS-1 imagery, 1973		2.50
18. Proceedings of Citizens' Forum on potential future sources of energy, 1975		2.00
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Oregon base map (22 x 30 inches)		.25
Landforms of Oregon (17 x 22 inches),		.25
Mining claims (State laws governing quartz and placer claims)		.50
Geological highway map, Pacific NW region, Oregon-Washington (pub. by AAPG)		2.50
Fifth Gold and Money Session and Gold Technical Session Proceedings, 1975 (including papers on gold deposits, exploration, history, and production		5.00
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DEPARTMENT OF GEOLOGY AND MINERAL INDUSTRIES

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The ORE BIN
Volume 39, No. 3
March, 1977

FIELD-ORIENTED GEOLOGY STUDIES IN OREGON DURING 1976

John D. Beaulieu
Geologist, Oregon Dept. Geology and Mineral Industries

During the 1976 field season at least 114 geologic investigations were conducted in Oregon. The list below includes those of which the Oregon Department of Geology and Mineral Industries is aware. For convenience, the State is divided roughly into six geographic sections; and several investigations of more regional extent comprise a seventh category - Regional. Listings within categories are alphabetical according to the investigator's name.

The Department would appreciate receiving information about studies in progress in the State which are not shown here. The summaries received thus far have been invaluable in completing this list, and the compiler is grateful for this assistance.

The Department has no information on completion dates of research or reports listed. Inquiries should be directed to the individuals named. Abbreviations of frequently cited institutions include:

DOGAMI	Oregon Department of Geology and Mineral Industries
OMSI	Oregon Museum of Science and Industry
OSU	Oregon State University
PSU	Portland State University
U of O	University of Oregon
SOSC	Southern Oregon State College
USBM	United States Bureau of Mines
USGS	United States Geological Survey
WRD	Oregon Water Resources Department

Northwestern Oregon

1. Columbia River Basalt in Clackamas River drainage: Jim Anderson, master's cand., PSU
2. Boring lava geochemistry: Darolyn Burch, master's cand., PSU
3. Foraminifers of the type Nestucca Formation: Arden Callender, master's cand., PSU
4. Wickiup Mountain-Big Creek area stratigraphy, sedimentology, and petrology: G. Coryell, master's cand., PSU
5. Post-glacial volcanism of Mount Hood: D.R. Crandell, USGS, Menlo Park

6. Structure of east Portland: J. D. Perttu, master's cand., PSU
7. Ground water of the Newberg area: F.J. Frank, USGS, Portland
8. Fossil woods from the Cascade Locks area: W.J. Fritz, master's cand.(biol.), Walla Walla College
9. Late Quaternary Tillamook Bay sedimentation: W. Frye, master's cand., U of O
10. Estuarine sedimentation of Tillamook Bay: J. Glenn, USGS, Denver
11. Ground water of the Dallas-Monmouth area: J.B. Gonthier, USGS, Portland
12. Johnson Creek geo-hydrology and environmental geology: B. Henderson, master's cand., PSU
13. Keasey biostratigraphy and gastropods: C.S. Hickman, res. assoc., Swarthmore College
14. Western Cascades heat flow: D.A. Hull, DOGAMI, Baker
15. Gravity of southeast Portland: Terry Jones, bachelor's cand., PSU
16. Ground-water pollution evaluation of coastal dunes: K. Mathiot, WRD
17. Bonneville Dam NW 7-1/2' quad geology: M. Moran, master's cand., PSU
18. Quartzville Mining District: S. Munts, master's cand., U of O
19. Columbia River Basalt-strontium isotopes, stratigraphy, and petrogenesis: Dennis Nelson, Ph. D. cand., OSU
20. Lewis and Clark and Youngs Rivers area stratigraphy: M.P. Nelson, master's cand., OSU
21. Natural gas storage structures of the northern Coast Range: V. Newton, DOGAMI, Portland
22. Astoria and Yaquina Formations: A. Niem, prof., OSU
23. North Santiam Mining District: J.P. Olson, master's cand., OSU
24. Columbia River Gorge landslides: L. Palmer, prof., PSU
25. West Cascades geothermal: N. Peterson, DOGAMI, Grants Pass
26. Southern Willamette Valley stratigraphy: W.O. Seeley, Mobil Oil
27. Ground-water monitoring of Sherwood-Wilsonville area, staff, WRD
28. Blue River Mining District: S.G. (Power) Starch, master's cand., OSU
29. Blue Creek District - massive sulfides: C. Taylor, master's cand., OSU
30. Columbia River Basalt of the Bull Run watershed: B. Vogt, master's cand., PSU
31. Detroit region stratigraphy: C. White, master's cand., U of O

Southwestern Oregon

1. Eocene stratigraphy and structure: E. Baldwin, prof., U of O
2. Mount Bailey geology: C. Barnes, master's cand., U of O
3. Land use geology of western Curry County: J.D. Beaulieu, DOGAMI, Portland

4. Land use geology of central Jackson County: J.D. Beaulieu, DOGAMI, Portland
5. Talent quadrangle amphibolites: L. Beskow, master's cand., U of O
6. Briggs Creek amphibolite: R.G. Coleman, USGS, Menlo Park
7. Josephine peridotite (petrology, poidform chromite, josephinite, structure): Henry Dick, Woods Hole Oceanog. Inst.
8. Rogue River stratigraphy between Agness and Illahee: W. Eaton, master's cand., U of O
9. Hornbrooke Formation: Monty Elliot, prof., SOSC
10. Wrangle Gap-Red Mountain peridotites, Talent quadrangle: M. Ferns, Ph. D. cand., U of O
11. Flournoy, Spencer, and Fisher Formations west of Eugene: W. Gandera, master's cand., U of O
12. Aeromagnetic interpretations over ultramafic rocks: A. Griscom, USGS, Menlo Park
13. Erosion at Siletz Spit: P.D. Komar, prof. (oceanog.), OSU
14. Ground-water evaluation of the Brookings area: F. Lissner, WRD
15. Eocene planktonics: G. Miles, Ph. D. cand., U of O
16. Kalmiopsis Wilderness area mineral evaluation: M.S. Miller, USBM, Spokane
17. Igneous petrology of Surveyor Mountain and Hyatt Reservoir quadrangles: H. Naslund, master's cand., U of O
18. Geology of the Medford-Coos Bay 2° sheets: N. Page and others, USGS, Menlo Park
19. Rogue River geologic river log - Grove Creek to Foster Bar: William Purdom, prof., SOSC
20. Curry County mineral resource inventory: L. Ramp, DOGAMI, Grants Pass
21. Dothan Formation reconnaissance: Loren Raymond, prof., SOSC
22. Mount Mazama eruption and geochemistry: J. Ritchey, master's cand., U of O
23. Ground water of the Winston area: J.H. Robison, USGS, Portland
24. Coaledo Formation sedimentation: P. Ryberg, master's cand., U of O
25. Bohemia Mining District: M.P. Schaubs, master's cand., OSU
26. Curry County aggregate resources: H. Schlicker and J. Gray, DOGAMI, Corvallis
27. Nickel laterites of Josephine and Curry Counties: staff, USBM, Spokane
28. Sedimentation of South Slough estuary: R.O. Van Atta, prof., PSU
29. Remote sensing of debris-avalanche-prone terrain: R. Vickers, Stanford Research Inst., for BLM

North-Central Oregon

1. Devonian biostratigraphy: C.T. Amundson, master's cand., PSU
2. High Cascades basaltic petrology and geochemistry between McKenzie Bridge and Three Sisters: B. Baker, prof., U of O

3. Geologic hazards of northern Hood River, Wasco, and Sherman Counties: J.D. Beaulieu, DOGAMI, Portland
4. Cascades Range geophysics: R.W. Couch, prof. (oceanog.), OSU
5. Paleogene plant fossils in Pilot Rock area (Clarno?): B.J. McLarty Elmendorf, master's cand. (biol.), Walla Walla College
6. Clarno palynology: L.H. Fisk, prof. (biol.), Walla Walla College
7. Basalts of Columbia River Basalt south of the Blue Mountain anticline: G. Goles, prof., U of O
8. Newberry rim gravity data: A. Griscom, USGS, Menlo Park
9. Paleobotany of the Clarno Formation: S. Manchester, OMSI
10. John Day Wild River study area mineral investigation: R.W. Morris, USBM, Spokane
11. Geology and mineral resources of Deschutes County: N. Peterson, DOGAMI, Grants Pass
12. Central Cascades geophysics: S. Pitts, Ph. D. cand., U of O
13. Strawberry Volcanics, geology and petrology: T.L. Robyn, Ph. D. cand., U of O
14. Ground-water monitoring of the Ordnance and Butler Creek area, staff, WRD
15. John Day area geology: T. Thayer, USGS, Menlo Park
16. Strawberry Mountain Wilderness Area geology: T. Thayer, USGS, Menlo Park

South-Central Oregon

1. Glacial geology of the southern Cascades: G. Carver, prof., Humboldt State
2. Brothers fault zone heat flow: D.A. Hull, DOGAMI, Baker
3. Geothermal investigations: N. MacLeod, USGS, Menlo Park
4. Geothermal investigations of the Klamath Falls area: N. Peterson, DOGAMI, Grants Pass
5. Northern Summer Lake geology: P. Travis, master's cand., U of O

Northeastern Oregon

1. Structural evolution of the Blue Mountains: H.G. Ave Lallement, prof., Rice U.
2. Sawtooth Ridge and Keating NW 7-1/2' quadrangles, geology: H. Brooks, DOGAMI, Baker
3. Hells Canyon Recreation Area mineral evaluation: T.J. Close, USBM, Spokane
4. Ground water of the Umatilla Indian Reservation: J.B. Gonthier, USGS, Portland
5. Conners Creek area geology, Snake River Canyon: S. Jenkins, master's cand., OSU
6. Tertiary structures of western Crook County: R. Lawrence, prof., OSU
7. Greenhorn area geology: E. Mullin, master's cand., OSU
8. Greenhorn quadrangle geology: J. Perkins, master's cand., U of O

9. Structural petrology of the Sparta quadrangle: D. Phelps, Ph. D. cand., Rice U.
10. Zeolites of Pliocene lacustrine deposits: R.A. Sheppard, USGS, Denver
11. Geology of the Hells Canyon Wilderness study area: G.C. Simmons, USGS, Menlo Park
12. Columbia River Basalt sampling of the Imnaha and Yakima Basalts for isotopic analysis: D.A. Swanson and others, USGS, Menlo Park

Southeastern Oregon

1. Vale-Owyhee geothermal region investigation: R.W. Couch and B.H. Baker, profs. (oceanog.), OSU
2. Sheldon-Antelope Wilderness: R.C. Greene, USGS, Menlo Park
3. Geothermal potential: N. MacLeod, USGS, Menlo Park
4. McDermitt mercury: J. Rytuba, USGS, Menlo Park
5. Grassy Mountain Formation: A. Storm, master's cand., U of O
6. North Beulah Reservoir area: J. Wood, master's cand., PSU

Regional

1. Relative age-dating techniques on Quaternary deposits - development and testing: P.W. Birkeland, prof., U. of Colo.
2. Continental shelf sedimentation dynamics: D. Cacchione, USGS, Menlo Park
3. Geology of the Oregon continental shelf (for EIS): H.E. Clifton, USGS, Menlo Park
4. Cretaceous-Neogene stratigraphic palynology: L.H. Fisk, prof. (biol.), Walla Walla College
5. Plant microfossils in Columbia River Basalt interbeds: L.H. Fisk, prof. (biol.), Walla Walla College
6. Copper and zinc inventory: D.A. Hull, DOGAMI, Baker
7. Guidebook to selected trips in Oregon: J. Hyde, instructor, Tacoma Community College
8. Tectonic settings and volcanic composition - correlations: J. Loëschke, Tübingen, W. Germany
9. Geophysics of Known Geothermal Resource Areas: D.R. Mabey, USGS, Menlo Park
10. Volcanic hazards overview: D.R. Mullineaux, USGS. Menlo Park
11. Nickel in Oregon: Len Ramp, DOGAMI, Grants Pass
12. Cenozoic vertebrates: C.A. Repenning, USGS, Menlo Park
13. Oregon and Washington onshore-offshore structure: P. D. Snavely, USGS, Menlo Park
14. Geologic map of eastern Oregon: G.W. Walker, ed., USGS, Menlo Park
15. Quaternary geochronology and fossil amino acid enantiometric ratios: J.F. Wehmiller, prof., U. of Delaware

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NORTHEAST OREGON MAPS PRINTED

Preliminary geologic maps of the Sawtooth Ridge and Keating NW quadrangles have been published and are available at the three offices of the Department. The maps are black-and-white. Hand-colored copies will be maintained on open file (O-77-1). The maps are at the scale of 1:24,000 (7-1/2 minutes) and cover the northeastern corner of the old Baker 30-minute (1:125,000) quadrangle, mapped by Gilluly in 1937. The maps include the type locality of the Clover Creek Greenstone. Other important map units are intrusive rocks of pre-Upper Triassic age and basalt flows and lake and stream sediments of Tertiary age. The Sawtooth Ridge map was compiled from mapping by H.C. Brooks, R.G. Bowen, D.A. Hull, and R.W. Hammitt. The Keating NW map is by H.C. Brooks. Price is $4.00 per set.

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RECORD NEW MINING CLAIMS

New mining claim recordation regulations have been adopted following public comment on proposed rules. The new regulations are among the first implementations of the Federal Land Policy and Management Act of 1976.

All new mining claims must be filed within 90 days of location, but claims dating prior to passage of the Act need not be recorded until October 21, 1979, according to Roger Dierking, Bureau of Land Management records chief in Portland. An exception is that any mining claim within a unit of the national park system must be recorded by September 27, 1977 with the National Park Service.

Dierking suggests to claim holders, "First, pick up a copy of the regulations to ensure that all filing requirements will be met. Second, since there are 3 years to record older claims, recording backlogs can be avoided if filings are distributed over the entire period."

The new law requires the recording of all unpatented lode or placer mining claims or mill or tunnel sites which are on Federal land or involve minerals retained in Federal ownership. This is done by filing a copy of the official notice of location (as recorded at the local county courthouse) with the Bureau of Land Management.

Federal law also requires filing of evidence of annual assessment work by December 31 of each year after the year of location.

Transfers of interest in claims or sites must also be recorded, and 60 days is allowed a transferee to file such notice without charge.

Failure to record claims, evidence of assessment, or transfers of interest with BLM constitutes abandonment of the claims, according to the new Federal Land Policy and Management Act.

The new regulations will protect the rights of miners and facilitate management of the Federal lands and their mineral resources by providing records which are current, accurate, and accessible, according to BLM officials. The Bureau of Land Management is responsible for administering the mining laws on all Federal lands.

Copies of the new regulations are available at offices of the Bureau of Land Management and Forest Service. All Oregon and Washington claims are to be recorded at the Bureau of Land Management, 729 NE Oregon Street, Portland. Cost of recording is $5.00.

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SOSC OFFERS DEGREE IN GEOLOGY

William B. Purdom, chairman of the Department of Geology at Southern Oregon State College, in Ashland, announces that the college now offers a bachelor of science degree in geology and expects to confer its first degree in June 1977.

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SOUTH MOUNTAIN-JUNIPER MOUNTAIN AREA MAPPED

Reconnaissance Geology and Geochemistry of the South Mountain-Juniper Mountain Region, Owyhee County, Idaho, by Earl H. Bennett, has been published as Pamphlet No. 166 by the Idaho Bureau of Mines and Geology, Moscow, Idaho.

The 68-page report describes a 450-square-mile area situated east of Malheur County, Oregon and south of the Silver City-DeLamar mining region of Idaho. In this area an extensive series of Tertiary volcanic rocks overlies a granitic-metamorphic complex.

Maps accompanying the report show geology, stream-sediment sampling locations, and linears from U-2 imagery.

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GRAVITY SURVEYS ON OPEN FILE

Two open-file reports recently received from the U.S. Geological Survey provide geophysical data on the Breitenbush KGRA. The reports, listed below, can be consulted in the Department's library in Portland.

Open-file report 77-66B (supplement to 76-701D): Telluric survey data for Breitenbush Known Geothermal Resource Area, Oregon.

Open-file report 77-67A: Principal facts for a gravity survey of Breitenbush Known Geothermal Resource Area, Oregon.

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WHAT HAPPENED TO THESE ROCKS?

Upper photo, opposite page.

These highly contorted folds are found on a sea cliff at the north end of Crescent Beach in Ecola State Park, north of the town of Cannon Beach. The folds occur in a 200-foot-thick sequence of rhythmically bedded, micaceous, fine-grained sandstones and silty mudstones that are equivalent in age to rocks of the Miocene Astoria Formation. The rocks were deposited in a marine embayment during lower to middle Miocene time (18 to 26 million years ago). They are described as graded beds because each separate unit contains sediments graded in size from coarse at the base to fine near the top. A sequence of graded beds is called a turbidite sequence; and turbidites form when large amounts of sediments are carried downslope in suspension by dense and rapidly moving turbidity currents which spread the sediments for great distances horizontally until they come to rest on the ocean floor. When the current stops moving, the heaviest sediment settles out first, with finer material settling out above. Foraminifera found in these rocks indicate that the sediments were deposited at a depth of 500 to 1,500 feet in cool water.

While these sedimentary beds were still water-saturated and plastic, they were deformed, either by slumping or by the intrusion of numerous slightly younger basalt dikes and sills (potassion-argon dated at 15.9 ± 0.4 m.y.). One of these sill-like bodies lies at the base of the folds.

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Lower photo, opposite page.

These folded limestone beds form the canyon walls of the Snake River near Big Bar, about 20 km (12.4 miles) north of the town of Oxbow. The folds are plainly visible from the road that follows the east side of the Snake River between Oxbow and Hells Canyon Dam.

The limestone is at least 1,700 feet thick, black on fresh exposure (but weathering to nearly white), and contains many kinds of fossil marine invertebrates. Fossil experts correlate this limestone with the Upper Triassic Martin Bridge Formation, named for thick exposures of limestone at Martin Bridge, on Eagle Creek on the south side of the Wallowas.

A brief history of the outcrop might go as follows: In Late Triassic time (about 190 million years ago) layers of calcareous material accumulated on a shallow sea floor inhabited by reef-building marine animals. Early in Jurassic time (about 170 million years ago) tectonic pressures folded the limestone beds and crushed or fractured the less pliable rocks in the vicinity. Uplift of the region in Late Cretaceous time was followed by the development of a vast erosion surface over which flowed the Miocene lavas of the Columbia River Basalt Formation. In more recent geologic time, deep dissection by the Snake River has carved the present canyon and revealed the ancient folded sea beds.

Folded rocks, northwest Oregon coast.

Folded rocks, northeast Oregon.

METALS AND MINERALS CONFERENCE IN MAY

The 1977 Pacific Northwest Metals and Minerals Conference will be held May 4, 5, and 6 at the Washington Plaza Hotel, Fifth and and Westlake, Seattle, Washington. It will be jointly hosted by the Puget Sound Chapter of the American Society of Metals and the North Pacific Section of the American Institute of Mining, Metallurgical, and Petroleum Engineers. Attendance is expected to exceed 300.

Co-chairmen W.E. Quist, A.S.M., and T.G. Stoebe, A.I.M.E., report the conference general session will be devoted to Minerals, Materials, and Energy, Their Reserves and Utilization. General session speakers include J. Granville Jensen, professor of geography at Oregon State University; John D. Morgan, Associate Director, U.S. Bureau of Mines; Robert S. Shoemaker, Bechtel Corp., San Francisco (1977 President, S.M.E.); and Harry Paxton, Vice President, U.S. Steel, Pittsburgh (1976 President, T.M.S.).

Technical sessions sponsored by the A.S.M., A.I.M.E., the American Ceramic Society, and the American Association of Engineering Geologists will follow, with lectures on Service Failures, Extractive Metallurgy, New Materials Advancements, Mining, New Analytical Techniques and Instrumentation, Geotechnical Aids to Mining, and Resources for Future Supply of Ceramics.

A new feature will be the Industrial Trade Exposition, displaying products and services offered by a variety of organizations. Remaining display space is limited but still available to those companies wishing to publicize their products or services.

Special events will include a social program for the ladies.

For further information on registration, reservations, or display space, contact S.D. Schwarz, c/o Shannon and Wilson, Inc. The address is 1105 N. 38th, Seattle, WA 98103. Telephone number is (206) 632-8020.

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K-FALLS SPACE HEATING REPORTED

The Oregon Institute of Technology (OIT) Geo-Heat Utilization Center at Klamath Falls has issued four reports on its studies of space heating by natural hot waters. The reports are:

1. Klamath Falls Hot Water Well Study, by G.G. Culver, J.W. Lund, and L.S. Svanevik, 1974.
2. Klamath Falls Geothermal Mini-heating District Feasibility Study, by P.J. Lienau, J.W. Lund, G.G. Culver, and D. Ford, 1976.
3. Optimization of Home Heating Systems, by G.G. Culver, 1976.
4. Corrosion of Down-hole Heat Exchangers, by J.W. Lund, J.F. Silva, G.G. Culver, P.J. Lienau, L.S. Svanevik, and S.D. Anderson, 1976.

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MINE NAMES

Apparently Oregon miners and prospectors name their claims for a variety of reasons. Perhaps they are motivated by the same impulses that lead owners of boats, race horses, and summer cabins to attach the wide variety of appellations to their possessions. The origins of some mining claim names are obvious. For instance, the Poverty claim and the Depression Breaker were undoubtedly located during the 1930's, while the Bomb Site (for optical calcite) was of World War II vintage, and the Trail's End property just has to be as far back in the hills as you can get.

Miners and prospectors seem to have preferences for colors as claim name prefixes. In Oregon are the Black Bear, Black Beauty, Black Diamond, Black Channel, Black Jack, Black Prince, Black Velvet, and Blackout. Blue appears in the Blue Mud claim, Blue Mule, Blue Pearl, Blue Ribbon; and, best of all, Blue Goo.

Any number of claims were named for a family member. The Baby claim, for unknown reasons, is also known as the Lamb Tongue. The Daddy Lode recognizes the man of the house, who long ago called the biggest strike of all the Mother Lode.

A menagerie of animal claim names includes Badger, Bald Eagle, Bay Horse, Bear Cat, Baby Elephant, White Elephant, Dodo, Humbug, and Gold Bug. Prospectors' optimism is evidenced in names starting with "big": Big Buck, Big Chief, Big Lode, Big Shot, and Big Sunshine. Easy Money, Hidden Treasure, and Quick Action connote high hopes. The Come and Get It claim, the story goes, was located merely for the purpose of quick sale.

Gold, of course, appears in many claims names, since most claims are located for gold. The Gold Bullion, Gold Chief, Gold Cluster, Gold Coin, Gold Crater, Gold Leaf, Gold Nugget, and Gold Wedge are examples.

Among the downright fanciful names are Moon Anchor, Analulu, Tillicum, and Cumtillie. More down-to-earth are Mud Spring, Potato Patch, Poison Oak, Doodle Bug, and Frog Pond. One miner, at once optimistic and realistic, named his property the Keg of Gold. Attitudes of owners are reflected in the names Last Chance, Bliss, Cloudy Day, and Miser. Expressing the fiercely competitive life of the gold miner is the claim name, Bone of Contention.

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MORE OREGON LAKES DESCRIBED

"Lakes of Oregon, Clackamas County," by M.V. Shulters, is the fourth in the State's inventory of lakes and reservoirs prepared by the U.S. Geological Survey in cooperation with the Oregon State Water Resources Department. Included are illustrations, descriptions, and water-quality data for 55 lakes, most with surface areas of more than 5 acres. The publication is designated as an open-file report dated 1976. A limited number of copies are available from the Oregon State Water Resources Department. Phone: Salem 378-3671.

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U.S. ENERGY INDEPENDENCE REQUIRES VAST AMOUNTS OF MINERALS

Achieving U.S. energy goals projected to 1990 will require the availability of large amounts of a wide variety of metals, minerals, and mineral products, according to a U.S. Geological Survey report.

The report presents estimates of the basic nonfuel materials needed and of supplies now available for five major energy industries - fossil fuels (coal, oil, gas, and oil shale), geothermal, hydroelectric, nuclear, and solar, as well as electric power transmission facilities, over the next 15 years or so.

The report says that minimum estimates of nonfuel mineral raw-material requirements for all energy types indicate that concrete and iron are needed in the largest tonnages, but that "substantial" quantities of other materials, such as aluminum, barite, bentonite, manganese, and nickel, must also be available if the Nation's energy goals are to be reached by 1990.

The report notes that significant increases in production above that of recent years for commodities such as aluminum, barite, bentonite, fluorite, iron ore, and tungsten are needed to satisfy the demand by the energy industries.

In a concluding statement, the report warns that, "Adequacy of mineral supplies for a sustained economy should be a matter of deep concern, particularly in view of the large quantities of minerals and materials required for energy production and the serious consequences in the event of deficiencies." The proposed energy independence of the United States depends upon adequate supplies of nonfuel mineral raw materials.

"As was evident in the 1973 oil embargo, political and economic changes and mineral shortages can occur swiftly," the report notes, adding that, "our mineral inventory developed and ready for immediate extraction is nil in the case of some commodities, and in many cases is not equivalent to projected requirements for a decade of U.S. consumption.

"The United States will not become self-sufficient in all minerals," the report says, "but for most minerals the Nation can become nearly self-sufficient through development of new resources." To achieve this, however, the report says, "Basic geologic research - often overlooked as the foundation on which exploration projects are planned - must be accelerated and continued into the future. Any delay reduces the Nation's flexibility to cope with mineral-supply problems, which are inevitable. Because of the lead-time required, as much as 20 years, crash programs are no substitute."

A few "briefs" abstracted from the report:

- The United States is self-sufficient in bentonite, copper, molybdenum, boron, magnesium metal, scrap mica, silicon, beryllium, hafnium, helium, lithium, and rare earths. Reserves are also considered adequate to meet the national demand to 1990 for barite, iron ore, lead, and zinc.

- The United States has no reserves of chromite, cobalt, manganese, and niobium and is totally dependent for these commodities on imports, supplemented by industry inventories and release from government stockpile.

- Imports provide more than two-thirds of the supply of aluminum (bauxite), fluorite, nickel, and tungsten, for which the energy demand through 1990 will be large, and of asbestos and tin, for which the demand will be much less critical.

- Some commodities for which we are dependent on imports for one-third to two-thirds of our supply are expected to pose no supply problems as long as imports are secure. These include antimony, cadmium, silver, and titanium. Others - barite, zinc, and zirconium - are available in large quantities domestically.

- Averaged over the next 15 years, the quantities of some materials needed for energy will be a large percentage of 1973 production; for example, aluminum (30 percent), barite (100 percent), bentonite (30 percent, fluorite (58 percent), shipping-grade iron ore (26 percent), and tungsten (78 percent).

- A minimum of about 2.5 billion barrels of oil-equivalent may be required to produce 20 selected mineral commodities needed by the energy industries through the next 15 years, and 18.5 billion barrels of oil-equivalent to produce sufficient supply to meet the domestic demand for those minerals during the same period. This amount of energy, equal to more than half of the known U.S. recoverable petroleum reserves, is only a fraction of the energy required to produce the 90 or more mineral commodities used in the total economy. Thus, imports of mineral raw materials and semifabricated or processed material also constitute energy imports. Substitution of domestically produced materials for imports will further stress domestic energy production.

The report, "Demand and Supply of Nonfuel Minerals and Materials for the United States Energy Industry, 1975-90 - A Preliminary Report," is published as USGS Professional Paper 1006-A,B. Copies may be purchased from the U.S. Geological Survey's Branch of Distribution, 1200 South Eads St., Arlington, VA 22202, for $1.70 each, prepaid; checks or money orders payable to the U.S. Geological Survey.

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Topographic maps of the south half of Mt. Hood (scale of 1:24,000) in a new folded pocket-sized edition, complete with plastic carrying pouch, will be available at the Department of Geology and Mineral Industries for $1.50 starting May 1, 1977.

WASHINGTON STATE GEOLOGIST REPORTS*

Ted Livingston

My friend and my former boss, Marshall Huntting, came in the other day. In the course of our conversation, he commented on some basic truths that I believe need to be reiterated until everyone, especially our decision-making leaders, really understand them. The subject was land planning, and Marshall mentioned that the way many leaders are approaching planning is to ask the citizenry this question: "What do you want for the future?" Marshall says this is like setting your family down and asking them to plan what they want to do for the rest of their lives.

Obviously the most important question the family needs to answer is, "What do we need to survive?" The same is true in developing plans for the use of our land. There is no doubt that if this question were asked and answered honestly by the decision makers, the safeguarding of our mineral deposits along with agricultural lands would receive the highest priority. I question if there is a higher, more intensive use for land than mining. As an example, the Bingham copper pit in Utah appears to be about 2 miles across, which would equal about 2,000 acres in area. From that 2,000 acres of land, approximately $6 billion worth of copper has been produced. This means that each acre of land in this pit has contributed $3 million worth of new wealth to the economy. I suspect it will be hard for any other industry or occupation to equal that kind of record. The real point, however, is not necessarily what the dollar value of the copper is but rather what the value has been to mankind in terms of homes, transportation, medicine, appliances, power generation, etc. This value is so large that it probably is incalculable.

All of this points out that in any kind of planning procedure we always need to begin by considering what the necessities are for survival. After we have taken the necessary steps to protect the necessities, we can afford the luxury of asking, "What do we want?" If we let our "wants" take precedent over our "needs," we will certainly experience some severe, and I might add, unnecessary shortages that will bring us very painfully to a realization of how necessary our minerals are and how dependent we are on them.

* Reprinted from Washington Geologic Newsletter, v. 3, no. 4.

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DON'T GO AWAY without telling us. Your ORE BIN follows you only if the Department has your new address. Advance notice is fine; we'll make the address change at the time you've set.

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THE MINER'S INCH

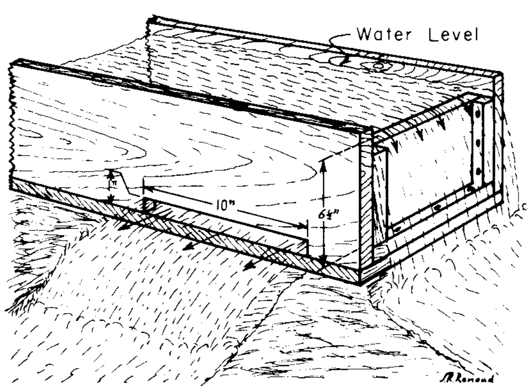
The miner's inch, now used as a measurement for irrigation water, originated back in the old gold mining days when water was as precious for gold washing as it is for farming today. In the spring, plenty of water ran in the streams from the snow melting in the mountains, and there was an ample supply for all. Ditches carried water from the streams to the placers. As the dry season came on, water became scarce; and it became necessary to devise a means of dividing it to suit the needs of the different types of washing - from the rocker which used very little water to the hydraulic giant which required hundreds of gallons per second. The miner's inch was the solution; it has come from yesterday's mining to today's farming as a unit for measuring water.

To get an amount of water in miner's inches, the water is run through a flume or trough. A hole one inch square is cut in the side of the flume four inches below the top level of the water flowing through. A miner's inch is the amount of water discharged from the hole under a given pressure - four-inch pressure in this case. The pressure is determined by the number of inches the hole is from the top of the water's surface. The number of holes in the side of a flume, discharging water, determine the number of miner's inches.

Fifty miner's inches are equal to one cubic foot per second or one second-foot. Twenty-five miner's inches under four-inch pressure, flowing for 24 hours, will release one acre-foot of water or the amount that will cover an acre one foot deep.

Many states do not accept this measurement as standard. The required pressure may vary from three to nine inches according to the state; and there is a difference in a number of miner's inches to a cubic foot in many states. Because of this, it is not considered a legal measurement. Nevertheless, farmers in most of the western states measure irrigation water in miner's inches.

From "DECO TREFOIL"



Sketch of typical flume for measuring water in miner's inches. Opening is designed to provide for 10 miner's inches.

NOTICE TO CONTRIBUTORS

ORE BIN editors welcome manuscripts about Oregon geology, such as field trip guides, descriptions of geology of state parks, results of student or faculty research, and information on interesting mineralogical and paleontological finds.

Although some technical and specialized articles are published, the aim is to emphasize subjects of general interest, written in a language understandable to the knowledgeable layman. Technical terms, when used, should be explained. Interesting geological photographs, along with brief explanations, are also acceptable.

Prospective authors should observe the following guidelines:

1. Manuscripts should be typewritten, double-spaced, with 1-inch margins.
2. In general, one and one-half pages of manuscript fill one ORE BIN page, which measures 5 by 7-1/2 inches. A major article, with accompanying maps, photos, and drawings, usually occupies 10 to 12 ORE BIN pages. (The ORE BIN usually contains 16 pages.)
3. Drawings and maps should be designed to be legible when reduced to fit within the page measurements. Drafted material must be submitted in final form.
4. Photos should be black-and-white glossy prints. Occasionally color prints with good contrast will be considered; but NO slides, please.
5. Supply numbers and captions for all illustrations. All illustrations become the property of the Department except by special arrangement with the author.
6. Standard U.S. Geological Survey form for references is used. Authors are responsible for accuracy and completeness of citations.

Department editors and geologists read each manuscript, and the Department has the privilege of acceptance or rejection. An accepted manuscript is edited and, if necessary, returned to the author for review or alteration before publication.

Authors receive 25 complimentary copies of the issue in which the article appears.

Address manuscripts and accompanying materials to ORE BIN Editor, 1069 State Office Building, Portland, Oregon 97201.

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ERRATUM

In the article, "Mined Land Reclamation" (ORE BIN, January 1977), the sentence beginning in paragraph two, line four, which reads, "Reclamation costs average $150 per acre," should read, "Program administrative costs to the State average about $150 per acre reclaimed."

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AVAILABLE PUBLICATIONS

(Please include remittance with order; postage free. All sales are final - no returns. A complete list of Department publications, including out-of-print, mailed on request.)

BULLETINS		Price
26.	Soil: Its origin, destruction, and preservation, 1944: Twenhofel	$ .45
33.	Bibliography (1st suppl.) geology and mineral resources of Oregon, 1947: Allen	1.00
35.	Geology of Dallas and Valsetz quadrangles, Oregon, rev. 1964: Baldwin	3.00
36.	Papers on Tertiary foraminifera: Cushman, Stewart and Stewart, 1949: v. 2	1.25
39.	Geol. and mineralization of Morning mine region, 1948: Allen and Thayer	1.00
44.	Bibliog. (2nd suppl.) geology and mineral resources of Oregon, 1953: Steere.	2.00
46.	Ferruginous bauxite deposits, Salem Hills, 1956: Corcoran and Libbey	1.25
49.	Lode mines, Granite mining district, Grant County, Oregon, 1959: Koch	1.00
52.	Chromite in southwestern Oregon, 1961: Ramp	5.00
53.	Bibliog. (3rd suppl.) geology and mineral resources of Oregon, 1962: Steere, Owen	3.00
57.	Lunar Geological Field Conf. guidebook, 1965: Peterson and Groh, editors	3.50
60.	Engineering geology of Tualatin Valley region, 1967: Schlicker and Deacon	7.50
61.	Gold and silver in Oregon, 1968: Brooks and Ramp	7.50
62.	Andesite Conference guidebook, 1968: Dole	3.50
63.	Sixteenth biennial report of the Department, 1966-1968	1.00
64.	Mineral and water resources of Oregon, 1969: USGS with Department.	3.00
65.	Proceedings of Andesite Conference, 1969: [copies]	10.00
66.	Geol. and mineral resources of Klamath and Lake Counties, 1970	6.50
67.	Bibliog. (4th suppl.) geology and mineral resources of Oregon, 1970: Roberts	3.00
68.	Seventeenth biennial report of the Department, 1968-1970	1.00
69.	Geology of southwestern Oregon coast, 1971: Dott	4.00
71.	Geology of selected lava tubes in Bend area, Oregon, 1971: Greeley	2.50
72.	Geology of Mitchell quadrangle, Wheeler County, 1971: Oles and Enlows	3.00
75.	Geology and mineral resources of Douglas County, 1972: Ramp	3.00
76.	Eighteenth biennial report of the Department, 1970-1972	1.00
77.	Geologic field trips in northern Oregon and southern Washington, 1973	5.00
78.	Bibliog. (5th suppl.) geology and mineral resources of Oregon, 1973: Roberts	3.00
79.	Environmental geology inland Tillamook and Clatsop Counties, 1973: Beaulieu	7.00
80.	Geology and mineral resources of Coos County, 1973: Baldwin and others	6.00
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FIELD GUIDE TO THE GEOLOGY OF CORVALLIS AND VICINITY, OREGON

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Introduction and Geologic Background

This field guide had its origin in a class in environmental geology taught in the spring of 1971. The original road log has been modified so that those with an introduction to elementary geology will find it self-guiding. It emphasizes the practical aspects of local geology. It is divided into two parts, each of which provides a pleasant bicycle trip for an afternoon. The first half of the trip discusses the area west and north from Corvallis and deals largely with the bedrock geology of the area and the structure responsible for major landforms. The second half covers the area east and south of town and deals largely with surface sediments and the behavior of the Willamette River.

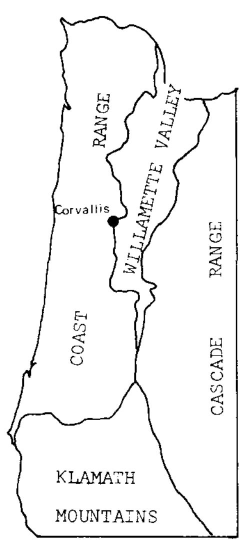


Figure 1. Geomorphic provinces of western Oregon.

Western Oregon is divided into four geomorphic provinces: the Cascade Range, the Willamette Valley, the Coast Range, and the Klamath Mountains. Corvallis, located at the western edge of the Willamette Valley adjacent to the Coast Range (Figure 1), lies on the west bank of the Willamette River, mostly north of the mouth of Marys River. The Coast Range reaches its maximum elevation about 15 miles west of town at Marys Peak. From Marys Peak, a long ridge called Vineyard Mountain (MacDonald State Forest) trends northeast past town. The Corvallis fault, located along the southeastern edge of this ridge, separates erosion-resistant volcanic rocks on the northwest from soft sedimentary rocks which are mostly covered by valley alluvium on the southeast (Figure 2). The Corvallis fault forms the eastern boundary of the Coast Range near Corvallis.

The four bedrock units under the Corvallis area are, from oldest to youngest: the Siletz River Volcanics, the Tyee Formation*, the Spencer Formation, and diabase dikes and sills (Vokes and others, 1954). The first three units were

* Mapped as Flournoy Formation by Baldwin (1974).

deposited during Eocene time (40-60 million years ago), and the dikes and sills were intruded into them during the mid-Oligocene (25-30 million years ago). No younger materials were preserved until the accumulation of unconsolidated terrace, flood, and floodplain deposits of Pleistocene to Recent age (less than 100,000 years old). The bedrock units are more widely exposed in the Coast Range, whereas the unconsolidated materials are typical of the Willamette Valley.

The Siletz River Volcanics are basaltic rocks many thousands of feet thick that erupted onto the early to early-middle Eocene sea floor from submarine vents (MacLeod and Snavely, 1973). They are the oldest rocks in the area and include basaltic pillow lavas, breccias, tuffs, and associated basaltic sedimentary rocks. The lower part of the unit is similar to oceanic crustal basalts and is thought to be oceanic crust which accreted onto the continental margin. In the upper part of the unit, rocks of more varied composition accumulated locally in sufficient thickness to form island similar to modern seamounts (Snavely and others, 1968). The Siletz River Volcanics crop out only northwest of the Corvallis fault in the vicinity of Corvallis. The unit is widely exposed in the Coast Range.

The Tyee Formation, which overlies the Siletz River Volcanics with little or no unconformity, is a thick sequence of rhythmically bedded sandstones and siltstones of middle Eocene age (Snavely and others, 1964). Many of the individual beds (6 inches to 3 feet thick) are composed of sediments which are graded in size from coarse at the bottom to fine at the top and are interpreted as marine turbidite deposits derived from the Klamath Mountains, to the south. The sediments, which become finer to the north, were deposited in a relatively deep trough which they gradually filled. The Tyee Formation is widespread in the Coast Range and is over 6,000 feet thick in places, such as west of Marys Peak (Baldwin, 1955). The few deep exploratory wells near Corvallis (Newton, 1969) suggest that it thins rapidly to the east. The Tyee Formation is exposed in several hills along the southeast side of the Corvallis fault.

The Tyee Formation is overlain unconformably by the Spencer Formation, a 4,500-feet thick series of basaltic, arkosic, and micaceous marine sandstones. Most outcrops of the Spencer Formation are thick bedded without the grading typical of the Tyee Formation. The unconformity, which is generally slight, is quite pronounced near the Corvallis fault northeast of Lewisburg, where a 50° discordance is reported (Vokes and others, 1954). The Corvallis fault apparently developed, at least in part, during the time between the deposition of the Tyee and Spencer Formations. Because the latter was deposited during late Eocene times, the fault must have been active during late-middle to early-late Eocene and probably continued to be active through late Eocene, as locally it cuts beds of the Spencer Formation. Indeed, the upper Spencer Formation was probably derived in large part from erosion of the Tyee Formation, which formed the block rising northwest of the Corvallis fault.

Figure 2. Aerial oblique view of Corvallis showing trace of Corvallis fault along the base of Vineyard Mountain. Note old millrace south of Marys River. (Photo courtesy of Western Ways, Inc.

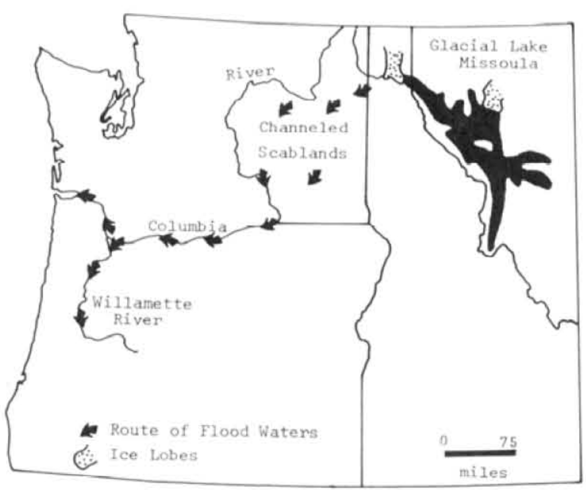


Figure 3. Origin and route of the Spokane Flood waters that deposited the Willamette Silt.

Marine Oligocene rocks, present to the south near Eugene (Baldwin, 1964) and to the east under the alluvium of the Willamette Valley (Newton, 1969), are not present near Corvallis. If they ever were present, they have been removed by erosion. During the middle Oligocene, dikes and sills of diabase (shallow intrusive rocks of basaltic composition) were injected into the Eocene deposits. Near Corvallis, sills seem to be common along the Tyee/Spencer contact. These dikes and sills are relatively erosion resistent and so support many of the ridges and hills, such as Marys Peak (4,097 feet), in the area. Neither Miocene nor Pliocene materials are present, and it is unlikely that they ever were. Thus the geologic record has a gap of about 25 million years, during which erosion probably occurred, before the most recent materials were deposited.

The most recent episode of uplift of the Coast Range occurred near the end of this period of erosion and may be continuing at the present. The Willamette Valley, a structural depression between the Coast Range and the Cascades, collects water draining from both the east and west to form a major north-flowing river, the Willamette. Thus, this is one case where a river did not carve its own valley. The bottom of the structural depression is interrupted by several sets of hills, and as it has only a gentle slope to the north, the river has often been unable to carry away all of its sediment load. Most of this sediment comes from the Cascades, as the largest part of the Coast Range drainage goes directly into the sea. During the Pleistocene, great fans of sediments from the Cascades repeatedly accumulated in the valley and forced the Willamette River over to the western edge of the valley (Beaulieu, Hughes, and Mathiot, 1974). Remnants of these sediments, sometimes deeply weathered, are preserved as terraces in the valley. In general, the higher the terrace is above the valley floor, the older it is (Balster and Parson, 1968).

Toward the end of the most recent of these periods of accumulation, the Willamette Valley was a minor participant in one of the most dramatic events in the geologic history of the Pacific Northwest - the Spokane Flood (McKee, 1972). In northern Idaho a lobe of the great continental ice sheet dammed the Clark Fork River, creating Lake Missoula, an enormous lake which extended into Montana. The ice dam failed abruptly, and the lake emptied in a period of a few days. Grand Coulee and the channeled scablands of southeastern Washington are a result of this great (estimated at 50 cubic miles), but brief, flood of water. All of this water reached the ocean via the Columbia River; and at the sharp bend in the river at Portland, a vast pileup of water occurred. An ephemeral iceberg dam may have been present at the bend. Backwash from this water filled the Willamette Valley to a maximum water level of 400 feet (Figure 3). Glenn (1965), working to the north near Portland, reports that as many as 40 floods of this origin, reflecting repeated advances and retreats of the continental ice lobes, may have washed up the Willamette Valley.

These short-lived lakes deposited a layer up to 30 feet thick, called the Willamette Silt, on the older terrace gravels. Included in these silts are boulders similar to rocks exposed in northern Idaho that were frozen in icebergs that washed up the valley (Allison, 1935). These exotic boulders are the principal confirmation of the Spokane Flood in the Willamette Valley.

Since the close of the Pleistocene, the Willamette River has been cutting into the older terraces and Willamette Silts. A new flood plain that has been established, as well as several low terraces not far above the flood plain, show many features related to river erosion processes. Parts of the flood plain are inundated annually during the winter rainy season. Other slightly higher parts are affected only during more infrequent major floods. Such a flood occurred in 1964 and will be discussed in the road log.

Road Log

(Refer to map, p. 62-63.)

Mileage*

Interval	Cumulative	
0.7	0.0	Leave the Earth Science Building (Wilkinson Hall), Oregon State University, and proceed northwest on Arnold Way to N.W. Harrison. Turn left on Harrison and go to 36th Street.
0.5	0.7	Turn right on 36th Street. The flat area you cross here to get to Witham Hill is an old terrace mantled with river deposits. At the base of Witham Hill, swing left onto Witham Hill Drive and look for the outcrop of rock beside St. Mary's Cemetery.
1.0	1.2	St. Mary's Cemetery outcrop, an outcrop of Spencer Formation sandstones intruded by diabase. The sandstone can be seen near the cemetery entrance; in places bedding is visible. The intrusive contact is under the spruce trees up the road; good exposures of the diabase follow. Near the uphill intrusive con- contact, small concretions can be seen in rocks of the Spencer Formation. These concretions are cemented by zeolite minerals (Enlows and Oles, 1966). Bedding occurs again, and careful observation suggests that the intrusive body crosscuts bedding at a low angle. Continue over the top of the hill past the University Park Apartments. From the crest of the hill to the sharp bend, the roadcuts expose deeply weathered Tyee sandstones and siltstone.
	2.2	At the sharp right-hand bend in the road, you cross the Corvallis fault for the first time. Weathered Siletz River Volcanics are in the first outcrops on the left. The low notch through which the small

* Left column, intervals; right column, cumulative mileage.

stream flows is carved out of the weaker rocks that were broken and ground up by the fault motion. The Siletz River Volcanics have moved up along the fault, and the sandstones have dropped down. The older volcanics are more resistant to erosion and support the hills northwest of Corvallis. Note the small white mineral blebs in the volcanic rocks. These blebs are zeolite vesicle fillings, and they help distinguish
0.3 these rocks where they occur elsewhere on the trip.

2.5 Turn right onto Walnut Boulevard. More Siletz River Volcanics are visible on the hillside above
0.4 the turn.

2.9 Hoover School. As the homes in this area were being constructed, the broken and sheared rock of the Corvallis fault zone could be seen in many of the basement and foundation openings. The fault comes down the small valley you just left, crosses the road just west of the school, and goes through the notch in the hills to the northeast. You will
0.9 see it again near Crescent Valley High School.

Continue along Walnut Boulevard. In several places weathered sandstones appear again in road cuts.

3.8 Intersection of Walnut Boulevard and Kings Road. In the small quarry just up the hill, another diabase intrusive body occurs. The rock has coarse crystals that show an interlocked texture characteristic of rock that crystallized from a melt. The presence of these intrusives in the hills around Corvallis is not coincidental. The more erosion-resistant rock of the intrusives supports the hills, preventing them from being carved away as rapidly as the rest of the Tyee and Spencer Formations. During the winter and spring, this locality will also have a spring which marks the place where the ground surface intersects the water table, proving that much
1.5 of the ground is saturated during the wet months.

Proceed down Kings Boulevard to Circle Drive and turn left. At Highland Drive, turn left again.

5.3 Stop sign at Highland Drive and Walnut Boulevard. Looking to the left at the profile shape of the hillside, you see the steep upper hillside that is underlain by bedrock; a lower, gentler slope across which debris from the higher slopes is transported; and the flat terrace upon which Corvallis is built. This slope pattern, typical of much of the area through which you are riding, created a slight problem during heavy winter rains; water that ran down the gentle "transportation slope" accumulated at the base in an almost imperceptible depression at the back of the terrace, drained toward the Willamette River until it

intersected Highland Boulevard, and then flowed along the roadway out onto the terrace. The sewer here is
0.6 needed to carry off future large amounts of water.

5.9 Proceed up the hill past outcrops of weathered Spencer sandstone exposed in the roadcuts. The beds dip about 25° to 30° to the east in the large cut on
0.2 the right just north of crossroads.

6.1 Here you cross the contact into the Tyee Formation. The Tyee dips about 40° to the north. The difference in degree of dip between the Tyee and the Spen-
0.7 cer Formations shows an unconformity between the units.

6.8 Crescent Valley School. At the entrance to the school, a spring in the pasture near the base of the hill keeps the ground moist and the vegetation green during all but the driest parts of the year. The Corvallis fault crosses just south of the school and then continues northeast through the notch followed by Highway 99W and the railroad. The basalt you see in the ditch of the road south of the school shows that you have crossed the fault. The spring in this location may be related to the proximity of the fault and the more permeable rock produced by the ground breakage.

The age of the fault is indicated partially from this area. You can see that since the fault crosses the middle of the broad eroded valley, and since the rocks on the northwest side are eroded back from the fault line for a long distance, it has been a relatively long period since the fault was last active. Other lines of evidence support this interpretation and suggest that the fault has not moved for several tens of millions of years. Thus this is not a feature that would be likely to offer an earthquake hazard to structures constructed across it.

1.0 The high school here is constructed on a low terrace that rises above the valley floor far enough to protect it from flooding. The terrace, however, is underlain by material containing abundant expansive clay minerals which swell up greatly when wet and contract when dry. They can be a very serious hazard to building foundations. The stream flowing through the middle of the school is beautiful and is also useful in that it is the visible portion of a drainage network that greatly reduces the expansion of the clays by maintaining a fairly constant moisture content in the ground.

Continue on Highland Drive. Note the terraces with elevation differences of only a few feet as you cross the valley. The lowest level is the modern flood plain of the small creeks.

7.8 Lewisburg Road. Turn right. Siletz River Volcanics are exposed in the roadcut at the turn, con-

firming that you are still northwest of the Corvallis
fault. Note the zeolite minerals again. Continue
0.3 east on Lewisburg Road.
8.1 Mountain View Drive. An optional loop on the
trip goes 0.6 miles up this drive to the Lewisburg
quarry, where good exposures of Siletz River Volcanics
0.1 can be seen. From the quarry return to Lewisburg Road.
8.2 The Corvallis fault, which you cross again here,
0.3 continues through the notch to the northeast.
8.5 This low hill is formed of Tyee Formation with
a cap of Spencer Formation. Sandstone occurs in the
0.3 ditch (as does poison oak).
8.8 Lewisburg. Turn right on Highway 99W. Climb
over a low sandstone hill and descend onto the ter-
1.0 race system.
9.8 At the bridge, note the extensive swampy ground.
This area, which is part of the flood plain of the
small streams draining Crescent Valley, has a high
0.7 water table and is often flooded during the winter.
10.5 This low hill is made up of Spencer Formation,
0.3 which can be seen poorly exposed in the roadcuts.
10.8 Swing sharply right onto Elks Drive. Climb to
the Elks Club parking lot for an overview of the valley. On a clear day the volcanic peaks of the Cascades are clearly visible from here.

From this vantage point you can see the pattern of the Willamette River terraces and flood plain. The channel of the river is to the east and can be located by the dense growth of conifer trees lining its bank. The foreground is occupied by a terrace, well above the river, which developed during the Pleistocene when the Willamette River partially filled the valley with debris. Willamette Silts from the Spokane Flood are found on top of these terraces in some places.

Where the Willamette Silts are present, the topography tends to be flat, with minor variations produced by old meander scrolls that have been partially filled with alluvium. Meander scrolls are arcuate landforms which are actually abandoned river channels left by the river as it has meandered back and forth in the valley. The river has since cut into the fill, leaving the terraces above its present level. During winter rains and spring snow melt, the Willamette will commonly rise out of its channel and cover part or all of the flood plain. The terraces, high enough to not be affected by this kind of flooding, have other high-water problems at these seasons. The sediments forming the terraces were also originally deposited during floods and are therefore old flood plains. The sediments are coarser in size close to the river and finer in size farther from the river. This sorting of sedi-

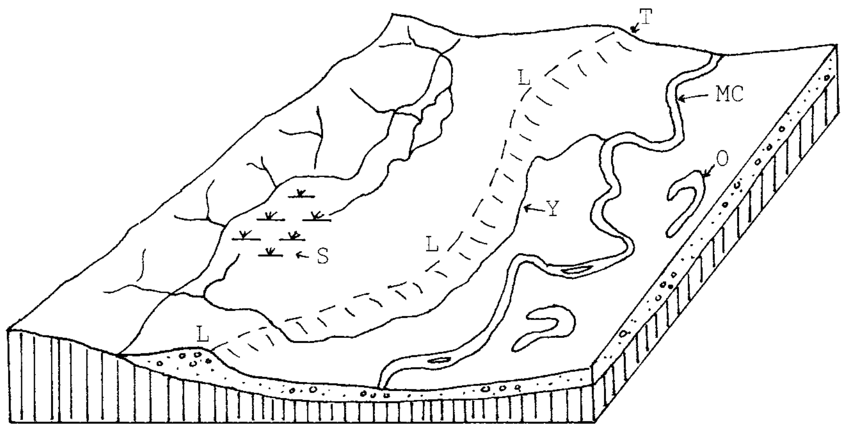
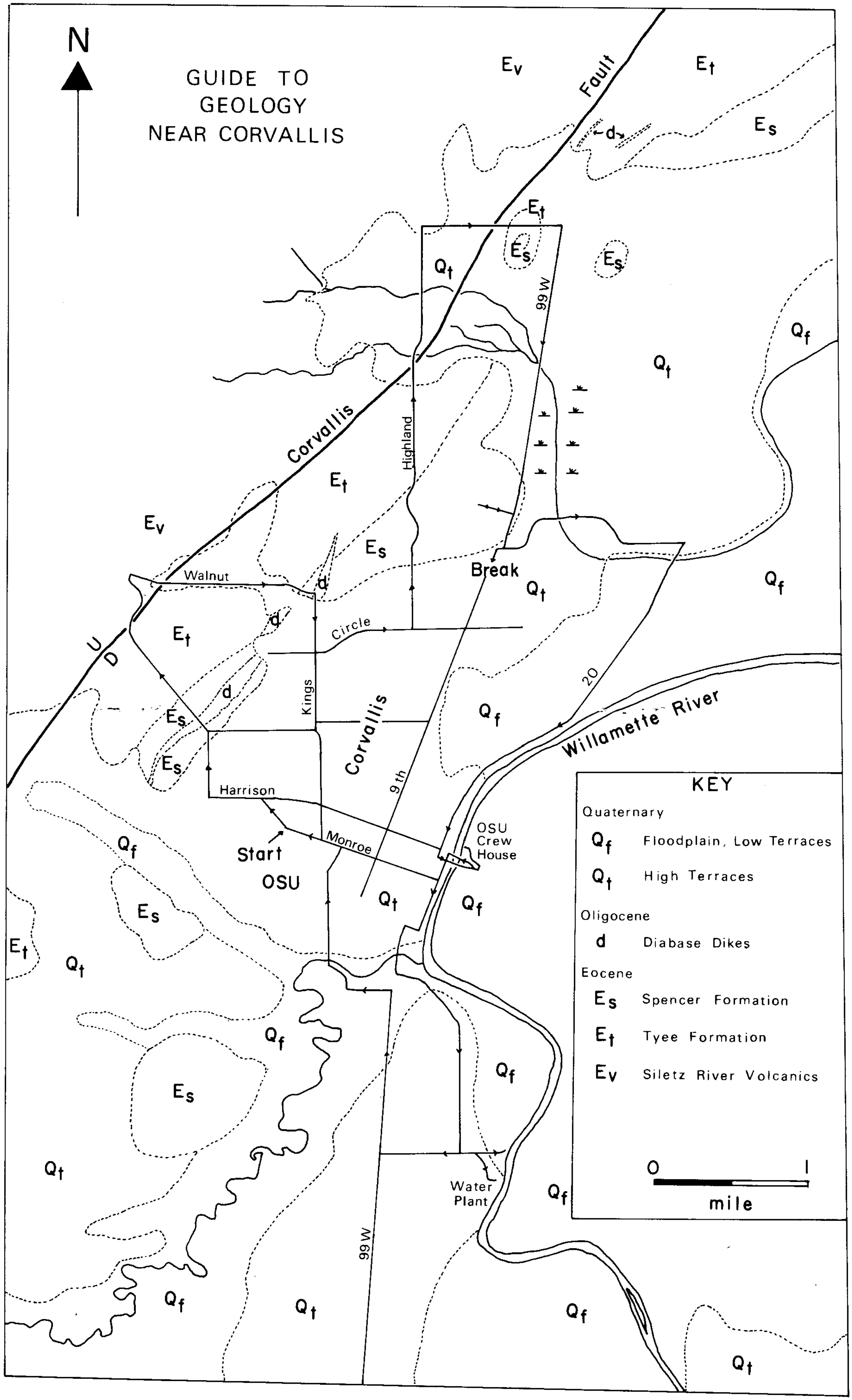


Figure 4. Block diagram of yazoo stream: MC = main channel of river; Y = yazoo stream; S = swamps; O = oxbow lake; T = terrace scarp; and L = levee.

ments by size occurs because fast-moving water carries coarser material than slow-moving water does. Once the fast-moving flood waters overflowed the riverbanks and spread out over the flood plain, their velocity dropped, the coarser material was deposited closest to the riverbanks, and the finer material was deposited
0.7 farther away.

This sorting of sediment produced a levee and backswamp effect, as shown in Figure 4. This effect can be seen in the area below you. The trailer court to the northeast is built on a site that is lower than the rest of the ancient flood plain to the east. The soil is fine-grained clay, in part from the backswamp; and during the rainy season standing water that cannot escape over the rising terrace is a serious problem. Even when water is not present above the surface, the ground-water table may be only inches below the surface, making it impossible to build and use basements. Consultation with an engineering geologist before development is very important in such an area.

For a wider perspective, look out toward the Cascade Range of volcanic mountains to the east. Behind you is the Coast Range. Cascade Range rocks are generally younger than those of the Coast Range, but both areas have undergone uplift in the recent past. The Willamette Valley has been left behind as a structural depression down which the Willamette River flows. Some of the volcanoes of the High Cascades have been active in the recent past, and it is possible that they could



MAP SHOWING FIELD TRIP ROUTE AND GEOLOGY NEAR CORVALLIS erupt again.

Ride back down the hill to Ninth Street. Turn right on Ninth and proceed.

11.5 THIS IS THE BEST SPOT TO SPLIT THE TRIP INTO TWO PARTS.

To return to Oregon State University from this point, continue along Ninth Street and then follow the bike route signs to the center of town and, eventually, the campus. If you plan to complete the trip at this time, turn left on Conifer Avenue, cross Highway 99W, and ride into Kings Village Housing Develop-
0.4 ment.

11.9 On the left is the area just viewed from the Elks
0.2 Club.

12.1 A small creek crosses the road here. The banks expose the Willamette Silt. Note the high clay content of the unit, how sticky and easy to mold it is when it is wet. This high clay content makes it difficult for water to sink into the ground and contributes significantly to the problem of standing water
1.0 when the creek floods.

13.1 Turn right onto Highway 20. Just after the turn, you drop over the terrace edge and go down onto the
0.1 present-day flood plain of the Willamette River.

13.2 Bridge across small stream. This swampy creek is the same one you crossed at mile 12.1, where you looked at the clay. There, at higher elevation, the creek flows south, parallel to the Willamette River but in the opposite direction. After crossing the terrace, the creek descends to the flood plain, where it is still trapped behind the levee of the river. It then flows north, parallel to and in the same direction as the Willamette, until the flood plain disappears on this side of the river and the river cuts into the high terrace (see Figure 4). A stream that becomes entrapped in this manner is called a "yazoo stream," named after a Mississippi tributary that shows this behavior.
0.2 Yazoo streams are common in the Willamette Valley.

13.4 From the intersection of Garden Drive and Highway 20, you can look back for a good view of the terrace scarp that you just rode down. For the next mile or so, watch the minor relief features of the fields, which are developed on more old Willamette River mean-
1.1 der scrolls.

14.5 At this curve in the road you are climbing up onto the higher terrace again. The city of Corvallis is built on this terrace level and thus is normally im-
0.8 mune from flooding.

15.3 The creek flowing under the road at this point permits the entry of flood water during high-water stages of the Willamette River. In the 1964 flood, the Corvallis sewage treatment plant in the low area just to the west was flooded. The east bank of the river is generally lower along here, except for tributary channels of this sort, and most flood waters

0.7 flow to the east.

16.0 Turn left on Van Buren Avenue and cross river on Highway 34. Just across the bridge, turn left across the highway and ride out to the OSU crew docks on the bank of the river.

From this lookout point you can see the main Willamette channel and a portion of the flood plain to the east. The river has not flooded the city of Corvallis to the west since 1861 because that part of the city sits on a higher terrace. The area to the east is frequently covered with water during floods and so is truly part of the flood plain. This is the widest portion of the Willamette flood plain in the Corvallis area, extending almost 2 miles to the east; and a stretch of Highway 34 is covered by flood waters fairly frequently (Figure 5).

During the very high "100-year" flood of December 1964 the Willamette rose to its crest in 4.5 days, at an average of 0.14 feet per hour. For 13 days the river was out of its channel. The velocity of water in the main channel was 13 feet per second. Even east of the highway bridge outside the deep channel, velocities of 5 feet per second were measured in water over 10 feet deep that was flowing across the highway. High-water marks from some of these floods can be seen on the Harrison Street Bridge pillars. Very large floods of this sort occur on the Willamette River from a combination of conditions. First, prolonged winter rains that saturate the soils of the surrounding mountains are followed by a major snow storm. Then a rapid thaw and melt, accompanied by rain, causes a very rapid release of water from melting snow, which promptly raises the rivers above their banks. This pattern is especially common for Coast Range streams.

Even though floods of this magnitude do not occur every year, they represent a serious threat to structures that may be constructed on the flood plain. Accordingly, wise land-planning efforts involve zoning regulations to restrict building on the flood plain. The Benton County Board of Commissioners has passed regulations prohibiting housing tracts of any kind on flood plains in Benton County; and the long-range plan for the county includes careful consideration of flood plain planning. Linn County, where you are at this stop, has even stricter ordinances for the Willamette flood plain than does Benton County. Here only agri-

Figure 5. Aerial oblique view of Willamette River on January 17, 1974 showing flood waters on flood plain east of Corvallis. (Photo courtesy of Western Ways, Inc.)

1.0 cultural use is allowed.

Return to Highway 34 and turn right to Corvallis via the Harrison Street Bridge.

17.0 Turn left on Second Street.

0.6

17.6 Turn right on Western Boulevard. Then turn left onto Third Street and cross the Marys River Bridge on the sidewalk on the left-hand side of the road. Continue on the sidewalk.

0.5

18.1 Turn left on Crystal Springs Drive. The first bridge at Evans Products Company is an old millrace that causes problems because it carries flood waters from the Marys River through this area.

0.4

18.5 Stop at the large gravel piles on the left side of the road and look down at the gravel plant operation, now being phased out.

The Willamette River, with its headwaters located in the recently uplifted Cascade Mountains, carries an abundant coarse sediment load. Following periods of high water, gravel deposits accumulate as point bars on the inside (concave side) of meander loops. The progressive development of such a bar can be followed on Figure 6. In time these accumulations may reach sufficient size to become economically valuable.

Gravel is an important economic resource. The 1974 value of $32.6 million for Oregon's sand and gravel represented well more than one third of the State's total mineral value of $81.5 million for that year. The tremendous bulk of gravel resources means that transportation is crucial in limiting the exploitation of a deposit. If gravel must be carried very far, it cannot be economically used.

The Corvallis area is fortunate in having ongoing gravel extraction operations in very large point bars adjacent to, but not in, the river channel. Elsewhere along the Willamette, quarrying has been carried out by dredging the river itself for its current load of gravel and sand, which unfortunately increases downstream erosion as the river supplies itself with new loads to replace its lost loads. River quarrying also dirties the water downstream with fine sediment, which in turn affects the quality of fishing and drinking water. Here the gravel operation, while not beautiful, is in a safe place and fulfills the gravel needs of the surrounding area.

One problem associated with population growth in an area is the tendency for urban developments to grow over potentially valuable gravel deposits that will soon be needed; another problem is the tendency to zone completely against gravel operations. This valuable industry may then be smothered by its own success in supplying building materials for a growing area. This loss of gravel resources is unnecessary; planning that first identifies gravel resource areas and then zones them for aggregate use can be combined with regulations requiring mined-land reclamation. Numerous mined-out quarries and gravel pits have been used as parks with lakes; and some gravel pits have been leveled and filled for residential construction.

1.0

Continue down Crystal Springs Drive.

19.5 Turn left on S.E. Park Avenue.

0.2

19.7 Turn left on Goodnight Road, then turn right on Clearwater Road and ride out to the Corvallis Water Treatment Plant. Ride to the bank of the Willamette River.

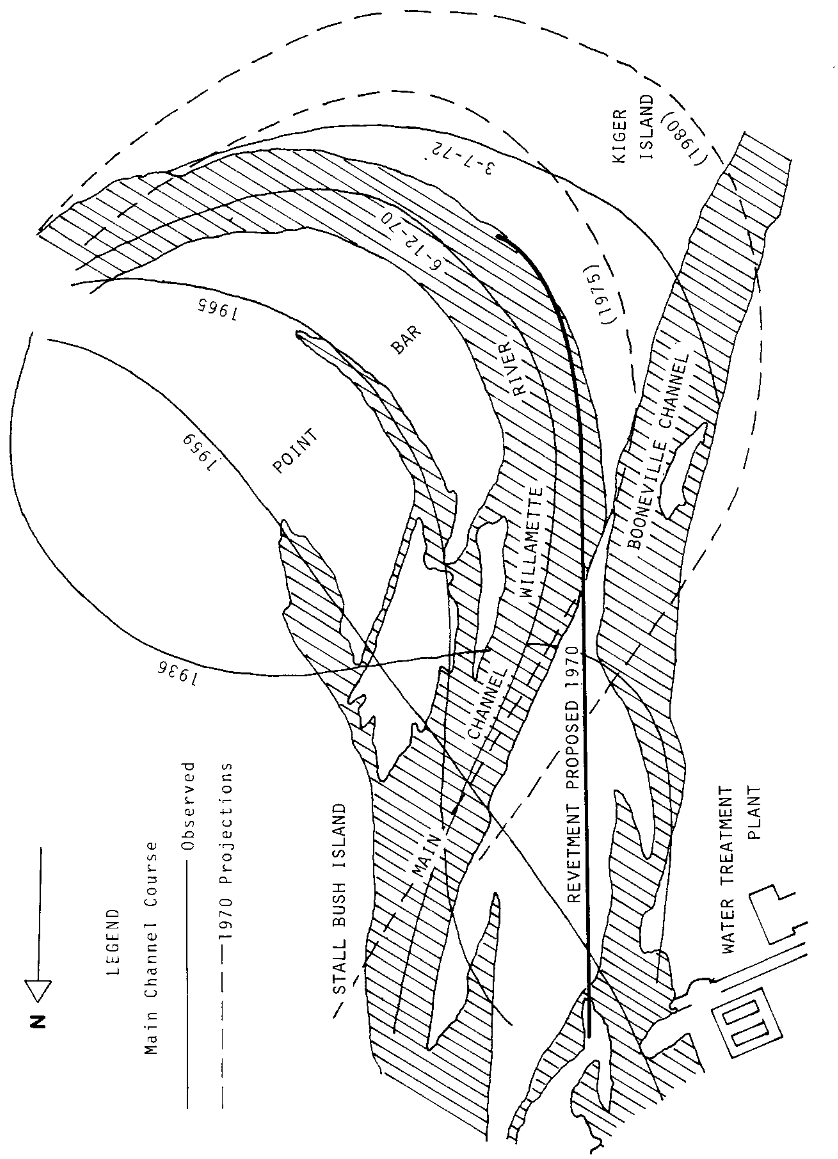


Figure 6. Channel changes in Willamette River near Corvallis water treatment plant showing revetment proposed in 1970 to maintain channel east of plant. Note growth of point bar from 1959 to 1972.

The H.D. Taylor Water Treatment Plant is used for municipal and irrigation water services by the City of Corvallis and the surrounding area during the summer months. Peak intake for the plant is approximately 20 million gallons per day. Recently the meandering of the Willamette River has seriously affected the outlook for the future usability of the plant.

In 1970 the U.S. Corps of Engineers undertook a survey of the Willamette River in the vicinity of the water treatment plant. The study revealed that the river was about to change the course of its main channel. At that time the plant obtained its water from the relatively quiet waters of the Booneville channel, a side channel for the river. The Corps predicted that about 1975 this channel would become the main course for the river. The rapid water of the main channel and the accompanying rapid erosion would threaten the effectiveness of the plant. A revetment was proposed to hold the river in its existing channel (see Figure 6). In the fall of 1971, 3 years ahead of schedule, the Willamette River cut through to the Booneville channel before the revetment could be constructed (Figure 7). Looking to the south, you can see the extensive erosion along Kiger Island that is a result of this change of channels. Two undesirable consequences may follow: First, the Willamette River may erode its west bank and undercut the treatment plant; second, the river may be deflected from the west bank and bypass the plant. Alternative revetments have been established along the new channel to try to prevent either of these events and to keep
0.5 the river in its present location

Return to Goodnight Road.

20.2 Turn right into Willamette Park on Goodnight Road. As you enter the park, you drop down onto the flood plain of the Willamette River from the terrace. At the base of the terrace scarp, notice the lowland area with large cottonwood trees growing in it. This is the low zone at the back of the flood plain behind the levee. By the riverside you can see part of the protective measures that have been taken along the
2.2 banks of the river.

Return to Goodnight Road. Turn right and return to S.E. Park Avenue. Continue on S.E. Park Avenue to Highway 99W. Turn right on Highway 99W.

22.4 Beyond the school crossing, you drop down into a lowland area containing the millrace, mentioned at mile 18.1, which is frequently flooded by the Marys
0.4 and Willamette Rivers combined.

22.8 Turn left on Avery Road and follow the bike route through Avery Park. By now you should be able to re-

Figure 7. Aerial oblique photo looking north across the Corvallis water treatment plant on January 5, 1971, after the Willamette River began using part of the Booneville channel as a main channel. (Photo courtesy of Western Ways, Inc.)

cognize the presence of numerous meander scrolls of
0.7 the Marys River in the park area.
23.5 Take the bridge across the Marys River and cross
1.2 Highways 20 and 34. Continue straight.
24.7 Turn left on Monroe Boulevard and return to the
Earth Sciences Building.

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MARGARET STEERE RETIRES

Margaret L. Steere

Nearly 30 years ago Margaret Steere came to the Department to organize the rock and fossil collection. Before long, all specimens were labeled and either carefully stored or neatly displayed.

Soon Margaret, who has a master's degree in geology from the University of Michigan, was producing articles and editing the manuscripts of would-be authors into Department publications.

The "Fossil ORE BINS," on which Margaret worked as editor and writer, were probably the most popular items the Department ever published. Margaret's last work before retiring was preparation of ORE BIN articles on fossil plants and animals of Oregon for publication as a bulletin.

During her long tenure with the Department, Margaret edited and assembled 55 bulletins and more than 300 issues of the ORE BIN, all camera-ready for the printer. She put forth this effort without fuss or bother. She came and left quietly, but she will be missed.

* * * * *

STEVE RENOUD TAKES TO THE WOODS

Steve Renoud, the Department's chief cartographer, has left to become assistant Director of the mapping section in the State Forestry Department in Salem.

During his 8 years in the Department, Renoud developed the technique for in-house production of camera-ready color-separated negatives for multi-colored geologic maps. The procedures he perfected are now in use by various other agencies.

Steve turned out numerous multicolor maps, charts, graphs, tables, and illustrations for the Department. In addition, he worked on state-wide job descriptions for classifying cartographers.

Steve Renoud

* * * * *

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POTENTIAL ENVIRONMENTAL ISSUES RELATED TO GEOTHERMAL POWER GENERATION IN OREGON

Rodney D. Wimer,* Phillip N. LaMori,** and Alan D. Grant*

Introduction

Geothermal energy, derived from the natural heat within the Earth, has been utilized for the generation of electricity since the dry steam field at Larderello, Italy, was tapped in 1904. In the United States, development of geothermal resources for electric power generation has progressed slowly since the first 11,000 kWe (kilowatts electrical) turbine was installed at The Geysers, California, in 1960. This field, with a present installed capacity of 502 MWe (megawatts electrical), is still the only geothermal resource that has been harnessed for commercial electricity production in this country.

Geothermal energy has historically been hailed by both developers and environmentalists as a clean energy resource. Bowen (1971, 1973), who was the first to attempt a detailed literature review of the environmental impacts of geothermal power production from vapor-dominated dry steam reservoirs, compared these impacts to those associated with more conventional coal and nuclear power generation. Recently Axtmann (1975) described the adverse environmental effects of chemical and thermal discharges from the Wairakei, New Zealand, geothermal power plant into the Waikato River. The Wairakei plant utilizes geothermal fluids from a liquid-dominated (hot water) reservoir to produce electric power.

This article discusses the present understanding of the nature and occurrence of geothermal resources in Oregon and emphasizes those critical environmental issues which must be addressed in public forums and ultimately in power plant design if significant utilization of this indigenous energy source is to become a reality. An emerging conversion technology known as the binary cycle, which will be demonstrated in 1980 in a 50-MWe plant near Heber in the Imperial Valley of California, is also described. The binary conversion process, which

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isolates the geothermal fluids in a closed system for eventual re-injection into the reservoir, has the potential to mitigate several adverse environmental impacts often attributed to geothermal power generation. The suspected liquid nature and thermodynamic quality of Oregon's geothermal resources may dictate utilization of the binary cycle for electric power generation.

Geothermal Resources in Oregon

Nature and occurrence of geothermal resources

Geothermal resources can be grouped into two broad classes which are largely defined by the nature of the heat source responsible for the observed upper crustal thermal anomaly: (1) igneous-related geothermal systems characterized by intrusions of magma into the upper crust, and (2) geothermal systems which are not related to igneous intrusions but which generally occur in sedimentary rocks in areas of high regional heat flow (Muffler, 1975). The first class can be further subdivided into three resource types: (a) magma, (b) hot dry rock, and (c) hydrothermal convection systems. Hydrothermal convection systems are further broken down into two main types depending on the nature of the dominant pressure-controlling phase in the geothermal reservoir: (a) vapor-dominated systems, wherein liquid water and vapor coexist in the reservoir with vapor as the continuous pressure-controlling phase; and (b) hot-water systems characterized by liquid water as the continuous, pressure-controlling fluid phase (White, Muffler, and Truesdell, 1971). The vapor-dominated reservoir systems are considered extremely rare; indeed, The Geysers, California, is the only large system of this type extensively drilled to date in the United States. The Mud Volcano system in Yellowstone National Park and Mt. Lassen Volcanic National Park may also be underlain by vapor-dominated reservoirs (Renner, White, and Williams, 1975).

Geothermal resource potential

Over 200 thermal springs and wells have been identified to date in Oregon (Bowen and Peterson, 1970). Most of these springs occur within two distinct geologic environments: (1) the structurally deformed and moderately altered Tertiary strata of the Western Cascades; and (2) individual grabens of the Basin and Range province of southeastern Oregon, usually adjacent to or astride major normal faults. Those thermal springs for which geochemistry data indicate subsurface temperatures greater than 90°C (194°F) are shown in Figure 1. The chemical compositions of these hotter spring systems indicate minimum reservoir temperatures ranging from 90°C (194°F) to 207°C (405°F) and further suggest that reservoirs supplying these thermal springs are of the hot-water type, with generally high contents of alkalis, chloride, and silica (Mariner and others, 1974, 1975). Hot springs which are surface manifestations of vapor-dominated systems are generally acidic

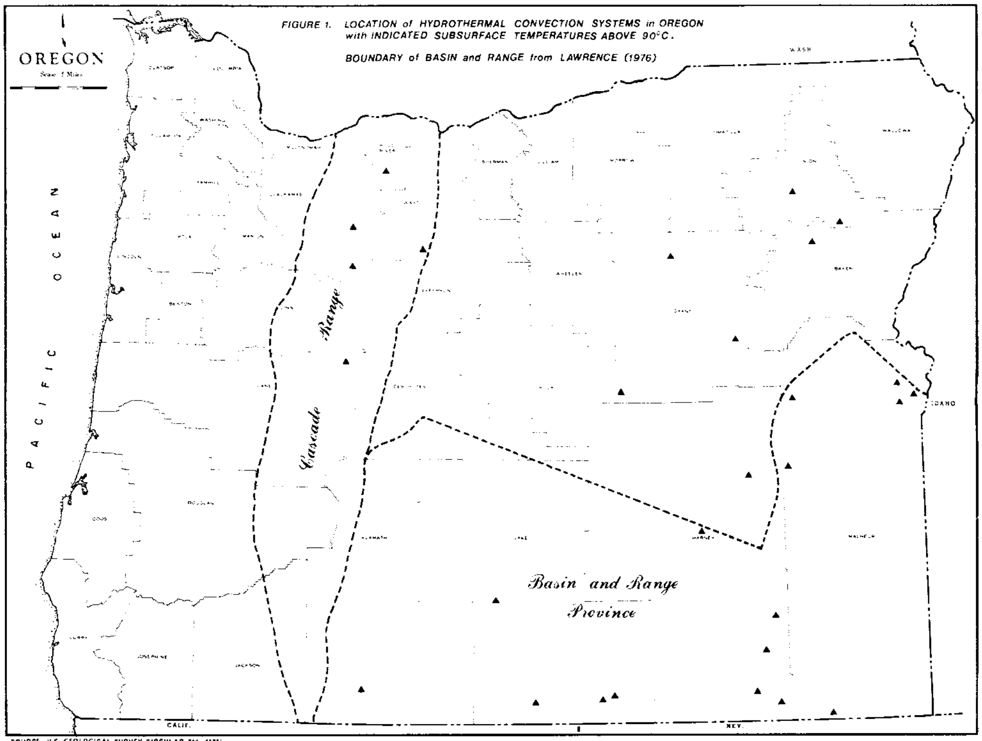

FIGURE 1. LOCATION of HYDROTHERMAL CONVECTION SYSTEMS in OREGON with INDICATED SUBSURFACE TEMPERATURES ABOVE 90°C.

BOUNDARY of BASIN and RANGE from LAWRENCE (1976)

SOURCE: U.S. GEOLOGICAL SURVEY CIRCULAR 726 1975

(pH as low as 2 or 3), low in chloride content (generally less than 50 ppm), and high in sulfate.

Although Oregon contains over 200 thermal springs and has been the site of more Tertiary and Quaternary volcanism than any other western state, the geothermal resource potential of this State is essentially unknown. In 1975 the U.S. Geological Survey (White and Williams, eds., 1975) made a preliminary estimate of the U.S. geothermal resource potential based on incomplete information. That survey indicated a total of about 30.4 x 10^{18} calories of recoverable thermal energy suitable for nonelectrical applications and 1,336 MWe (at a 30-year plant life) of electric power generation potential from all identified hydrothermal resources in Oregon (see Table 1).

These estimates, developed from a small data base, translate into the equivalent electrical energy generated by slightly more than one nuclear plant the size of Trojan. Note, however, that these are minimum estimates which will probably be continually revised upward as knowledge of the nature and occurrence of Oregon's geothermal resource improves through regional and site-specific exploration programs. The above estimates do not include possible concealed hydrothermal resources, igneous-related systems, and resources in above-average conductive heat-flow environments. As techniques are developed to evaluate and utilize these resource

Table 1. Estimated Potential Electric Energy from Identified High Temperature[1] Hydrothermal Convection Systems in Oregon

Spring Name	Subsurface Temperature (°C)	Volume (km^3)	Stored Heat (10^{18} cal)	Recovery Factor e_r	Electrical Potential[2]
Mickey H.S.	210	12	1.4	0.025	154
Alvord H.S.	200	4.5	0.5	0.025	57
Hot Lake	180	12	1.2	0.02	107
Vale H.S.	160	100	8.7	0.02	770
Neal H.S.	180	4	0.4	0.02	37
Lakeview	160	16	1.4	0.02	123
Crumps Spring	180	8	0.8	0.02	70
Weberg H.S.	170	2.25	0.2	0.02	18
Total					1336

[1] High temperature systems are those with estimated subsurface temperatures greater than 150°C, which is presently considered the minimum threshold for electric power generation.

[2] Electrical potential assumes commercial power generation at a 30-year plant life.

Source: U. S. Geological Survey Circular 726 (1975)

types, the total energy potential will probably increase significantly.

Geothermal Power Conversion Cycles

Dry steam cycle

At The Geysers, California, a dry steam (vapor-dominated) resource, the first unit in 1960 consisted of an 11 MWe turbine, a direct contact condenser, and a cooling tower. Power production was accomplished in a manner similar to conventional fossil-fired plants. Noncondensible gases naturally occurring in the steam were vented to the atmosphere through gas ejectors above the condenser and in the cooling tower exhaust. Excess cooling tower fluids were discharged to local streams. Natural dry steam was produced by drilling a well into the subsurface instead of by burning nonrenewable fossil fuel. A schematic diagram of The Geysers-type dry steam conversion process is shown in Figure 2.

Development at The Geysers field proceeded slowly in the early years, primarily because of uncertainties regarding the longevity of the resource. The pace of development increased, however, as the longevity of the resource was established and more reserves were located. This increased rate of development resulted in accompanying environmental concerns and required the establishment of mitigation procedures to control environmental problems. The

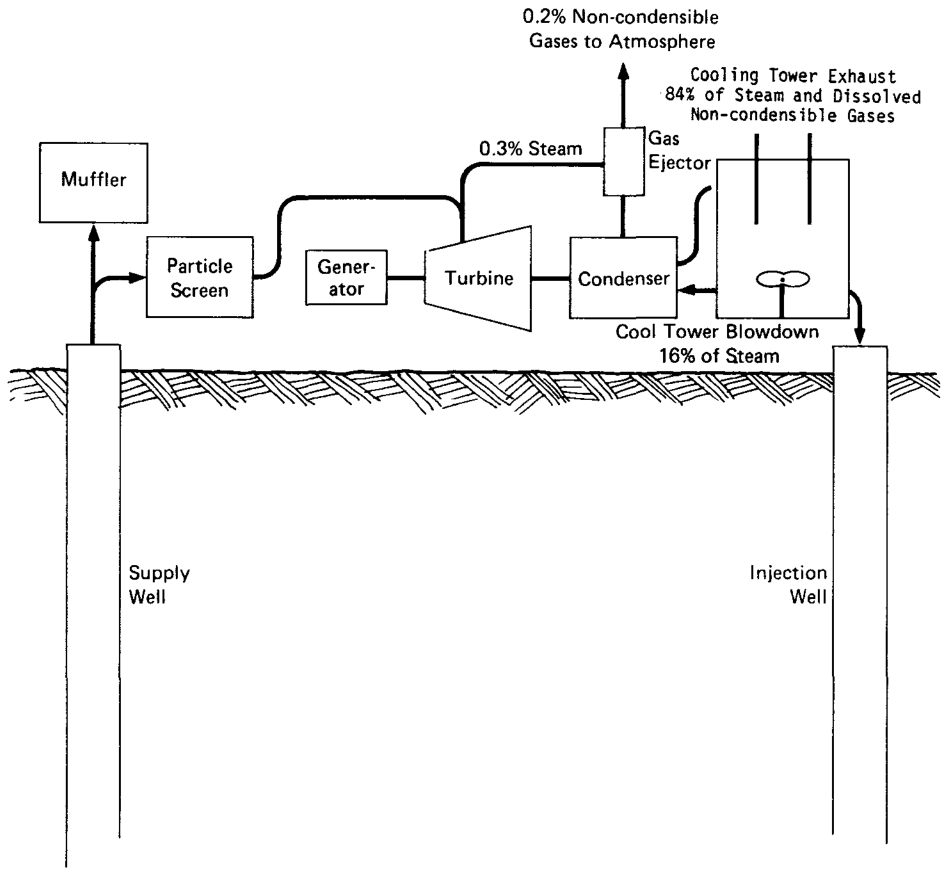

Figure 2. Geysers-type dry steam power production cycle.

once-through discharge of cooling tower blowdown into local streams was soon stopped and the excess condensate was disposed of in re-injection wells. Venting of wells prior to production and during power plant shutdown had originally resulted in high noise levels, but the development of effective muffling devices greatly reduced these noise emissions to allowable levels. Concern over the release of hydrogen sulfide (H_2S) in the noncondensible gas stream led to the development and testing of several processes to reduce such emissions. The Stretford process, which chemically converts H_2S to elemental sulphur, can reduce H_2S emissions by over 90 percent and is now planned for all new units and will be retrofitted to existing units (Pacific Gas and Electric Co., 1975).

The dry steam geothermal resource, while easily exploitable, is an uncommon occurrence. Thus, The Geysers field is not a truly representative model of the environmental impacts associated with

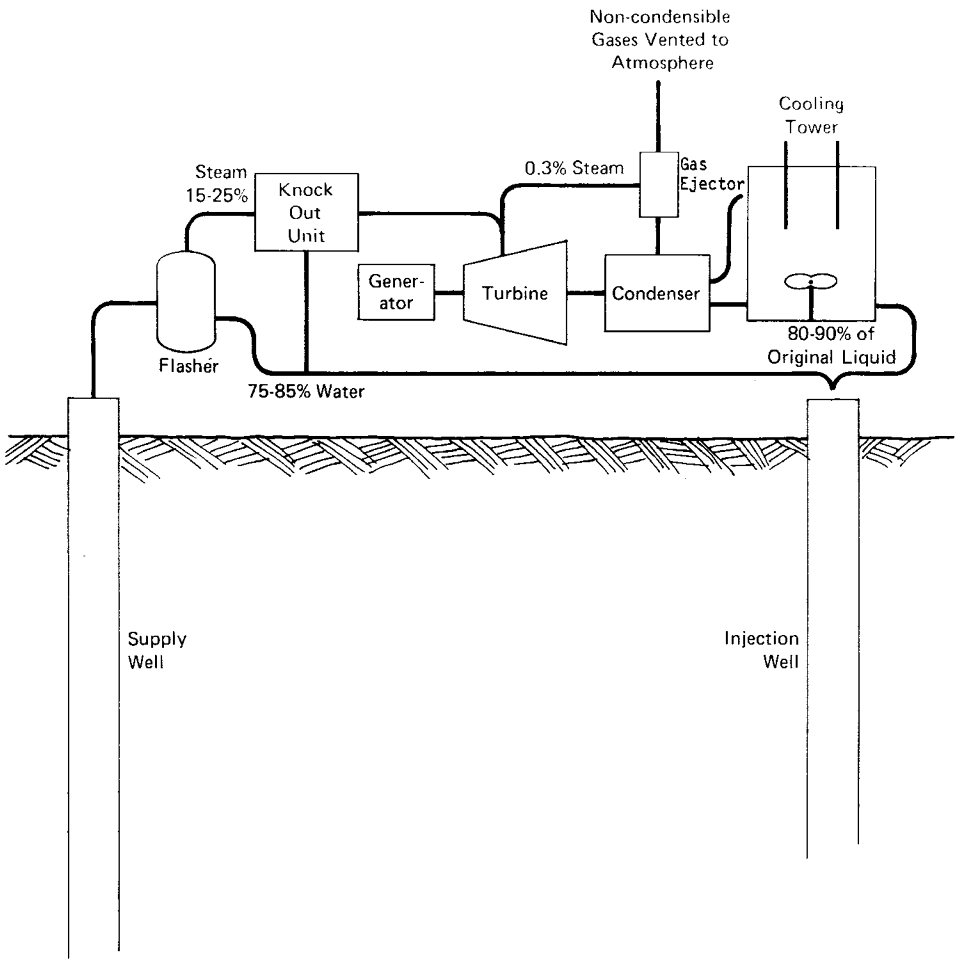

Figure 3. Flashed steam power production cycle.

geothermal power production because over 95 percent of the world's hydrothermal geothermal resources are believed to be of the hot-water (liquid-dominated) type. The more common hot-water resources will be exploited by one of two power conversion cycles: the flashed steam cycle or the binary cycle.

Flashed steam cycle

The flashed steam geothermal power cycle (see Figure 3) is similar to the dry steam cycle, except that a flasher and water knock-out unit are required. Flashing results in significantly larger quantities of fluid to be eventually reinjected into the geothermal reservoir. A primary requirement of the flashed steam cycle is fluid temperature high enough to provide economic quantities of steam (generally above 400°F). The environmental concerns associated with the flashed steam cycle are similar to those accompanying the dry steam cycle, although noise emissions from venting wells is not a problem. Presently, worldwide power generation capacity using the flashed steam cycle totals approximately 500 MWe from about a dozen widely scattered locations, none of which are in the United States. The power plants in Cerro Prieto, Mexico, and Wairakei, New Zealand, utilize the flashed steam process and are the two largest power producers, with 75-MWe and 190-MWe of installed capacity, respectively.

Binary cycle

The binary power cycle (see Figure 4) has been proposed for power production where geothermal resource temperatures are too low for economic utilization of the flashed steam cycle or where the produced fluid contains undesirable amounts of dissolved solids or noncondensible gases. In the binary cycle the geothermal fluid is maintained in a closed loop from the production to the reinjection wells and therefore should not result in environmental degradation. The thermal energy contained in the geothermal fluid is transferred to a low-boiling-point working fluid which expands through a turbine to generate power and is then condensed and recirculated. The spent geothermal fluid is pumped from the plant to reinjection wells for ultimate disposal back into the reservoir.

The main advantages of the binary cycle over the flashed steam cycle are the closed-system operation and the ability to extract energy from the total produced fluid. This latter factor makes the more complicated and somewhat higher capital-cost binary cycle economically competitive with other geothermal power production options. The major disadvantages of the binary cycle include the increased capital costs, requirements for additional heat exchangers, and the probable need for supplemental cooling water supplies.

The binary conversion cycle has yet to be demonstrated in a commercial-sized power plant in the United States. However, the San Diego Gas & Electric Co. is sponsoring a 50-MWe binary cycle demonstration plant jointly with the Electric Power Research Institute (EPRI) and several other utilities. This plant is to be constructed at the Heber thermal anomaly in the Imperial Valley of California and is presently scheduled for operation in late 1980. Successful demonstration of the binary cycle conversion technology at the Heber plant will encourage development and economic utilization of geothermal resources with temperatures ultimately as low as 150°C (300°F).

Environmental Impacts of Geothermal Exploration and Field Development

As with all forms of power generation, environmental impacts are associated with the conversion of geothermal energy to elec-

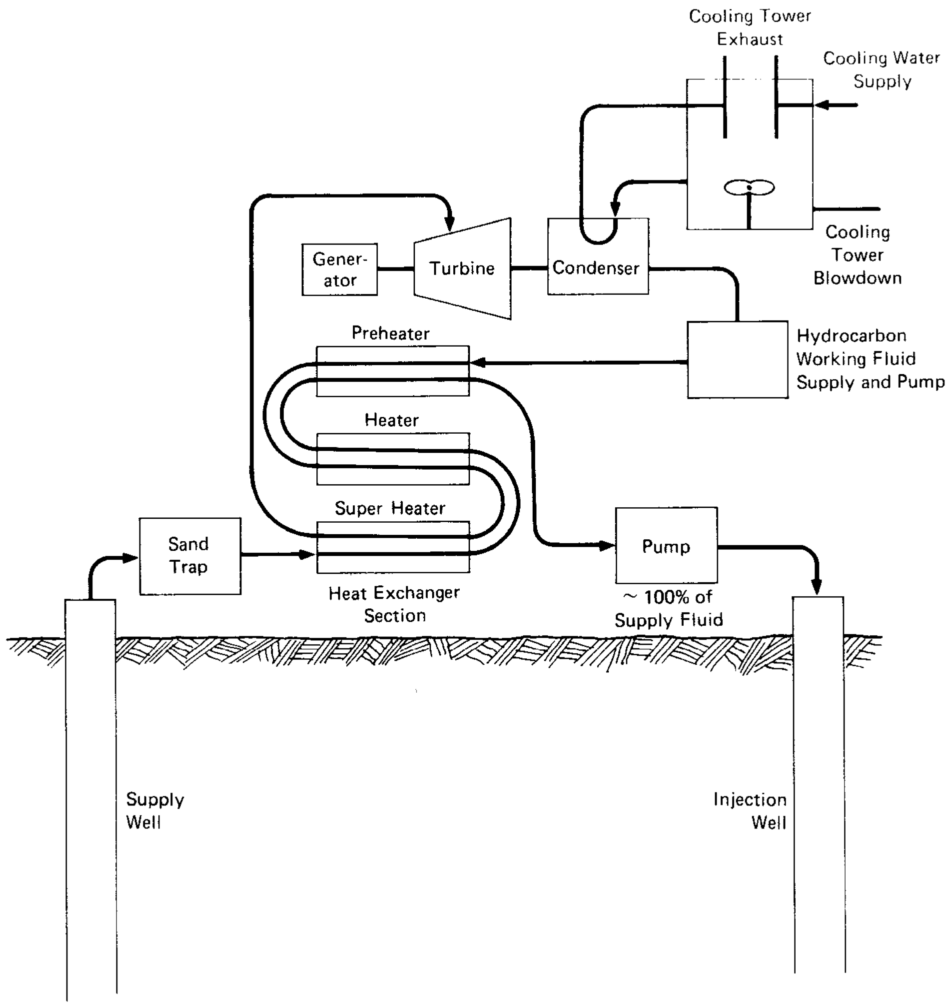

Figure 4. Binary power production cycle.

trical energy. The list of environmental concerns relative to the development and utilization of geothermal resources includes many of those impacts attributed to other forms of power generation (e.g. air quality, land use). Others, such as subsidence and possible induction of earthquakes, are unique to the geothermal industry. Furthermore, the types and magnitudes of environmental impact associated with geothermal power production will be dependent upon the nature of the reservoir system being developed (i.e. vapor-dominated vs. hot-water systems) and will be site specific. Unlike fuel cycles of coal or nuclear alternatives, the entire fuel cycle of a geothermal plant is concentrated at the point of resource extraction. This geographic concentration results in economic and land use advantages over the often expansive and geographically dispersed fuel cycle steps associated with coal and nuclear options but presents constraints with respect to power plant siting.

The environmental impacts associated with geothermal power production can be categorized according to the three separate stages of resource development: (1) resource exploration, (2) test drilling and field development, and (3) power plant construction and operation. The first two stages are discussed below; the third stage is discussed in the section entitled Potential Environmental Impacts of Binary Cycle Power Generation in Oregon.

Exploration

Environmental impacts in the exploration phase resulting from geological, geophysical, and geochemical investigations are transitory and are generally of small magnitude. These investigations are usually conducted on the ground, although aircraft are used for transportation, airborne geophysical techniques, and aerial photography.

Existing roads are used whenever possible; but surficial investigations may require off-road vehicular travel. Little road construction would be required in the Oregon Cascade Range because of the numerous existing Forest Service and logging roads in the area. Gravity, magnetic, and microseismic surveys are conducted with portable equipment which can usually be backpacked into areas that are inaccessible to vehicles. Seismic and electrical resistivity surveys might result in minor temporary surface disturbances from vehicular movement, depending on the particular technique employed.

Shallow holes (generally less than 500 feet deep) are sometimes drilled during the exploration phase for temperature-gradient measurements and heat-flow determination. Small truck-mounted rotary drill rigs are generally used, and drill cuttings or chips are removed by introducing a jet of air during drilling. The extracted cuttings tend to form a small conical pile above the drill hole and are easily removed upon completion of drilling. The hole is usually plugged, covered, and rehabilitated after the temperature-gradient measurements have been monitored over a period of several months. Since these shallow holes are usually drilled adjacent to existing roads, they result in little surface disturbance.

Test drilling and field development

Adverse environmental impacts from geothermal energy utilization may occur during the test drilling and field development phase. Activities in this phase include: (a) test hole drilling to delineate reservoir boundaries; (b) fluid sampling for determination of the reservoir's physical and chemical properties; (c) production testing to determine the flow rate, composition, temperature and enthalpy of fluids and gases, recharge characteristics, reservoir pressures, and hydrodynamic properties; and (d) the drilling and testing of production wells to supply geothermal fluids to the power plant if favorable results are obtained during initial reservoir tests.

Potential adverse environmental effects during the test drilling and field development phase can be grouped into four categories: land use conflicts, air pollution, water pollution, and noise. Land use conflicts and water pollution appear to be of greatest concern. The magnitude of these impacts will vary according to the type of resource being exploited (e.g. vapor-dominated vs. hot-water reservoirs), topography, type and extent of vegetation cover, and subsurface geologic and hydrologic conditions.

Land use conflicts: Various land use disturbances occur during drilling and field development from access-road construction and well-site preparation. These impacts range from temporary nuisance conditions such as blowing dust to the disturbance of vegetative cover and displacement or loss of wildlife habitats.

The amount of land disturbed is dependent upon the number and spacing of production wells required to supply fluids to the power plant, which in turn are functions of topography and the physical characteristics, extent, and thermodynamic quality of the geothermal reservoir. For example, during early development of The Geysers dry steam field, the average well density was one well per five acres (Budd, 1973). The recent initiation of directional drilling at The Geysers has greatly reduced land requirements, and three production wells are now being located on individual well pads. Present plans for the 50-MWe binary cycle demonstration plant to be constructed near Heber, California, provide for the location of all 12 directionally drilled production holes on a single pad. This optimum well spacing can only be achieved under very special circumstances, such as the pressurized sedimentary reservoirs of moderate primary permeability in the Imperial Valley. Such compact spacing through directional drilling may not be possible in Oregon, where geothermal reservoirs will probably produce from secondary permeability zones (faults, fractures, joints, etc.) in volcanic rocks of varying lithologies. Land requirements for the surface installations (pumps, piping, etc.) necessary to transport the geothermal fluids to the power plant are also directly related to well spacing and terrain conditions.

Geothermal field development does not preempt multiple land usage of the impacted area. For example, the Larderello field in Italy is in an area where farms, vineyards, and orchards are adjacent to production wells, pipelines, and power plants (Bowen, 1973, p. 201-202.)

Water pollution: During the drilling and field development phase the most serious potential water and air pollution problems will occur if there is a well blowout. A blowout occurs when well bottom-hole pressures build up and become sufficient to overcome the well's hydrostatic weight. Well blowouts, which were occasionally a major problem in the early development of The Geysers field, were apparently instigated by slope instabilities resulting from heavy precipitation, rugged terrain, and altered surficial geologic units. Well blowouts appear to be controlled completely now through improved drilling and casing techniques and the implementation of stringent federal and state regulations requiring blowout prevention equipment on each wellhead. Blowouts are still a potential hazard, however, in the test drilling and field development stage.

Ground water contamination can occur during the drilling of production wells through use of improper drilling and cementing procedures. Adverse impacts could result from the loss of formation integrity, permitting the upward migration of generally poor quality geothermal fluids under high pressure into shallow aquifers. Avoidance of such adverse impacts is possible through use of proper well completion and operation practices, along with the design and implementation of appropriate well monitoring programs.

Atmospheric pollution: Atmospheric pollution is not a major problem during the drilling and field development stage. Release of hydrogen sulfide and other noncondensible gases could occur when production wells into vapor-dominated reservoirs are being blown for cleanout of rock particles and other debris, but such releases would occur only over a period of several weeks. Uncontrolled releases should generally not occur from wells drilled into liquid-dominated reservoirs.

Noise: High-frequency and high-intensity noise emissions can occur during drilling and testing of geothermal wells, particularly in vapor-dominated reservoir systems when compressed air is used as the drilling medium instead of mud. When the production well is being blown for cleanout, sudden release of compressed air and natural steam can also result in objectionable noise levels. The development of muffling devices, such as those in use at The Geysers, has resulted in noise emissions being held within acceptable limits during testing of geothermal wells. As most prospective geothermal resource areas in Oregon are in regions of low population density, noise emissions from geothermal developments should have no significant adverse effects on the general populace. Furthermore, noise is generally not a problem with flowing fluid wells.

Potential Environmental Impacts of Binary Cycle Power Generation in Oregon

The types and magnitudes of environmental impacts associated with the construction and operation of geothermal power plants are dependent upon differences in reservoir type and upon the conversion process used to convert the thermal energy contained in produced fluids to electrical energy (direct steam, flashed steam, or binary cycle). Nonresource-related and site-specific differences in topography, climate, geology, hydrology, vegetation, and land use are also of importance.

As geothermal reservoirs in Oregon will probably be medium temperature (325°-400°F) and of the hot-water type (see Geothermal Resources in Oregon), this discussion assumes utilization of the binary conversion process. Depending on the chemical and thermodynamic quality of individual reservoir systems, greater thermal efficiencies may be realized through utilization of the flashed steam process. However, the environmental impacts associated with the utilization of the direct and flashed steam conversion technologies are well documented in the literature (Bowen, 1973; Axtmann, 1975; and Mercado, 1975).

In the binary conversion process, the hot geothermal fluids which are used to heat and vaporize a low-boiling-point working fluid, such as isobutane, are isolated in a closed system and reinjected into the reservoir. Therefore, the adverse environmental impacts associated with power generation utilizing the binary cycle are potentially fewer and of less magnitude than those associated with existing direct and flashed steam technologies. These potential impacts are described below; and, to the extent possible, differences in the magnitudes of each, assuming hypothetical sites in both the Cascade Range and in eastern Oregon, are estimated.

Impacts on land

The land use requirements of a binary cycle geothermal power plant are primarily dependent upon the number and spacing of production and reinjection wells and upon the acreage required for cooling towers, the turbine-generator building, isobutane and condensate storage tanks, and shops and warehouse facilities. At the Heber 50-MWe demonstration plant site these power block facilities will require 4 to 6 acres, and the total development including well locations and necessary buffer zones will involve 20 acres. Figure 5 shows an artist's conception of the Heber facility. Slightly larger sites might be required in Oregon, where reservoir differences may necessitate location of separated production wells.

In Oregon, geothermal power plants must be located within areas designated as suitable for such purposes in the Oregon Nuclear and Thermal Energy Council's (now the Energy Facility Siting Council) "Statewide Siting Task Force Report" (1974). Many natural resource areas, including wilderness, roadless, historic, botanical, and research natural areas; wildlife refuges; and geologic areas are presently withdrawn as potential geothermal plant sites by this legislation. Several Known Geothermal Resource Areas (KGRA's) in the Cascade Range are within or immediately adjacent to areas designated as unsuitable and thus will probably not be developed for electric power generation unless the earlier designation is reviewed and changed.

Subsidence and induced seismic activity resulting from fluid withdrawal and reinjection are other potential land use impacts of geothermal development. Prolonged withdrawal of fluids from liquid-dominated reservoirs in sediments is a potentially serious problem. The Wairakei field in New Zealand is the only geothermal field in which documented ground movement has been reported. The area affected is greater than 65 km^2 and the total maximum vertical movement since 1956 has been approximately 4 m (Axtmann, 1975, p. 801). Although the risk of subsidence can be greatly reduced through reinjection of the geothermal fluids, they are presently not reinjecting at the Wairakei field. With the binary cycle, almost the entire volume of withdrawn fluids will eventually be returned to the reservoir and subsidence should not be a problem.

In Oregon, subsidence is not expected to occur in the generally competent volcanic formations of the Cascade Range (U. S. Forest Service, 1977). The risk of subsidence may be greater in the Basin and Range grabens, particularly those in which the geothermal fluids are contained in reservoirs within the generally thick sedimentary fill.

Whereas the reinjection of geothermal fluids reduces the likelihood of subsidence, high pressure injection into geologic units that are in hydraulic communication with an active fault should be avoided because such injection may trigger minor earthquakes. Present experimental evidence suggests, however, that the potential for inducement of minor earthquakes can be greatly reduced by not injecting along an active fault and by controlling injection pressures and fluid flow rates (Healy and others, 1968; Raleigh and others, 1976).

New transmission corridors will be needed to interconnect the potential geothermal resource areas of southeastern Oregon with the regional grid system. As much of this region is arid, sparsely populated, and nonforested, no major adverse environmental impacts should result from construction of new 230-kV or 500-kV transmission lines. If capacity is available on transmission lines that already cross the Cascade Range, they could be used to transmit the electrical energy from geothermal power plants. Additional lines would be required, however, to connect any future geothermal plant with the existing system.

Impact on water

Geothermal plants, because of their low thermal efficiency (11 to 16 percent vs. 32 to 34 percent for a nuclear plant and 36 to 40 percent for fossil-fuel plants), require rejection of large amounts of waste heat per kilowatt of plant capacity. Geothermal plants which use either the direct or flashed steam conversion cycles provide their own cooling water and generally do not require supplementary sources. After passing through the turbine, the natural steam is condensed, piped to the cooling towers, and recirculated back to the condensers for cooling. The excess condensate not evaporated through the cooling tower is reinjected into the geothermal reservoir where it originated, thus prolonging useful production from the field.

On the other hand, geothermal power plants utilizing the binary cycle may require large amounts of supplemental cooling water from outside sources because the geothermal fluids usually remain in a closed system; and since the total extracted volume, excluding losses, is reinjected into the reservoir, it is not available for cooling tower water supply. In some cases, it may be desirable and possible to use some geothermal fluid for power plant cooling water.

Consumptive water requirements for a 50-MWe binary cycle geothermal power plant utilizing a wet cooling tower will probably range from 1,000 to 2,000 gallons per minute, depending on the total amount of waste heat to be rejected (Holt/Procon, 1976). Assuming an 80 percent annual plant factor, this would result in the need for obtaining 1,300 to 2,600 acre-feet of water annually from either surface or regional ground water supplies, or perhaps the geothermal reservoir itself. For a 200-MWe geothermal field, the total consumptive water requirements would be increased to between 5,000 and 10,000 acre-feet annually.

Cooling water requirements of binary cycle plants could be reduced substantially through use of either a combination wet-dry or dry cooling tower technology. For example, the consumptive water requirements of a wet-dry cooling tower are 40-70 percent of those for a conventional wet tower, depending on design (Olesen and Budenholzer, 1972). Dry cooling towers require no makeup to the circulating water system but do require a much greater land area than evaporative towers and may result in reduced generator output during hot summer days. Wet-dry and dry cooling towers would also require much higher initial capital investments than the more conventional wet cooling towers and higher auxiliary power to operate fans and pumps.

The availability of cooling water may be a limitation to geothermal development in certain water-short areas. This could seem particularly true for portions of southeastern Oregon such as the Alvord Valley and Glass Buttes. Cooling-water supplies may be more readily available in the Cascade Range because of normally high precipitation and runoff amounts and the expected presence of large amounts of ground water.

Thermal and chemical pollution of possible nearby natural surface water bodies should not be a problem with binary cycle geothermal power plants under normal operation. Waste heat rejection in most cases will be accomplished by evaporation to the atmosphere in either wet or wet-dry cooling towers, spray ponds, or cooling reservoirs. Blowdown from the cooling towers can be routed to an evaporation pond or reinjected into the geothermal reservoir.

Improper injection of geothermal effluents back into the reservoir could cause contamination of shallow ground-water aquifers. Because of higher temperatures, geothermal effluents are expected to be of poorer quality than these ground-water supplies, particularly in the concentration of dissolved solids and certain trace elements such as mercury, arsenic, and boron. If proper injection well drilling and completion practices are followed and if a shallow ground-water aquifer surveillance program is implemented in the area surrounding the reinjection field, contamination of domestic supplies can be obviated.

Impact on the atmosphere

Air quality impacts from geothermal power plants are of two main types: (1) those associated with the discharge of water vapor from cooling towers, and (2) those associated with the release of noncondensible gases, primarily hydrogen sulfide.

The discharge of water vapor to the atmosphere from wet evaporative cooling towers results in the development of a steam plume above the tower. Under adverse meterological conditions, this steam plume could descend to the ground and cause localized fogging and icing problems on plant structures and nearby roads; but this problem should not occur frequently under normal atmospheric conditions. The use of wet-dry or dry cooling towers would greatly reduce or, in the case of the latter, eliminate these adverse impacts.

Geothermal fluids, both liquid and steam, may contain noncondensible gases including carbon dioxide (CO_2), hydrogen sulfide (H_2S), methane (CH_4), and ammonia (NH_3). The gas of principal concern is H_2S, because of its potential danger to plant and animal life (see California Division of Oil and Gas, and others, 1975), high corrosiveness, and objectionable "rotten egg" smell. With the direct and flashed steam technologies, such as those in use at The Geysers and Cerro Prieto, Mexico, respectively, the noncondensible gases have been vented to the atmosphere through air ejectors above the condensers and rapidly diluted under favorable meterological conditions. Under adverse meterological conditions, however, concentrations of H_2S in air can exceed ambient air quality standards. An H_2S abatement program presently underway at The Geysers will provide technology for controlling hydrogen sulfide to within acceptable levels (see, for example, Allen and McCluer, 1975).

Development and utilization of the binary conversion process should greatly reduce, or eliminate altogether, the discharge of noncondensible gases. As the binary cycle operates as a closed system with a single-phase liquid flow, the noncondensible gases will remain in solution and be reinjected into the reservoir without release to the environment. If the produced fluids are in a two-phase flow and steam flashing occurs at the wellhead, the noncondensible gases will concentrate in the steam phase and be removed and treated in a separator following the steam condenser.

Socioeconomic and aesthetic impacts

Socioeconomic impacts, both beneficial and adverse, will result from development and utilization of geothermal energy in Oregon. Major benefits will include economic stimulation through the development of an indigenous energy resource and increased electrical system reliability through dispersed power plant siting and a broader generation resource mix. Changing land use patterns, population growth, and accompanying stresses on certain community facilities may result from power plant construction and operation, but the magnitude of these impacts will depend on the existing community structure of those areas affected.

Construction of a geothermal plant will employ on the order of 200 workers at all levels over a period of several years. Some of this labor could be drawn from local communities, especially for such jobs as plumbing, welding, and operation of heavy equipment. A permanent operational staff of between 10 and 20 will be needed. Several additional permanent workers would maintain the wells, piping, pumps, and equipment in the geothermal field itself.

A significant positive impact would result from increased county revenues due to real estate and ad valorem taxes. Furthermore, geothermal power generation in portions of eastern Oregon could aid in diversification of the economy, which is currently dependent upon the primary sector. Such diversification would result in the introduction of additional employment opportunities.

The aesthetic impact of a geothermal power plant will depend on existing land uses, type and extent of vegetation, topography, and geographic location. As Figure 5 shows, a binary cycle plant is not obtrusive in appearance, although this is certainly a matter of individual judgment. The largest and tallest structures are the mechanical draft cooling towers, which are approximately 15 m (50 feet) high. In the Cascade Range, most if not all of the power plant and field facilities could be easily harmonized with the forested landscape, and from a distance the steam plume above the cooling tower is all that would be visible from most vantage points. In the generally nonforested landscape of southeastern Oregon the plant would be much more visible, although potential geothermal occurrences are somewhat remote from major population centers and high-use recreation areas.

Conclusions

Based upon our present, albeit sketchy, knowledge, potential geothermal resources in Oregon are likely to be of the liquid-dominated (hot water) type with estimated temperatures of the hotter reservoir systems approaching 200°C (392°F). The binary cycle appears to be the most favorable conversion process for electric power generation from geothermal systems with temperatures in the range of 150°C (302°F) to 210°C (410°F). Utilization of the binary cycle, which isolates the geothermal fluids in a closed system, will greatly reduce the adverse environmental impacts generally attributed to geothermal energy based on the uncommon Geysers model. Air pollution impacts resulting from the release of hydrogen sulfide and other noncondensible gases will be nonexistent during normal plant operation. With the application of

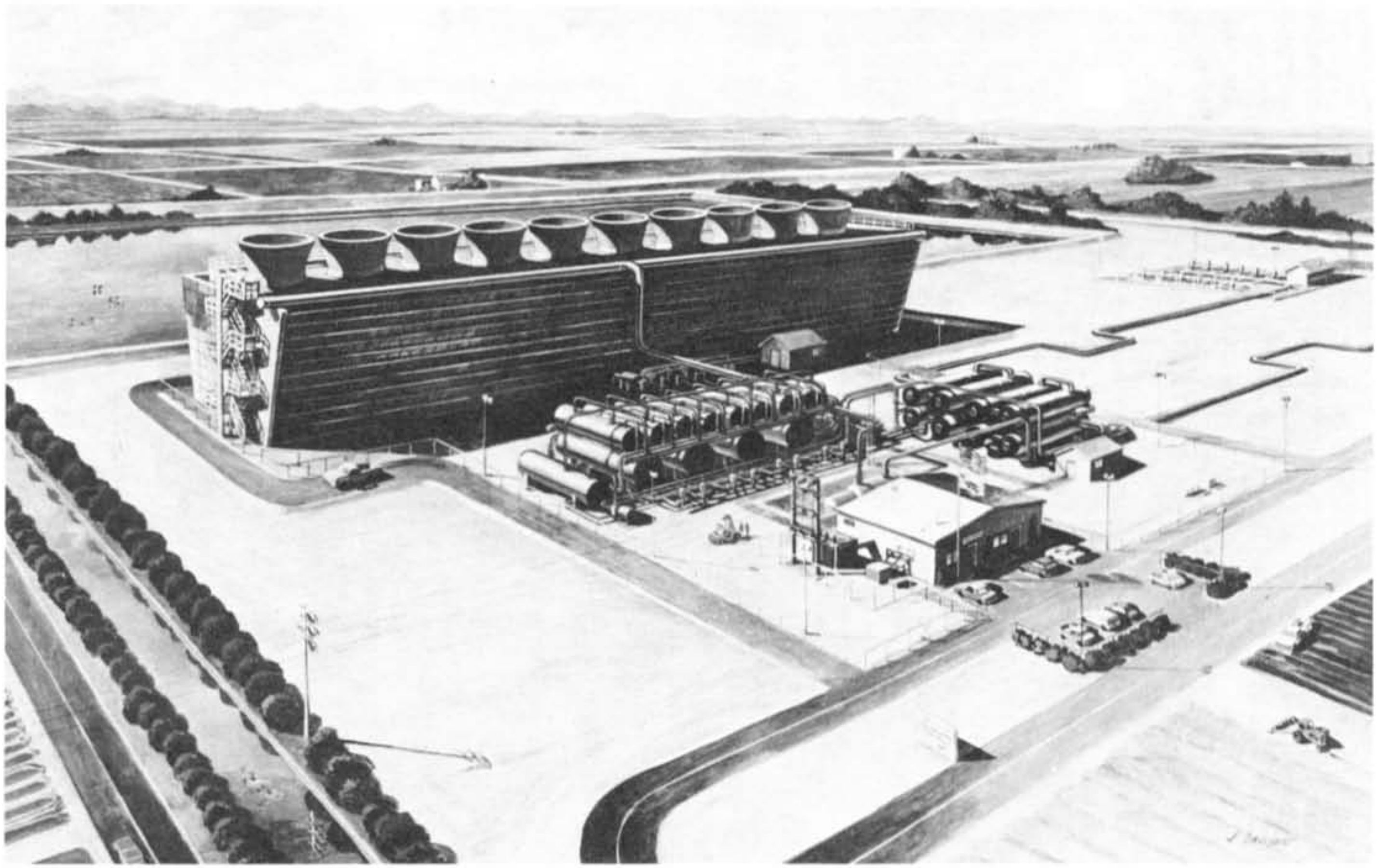

Figure 5. Artist's Conception of the Heber 50-MWe Binary Cycle Demonstration Geothermal Power Plant.

directional drilling techniques to tap geothermal reservoirs, land requirements and the concomitant impact of surface installations can be reduced. Reinjection of the geothermal effluents will eliminate the need to discharge these fluids to surface waters and reduce the possibility of subsidence. When accomplished properly, deep reinjection will not adversely impact domestic ground water supplies. Improved drilling and casing techniques and the utilization of blowout-prevention equipment on the wellhead will greatly reduce the probability of well blowouts during the drilling and reservoir testing phase.

The greatest and most significant uncertainty in geothermal energy utilization for electric power generation in Oregon is associated with the existence or availability of commercial reservoirs which can produce large volumes of fluids for at least 30 years. The next most significant uncertainty is the availability of water for binary power plant condenser cooling. In this regard, it appears desirable to conduct hydrological studies of surface and ground waters in potential geothermal areas parallel with exploration. The need for cooling water is probably not a major obstacle to geothermal development, but the availability of cooling water warrants careful consideration in the early stages of resource evaluation.

If commercial geothermal reservoirs are present in Oregon, the binary cycle will enable their utilization for power generation in an environmentally compatible manner. Furthermore, if these reservoirs can be developed economically, geothermal power may eventually become an important supplement to Oregon's present hydropower, nuclear, and fossil generation resources mix. The important advantage is that geothermal energy would be a fuel resource indigenous to Oregon and not imported from out of state.

Acknowledgments

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GEOTHERMAL OPEN-FILE REPORT RELEASED

The Department has released Open-file Report 0-77-2, "Geothermal Gradient Data," by Donald A. Hull, David D. Blackwell, Richard G. Bowen, Norman V. Peterson, and Gerald L. Black. The 135-page report contains a brief text, maps, and tables and graphs showing geothermal data collected in Oregon by the authors between September 1975 and December 1976. The report is available in the Department's Portland, Baker, and Grants Pass offices at a cost of $5.00 per copy.

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STUDY OF GROUND EFFECTS OF EARTHQUAKES IN PORTLAND NOW AVAILABLE

Copies of "A Preliminary Geological Investigation of the Ground Effects of Earthquakes in the Portland Metropolitan Area, Oregon" (1974), by Paul Hammond, G.T. Benson, Dan J. Cash, L.A. Palmer, Jan Donovan, and Brian Gannon, may be purchased for $4.00 at the Department's Portland office. The publication, which summarizes Portland's earthquake history and discusses potential geologic hazards related to earthquakes, contains six Portland area maps: a preliminary tectonic map, a lineation map, a map showing the crack analysis of lineations in East Portland, a slope map, a landslide map, and a map showing potential geologic hazards related to earthquakes.

* * * * *

NEW BUREAU OF MINES STATE LIAISON OFFICER APPOINTED

On April 1, 1977, John M. West became the new Bureau of Mines State Liaison Officer in Oregon, replacing Walter E. Lewis, who retired. Mr. West, a native Oregonian, has served the Bureau as minerals resource investigator in Spokane; nonmetallic commodity specialist in Washington, D.C.; foreign minerals specialist, doing studies on South Asia and the Far East; commodity specialist on boron, mercury, and diatomite in San Francisco; and gold specialist in Washington, D.C. As Liaison Officer he will strengthen Federal-State cooperative efforts to solve supply and environmental quality problems associated with the development of mineral resources and provide information and assistance related to Federal programs conducted or administered by the Bureau of Mines. West's business address is: Suite 7, Standard Insurance Building, 475 Cottage Street N.E., Salem, Oregon 97301; telephone (503) 399-5755.

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A GEOLOGICAL FIELD TRIP GUIDE FROM SWEET HOME, OREGON, TO THE QUARTZVILLE MINING DISTRICT

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Introduction

This article is designed to be a self-explanatory field trip guide to the geology and mining history of the Quartzville mining district and the area between Quartzville and Sweet Home. Much of the information is taken from unpublished works by Steven R. Munts, consulting geologist, Sweet Home, Oregon, and the unpublished "Linn County Water Resources Study - Mining Subcommittee Report," by A.J. Kauffman, Jr. (1961). More detailed information on individual mines and the geology of Linn County can be found in the sources listed at the end of the article.

All persons taking this field trip are warned of the dangers of entering abandoned mines, caves, and open pits. Remember, you enter any mine at your own risk; and the greatest dangers are those that you cannot see until it is too late.

Location and Geography

The Quartzville mining district is in eastern Linn County, 40 miles east of Albany, on the headwaters of Quartzville Creek, a tributary of the Middle Santiam River. The Quartzville 15-minute topographic map covers the mining district; the entire field trip is covered by the Quartzville, Cascadia, and Sweet Home 15-minute topographic maps. The district is reached by a major access road which leaves U.S. Highway 20 six miles east of Sweet Home. The field trip begins at Sweet Home, which is 27 miles southeast of Albany on U.S. Highway 20.

Most of the actively prospected part of the district lies in the southeastern part of T. 11 S., R. 4 E., but the district extends into the northeast corner of T. 12 S., R. 4 E. Almost all production has come from the ridge south of Dry Gulch in sec. 22 and 23 (Callaghan and Buddington, 1938).

The Quartzville district, which lies in the central part of the Western Cascades, is steep and heavily timbered, with elevations ranging from 1,500 feet on Quartzville Creek to about 3,500 feet on the ridges. The entire district is drained by Quartzville Creek and its tributaries, most of which are characterized by steep gradients. A series of terraces and alluvial fills extend from the mouth of Canal Creek to Dry Gulch, and bed rock is not exposed in the lower 2 miles of Dry Gulch. As the stream in Dry Gulch flows on the surface only during periods of excessive runoff, mining and prospecting operations have been generally curtailed throughout the summer months.

Geology

The bed rock of the Quartzville mining district is composed primarily of basalt, andesite, and rhyolite flow rock with interbedded tuffs, volcanic breccias, and scattered dacite, diorite, and basaltic intrusives. Peck and others (1964) mapped most of the rocks in the area as Oligocene to early Miocene Little Butte Volcanic Series, middle Miocene Columbia River Basalt, and middle to late Miocene Sardine Formation. Many of the rocks mapped by Peck as Sardine Formation and Columbia River Basalt are classified by Beaulieu (1974) as part of the Little Butte Formation, which he considers the most extensive bedrock unit in the area. The youngest rocks are Recent volcanic flow rock and pyroclastic debris which are found at the confluence of Quartzville and Canal Creeks.

No formal names have been given to individual rock units exposed in the Quartzville area; therefore, modifiers of "lower," "middle," and "upper" are used in describing distinguishable units in the district. The lowest unit exposed in and near the abandoned Quartzville town site consists of several pyroclastic flows, tuffs, lapilli tuffs, andesite flows, and flow-banded tuffs. Resting conformably above the lowest unit is the middle unit, a 200-foot-thick rhyolite flow which thins to the west. The rhyolite is generally gray but in places has been altered to various shades of red, yellow, and orange. Above the rhyolite is the upper unit, which consists of interbedded flows of tuff, lapilli tuff, and volcanic breccia, with a few intercanyon flows of dark-green porphyritic andesite. The Recent volcanic rocks (see Checkpoint 28) lie unconformably above the older units and are basaltic in composition.

Within this district are areas of propylitic alteration surrounding small stocks, dikes, and plugs (Peck and others, 1964). Many veins follow faults and shear zones that are also present, and all of the ore mineral deposits that have been worked to date have occurred along these fissures and faults (Munts, 1976).

Mining History

The Quartzville mining district has been the site of both hard-rock and placer mining for gold. Dr. E.O. Smith is credited with the original discovery of lode gold in the district. Jeremiah Driggs located the first claims, the White Bull and Red Bull claims, on September 5, 1863; and a mining district was organized in 1864. Several large stopes in the Lawler mine and a small stope in the Albany mine were worked, and mills were installed in the early 1890's.

Although most mining operations ceased by 1900, hard-rock prospectors have been in the district almost every year since; and some of them have recovered small quantities of gold from pockets, as Table 1 shows.

Table 1. *Known hard-rock mine development in the Quartzville district*

[in feet]

Mine	Drifts	Open cuts	Shafts	Cross cuts	Raises	Total
A - Albany group	1,500	-	-	-	60	1,560
B - Bob & Betty	700	-	100	550	300	1,650
D - Lawler	1,050	-	-	250	700	2,000
I - Riverside	303	700	-	-	-	1,003
J - Savage (Vandalia)	600	-	80	-	300	980
E - Snowstorm (Edson)	570	-	-	80	-	650
F - Munro	217	-	-	263	-	480
G - Paymaster	150	-	-	-	-	150
C - Galena	-	-	-	725	-	725
H - Red Heifer	-	-	-	60	30	90
K - Tillicum & Cumtillie	300	-	-	-	-	300
Others	690	40	-	370	-	1,100
Total	6,080	740	180	2,298	1,390	10,688

Gold has also been recovered from placer deposits. Gravel bars along the Quartzville Creek drainage and parts of the Middle Fork of Santiam River were placered in the middle 1800's, and small-scale placer mining has continued to the present.

During the depression of the early 1930's, miners using hand-placering mining equipment were able to recover enough gold to survive. Merrill and others (1937) reported that during 1935 eleven mines were being worked on three creeks in Linn County. Small gold miners in Oregon in 1935 sold bullion buyers 8,032 parcels of gold with total weight of 4,021 ounces and value of $140,730. Average daily gross income for all miners was $1.19 per day, and their average annual income from mining was $44, since miners worked an average of 37 days per year.

Table 2 summarizes small-scale gold placer operations in 13 of Oregon's 36 counties and in 358 creeks and dry placers in the State during 1935. The two principal placer mining counties were Jackson and Josephine. The only other counties with more than 100 miners were Baker, Grant, and Douglas.

Table 2. *Small-scale gold placer operations in Oregon in 1935*
[Production and income of all placer miners, by counties]

County	No. miners working	No. creeks worked	Gold produced Fine ounces	Gold produced Value	Ave. gross ann. income per miner
Baker......	490	61	339.23	$11,873	$27
Coos.......	17	9	10.65	373	25
Curry......	75	15	110.28	3,860	57
Douglas....	145	26	169.06	5,917	46
Grant......	313	37	235.99	8,260	29
Jackson....	1,454	84	1,563.53	54,724	43
Josephine..	1,039	110	1,496.56	52,380	56
Lane.......	1	1	.84	29	33
Linn.......	11	3	12.96	454	46
Malheur....	28	6	27.05	947	38
Marion.....	2	1	8.73	305	172
Umatilla...	10	2	14.16	495	56
Union......	21	3	10.96	383	20
Unallocated	25	-	20.86	730	33
Total	3,631	358	4,020.86	140,730	44

Present Status of Exploration Activity

Prospecting and hard-rock and placer mining in the Quartzville district are now undertaken only as hobbies. The prospecting, claim work, and portable dredge operations take place during weekends and vacation time.

Production

According to U.S. Mint reports for the years 1884 through 1886, the Quartzville district has been credited with production of 8,359.33 ounces of gold valued at $172,786.35 based on gold value of $20.67 per ounce. Silver produced during this period was valued at $2,869.00. No production was recorded from 1897 through 1924.

U.S. Bureau of Mines data show that from 1925 through 1940 seven operations produced 281 tons of crude ore which yielded 112.53 ounces of gold and 56 ounces of silver. No production has been recorded for the Quartzville district since 1940. Unofficial estimates put the production of the Lawler mine alone at $1 million.

Road Log

(Refer to map, p. 100-101.)

(1)	(2)	(3)*	
1	0.0	0.0	West city limits of Sweet Home, on Highway 20, 0.6 miles east of milepost 26. (At the time of publication, the city limits sign had been taken down because of road construction.) Dense, dark rocks with columnar jointing that are found on the south or right-hand side of the road are basalts that have been classified by various authors as Columbia River Basalt, Stayton Lava, or Little Butte Volcanics. Drive east through town on Highway 20.
2	4.6	4.6	On the left side is the Foster Reservoir viewpoint.
3	1.3	5.9	In the roadcut on the right-hand side of the road at the traffic separator sign, just before the road curves to the right, note the irregular contact between underlying sedimentary beds of siltstone and shale and an overlying basalt flow (see Figure 1). Note also the baked zone along the edges of the sedimentary rocks, caused by the heat of the basalt. Slickensides (scratches or grooves) occur in this zone, indicating movement of the sediments, probably from the weight and flowing motion of the lava.
4	0.5	6.4	You are now at the junction of Highway 20 and the Green Peter Dam-Quartzville townsite road. Note the columnar jointed basalt to the right of the junction. Turn left here and drive toward Quartzville. After you have crossed the bridge, you again see basalt overlying sediments, as at Checkpoint 3.
5	0.8	7.2	Before you cross the north arm of Foster Reservoir, note the paleoriver terraces in the roadcut to the left, indicating that the Santiam River was once at this level. Some of the old river terrace gravels contain gold and have been mined in the past.
6	0.5	7.7	In the roadcut on your left, below the schoolhouse, you can see graded stream gravels and alluvial fan deposits. This material was probably deposited by a fast-moving stream which flowed into a slower-moving body of water and

*(1) Checkpoints; (2) Mileage intervals; (3) Cumulative mileage.

dropped its load of sand and gravel. Imbrication (shingling or overlapping) of the rocks can be used to determine stream-flow direction. Note also that some of the bedding is abruptly terminated or truncated.

7 0.2 7.9 The Sunnyside Park entrance is to the right. The park is located on an old river terrace known as the Green Horn Bar, which was placer mined for gold in the late 1850's and 1860's. The men working the bar were called "greenhorns" because of their lack of mining experience. In their hydraulic mining, they used California-type riffles in the sluice boxes, resulting in the loss of most of the gold.

8 0.6 8.5 Across the river to your right are a series of cliff-forming basalt flows, locally named the Green Peter Basalts by the U.S. Army Corps of Engineers. These basalts are faulted and cut in some places by dikes.

9 1.0 9.5 Note the zone of alteration in the roadcut to the left. Stop at the small turnout on the right, just before the road curves to the left. In this outcrop you are looking at the mineralization of the Quartzville mining district in miniature (see Figure 2). Notice the three types of alteration that occur here, ranging from propylitic (hydrothermal alteration that has produced epidote, chlorite, and pyrite) at the edges through argillic (alteration producing clay minerals) to phyllic (alteration to quartz and sericite) at the center of the zone. The phyllic alteration occurs along a very narrow fracture which acted as a channel for ascending hydrothermal fluids through otherwise impermeable basalt. Dioritic and granodioritic intrusive rocks are exposed to the west (left) of this fracture. This intrusion and associated alteration are indicative of the type of hydrothermal fluid at depth that was the carrier for the mineralization in the Quartzville mining district. The zonation of alteration that you see here is present in most large mining districts, but it usually covers hundreds of feet, rather than inches, as here.

10 2.0 11.5 Green Peter Dam. To your right is a parking area and viewpoint. Work on the dam and its reservoir lasted from 1961 to 1967. The dam, which used 1,142,000 cubic yards of concrete, is 320 feet high, with deck elevation of 1,020 feet.

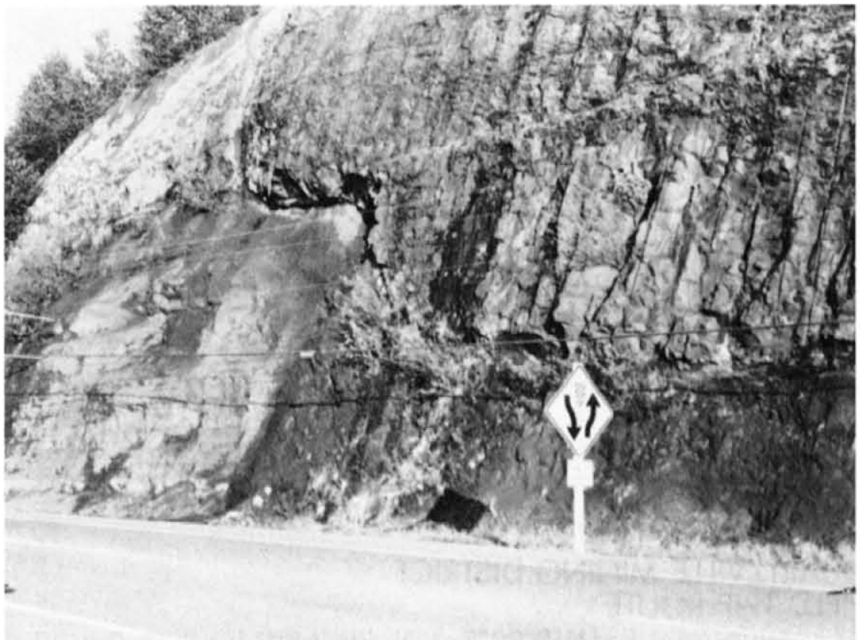


Figure 1. Checkpoint 3. Irregular contact between basalt and sedimentary rocks.

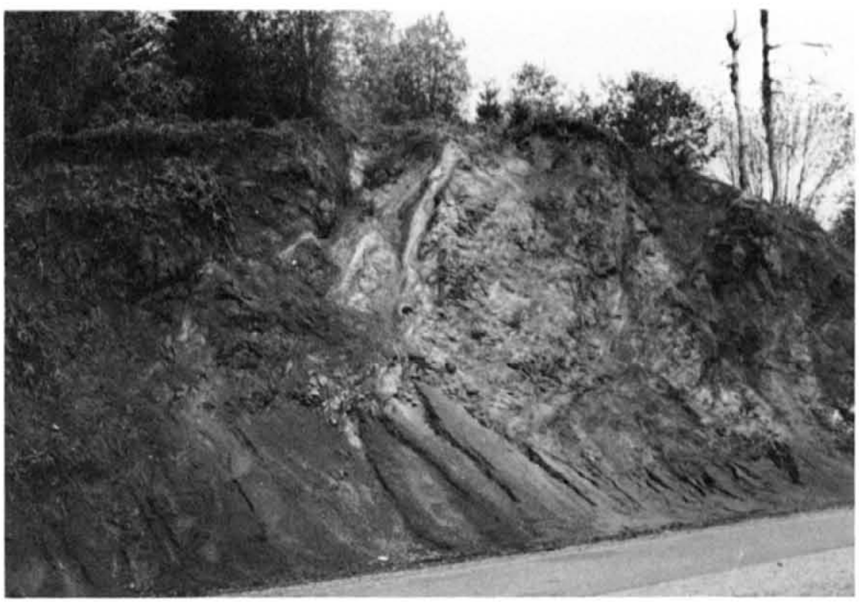
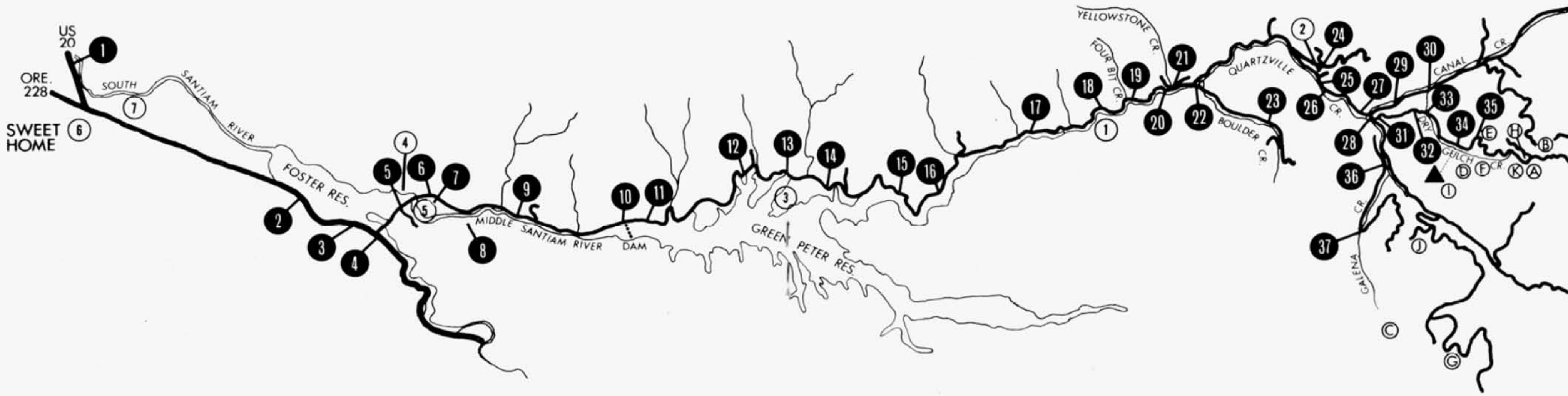


Figure 2. Checkpoint 9. Alteration zone.



QUARTZVILLE MINING DISTRICT FIELD TRIP ROUTE

LOCATION MAP

LEGEND

(3) CAMPGROUNDS, PICNIC AREAS & OTHER RECREATIONAL FACILITIES

1. Dogwood (B.L.M.), 14 sites, picnic
2. Yellow Bottom (B.L.M.), 12 sites, picnic
   22 sites, camp
3. Whitcomb Creek (Linn County), 60 sites, picnic
   34 sites, camp
4. Lewis Creek (Linn County), picnic
5. Sunnyside (Linn County), 65 sites, camp
6. Sankey Park (City), picnicking, ballfield, playground equip.
7. Northside Park (City), tennis court, handball court, basketball court, softball field, swimming, picnicking, 18 sites

(14) CHECKPOINT

(B) MINES & PROSPECTS

A. Albany
B. Bob and Betty
C. Galena
D. Lawler
E. Lucille (Snowstorm)
F. Munro (Mayflower)
G. Paymaster
H. Red Heifer (Silver Signal)
I. Riverside
J. Savage (Vandalia)
K. Tillicum & Cumtillie (Golden Fleece)

Do not enter any mines except E

▲ QUARTZVILLE TOWNSITE

Figure 3. Checkpoint 12.

Figure 4. Checkpoint 15. Slickensides on fault plane.

Figure 5. Checkpoint 18. (Photo courtesy Albany Democrat-Herald.)

Figure 6. Checkpoint 23.

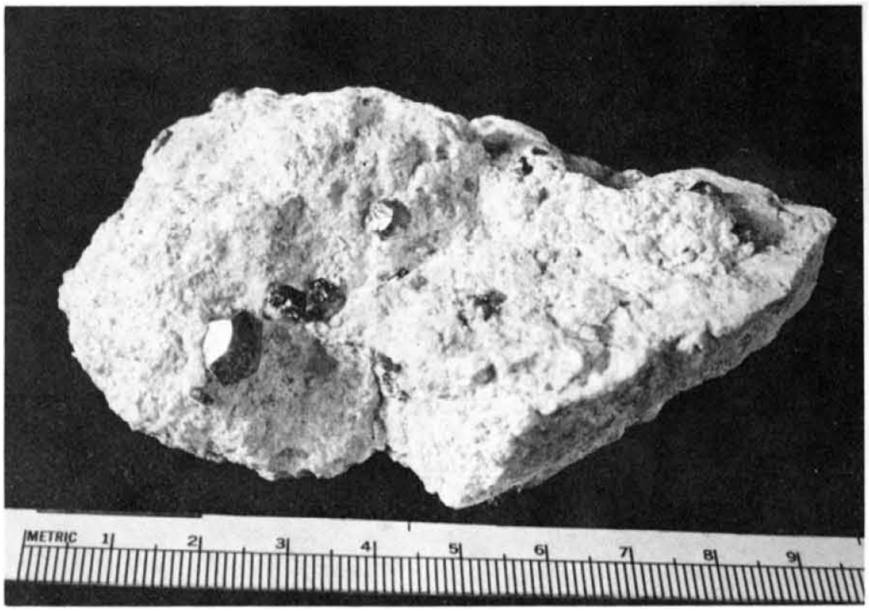


Figure 7. Checkpoint 23. Pyrite crystals found in alteration zone.

Figure 8. Checkpoint 35. Snowstorm tunnel. (Photo courtesy of Albany Democrat-Herald.)

The reservoir holds 430,000 acre-feet of water and covers 3,720 acres of land. During construction of the dam, emery boulders were uncovered at the bottom of the river. The original emery outcrop was located by tracing emery "float" (loose boulders of emery) back to the source, 36 river-miles up the Middle Fork of the Santiam River.

11 0.5 12.0 Park in the pulloff to your right and look to your left at the basaltic lava flow rock which is cut by several vertical basalt dikes. The dikes, which look very much like the flow rock because of similarities in composition, can be identified by their horizontal jointing which formed perpendicular to their cooling edges. At the west end of the roadcut are southeastward-dipping basalt flows which were deformed before being covered by the younger basalt flow you can see above them. The white blebs in the basalt are amygdules (secondary quartz, calcite, or zeolite minerals that filled small cavities left in cooling lava by escaping gas bubbles).

12 3.3 15.3 Just after crossing a small stream, the road curves to the right. In the roadcut to the left, note the orange and yellow alteration, which is due to hydrothermal processes that have altered the minerals to clay and deposited pyrite, which in turn weathered to various iron oxides (rust) (see Figure 3). Because the alteration has affected all of the different types of rock exposed here, you can see that it is younger than they are.

13 1.7 17.0 You are now crossing an arm of the Green Peter Reservoir.

14 0.8 17.8 On the right is the entrance to Whitcomb Creek Park.

15 1.7 19.5 At the curve just past milepost 12, note the slickensides in the rocks to your left (see Figure 4). Slickensides are polished and striated (scratched) surfaces resulting from rocks moving past one another along a fault plane. This particular fault plane has been exposed to weathering; therefore the striations and polish are not as distinct as those on a freshly exposed surface.

16 1.2 20.7 Note the alteration zone with abundant iron staining. This area and the associated river bank (now under water) are known locally as the Donnaca Bar, the site of some large placer-mining operations in the late 1890's and again in the 1930's. Several thousand dollars in gold was removed from

these gravels. One possible source for the gold is the bright yellow and chocolate-brown alteration zone you see in the roadcut.

17 2.2 22.9 Upper end of the Green Peter Reservoir. On the south or opposite side of Quartzville Creek is a river terrace. Notice the gravel bar on the inside of the bend in the creek. Gravel is deposited here because the velocity of this side of the creek drops as the creek flows around the curve. To the left is a roadcut in which sandstone, siltstone, and volcanic material are exposed as bedded units. Note the eastward dip of the beds. At the east end of the roadcut the sedimentary sequence is overlain by a basalt flow. The black layer which separates the two units is a paleosoil horizon which was baked by the heat of the basalt flow. This soil zone contains some petrified wood fragments.

18 1.8 24.7 You are now at Dogwood Park, located on a gravel bar which was the site of placer-mining operations from the 1890's through the 1930's.

During the summer you can see weekend miners using small dredges, sluice boxes, and gold rockers here and all along the creek. Figure 5 shows gold-panning and a gold rocker powered by a gasoline engine.

19 0.7 25.4 After you cross Four-bit Creek, the BLM road shops are on your right.

20 1.0 26.4 The rocks in the stone quarry on your left contain much pyrite and some tourmaline, indicating a highly mineralized area. At least one rock sample taken from here contained a trace of silver.

21 0.2 26.6 Just before the Yellowstone access road and Yellowstone Creek, notice the alteration in the rocks to your left. The iron staining is from the oxidation of pyrite and minor amounts of chalcopyrite. Some silicification has occurred, and tourmaline is also present.

22 0.1 26.7 To the right a bridge crosses Quartzville Creek. This is the Boulder Creek road. Cross bridge, turn left, and drive 1.6 miles.

23 1.6 28.3 Note the white-colored, 25-foot-wide alteration zone in the roadcut on your left (see Figure 6). Pyrite crystals up to 3/8-inches in diameter occur in this alteration zone (see Figure 7). Many of the crystals are in the form of pyritohedrons, which means they have 12 crys-

tal faces, each of which has five sides.

After collecting some choice samples, return to the main road, turn right, and continue.

24 5.2 33.5 On the left is the entrance to the Yellow Bottom Creek Recreation Area.

25 0.1 33.6 The roadcut to the left exposes a coarse-grained buff-colored intrusive rock called diorite. The light minerals in it are primarily plagioclase feldspar; most of the dark minerals are hornblende. This diorite is part of the plutonic (intrusive) complex which is probably responsible for the mineralization in the Quartzville area.

26 0.1 33.7 At the curve in the road, note the outcrop in the roadcut to the left. Part of the rock in this outcrop is the same diorite you saw at Checkpoint 25. The diorite formed from the cooling and crystallization of molten rock in an underground magma chamber. In addition, near the center of the roadcut is a section of light-colored, fine-grained, and sugary-textured rock called aplite, which has a different chemical composition (more silica, less iron and magnesium) than the diorite. The aplite formed toward the end of the cooling history of the magma chamber, after most of the iron and magnesium minerals had already crystallized out of the melt. Note that the outcrop is cut by basalt dikes; therefore the basalt is younger than the diorite and the aplite.

27 1.0 34.7 In the roadcut to the left, just opposite the small building on the right, a basalt flow conformably overlies a lacustrine (lake) ash deposit which has thin layers called laminae. The laminae are interbedded with layers of air-fall ash. Occasional rip-up clasts (fragments of partly consolidated sediments that have been ripped up and transported by strong currents) can be found in the sediments.

28 0.2 34.9 You are now at a road junction. The blacktop road (Road 1177) follows Quartzville Creek; the road to your left (Road 1162) follows Canal Creek; the center road (Road 1158) goes up the hill and leads to the Quartzville townsite. Note the columnar basalt in the roadcut. This vesicular basalt, which contains some olivine (the bottle-green minerals on a freshly broken surface), is classified as Recent in age because it is only a few hundred thousand years old.

Follow Road 1162, the Canal Creek road, to your left.

29 0.4 35.3 Stop for a moment and look across the creek at the rock projecting like a wall from the creek and hillside on the other side. The country rock was originally solid; but when deep-seated forces within the earth caused the rock to fracture, molten rock which was under great pressure moved up from great depths through the fractures to an environment where there was less pressure. As the magma passed through the fracture, some of it remained, cooled, and solidified, forming a tabular body called a dike. The surrounding rock, softer than the dike, eroded away more quickly, leaving the diorite dike exposed, as you see it, in the shape of a wall.

30 0.7 36.0 To your right is a quarry of columnar basalt that was a small intracanyon lava flow. Note that the base of the flow is lower than the rocks on either side.

Now walk to the edge of the road and look down at Canal Creek. You should be able to see water running out of the ground below you into the creek. The source of this water, which old-timers call Cold Spring, is in Dry Gulch. The gravels of Dry Gulch and those covered by the intracanyon basalt flow act as a channelway for water. All year this spring carries water from the slopes of Dry Gulch. The underground channelway can carry all of the summer runoff, so Dry Gulch remains dry during summer months. But the capacity of the underground channelway is insufficient during other seasons of the year, and then the excess water flows through Dry Gulch.

Return to the junction, turn left, and take the center road (Road 1158) toward the Quartzville townsite.

31 1.2 37.2 At the first switchback in the road, the cinders and basalt you see in the upper part of the roadcut at the right are part of the same sequence of Recent volcanics you saw at the junction (Checkpoint 28). Below the volcanic material is a layer of unconsolidated glacial drift. This sequence of deposits can be used to give a rough maximum age for the lava, for the lava lies above the glacial drift and is therefore younger.

32 0.9 38.1 To your right is a cinder pit. Few Recent volcanic cinder cones have been found this far west of the High Cascades. Note the dip of the

layers of cinders in the pit wall. Normally all the layers of a cinder cone dip away from the center of the cone; so the dip of these layers indicates that the cone itself should be upslope and to the south of this location, which it is. You will find scoria, cinders, a few lava bombs, and chunks of light-colored granitic rocks which were ripped from the magma conduit by the upward-flowing magma. These granitic fragments are indicative of at least one type of rock present below this location. The extreme youthfulness of the Recent volcanic rocks seen in this part of the Quartzville district suggests that they occurred too recently to have been responsible for the mineralization of the district.

33 0.3 38.4 The bridge crosses Dry Gulch. This is the drainage that feeds Cold Springs (Checkpoint 30). Only during times of high water can flowing water be seen here.

34 0.9 39.3 To your right is a signboard identifying the Quartzville townsite. The district's largest producing mine, the Lawler, is located across the valley but is hard to see because of second-growth timber. IT IS UNSAFE TO ENTER THIS MINE!

35 0.6 39.9 On your left, 10 feet above the road, is the lower Snowstorm (Edson) tunnel, which was driven in a rhyolite breccia cemented with quartz. A second tunnel can be found by walking to the road switchback and entering the upstream side of the stream valley (staying to the left side of the stream valley). Shortly after leaving the road, follow the trail which goes straight up the hillside to the left. Where the trail forks, follow the steeper trail.

Both of these tunnels are reasonably safe to enter if you carry a flashlight. The second tunnel follows a fault gouge seam which you can see overhead in the tunnel. Figure 8 shows why these tunnels are safe to enter. The roof has a natural arch with no loose hanging rocks. The rock is hard and strong and will not cave in. No shafts into which you might fall have been dug below the tunnel floor. No mine timber was left to rot and form bad air. Most other mines, tunnels, and shafts in the Quartzville and other mining districts are NOT safe to enter.

The Snowstorm tunnels are owned by a private party; permission is not needed to enter these tunnels but may be required in the future.

Return to the fork in the road, turn left, and follow the blacktop road (Road 1177), the Quartzville Creek road.

36 3.6 43.5 Quartzville Creek-Galena Creek road junction. Take the right-hand road (Road 1177-A), which crosses Quartzville Creek.

37 1.7 45.2 At this point the road crosses Galena Creek. The gravel in this creek contains specimens of tourmaline hornfels, fine-grained rocks which have been metamorphosed by contact with a hot intrusive body. These hornfels are indicative of a higher grade intrusive activity; and the original outcrop where the hornfels occurred, if cut by a vein, would be a good place to look for mineral values and interesting mineral and rock specimens.

Turn around and retrace route to Sweet Home.

End of road log.

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PRELIMINARY HEAT-FLOW MAP AND EVALUATION OF OREGON'S GEOTHERMAL ENERGY POTENTIAL

Donald A. Hull,* Richard G. Bowen,**
David D. Blackwell,*** and Norman V. Peterson*

Introduction

The utilization of Oregon's long-recognized geothermal energy resources has been increasing in recent years as the economic and environmental costs of conventional energy sources have risen. By focusing attention on the depletable nature of fossil fuels, the 1973 petroleum crisis emphasized the importance of finding and developing alternative domestic energy sources. At the same time, a heightened public environmental consciousness led to the consideration of different kinds of energy sources that offered more favorable environmental tradeoffs than those of conventional energy sources.

An initial, but farseeing, overview of Oregon's geothermal resource potential by Groh (1966) was based on geological considerations. Since then, the Oregon Department of Geology and Mineral Industries has been conducting geological, geophysical, and geochemical investigations of the State's geothermal resources. The results of these studies have been published or released to open file. The present article is a summary of Oregon's geothermal energy potential, based on these studies and work by others, especially the U.S. Geological Survey.

Methods

Geothermal energy resources that can be utilized under existing technology and economic conditions occur as localized concentrations of natural steam and hot water in permeable rocks of the earth's crust at depths generally no greater than 3,000 m (about 10,000 ft). The primary tools we have utilized to evaluate geothermal resources on a regional basis are (1) heat-flow calculations based on measurements in drill holes; (2) an inventory of geothermal phenomena such as hot springs, fumaroles, and

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hot-water wells; and (3) geologic mapping to indicate faults and areas of young volcanic rocks. Other geophysical techniques, such as gravity, magnetic, and electrical resistivity surveys, aid in the delineation of geologic structures in potential geothermal resource areas; and geochemical analyses of hot-spring fluids aid in the interpretation of the temperature and fluid quality of individual geothermal reservoirs.

Heat flow

Heat flows from the hot interior of the earth toward the surface. Usable geothermal energy under existing technology is based upon the location of concentrations of hot fluids that may occur either in areas of Quaternary volcanism where subsurface bodies of magma or cooling igneous rocks are present or in areas where favorable structural conditions allow the deep circulation and heating of ground water in faults and permeable rocks. The latter mechanism normally produces geothermal resources only in areas of high crustal heat flow. Heat-flow measurements thus represent a direct means of outlining regions of higher-than-average heat flow where geothermal energy may be expected to occur and then locating concentrations of geothermal resources within these regions.

Heat flow is calculated as the product of the geothermal gradient (the increase in temperature with depth) measured in the drill hole and thermal conductivity (ability of a material to transfer heat by conduction) measured on rock samples taken from the drill hole.

The gradient data are corrected for influence of irregular topography near the drill hole; and the heat-flow value, if necessary, is corrected for the heat produced by natural radioactivity in the earth's crust. Because the solar heat flux at the surface is several thousand times greater than the normal heat flux from depth, reliable values of geothermal heat flow can be obtained only from drill holes deeper than 20 m (65 ft).

The results of the Department's heat-flow studies over the past five years have been given by Bowen (1972, 1975), Bowen and Blackwell (1973, 1975), Bowen and others (1975, 1976, and 1977), Hull (1975), Hull and others (1976, 1977a, and 1977b), and Blackwell and others (1977). Similar work by the U.S. Geological Survey has been reported by Diment and others (1975) and Sass and others (1973, 1976a, 1976b, and 1976c).

Geothermal phenomena

Natural leakage of hot fluids from geothermal systems within the earth's crust to the earth's surface results in hot springs (springs with a temperature 10°C above ambient temperature) and fumaroles (volcanic vents from which gases and vapors are emitted). An inventory of these phenomena in Oregon was made by Bowen and Peterson (1970). Hot springs and fumaroles are not associated with all geothermal resources, however; and other search techniques, such as heat-flow measurements, are desirable in geologically favorable areas.

Geologic mapping

Geothermal energy resources are often found in areas of geologically recent volcanic activity. As geologic mapping and age dating of volcanic rocks are the most efficient methods of locating and outlining these areas, there is a continuing need for detailed geologic mapping as an aid in systematic geothermal resource appraisal.

Geothermal Energy Potential

The heat-flow data, inventory of hot springs, and geologic maps have been combined and interpreted by the authors to give a preliminary regional evaluation of Oregon's geothermal energy potential. Since heat flow and the distribution of hot springs are closely related to the State's geologic history, the evaluation is discussed in terms of Oregon's physiographic provinces, which are shown in Figure 1. A preliminary heat-flow map of the State is included as Figure 2. The preliminary nature of this evaluation should be stressed, because the exact boundaries of the areas of various potential are not yet accurately delineated; and the search by both industry and public groups for resources within the areas of higher potential has barely begun. To date, only four deep production tests (holes deeper than 610 m [2,000 ft]) for geothermal resources have been drilled in Oregon.

The geothermal energy potential of the various provinces is categorized into three subdivisions, based on existing technology and economics: (1) areas of maximum inferred potential, (2) areas of intermediate potential, and (3) areas of low potential. Areas of maximum potential have a geologic environment favorable for the formation of geothermal resources of temperatures that are high enough to be used for electric power generation as well as for lower temperature nonelectric applications such as space heating and industrial-process heating. The exploration for and subsequent development of these resources will be expensive and time consuming. Areas of intermediate potential most likely contain resources suitable for nonelectric applications. Under existing economic conditions and current technology, electric power generation from geothermal energy will be unlikely in regions with intermediate potential. Areas of low potential will not likely produce geothermal energy in substantial quantity in the foreseeable future.

Areas of maximum potential, shown as "High" in Figure 2, have regional heat-flow values ranging from 1.9 to more than 2.5 microcalories per cm^2 sec (heat-flow units or HFU), numerous thermal manifestations in the form of hot springs and fumaroles, and volcanism that occurred within the last 2 million years. Areas of intermediate potential are characterized by scattered hot springs and/or warm-water wells, heat-flow values between 1.5 and 2.0 HFU, and most recent volcanism generally ranging in age from Miocene to Pliocene. An exception is the pattern of heat flow in the Western Cascades which ranges from less than 1.5 HFU at the west margin of the province to about 2.5 at the east margin adjacent to the Holocene volcanism in the High Cascades. Areas shown as "Low" in Figure 2 are considered to have low potential under present utilization technology as they have heat-flow values generally less than 1.2 HFU, volcanic rocks that are Miocene in age or older, and no thermal manifestations.

The interpretation of the potential of some geologic provinces will change as (1) future field studies shed new light on resource occurrence, (2) utilization technology improves, and (3) economic conditions change, with respect to alternate energy sources. It may eventually be possible to transport geothermal energy from areas of resource occurrence to areas of high energy demand, either by conversion to electricity or as hot water via pipelines.

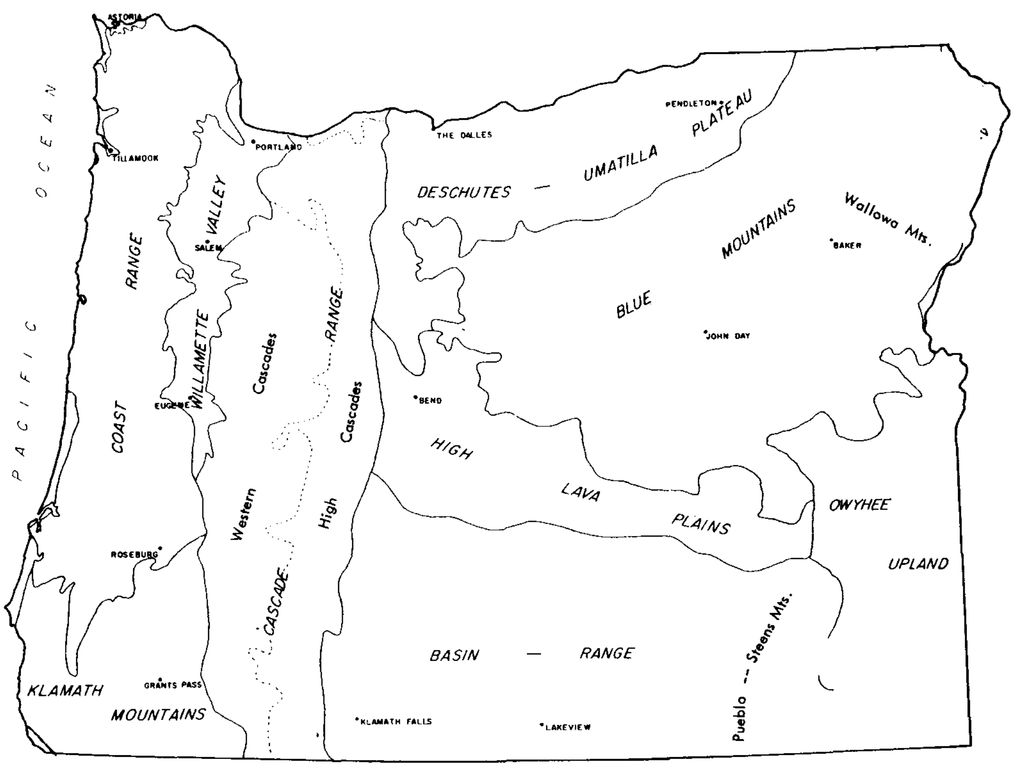

Figure 1. Physiographic provinces of Oregon.

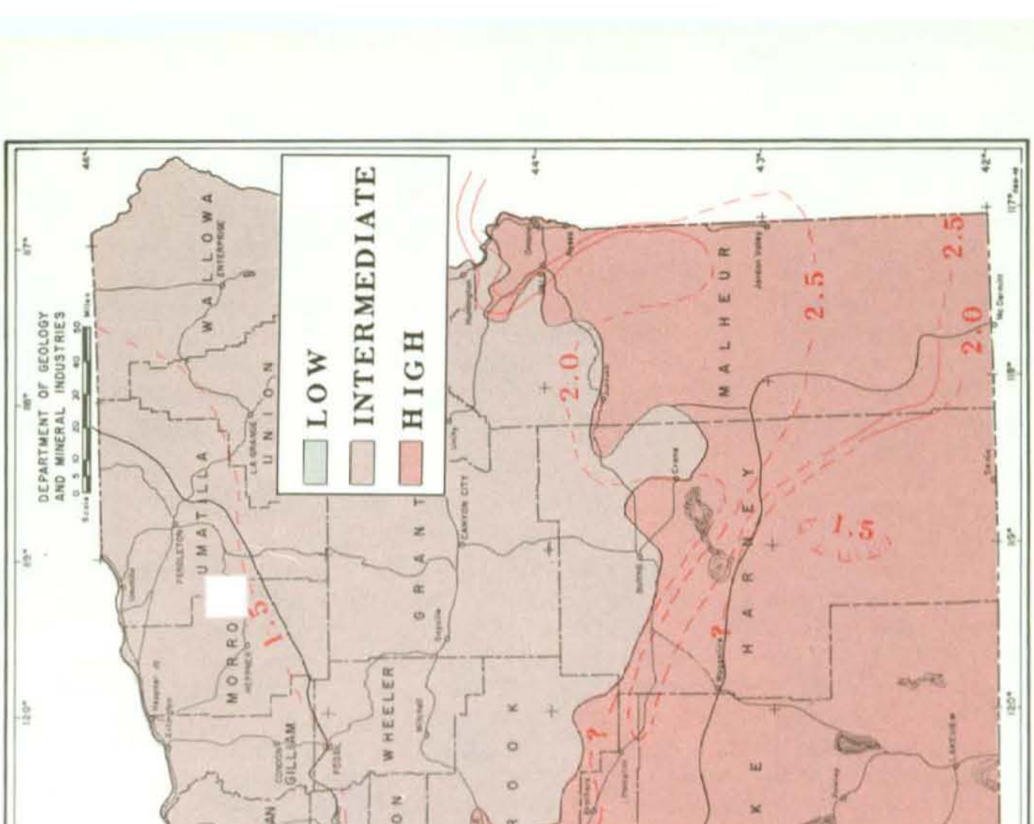

Figure 2. Preliminary heat-flow map of Oregon showing geothermal energy potential of various physiographic provinces. Heat-flow contours indicate heat-flow units of microcalories per cm^2 sec.

Coast Range

No hot springs are reported in the Coast Range in Oregon, heat flow based on meager data is less than 1.0 HFU, and the youngest volcanic rocks are Miocene in age (more than 12 million years old). Heat flow in the Coast Range, as shown in Figure 2, is based on scattered measurements in shallow wells and on approximate bottom hole temperatures reported for deeper wells drilled for oil and gas. No holes have been drilled for heat-flow data in the province. Existing information, however, suggests that the area has a low potential for geothermal energy resources.

Willamette Valley

Heat-flow values for the Willamette Valley are reported by Bowen and others (1977) and Blackwell and others (1977). Systematic measurement of temperature gradients in predrilled wells in 1976 in the vicinity of Portland, Salem, and Eugene failed to detect any obvious concentrations of geothermal resources (Hull and others, 1977b). There are no known hot springs or other geothermal phenomena in the province. Although most volcanic rocks are Eocene to Miocene in age, the youngest volcanic rocks near Portland may be less than 1 million years old (Allen, 1975). Further work to evaluate the potential near Portland is desirable.

Temperature gradients measured to date in the Willamette Valley are typically 20° to 40°C per km. Extrapolation of these gradients indicates that the 180° to 200°C temperatures required for electricity generation will not likely be encountered at depths less than 4 or 5 km, depths beyond the economic limit of drilling.

Klamath Mountains

The Klamath Mountains geologic province encompasses a broad area of rocks of Mesozoic age (65 to 225 million years). Hot springs are not found in the province except at its eastern border adjacent to the younger rocks of the Western Cascades province. Measured temperature gradients are extremely low, ranging from 10° to 20°C per km; and observed heat-flow values reported by Diment and others (1975) are less than 1.5 HFU. The geothermal energy potential of the Klamath Mountains province is adjudged to be low. The very low temperature gradients indicate that hot fluids would be encountered only at depths too great for economically feasible resource development.

Western Cascades

The Western Cascades province is a belt of volcanic and volcaniclastic rocks of Tertiary age which lie on the western flank of the present Cascade Range. The volcanic rocks of the zone appear to be too old to be a heat source for geothermal resources;

yet there is a north-trending belt of hot springs in the eastern third of the province, and a regional heat-flow study has revealed values ranging systematically from 1.0 HFU in the west to about 3.0 HFU in the east.

The high heat-flow values at the east boundary (Figure 2) are considerably in excess of normal, suggesting either localized heat source(s) at the eastern border of the province, deep circulation of hot fluids from the High Cascades to the east, or lateral effects of crustal heating associated with the volcanism of the High Cascades.

Although the potential of the province is considered to be intermediate, except along the eastern border, it may ultimately prove to be one of Oregon's most important geothermal energy sources because of its proximity to major population centers and energy markets in the Willamette Valley. Additional work is clearly needed in order to define the geologic controls over hot spring systems, to ascertain the nature of the heat source, and to establish more accurately the transition zone between low heat flow at the west edge of the Western Cascades province and the much higher heat flow at the east boundary of the area.

High Cascades

The High Cascades are characterized by numerous Holocene volcanoes, some of which have been active within the past few thousand years. Volcanoes such as Mount Hood and the Three Sisters and their underlying magma are obvious heat sources. No reliable heat-flow values have been reported for the High Cascades, and the only known geothermal manifestations are warm springs and fumaroles on Mount Hood. The paucity of hot springs in the High Cascades is not surprising in view of the abundant precipitation that soaks through the porous rocks to mask the heat that must be underground. The areas surrounding the High Cascade volcanoes are some of the most promising geothermal resource areas in the state, but few factual data are available for this province.

Deschutes-Umatilla Plateau

The northern part of Oregon east of the Cascade Range is a broad plateau underlain by a thick sequence of Miocene flood basalts of the Columbia River Group. There are few hot springs or warm wells, no Quaternary volcanic rocks, and few reliable heat-flow values in the province. Heat flow, based on values reported by Sass and others (1971) and Munroe and Sass (1974) from holes in southern Washington and geothermal gradients measured in Oregon, appears to be approximately 1.5 HFU. The Oregon gradient values, which were measured in relatively shallow holes, are affected by ground-water aquifers in the somewhat permeable basalt. A single heat-flow value of 1.9 HFU was obtained from a hole drilled in a pre-Tertiary granitic intrusive body at the southern boundary of the province. Existing data show typical geothermal gradients of 30° to 40°C per km for the province. The geothermal energy potential of the Deschutes-Umatilla Plateau is considered to be intermediate.

Blue Mountains

The Blue Mountains province is an area of complex geology, numerous hot springs, and poorly known heat flow. The geology is dominated by Mesozoic volcanic, sedimentary, and intrusive igneous rocks overlain by Tertiary volcanic and sedimentary units. The youngest dated volcanic activity is Pliocene in age, although basalt of Quaternary age was mapped by Brown and Thayer (1966). Heat flow based on a few scattered values appears to be in the range of 1.5 to 2.0 HFU. Several of the hot springs are located near the larger towns of the region, and utilization of the geothermal resources for nonelectric applications may be feasible. The overall potential of the Blue Mountains province is believed to be intermediate.

High Lava Plains

A belt of extensively faulted young volcanic rocks extends across central Oregon from the Cascade Range on the west to Harney Basin on the east. The volcanic rocks, ranging in age from Eocene to Holocene, are a bimodal suite of basaltic and silicic lavas with intercalated sedimentary strata, widespread silicic ash flow tuff, and scattered rhyolite domes. Silicic volcanic activity generally shows a progressive decrease in age from east to west (MacLeod and others, 1975). Basaltic volcanism lacks this pattern, and Holocene basalts are found at both the western and eastern ends of the belt.

Numerous hot springs and wells occur at the east end of the province, but only a few hot springs are found in the western portion where the age of silicic volcanism is youngest. Extensive heat-flow work along the Brothers fault zone, which spans the province, has shown heat-flow values to be higher in the zone than in areas to the north (Hull and others, 1977a). Portions of the zone are characterized by heat flow in excess of 2.5 HFU; and "blind" heat-flow anomalies (anomalies without nearby hot springs or fumaroles) have been found along the zone, for example, at Glass Buttes in northeast Lake County (Bowen and others, 1977; Hull, 1976).

The young volcanism, areas of high heat flow, and scattered hot springs and wells suggest that the High Lava Plains province has a high potential for discovery and future development of geothermal resources (Figure 3). In the Harney Basin near Burns is clear evidence of geothermal fluids with temperatures adequate for nonelectric applications (Hull and others, 1977a). There are no identified systems with temperatures suitable for electric power generation, but the available evidence suggests that higher temperature fluids may be found by future exploration.

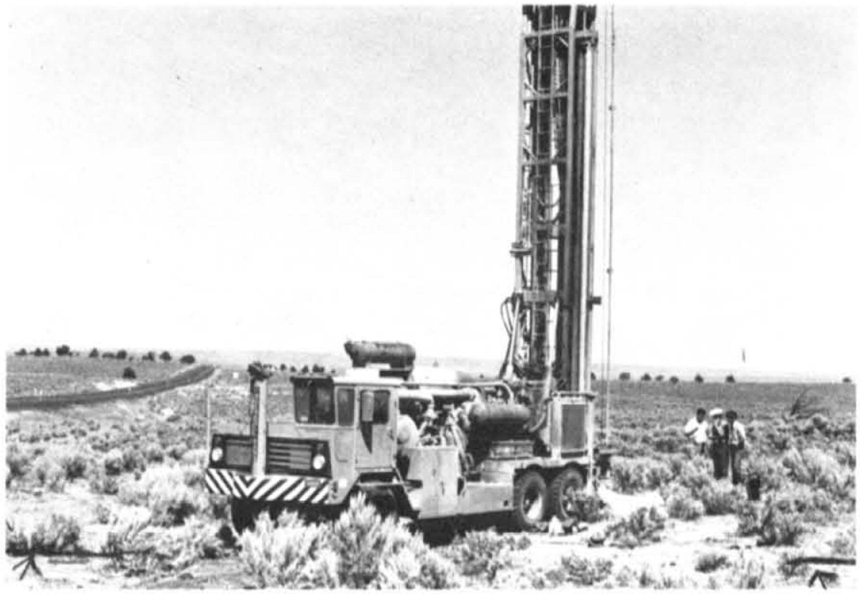

Figure 3. Drilling rig at site of heat-flow hole near Riley Junction in Harney County.

Basin and Range

The geology of the Basin and Range province is generally similar to that of the High Lava Plains to the north. The Brothers fault zone, which crosses the High Lava Plains, marks the northern terminus of the structural style characteristic of the Basin and Range (Lawrence, 1976).

The Basin and Range province, characterized by numerous hot springs, contains areas of established geothermal resource utilization at Klamath Falls (Figures 4 and 5) and Lakeview (Figure 6). Heat-flow studies have shown a wide variation in values, and many individual values appear to be affected by shallow groundwater movement. The average heat flow in the province is between 2.0 and 2.5 HFU (Bowen and others, 1977). Typical geothermal gradients for the province range from 50° to 80°C per km.

Most of the volcanic rocks of the province are too old to represent a direct heat source for geothermal fluids, yet the numerous hot springs and overall high heat flow suggest a high potential. The key unanswered question is whether temperatures sufficiently high for electric power generation are to be found in the region. The presence of hot water at the boiling point is well known at Klamath Falls and Lakeview, and geochemical studies of hot springs indicate that reservoir temperatures of approximately 200°C may be present in the Alvord Valley at the eastern edge of the province (Mariner and others, 1974). The nature of the heat source at Klamath Falls and Lakeview is still unclear, and additional research and deep drilling are needed.

Figure 4. Klamath Falls dairy which uses natural hot water for pasteurization.

Figure 5. Snell Hall, Oregon Institute of Technology, Klamath Falls. All nine OIT campus buildings are heated by geothermal energy.

Figure 6. Lakeview greenhouse heated by geothermal energy.

Owyhee Upland

The southeastern corner of Oregon lies in the Owyhee Upland province, underlain mainly by Miocene to Holocene volcanic rocks and intercalated sedimentary units. Hot springs are scattered throughout the province. Heat-flow work to date has been concentrated near the Idaho border in the eastern part of the province in the western portion of the Snake River Basin. Hot springs and anomalous heat flow are associated with faults (Bowen and Blackwell, 1975; and Couch, 1977); and detailed heat-flow work has revealed "blind" heat-flow anomalies (Bowen and Blackwell, 1975). Heat flow over much of the province appears to be in excess of 2.0 HFU.

Currently some geothermal resources are utilized at Vale in northern Malheur County, and the overall potential for nonelectric applications of geothermal energy is high. The potential for fluids of sufficiently high temperature for generation of electricity is not known. Estimates based on geochemical studies of the Vale hot springs suggest a reservoir temperature of approximately 160°C (Renner and others, 1975). At Neal (Bully Creek) hot springs, the estimated reservoir temperature is 180°C.

Summary

Available geologic mapping; ages of volcanic rocks; heat-flow measurements; and the distribution and chemistry of fumaroles, hot springs, and wells are collectively utilized to evaluate the geothermal energy resource potential of the various physiographic provinces in Oregon. Provinces having high potential are the High Cascades, High Lava Plains, Basin and Range, and Owyhee Upland. Areas of intermediate potential on a regional basis are the Deschutes-Umatilla Plateau, the Blue Mountains province in northeastern Oregon, and possibly the Western Cascades province. Several provinces in western Oregon appear to have a low potential for geothermal resources under existing economic and technological conditions.

The existing data base is generally insufficient for outlining areas of greater or lesser potential within each province, although the potential of some selected specific sites has been estimated by White and Williams (1975). Exploration has indicated that potentially important geothermal resources may occur in areas lacking nearby surface manifestations such as hot springs, hot-water wells, or fumaroles.

The geothermal energy potential of the Western Cascade and High Cascade provinces is poorly understood. Reliable heat-flow measurements are lacking for the High Cascades, and data for the Western Cascades are sparse. There may be a rather sharp transition between low heat flow in the Willamette Valley (0.8 to 1.0 HFU) and significantly higher heat flow in the Cascade Range (greater than 1.5 HFU); and the location of this boundary is important for prediction of the area of geothermal resource potential. An area of low heat flow extends over the western third of the State, although there could be localized exceptions to this pattern in areas of younger volcanic rocks.

Within the High Lava Plains and Basin and Range provinces, heat-flow values vary widely because of complexities in geologic structure and the influence of moving ground water. Detailed hydrologic and heat-flow studies will be required to learn the causes and areal extent of many of these variations. A better understanding of these anomalies will be necessary in order to properly evaluate the geothermal energy potential of these provinces.

This paper is presented as a progress report summarizing a continuing geothermal resource assessment by the Department. It is hoped that the evaluation presented herein will be of value to land use planners, government agencies, and public and private energy research groups.

Acknowledgments

In addition to those noted in the references listed below, a number of individuals and organizations have aided in the collection and interpretation of the data discussed herein. We have

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* * * * *

GEOTHERMAL OPEN-FILE REPORT RELEASED

"Heat Flow Study of the Brothers Fault Zone, Oregon," by Don Hull, David Blackwell, Richard G. Bowen, and Norman V. Peterson, has been issued by the Department as Open-file Report 0-77-3. The 1975-76 study, which was financed by U.S. Geological Survey Extramural Research Grant 14-08-0001-G-200, covers an area east of the Cascades between Burns and Bend.

Heat flow along the Brothers fault zone is characterized by a wide range of values. Anomalously high heat flow detected between Glass Buttes and Harney Basin, near the town of Burns, may be evidence of widespread geothermal resources near the east end of the Brothers fault zone.

The 101-page report, available at the Portland office, sells for $3.00. It includes geothermal data and location maps.

* * * * *

DEPARTMENT PUBLISHES REVISED REGULATIONS

Miscellaneous Paper No. 4 has been revised as of July 1, 1977 into two parts: Part I, Rules, Regulations and Laws Relating to Oil and Gas Exploration; and Part II, Rules, Regulations and Laws Relating to Geothermal Resources. The price is $1.00 each or $2.00 per set.

* * * * *

USGS PRELIMINARY GEOLOGIC MAP ON OPEN FILE

"Preliminary Reconnaissance Geologic Map of Part of Jackson County, Oregon," by James G. Smith and Norman J. Page, is USGS Open-file Map 77-318.

The black-and-white map may be seen in the Department's Portland office, and copies may be ordered for $2.00 each.

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TWO NEW MAP SETS FROM USGS

The Geothermal Gradient Map of North America and the Subsurface Temperature Map of North America, showing temperatures at various depths beneath the ground surface of the continent, have been issued by the U.S. Geological Survey. Each map is published as two sheets of 40 by 63 inches. The scale is 1:5,000,000. These multicolored maps are based on data from more than 30,000 wells.

The maps may be purchased prepaid for $4.00 per set, payable to U.S. Geological Survey, from the Branch of Distribution, U.S. Geological Survey, 1200 South Eads St., Arlington, Va. 22202, or from the Branch of Distribution, USGS, Box 25286, Federal Center, Denver, Colo. 80225.

* * * * *

COMMITTEE ESTIMATES FUTURE NATURAL GAS POTENTIAL

Since 1964, the Potential Gas Committee, whose volunteer members represent the natural-gas industry, government agencies, and academic institutions, has prepared estimates of the undiscovered potential natural-gas supply of the United States.

The committee presents its estimates in three categories: Probable Resources, the expectable extensions of gas fields that have already been discovered; Possible Resources, discoveries which might be reasonably expected to be found by future exploration in formations which are currently productive elsewhere in the same province; and Speculative Resources, amounts of gas which members of the committee feel might be found in formations or areas in which there is no current production and where geological information is relatively limited. All are exclusive of Proved Reserves.

The committee's most recent estimates are based on supplies remaining as of December 31, 1976. Probable Resources are thought to be 215 trillion cubic feet (TCF) of natural gas. Possible Resources to be developed are believed to be 363 TCF. Speculative Resources are estimated to be between 345 and 395 TCF.

The amount of natural gas estimated in the Probable category is almost equal to the current volume of Proved Reserves (216 TCF) and is approximately 10 times the U.S. 1976 production of 19.5 TCF. The quantities estimated in the Possible and Speculative categories are each more than one and one-half times the volume of current Proved Reserves.

Quantities estimated by the committee are "most likely" or mean values, representing the consensus of the committee as to the most likely quantity of natural gas remaining to be developed in each of the three categories. As the values for each category represent estimates of potential volumes of natural gas under quite different conditions and levels of geologic knowledge, committee members suggest it is not appropriate to add the estimated quantities to determine a single "most likely" total amount of potential supply.

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THE GEOLOGY OF JORDAN CRATERS, MALHEUR COUNTY, OREGON

Bruce R. Otto and Dana A. Hutchison*

Introduction

Many areas in Malheur County in southeastern Oregon have surprisingly young volcanic features. At Jordan Craters (Russell, 1903), comparatively recent olivine basalt flows filling a broad valley once occupied by Cow Creek cover an area of approximately 72 sq km (28 sq mi). Figure 1 shows the location of Jordan Craters. The entire volcanic field is covered by three 7-1/2' topographic maps: Jordan Craters North, Jordan Craters South, and Cow Lakes. The area discussed in this article lies within the Jordan Craters quadrangle and can be reached by a 26-mile dirt road which runs west from U.S. Highway 95 (see Road to Jordan Craters, p. 138-139).

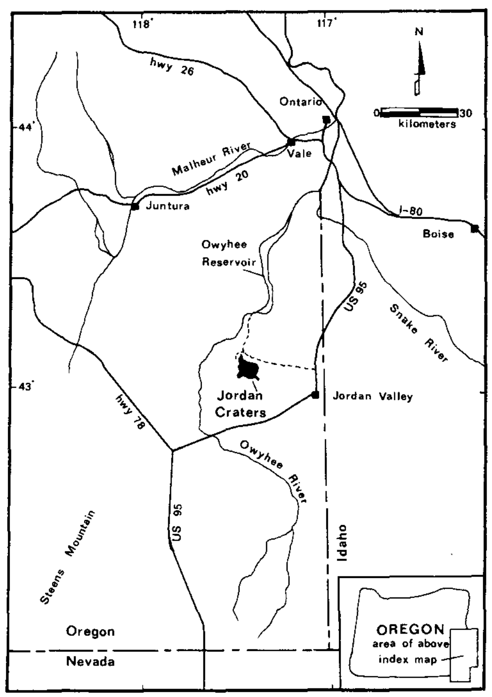


Figure 1. Index map showing location of Jordan Craters in southeastern Oregon.

The climate of the area is typical of high desert regions, having wide annual and diurnal temperature ranges and low annual precipitation. Typical plants of the area are sage brush, cheat grasses, mosses, and lichens.

Previous geologic work in the area includes a master's thesis on the petrography of the Cow Lakes basalts (Millhollen, 1965). Kittleman and

* Article written while the authors were students at Boise State University, Boise, Idaho.

others (1965) briefly described the extrusive volcanics and published a regional map (Kittleman and others, 1967) which shows the general extent of the lava field. The same area is also covered by Walker (1977) in his geologic map of eastern Oregon.

Our interest in the Jordan Craters volcanic field was aroused during field trips to the area when numerous questions were raised about the geologic history of many features at the northwest end of the flow. Of prime interest was Coffeepot (Morcom) Crater because of its complex history and relationship to the rest of the volcanic field.

Regional Setting

The Jordan Craters volcanic field lies in a topographic depression of the Owyhee Plateau. Elevations range from 1,200 to 1,400 m (4,000 to 4,600 ft). Rocks in the area are mostly volcanic, predominantly basalt, rhyolite, and welded ash-flow tuffs. Although Millhollen (1965) has defined and described six basalt flows, only the youngest is discussed here.

The youngest lava, an olivine basalt, flowed southeastward from Coffeepot Crater for a maximum distance of 16 km (10 mi), filling stream valleys that were part of the Cow Creek drainage system. The lava overlies Tertiary Leslie Gulch Tuff to the west and Plio-Pleistocene basalts to the north, east, and south (see Geologic Map of Coffeepot Crater, centerfold). Kittleman (1965) believes that the youngest Jordan Crater basalt flow might have originated during historic times because it shows a high degree of surface-feature preservation and lacks soil cover. Studies based on growth rates of lichen and weathering rates of exposed and unexposed basalt suggest that the flow may be between 4,000 and 9,000 years old (Robert R. Kindschy, personal communication to editor, 1977).

Millhollen (1965, p. 21) suggests the presence of a north-south structural trend in the area because of the alignment of four source vents of older flow fields. Clark's Butte, to the south of Jordan Craters, and other shield cones are also located along this lineament. This regional trend is also evident on LANDSAT imagery in the form of lineations extending from the north through Vale, Oregon, and terminating in the Jordan Craters area. Kittleman (1965, p. 13) suggests the possibility of structural control of the Owyhee Canyon along this same north-south line.

Geomorphology

Geomorphic features found at Jordon Craters (Figure 2) fit into one of two categories: major flow features or features found in the crater area.

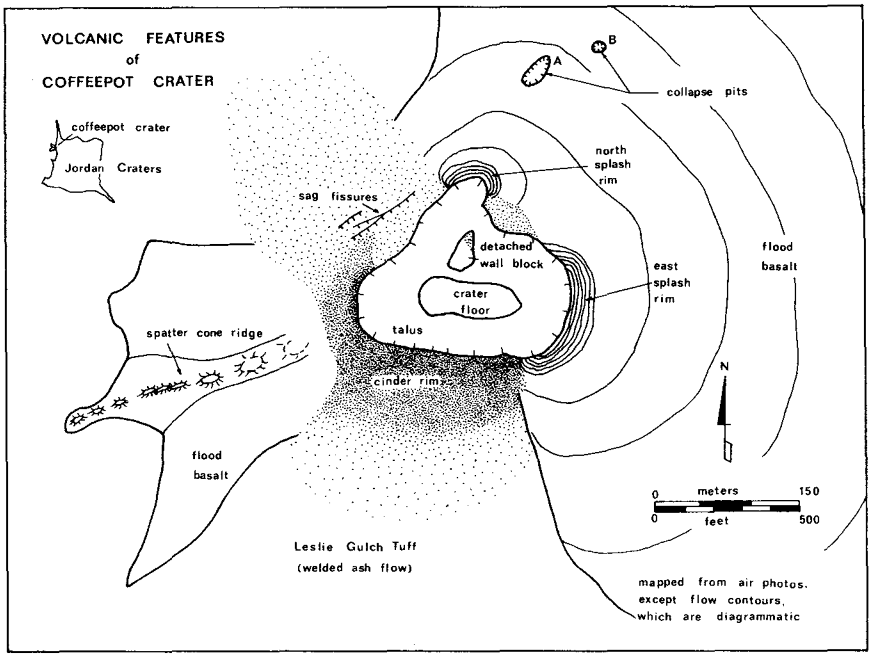


Figure 2. Volcanic features of Coffeepot Crater.

Major flow field

The major flow field is roughly square in planimetric view and approximately 8 km (5 mi) on each side. The southeastern corner is somewhat extended where the lava followed the Cow Creek drainage. Minimum flow thickness near Coffeepot Crater in the small collapse pit is estimated to be 23 m (75 ft). Approximately 1.6 cu km (0.4 cu mi) of basalt issued from the crater.

The major flow, 98 percent of which lies to the east and southeast of the crater, was an extremely liquid, high-temperature, pahoehoe lava flow, with a smooth, undulating, and sometimes ropy surface (Figure 3). Surface features include gas release formations, such as lava blisters and tumuli (small solid mounds on the crust of a lava flow); crustal flow formations, such as pressure ridges and squeeze-ups (small extrusions of viscous lava through fractures on the solidified surface of a lava flow); collapse features, such as pits and sags; and numerous flow structures, such as ropy surface (Figure 4) and lava channels (Figure 5).

A pressure ridge is an elongated piece of congealed crust that has been pushed upward by movement of lava below the crust. One pressure ridge at Jordan Craters (Figure 6) is 92 m (300 ft) long and more than 9 m (30 ft) deep in the central fracture. On the flanks of the pressure ridge, many polygonal blocks of basalt

Figure 3. Pahoehoe lava-flow surface at Jordan Craters.

Figure 4. Ropy surface on pahoehoe lava flow.

Figure 5. Lava channel.

Figure 6. Pressure ridge.

have been "popped" from the surface of the flow and now lie strewn about in a blocky mass.

Two large collapse pits are located just northeast of the main crater (Figure 7). The two pits (Figure 8, A and B) are parts of a large lava-tube system which may have been the main route of lava transport from the source vent to the far reaches of the major flow field. Figure 8 shows a portion of the major flow field from the western edge to about midway into the field. Outlined in the figure are collapse or withdrawal features which probably indicate a lava-tube system of major proportions. It is reasonable to assume that the deepest portions of the lava flow followed the drainage patterns of Cow Creek and that a major tube system was confined to this deep part of the flow. Be careful when walking near the rims of the collapse pits. The crust is thin and might break, and a fall into one of the pits could be fatal.

Lava tubes fall into two categories, large and small (Greeley, 1971, p. 5). The small tubes, which are generally less than 10 m (33 ft) wide and a few hundred meters long, are often feeder tubes that extend from the larger tubes to the front of the flow. Large lava tubes (Ollier and Brown, 1965) form in lava flows that are several kilometers long. These larger lava tubes tend to meander, like a river on a flood plain, within the molten flow field. Meandering continues until the cooling lava confines the mobile conduit to a definite channel. When the lava is eventually extruded from the tube near the flow front, a lava coating is left lining the walls of the tube. Remnants of this coating may be seen in many

Figure 7. Air photo of Jordan Craters. South is at top of photograph, Coffeepot Crater is to the right, collapse pits are at lower center and left. The pits are not filled with water; they are in deep shadow.

portions of tubes and collapse pits. In some instances, when all the lava is not extruded from a tube, it congeals instead within the tube.

Figure 8 shows four types of large tube features preserved at Jordan Craters. Figures 8C and 8D show spalling of roof material, which eventually produces a collapse pit (Figure 8A). Figure 8B shows a cluster of tubes, each of which has formed adjacent to or on top of other tubes. Figure 8D shows a portion of a dome along the path of the larger lava-tube system which was still semimolten when the lava was withdrawn, causing the roof to deform plastically downward.

The two large collapse pits have distinctive features. The larger of the two (A) is 29 m (95 ft) long, 15 m (50 ft) wide, and 15 m (50 ft) deep. The east rim shows minor amounts of flow and spatter which may have resulted from outgassing or outdraining at that point to relieve pressure produced by partial damming of the lava conduit. The interior of this pit has flow lines and a well-developed lava lining on the walls.

The smaller pit (B) is more nearly circular in shape and has had less roof material removed by spalling. The pit has an opening diameter of about 12 m (40 ft) and is 16 m (52 ft) deep. It has the same interior features as the larger pit, with some important

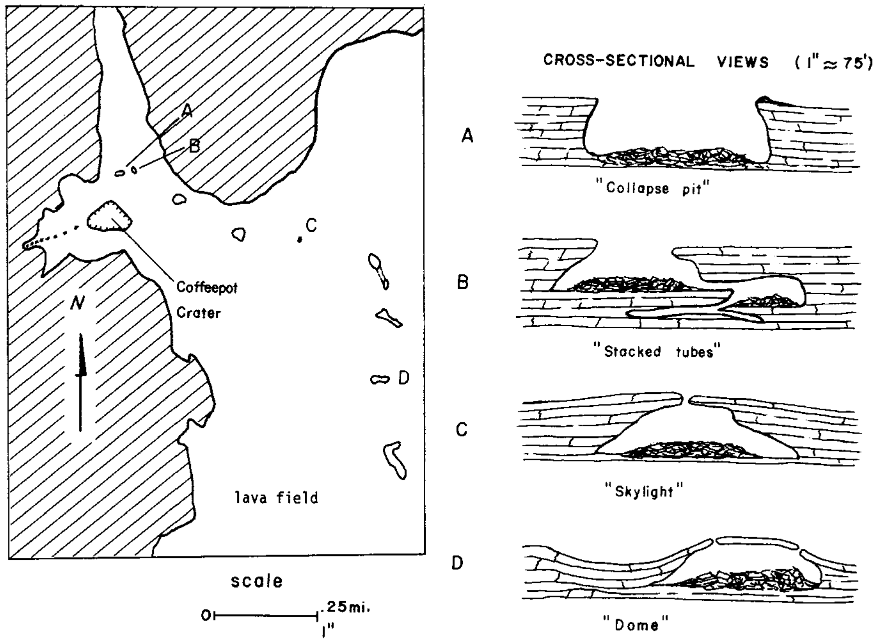
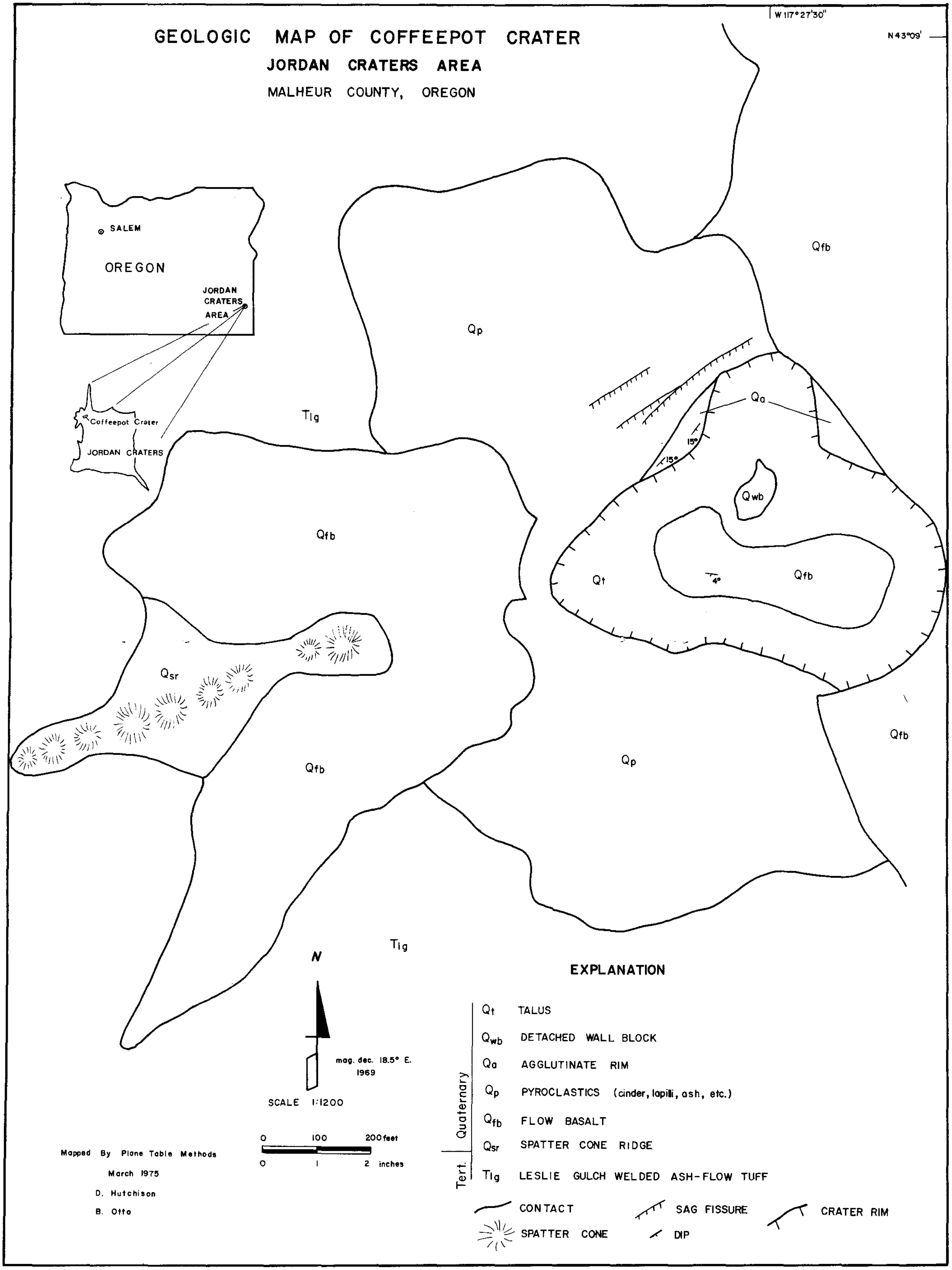


Figure 8. Outlines of collapse features indicative of major lava-tube system. Map adapted from air photos.

additions. The floor of the pit is false, in that another tube lies beneath it. Figure 8B shows multiple lava tubes stacked upon one another. A false floor like this can be produced by multiple flow activity or by downward erosion by the lava within the tube (Greeley and King, 1975, p. 27). A most interesting phenomenon, seen in pit (B) on the under side of the false pit floor (deep lava-tube ceiling), is the incorporation of rounded, heat-altered, nonbasaltic rocks into the flow basalt. These rocks, which appear to have the same properties and composition as the surrounding country rock, the Leslie Gulch Tuff, are rounded, perhaps by a stream. Since the location of the pit crater is near the geometric center of the former stream valley, the stream cobbles were undoubtedly picked up by the flowing lava. Some of the cobbles were melted by the heat of the lava to form glass which hangs from the ceiling of the deeper tube. In addition to the cobbles, very large clusters of gypsum crystals that line portions of the walls can be found in lava tube (B).

Crater area

A line of spatter cones forms a ridge which trends S. 54° W. for a distance of 304 m (1,000 ft) from the rim of Coffeepot Crater



GEOLOGIC MAP OF COFFEEPOT CRATER, JORDAN CRATERS AREA, MALHEUR COUNTY, OREGON

Figure 9. Coffeepot Crater with line of spatter cones in foreground. Note cracks in left (northwest) wall of crater.

(Figure 9). On the same linear trend 0.8 km (0.5 mi) to the west is an isolated spatter rampart consisting of three small, low-profile cones. Alignment of the spatter cones and crater over a distance such as this suggests a zone of crustal weakness. The spatter cones increase in size toward the crater, with the smallest approximately 5 m (16 ft) high and 5 to 6 m (16 to 20 ft) in diameter. The largest cone, which apparently had its top blown off, is 18 m (60 ft) in diameter and 6 m (20 ft) high. Many of the spatter cones are still intact and have a distinct bubble shape. Some are as much as 6 m (20 ft) deep with an opening at the top that is only 30 cm (12 in) in diameter. Compositionally, the spatter cones resemble the agglutinated (lumps of lava stuck together while still hot) portion of the crater rim. One of the spatter cones, approximately 12 m (40 ft) high and 9 m (30 ft) in diameter, has been incorporated into the west crater wall. A cross-sectional view of this feature shows basalt flows interbedded with the agglutinated spatter.

Coffeepot Crater, which is approximately 80 m (260 ft) deep from the highest portion of the crater rim, is a small-scale example of a stratovolcano. The crater is basically heart shaped, with a 230-m (1,050-ft) east-west axis and a shorter 170-m (560-ft) north-south axis (see Geologic Map of Jordan Craters, centerfold). In a clockwise direction, the crater walls show the following features: In the west wall is red- to gray-colored cinder, interbedded with flows of dense olivine basalt. The beds in the west wall dip 15° toward the center of the crater and appear to have sagged downward several meters while still in a semiconsolidated state. On the northwestern rim of the crater, downward and inward movement has created three large cracks, 30 m (100 ft) long and 1

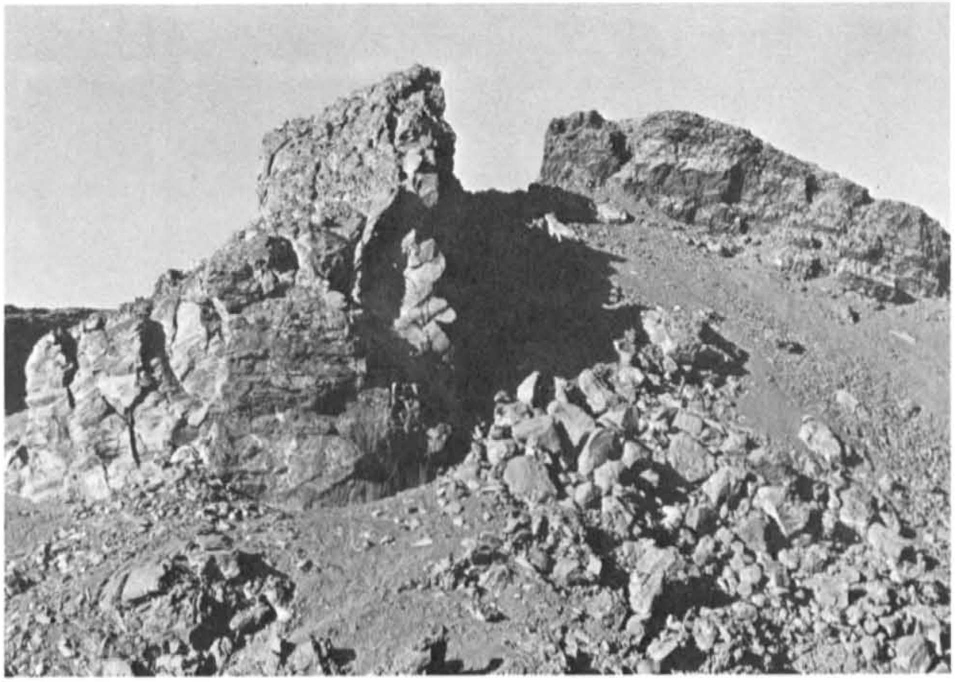


Figure 10. Detached wall block, north crater wall.

to 5 m (3 to 16 ft) wide, subparallel to the crater wall (Figure 9). The agglutinate which forms the upper part of the crater rim can be seen in these cracks. To the north, the stratified volcano walls are missing; and thinly laminated flows of vesicular olivine basalt form the rim.

On the northeast side of the vent, another segment of the interbedded agglutinate is visible in a prominent point which projects toward the center of the crater. Southwest of this point a large slump block dips toward the center of the crater (Figure 10). The northern part of this block is composed of interbedded layers of cinder, agglutinate, and massive olivine basalt. The lava which coats the south face of the block is striated and grooved (Figure 11).

The north and east sections of the crater wall are composed entirely of thinly laminated, vesicular olivine basalt. The uppermost part of the east crater rim is composed of an accumulation of basalt which splashed over the rim and built up to a height of 3 to 4 m (10 to 13 ft). Below this splash rim, on the inside of the vent, are large detached segments of congealed lava-lake crust, some of which are as much as 15 m (50 ft) across.

The entire south wall of the crater is composed of interbedded cinder, agglutinate, and massive basalt. The beds range in thickness from 0.5 to 10 m (1.5 to 33 ft). Toward the west end of the

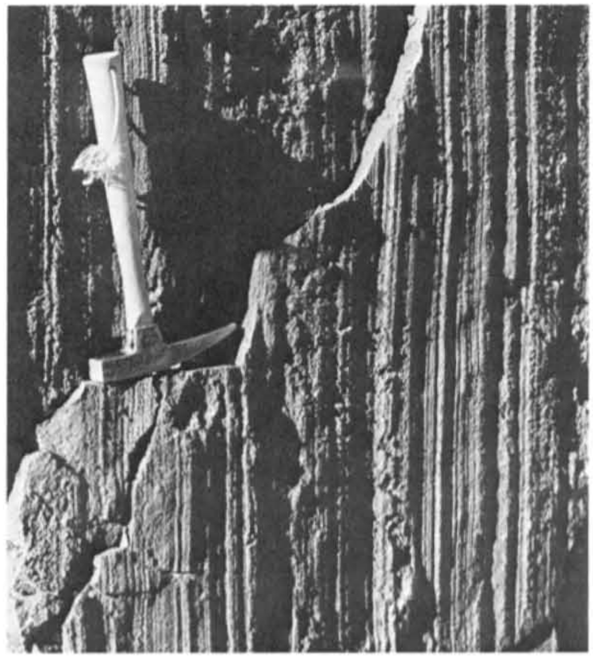


Figure 11. Grooves left by subsidence of lava-lake crust.

south wall, the volcanic beds are underlain by a soil horizon which in turn overlies the Leslie Gulch Tuff. The soil zone, which is approximately 1 m (3 ft) deep at its thickest part, pinches out in both directions over a distance of 90 m (300 ft) and contains numerous fragments of the underlying tuff.

Above the soil horizon in the southwest wall lies a plano-convex cinder deposit which is approximately 90 m (300 ft) long and 6 m (20 ft) thick, which appears to be part of a buried cinder cone. Mass wasting (downslope transport of soil and rock because of gravity) has removed part of the original 4- to 6-cm (1.6- to 2.4-in) lava coating which once covered the entire cinder cone.

The floor of the crater itself is composed of vesicular olivine basalt which shows many pahoehoe flow features such as pressure ridges, lava tubes, ropy structure, and tumuli. The crater floor has been tilted slightly toward the south. Debris which has fallen from the crater walls covers approximately 50 percent of the floor.

Interpretations of Geologic History

Volcanism over a long period of time has largely destroyed evidence of the earliest events. Mass wasting of rock debris into the crater has also decreased visibility of the crater walls. Enough features remain, however, to be able to interpret a generalized geologic history.

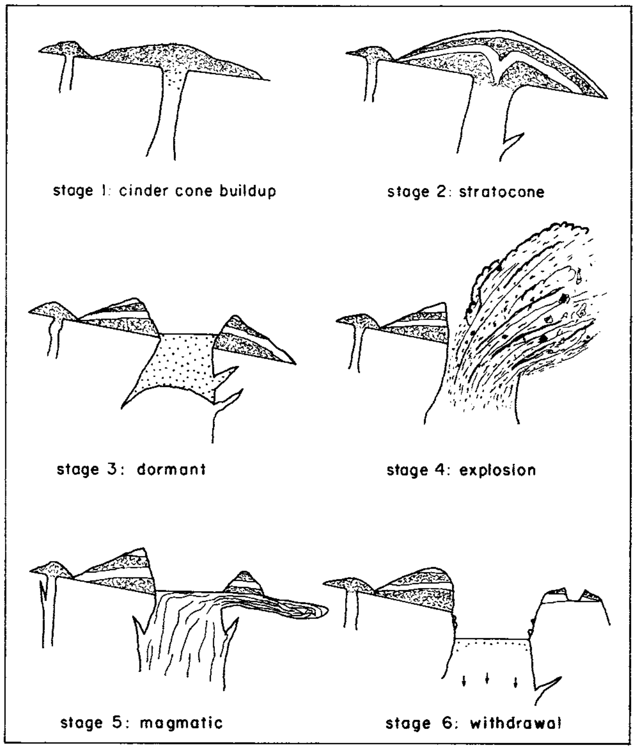


Figure 12. Cross-sections from east to west showing stages in geologic history of Coffeepot Crater. Not to scale.

Before volcanism began, the area now covered by the Jordan Craters lava was part of the Cow Creek drainage. A small portion of the old horizon is seen in the vent. An eruption from small cinder and spatter cones in the sagebrush-covered hills was likely to have been the first event (Figure 12, stage 1). As the spatter cones continued to grow, the greatest activity was concentrated at the east end of the zone of weakness. Here a cinder cone progressed through stages of stratovolcano formation (Figure 12, stage 2) until it reached the height of the south crater rim. Volcanic activity stopped; and during subsequent degassing of the lava lake in the crater, the agglutinated part of the rim was formed.

As time progressed, Coffeepot Crater became dormant (Figure 12, stage 3), and the magma in the plumbing system cooled downward, forming a volcanic plug. Volcanic activity resumed when the resurging magma developed enough pressure to blow the plug along a zone of weakness and destroy portions of the crater wall (Figure 12, stage 4). The zone of failure of the volcanic plug controlled the direction of the explosion; and pressure was relieved by an explosion directed toward the north and east, resulting in destruction of those sections of the crater wall except for one large block, which was torn loose from the crater wall and tilted toward the center.

After this explosion, the fluid lava was able to flow freely from the vent (Figure 12, stage 5), forming the bulk of the lava field seen today. Lava flowed downslope and was confined to an old stream valley where it formed a major lava-tube system.

When the hydrostatic head of the lava was relieved, the lava pooled in the vent. As minor fluctuations in the levels of the lava lake occurred, thin laminar flows issued from the vent and formed the north and east walls of the crater. As the flows built up, it became increasingly difficult for the lava to escape; and a splash rim developed.

Concurrent with or subsequent to the buildup of the splash rim, the lava lake went through a period of degassing, causing small eruptions and lava fountaining. This activity produced most of the cinders which cover the vent area.

The last events were crusting of the lava lake, followed by withdrawal of the magma (Figure 12, stage 6). As withdrawal occurred, the semisolidified crust was warped and deformed; and as it was drawn down, it left vertical grooves and striations on the crater walls.

After volcanism ceased, gravity caused sliding and slumping of material from the crater walls into the crater itself. What is left today is a remnant of a stratovolcano partially buried in its own debris.

Other volcanoes have features similar to those of Coffeepot Crater. Wildhorse Corral, in the Great Rift of Idaho, has terraces on the crater walls. According to Greeley and King (1975, p. 12), these terraces, which are the result of a fluctuating lava-lake level, indicate a multiphase eruptive history. Mt. Vesuvius in Italy also has a multistage history, stratovolcano walls similar to those of Coffeepot Crater, and a history of explosive eruptions (Green and Short, 1971, p. 12).

Road to Jordan Craters

These directions begin at the junction of a dirt road going west and U.S. Highway 95, 7.6 miles north of Jordan Valley and 2.8 miles south of Sheaville. The junction is marked by a sign, and the road is easy to follow. When in doubt, follow the most heavily traveled road. The route is covered by five 7-1/2 topographic maps: Hooker Creek, Downey Canyon, Mahogany Gap, McCain Creek, and Jordan Craters North. During wet weather, the road is extremely muddy. Watch out for cattle.

Mileage *	**	
0.0	0.0	Junction of dirt road and U.S. Highway 95.
0.9	0.9	Farm road marked "Carter-Baltzor" to right. Go straight.

* Intervals (in miles)
** Cumulative mileage

7.0	7.9	Bridge.
0.8	8.7	Junction with small road. Go right.
1.5	10.2	Bridge.
1.0	11.2	Junction. Go right, following sign pointing to Jordan Craters.
6.7	17.9	Junction. Go straight, ignoring first side road to left and second side road to right. From here on you can see Coffeepot Crater and the lava field to your left in the distance.
5.8	23.7	Fence and cattleguard. Ignore small roads going to right on each side of fence. Cross cattleguard and stay on main road.
1.5	25.2	Junction. Sign points to Jordan Craters. Leave main road and take road to left.
2.9	28.1	Parking lot at base of Coffeepot Crater.

Editor's Note

Because of its geology, flora, and fauna, Jordan Craters has been designated a Federal Research Natural Area under the management of the Vale District Bureau of Land Management. A Research Natural Area is a naturally occurring physical or biological unit where natural conditions are maintained as much as possible for research and educational purposes. Readers interested in learning more about the Jordan Craters Research Natural Area may contact Robert R. Kindschy, BLM Wildlife Biologist, Box 700, Vale, Oregon 97918.

Visitors to Jordan Craters are urged to do nothing to disturb this unique area and are warned to exercise caution when walking because portions of the crater walls and lava-tube roofs may collapse unexpectedly.

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COPIES OF VIRTUE FLAT GEOLOGIC MAP AVAILABLE

The geologic map of the Virtue Flat 7-1/2-minute quadrangle, Baker County, Oregon, is now available as an Ozalid print at the Department's Portland and Baker offices. The map is at the scale of 1:24,000. Different shades of gray and white distinguish rock units. The map covers part of the Virtue gold mining district. Major rock units are argillite, chert and tuff of the Elkhorn Ridge Argillite Formation, altered gabbro and associated rocks of pre-Upper Triassic age, basalt flows of Miocene age, and lake and stream deposits of Pliocene age. Price of the map is $2.00.

* * * * *

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GEOLOGY AND HYDROLOGY OF THE LOST CREEK GLACIAL TROUGH

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Introduction

In most valleys, the stream that enters the upper part has the same name as the stream that flows out the lower end. The water of the Lost Creek glacial trough, the valley followed by the McKenzie Highway (Highway 242), is an exception (see map, centerfold). Along most of its length, the watercourse bears the name White Branch, but the stream that flows out the lower end of the valley into the McKenzie River is named Lost Creek.

Lost Creek glacial trough lies to the west of the High Cascades in the northeast corner of Lane County. The area may be reached by traveling east on Highway 126 from Springfield to the junctions of Highways 126 and 242 and then continuing east on Highway 242 (the McKenzie Highway) or by going west from Sisters on Highway 242.

The watercourse that bears the name White Branch begins below Collier Glacier and continues to its junction with Lost Creek. Lost Creek originates in a cluster of springs about three miles southeast of its junction with the McKenzie River. The entire watercourse is about 20 miles long.

Because much of the water in this valley flows underground, a long stretch of the White Branch bed is dry most of the year. White Branch, a name of questionable validity as explained below, is therefore referred to here as a watercourse. Two porous, blocky lava flows that occupy the valley floor along most of its length divert the water from the surface into a complex system of subsurface channels that discharge their water at Lost Creek Springs, which issue from one of the lava flows about 2 miles above the lower end of the flow.

Geologic Setting

The history of the Lost Creek trough goes back to the time when the mountains themselves were formed and when water accumulated to form a westward-flowing stream. With the onset of Pleistocene glaciation in the High Cascades, glacial ice originating in the vicinity of North and Middle Sisters moved down this stream valley. The valley was occupied by ice more than once during the Ice Age, and at its farthest advance, glacial ice extended down the McKenzie River valley to a few miles beyond Blue River.

The most recent glacier to occupy the trough terminated where the trough joins the McKenzie River valley. Glacial till is exposed in the roadcuts along Highway 126 on either side of its junction with Highway 242 and along Highway 242 to Limberlost Forest Camp about 2 miles southeast of the junction.

The steep walls and the U-shaped cross section of the Lost Creek trough where it has not been affected much by recent volcanism are characteristic of glacial valleys. The moving ice eroded deeply into the lava flows that make up the mountains, exposing in excellent cross section many of the flow units. Of particular interest is the valley wall at Deer Butte (Figure 1), where the glacier cut away part of a volcanic cone.

About 3,000 years ago, thousands of years after the ice had disappeared from the valley, a volcanic eruption at Sims Butte, located about 5 miles west and a little north of North Sister, sent flows of basalt lava, described by Taylor (1965, p. 137-138), down the Lost Creek trough in thin sheets to within a quarter of a mile of Limberlost Forest Camp, covering the veneer of glacial drift and stream gravel on the valley floor. As the lava flow moved along, parts of the flow solidified and then were broken by continuing movement. This fragmented lava rock with abundant void space between the fragments now provides subsurface channels for water. The pore space of the lava flows and of the gravel beneath them is enough to accomodate the large volume of water that goes underground along this glacial trough. The Sims Butte flows are old enough to have developed sufficient soil to support a dense forest, though in places blocky rock is exposed (Figure 2).

A later eruption at Collier Cone, the most recently active volcano in the vicinity of North Sister, sent another lobe of basalt lava into the Lost Creek trough. Flows from this cone, located at the base of North Sister and a little west of its north side, extended down the valley to about half a mile beyond Lower Proxy Falls, partly covering the Sims Butte flows. According to Taylor's lava chronology (1965, p. 145), the Collier eruption is older than 400 years. Conceivably it took place within the past 500 years, but it did not occur more than about 1,600 years ago. Very sparse vegetation on the lava rock in the higher altitudes and thin vegetation in the lower altitudes indicate a young age for these flows. The flows are very highly fragmented, and the surface is a jumble of large blocks (Figure 3). Taylor (p. 143) describes the lobe as "a mass of tumbled blocks and scoria." This condition provides high porosity.

Figure 1. Deer Butte from Proxy Falls trail.

Figure 2. Moss-covered rock of Sims Butte flow just east of Limberlost Forest Camp.

Hydrology

Meltwater emerging from below the Collier Glacier at the western edge of its terminus fed White Branch until about 1940. In the late 1800's, when observations were first recorded, the glacier terminated against Collier Cone, and ice stood high on the cone's south flank. Earlier in the glacier's history, ice rose to or above the level of the south rim of the crater, and meltwater spilled into the crater, distributing sand and gravel over its floor. Meltwater flowed toward a breach in the west wall of the crater (Oppie Dildock Pass), where it disappeared into the lava rock.

By the early 1920's, when the glacier was observed by Campbell (1923, Figure 4C) and Hodge (1925, Figure 55, p. 74), the ice level was considerably lower; but the glacier still terminated against Collier Cone. A terminal moraine now lies on the south side of the cone, but the glacial front has receded far up the mountain (Figure 4).

The glacier continued to shrink, but Ruth Hopson (1960, p. 6) reports that in the summer of 1933 the snout of the glacier extended to the terminal moraine. Returning to the glacier again in September 1934, she discovered a newly formed lake fed by the meltwater. The lake continued to grow, reaching its maximum size in the summers of 1940 and 1941. By 1940 it had reached a level that allowed water at the northwest side of the lake to spill out over the moraine and into White Branch. Hopson reports that water flowing out of the lake in the summers of 1940 and 1941 moved through the rocks without cutting a distinct channel. In the summer of 1942, however, after a winter of heavy snowfall and a hot spell in July, overflow from the lake breached the moraine and cut a channel several feet deep. This event clearly established the lake as the source of White Branch.

Surface flow from the lake, for which Hopson (1962, p. 47) proposed the name Collier Lake, fed White Branch until 1960. Hopson (1961, p. 37, 38) reports that in 1960, although meltwater from the glacier was still flowing into the lake, the lake had shrunk and that ". . . the surface was not high enough to overflow into White Branch." By August 1961 Hopson noted that the level of the lake had dropped far below its former outlet and only a small pond remained. The stream of meltwater no longer entered the lake but flowed to the northeast, where it disappeared into a hole (Figure 5). Hopson believes that ice remaining from the glacier and lying beneath the lake had acted as a seal until "Melting of some of this ice. . . in effect pulled the plug, allowing the water to flow into an unknown aquifer."

With the change in drainage into a subsurface aquifer, White Branch lost its source and ceased to exist. The stream originating at the glacier still flows into the hole, which is located at the base of Collier Cone in the northeastern corner of the basin. Hop-

Figure 3. Collier Cone flow from Obsidian Trail.

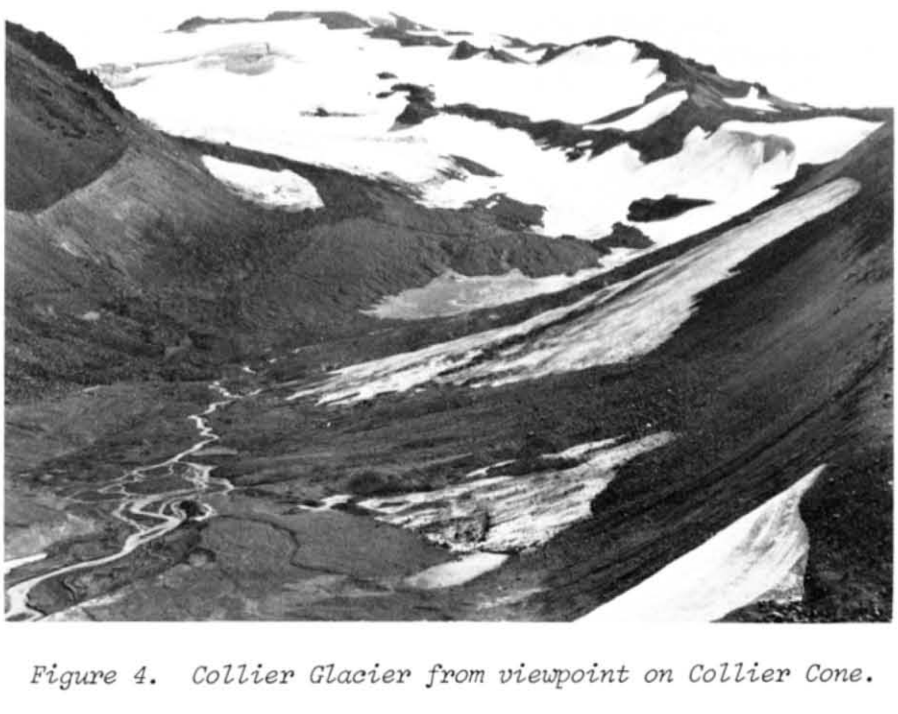


Figure 4. Collier Glacier from viewpoint on Collier Cone.

son (1962, p. 47) proposes the name Little White Branch for this stream because it was never a part of White Branch.

It is not known where the water goes after it enters the Melt-hole (name proposed by Hopson, 1962, p. 47). Although it could move toward the east and emerge somewhere east of the Cascade Range, it probably moves westward through the very porous rock of the Collier Cone flow. The Melt-hole is located west of the Cascade crest, and although no one knows how deep into the subsurface the water goes, if it enters flows that originated at North Sister, it should be directed toward the west because flows from North Sister should have a western component of dip at this locality.

If the water moves through or under the Collier Cone flow, it should not be expected to come to the surface until it reaches Lost Creek Springs because it would move from the Collier Cone flow into the Sims Butte flow in the subsurface where Collier Cone flow overlaps the Sims Butte flow.

The former channels of White Branch (Figure 6) between the moraine and Glacier Creek about 2 miles to the west are now dry except for a short time when the snow is melting. Even then, the volume of water is small. The headwater for the system is now Glacier Creek, a spring-fed stream that originates a short distance east of the Pacific Crest Trail about a mile southwest of Little Brother. This stream flows through the Sunshine Shelter locality and joins the White Branch watercourse a few hundred yards above the Obsidian Trail crossing. Another small unnamed stream joins the channel about 2 miles below the Obsidian Trail crossing. This stream deserves a special note and bears watching, because it is in the process of beheading Obsidian Creek and capturing its flow.

Obsidian Creek originates at Sister Springs, a group of springs emerging from the base of a talus slope on the east edge of the Obsidian Plateau along the Pacific Crest Trail about a mile and a quarter southwest of Little Brother. A short distance below its source, Obsidian Creek plunges off the Obsidian Plateau at Obsidian Falls and flows out onto a gently sloping meadow area. About a quarter of a mile below the falls, the stream divides; about half the water continues on in Obsidian Creek and the other half goes into the unnamed creek (Figure 7).

Conditions at the place where the water divides are not stable; in time all the water will flow into the unnamed creek. The capture might have been completed before now if it were not for a row of stones that helps keep water flowing into Obsidian Creek. From their alignment it appears that the stones were placed there by man.

A short distance below its beginning at the Collier Glacier moraine, the bed of White Branch comes against the Collier Cone flow and follows its south edge to a place south of Sims Butte.

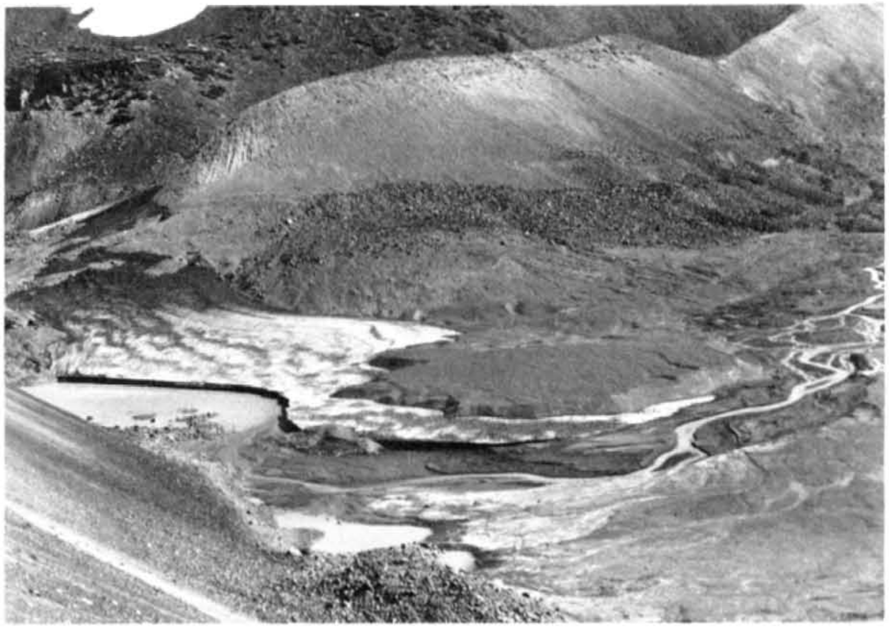
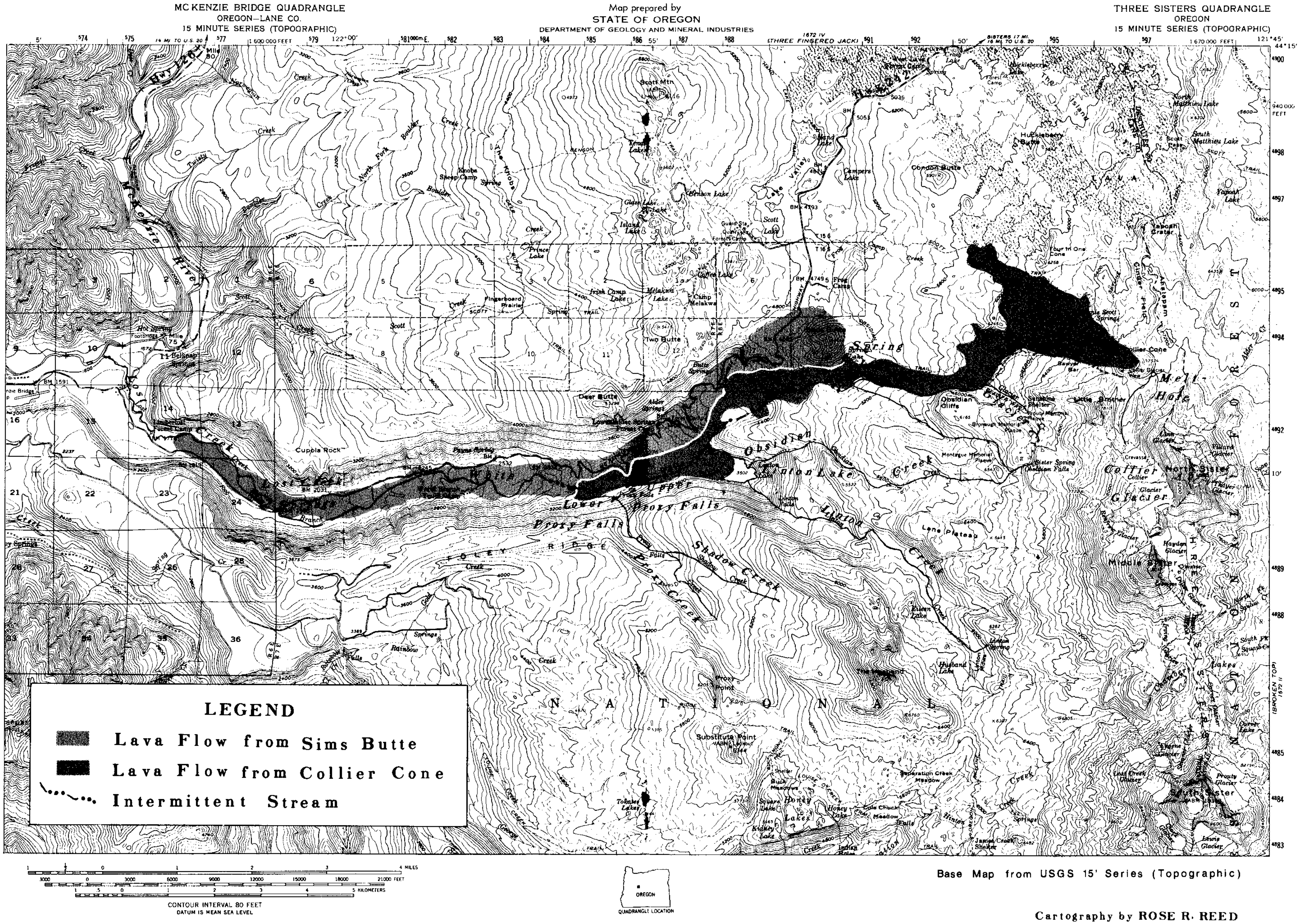


Figure 5. Hole where Collier Glacier meltwater disappears.

Figure 6. Dry White Branch channels at Sawyer Bar viewed from Pacific Crest Trail.



MAP OF LOST CREEK GLACIAL TROUGH, LANE COUNTY, OREGON

Figure 7. Place of capture of Obsidian Creek by an unnamed Creek.

Figure 8. Spring Lake viewed from its south end.

Along much of the way the stream has cut into the sides of the flow and in places through small lobes of the flow. Because the stream bed along this stretch is on older and denser rock, there is little or no loss of water to the subsurface. South of Sims Butte, however, the stream channel moves onto the surface of the flow, where it remains to the end of the flow below Proxy Falls.

Because of the high porosity of the Collier Cone flow, and except for periods when there is a large volume of water from rapid melting of snow, all water is lost to the subsurface within a short distance of the place where the channel comes onto the lava flow. Through most of the year, and in some years all year long, a 4-mile stretch of the stream bed is dry. From the small size of the channel at the trail to Linton Lake and at the trail to Proxy Falls, one would judge that during the time White Branch existed, even at the peak of runoff, only a small volume of water flowed along this part of the watercourse.

Neither Spring Lake nor Linton Lake, both of which are impounded by the Collier Cone flow, has a surface outlet, even though a large volume of water enters Linton Lake through Obsidian and Linton Creeks. Instead, drainage from these lakes is directly into the lava flow.

Spring Lake (Figure 8) is a small lake, a few hundred yards long and about half as wide, located at the base of Sims Butte on its southeast side. It occupies a basin formed where the lava flow dammed a small stream valley and is fed by a number of springs and a small creek. It is accessible by an easy trail that branches off the Obsidian Trail.

Linton Lake is much larger, measuring about half a mile in its longest dimension. It lies a little more than a mile southeast of Alder Springs Forest Camp and is accessible by an easy trail that begins at Lower Alder Springs picnic area. Linton Lake was formed when the lava flow dammed the water of Obsidian and Linton Creeks. The configuration of the terrain around the lake, with the steep valley walls and amphitheater-like form, suggests, however, that the lake does not occupy a stream valley but instead occupies a cirque at the head of a glacial trough.

Two of the most beautiful features of this remarkable drainage system are the Proxy Falls. After a half-mile hike along an easy trail, the visitor's efforts are well rewarded by the sight of white water tumbling down the steep valley wall. There are two main falls, named Upper Proxy Falls (Figure 9) and Lower Proxy Falls (Figure 10), and a number of smaller ones that are so small or secluded that they escape the attention of most visitors. The two main falls are different, both in form and in origin.

Water for Upper Proxy Falls originates in a large group of small springs that emerge from moss-covered lava flows about 600 feet above the valley floor and collects in one of two ravines.

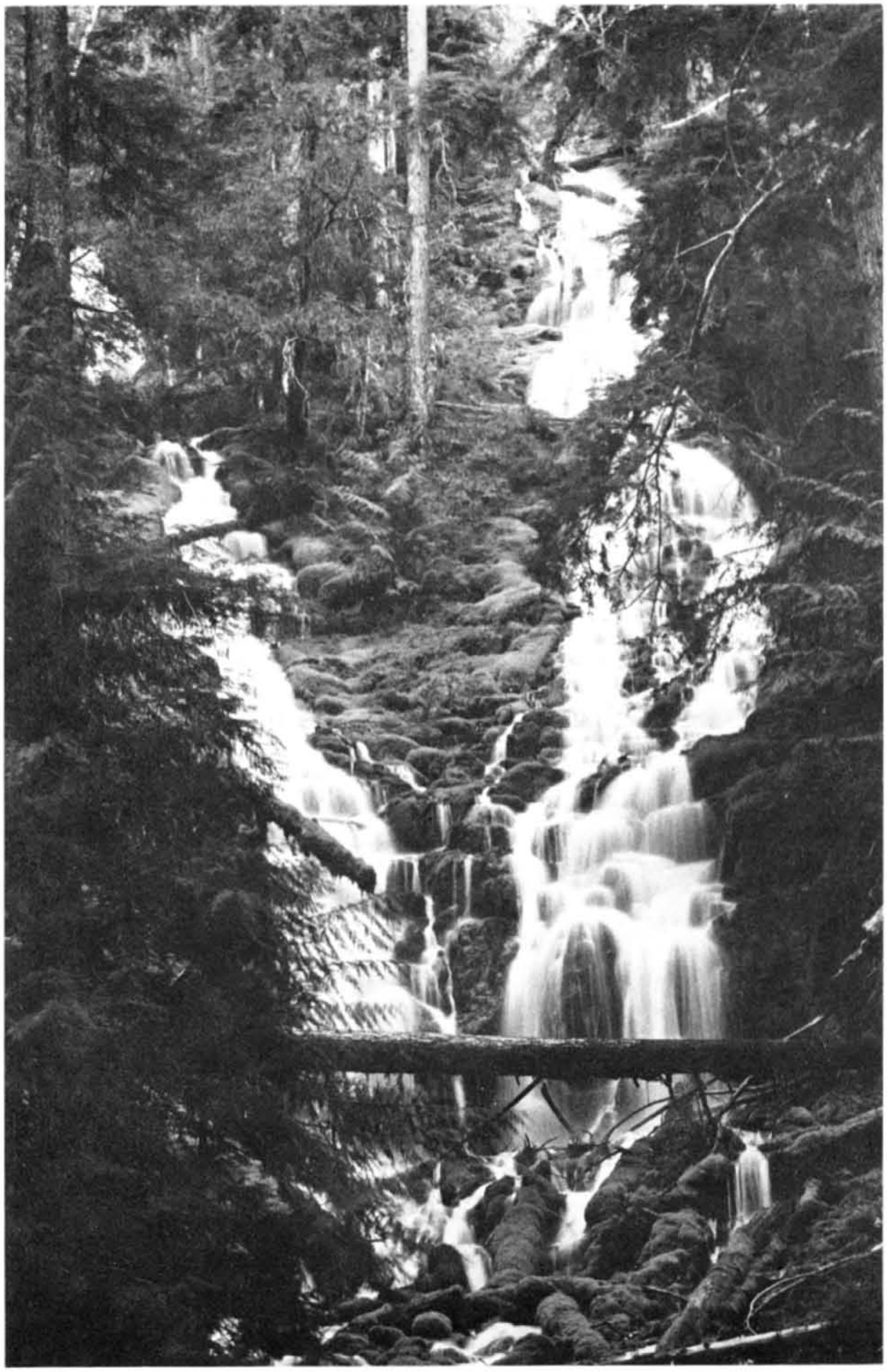


Figure 9. Upper Proxy Falls (Ore. Hwy. Div. photo).

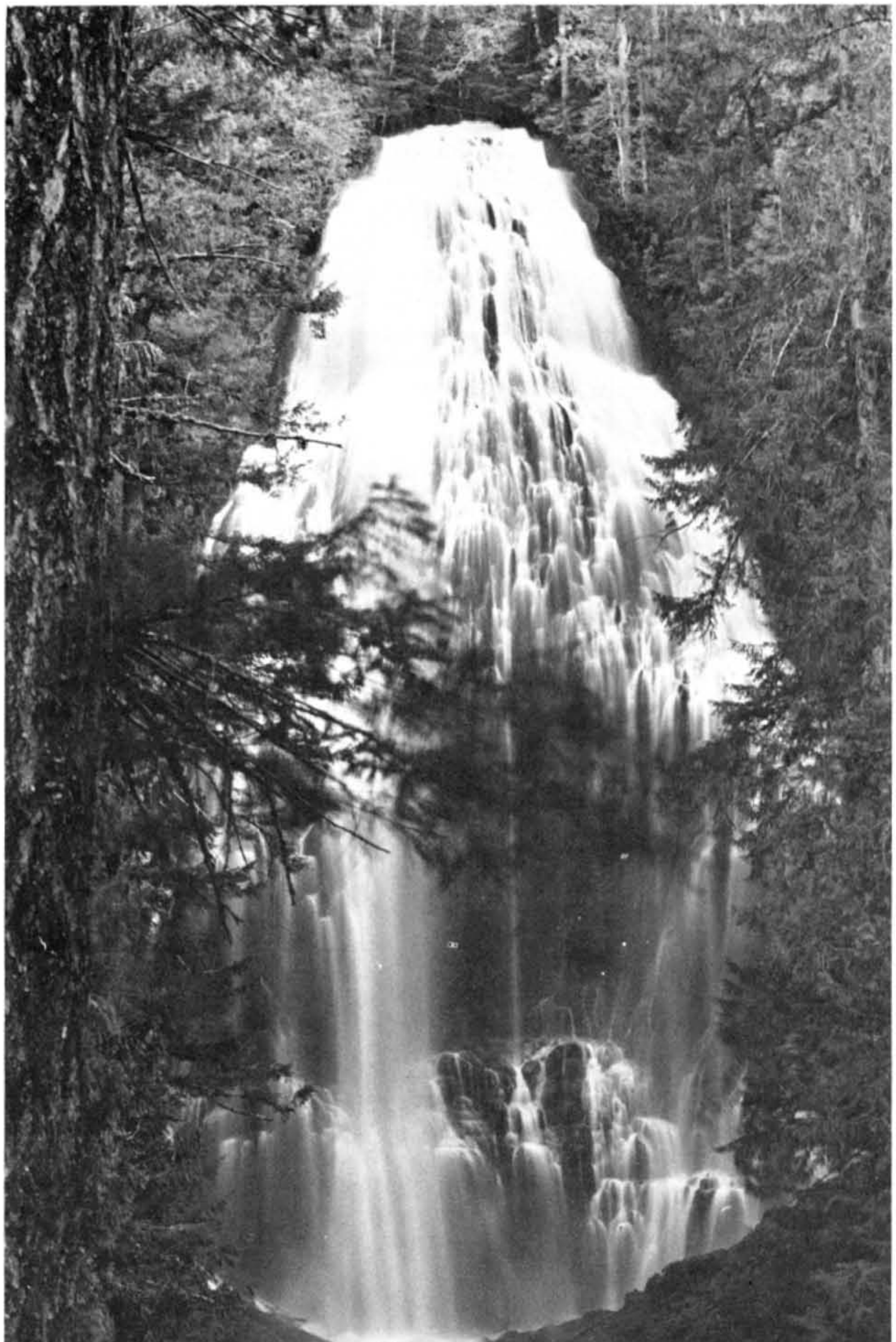


Figure 10. Lower Proxy Falls (Ore. Hwy. Div. photo).

The stream in each ravine flows over the steep slope between borders of moss-covered rock, and the two streams join in the lower part of Upper Proxy Falls, which is actually two falls that come together as one. At the bottom, the water flows into a nearly circular basin (Figure 11) from which there is no surface outlet. Without noticeable eddy motion or an apparent opening in the bottom of the basin, the water percolates into the lava flow and enters the subsurface drainage system.

Some of the water from the springs does not enter either of the ravines that supply water to Upper Proxy Falls but instead comes down over the valley wall in miniature versions of the larger falls. Several of these small waterfalls lie between Upper Proxy and Lower Proxy Falls; others are east of Upper Proxy Falls. Water from some of these small falls flows along the ravine that lies between the Collier Cone flow and the valley wall and enters the pool at the base of Upper Proxy Falls.

The water for Lower Proxy Falls comes from Proxy Creek and its tributary Shadow Creek, which flow out of the mountain area southeast of the falls. Proxy Creek enters the glacial trough through a hanging valley left perched high above the valley floor when the glacier disappeared. In the last 200 feet of its trip toward the valley floor, the stream rushes over a steep, bulging rock surface and then plunges into free fall near the bottom.

Below the falls Proxy Creek follows the ravine between the Collier Cone flow and the valley wall until it reaches the end of the flow. Below that, the stream takes a crooked course, primarily over the Sims Butte flow. Some water is lost to the Sims Butte flow, but generally there is enough water to sustain a surface stream to the junction with Lost Creek. During years when the runoff is low, however, much of the channel below Lower Proxy Falls goes dry. Most of the numerous small streams that originate at springs along the valley walls below Proxy Falls disappear into the lava flow, supplying little water to the creek.

Because White Branch no longer exists, the stream below Lower Proxy Falls, which is still called White Branch, is misnamed. It is questionable whether this name was ever appropriate. Even when there was a White Branch, it supplied water to this part of the watercourse only intermittently, and then in small amounts. Instead, Proxy Creek has supported permanent flow along this part of the channel and, since 1960, has been practically the only stream supplying water to it. However, a large spring about a quarter of a mile below the "White Branch" bridge also feeds water into the channel.

Water from Glacier Creek, the unnamed tributary, Spring and Linton Lakes, Upper Proxy Falls, Proxy Creek, and the many small spring-fed streams along the valley enters the subterranean passages of the lava flows and reappears in many springs that supply water to Lost Creek. Most of the springs are clustered in an area

Figure 11. Basin at base of Upper Proxy Falls.

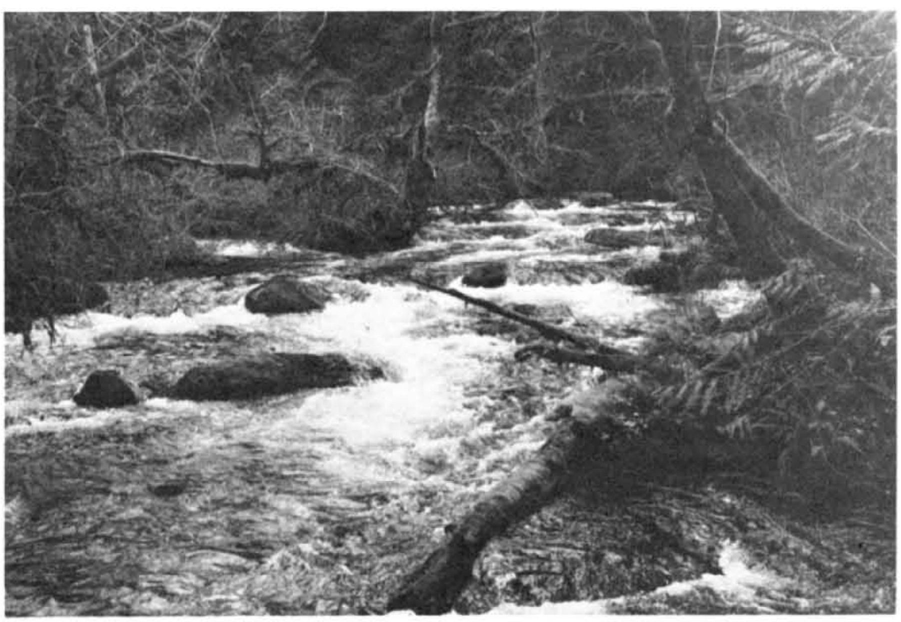


Figure 12. Cascades in Lost Creek near its confluence with the McKenzie River.

about 2 miles above the lower end of the Sims Butte flow and a short distance north of the "White Branch" bridge. The springs in this area form three main groups, each with a pond, and water from the three ponds flows into a larger pond that empties into Lost Creek. Lost Creek is joined by "White Branch" a little more than half a mile below the pond, and the resulting stream, retaining the name Lost Creek, follows a channel along the north edge of the lava flow to its end. Numerous springs emerge from the lava flow along the channel.

Below the Sims Butte flow, the lower 2 miles of Lost Creek's course lie over glacial drift. In its last half mile, Lost Creek plunges and cascades along its channel through a forested glen (Figure 12) and then joins the McKenzie River.

Acknowledgment

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THE AGE OF LAVA BUTTE

Lawrence A. Chitwood*, Robert A. Jensen**, and Edward A. Groh***

Lava Butte and its jagged black fields of lava, located 10 mi (16 km) south of Bend along U.S. Highway 97, have been major scenic and geologic attractions since at least 1900 (Figure 1). Public interest in the natural history of Lava Butte and the vast volcanic and glacial panorama seen from its summit led the U.S. Forest Service to construct Lava Lands Visitors Center near the base of the butte. Dedicated in September 1975, the center hosted 163,000 visitors in 1976.

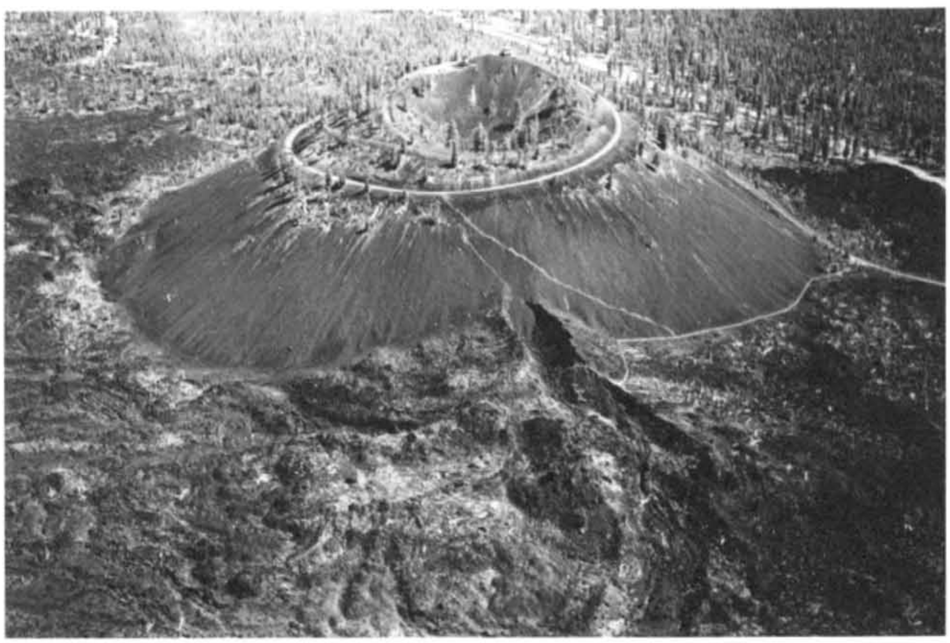

Figure 1. Lava Butte, a 500-foot-high (152 m) cinder cone.

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The 500-ft-high (152 m) butte is actually a classic basaltic cinder cone. A paved road spirals to the top, where, from the rim of the deep crater, much of the 9.5 sq mi (25 km^2) of rugged lava that poured from the south flank of the cinder cone can be seen. Trails leading from the Lava Lands Visitors Center below pass over the fresh-looking, clinkery, basaltic lava. A small observation center that for many years served as an interpretive center at the top is capped by a U.S. Forest Service fire lookout.

Lava Butte and its associated lava flows and plume deposit erupted from the northwest end of the Northwest Rift Zone, a narrow zone of discontinuous faults and deep fractures that cut the northwest flank of the 500-sq-mi (1,300 km^2) Newberry Volcano (Figure 2). Numerous other recent lava flows and cinder cones also erupted from these fractures (Peterson and Groh, 1969).

For decades Lava Butte has hidden its age from both visitors to the area and geologists. The nearly barren surface of the lava appears starkly younger than other volcanic features nearby, even to the casual observer. Indeed, some visitors wonder if the rocks are still hot. Adventuresome people at the turn of the century may have been enticed to visit Lava Butte by this early description: "The whole surface of the lava beds looks as if the fire were smouldering beneath, and one can scarcely content one's self to remain alone in the solitude of this ruin" (An Illustrated History of Central Oregon, 1905). While the impression of a semi-demonic "ruin" lingers in the minds of many who visit Lava Butte even today, a less fearful but more provocative history lies hidden in these rocks.

Israel Russell was the first geologist to estimate a minimum age of Lava Butte; in 1905 he wrote, "The presence of pines on Lava Butte, and the occurrence of both living and dead trees on the lava flow that escaped from it, furnish evidence that the activity of the volcano ceased at least a hundred and probably more than a hundred and fifty years ago."

Howel Williams wrote in 1957, "The youngest of these [cinder cones and lava flows] are almost surely less than 1,000 years old; among them are the flows that poured from Lava Butte. . . . and those that poured through forests on the northwest flank of Newberry Volcano . . . ."

The first radiocarbon age (Lava Cast Forest Flow, 6,150±120 years B.P.[1]) of the very young-looking lava that poured from the Northwest Rift Zone astonished geologists so much that they asked the laboratory that had determined the date to check its figures. Peterson and Groh (1969) wrote, "We were rather surprised to find that such fresh-looking rocks were this old, but several other radiocarbon dates obtained later confirmed this age."

The surface of the lava from Lava Butte appears fresher than nearly all other nearby recent flows along the Northwest Rift Zone.

[1]Before present.

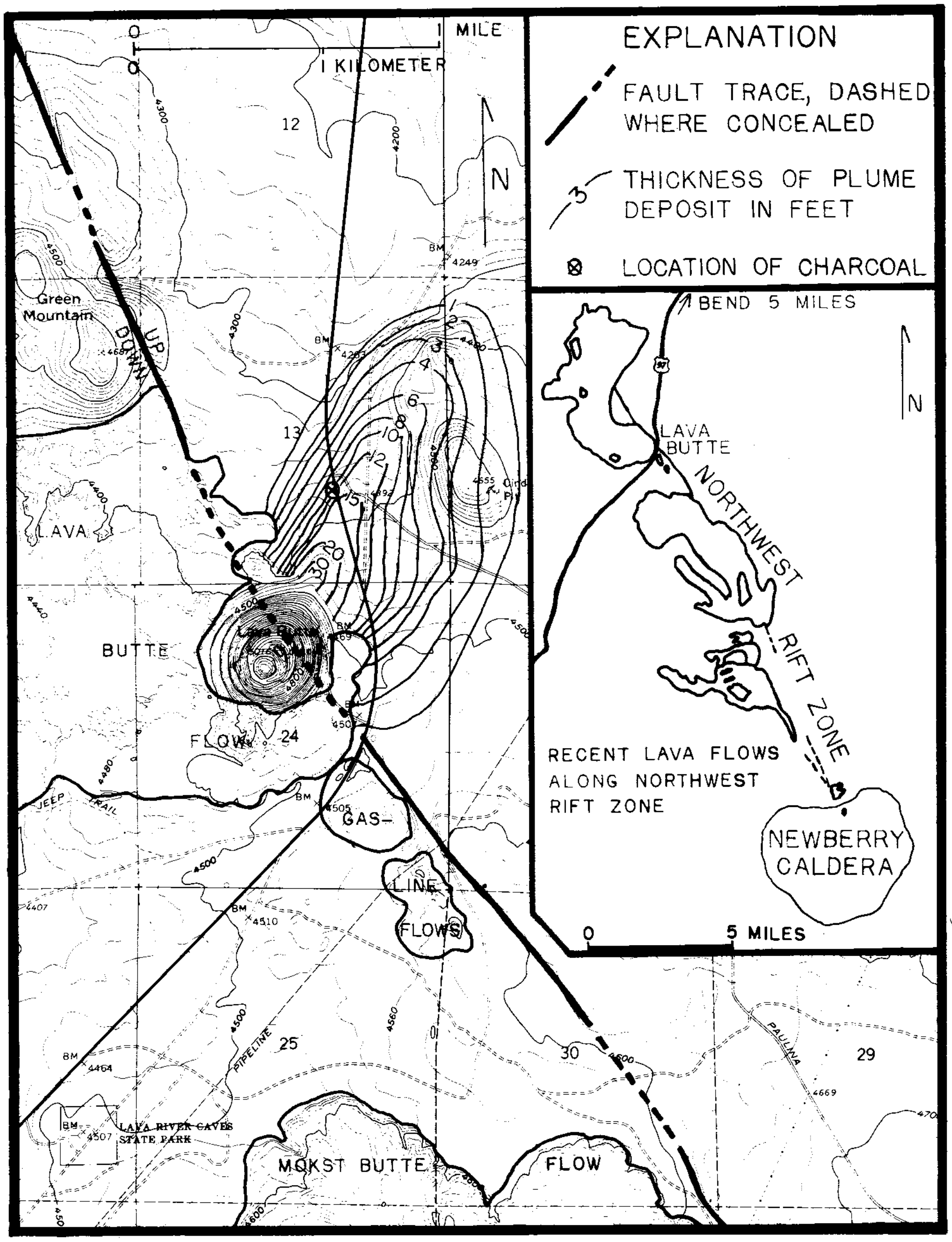

Figure 2. Lava Butte and several other young cinder cones and lava flows that were formed at different times by eruptions along the Northwest Rift Zone. During the eruption that formed Lava Butte, three types of volcanic deposits were created: a cinder cone, formed when cinders fell out of cinder-filled eruption clouds into a great pile to form Lava Butte; a plume deposit, formed when a southwest wind blew smaller cinders to the northeast; and lava flows.

Although all of those that have been dated have radiocarbon ages of about 6,000 years B.P., for a decade Lava Butte has been thought to be only about 2,000 years old because of its fresh-appearing lava.

Lava Butte is known to be younger than the Gas-Line Flows (Figure 2), named for a nearby natural-gas pipeline, because volcanic ash from the eruption that built Lava Butte lies on these flows. The radiocarbon age of the Gas-Line Flows is 6,150±65 years B.P. (USGS-80)[2]. This date supersedes the date reported by Peterson and Groh (1969).

During the last few months, 14 geologists who are familiar with Lava Butte and its geological setting were informally polled for their opinions on its age. Estimates ranged from 1,800 to 5,650 years, and the average of all the age estimates was 4,060 years.

Until recently, the search for wood suitable for radiocarbon dating has been discouraging. In this environment, wood must be carbonized[3] to be preserved; otherwise, bacterial action or rodent activity will destroy it over a long period of time. Lava molds of splintered trees have occasionally been found along the edges of lava flows, but none have contained carbonized wood. Presumably the first lava flows invaded a forest and toppled, buried, or burned virtually every tree they encountered. Then, to make the search even more difficult, additional lava flowed over some of the first flows.

Fortunately, during the eruption that formed Lava Butte, a southwest wind winnowed[4] small-sized ejecta from cinder-filled eruption clouds and carried them northeastward, forming a plume. Small cinders (lapilli) and volcanic ash rained from this plume and fell to earth, forming an ash-plume deposit (Figure 2) that extends northeastward from the base of Lava Butte for about 1 mi (1.6 km) and covers an area of at least 0.7 sq mi (1.8 km^2). The approximate bulk volumes and proportions of each of the three volcanic deposits formed by the Lava Butte eruption are (1) the plume deposit, 130 million cu ft (3.7 million cu m), 1 percent; (2) the cinder cone, 1 billion cu ft (30 million cu m), 9 percent; and (3) the lava flows, 10 billion cu ft (300 million cu m), 90 percent.

Groh suggested that the ash-plume deposit might be the best place to find carbonized wood because the ash and cinders might have retained enough heat when they fell to earth to carbonize roots growing in the ground. We therefore dug 50 holes with hand shovels to search for wood and also to determine the shape and thickness of the deposit.

[2]Sample reference number used by the Branch of Isotope Geology, U.S. Geological Survey, Menlo Park, California.

[3]Reduced to carbon by being subjected to intense heat in an enclosed space.

[4]Selectively removed fine particles by wind action, leaving the coarser material behind.

Figure 3. Location along U.S. Highway 97 north of Lava Butte (in background) where carbonized roots used to determine the age of Lava Butte were found about 2 ft (0.6 m) below the level of the road.

Carbonized wood was finally found in August 1976 within the Mazama pumice that underlies the cindery plume deposit (Figures 3 and 4).

The carbonized wood appeared to be from small roots a few millimeters in diameter that had been carbonized by residual heat from the plume deposit. The Mazama pumice is 21 in thick (53 cm), but the carbonized roots within it were found only in the upper 6 in (15 cm). The pumice blanketed much of the Pacific Northwest 6,600 years ago during extraordinarily violent eruptions of Mount Mazama, which now holds Crater Lake (Williams, 1942; Wilcox, 1965).

The radiocarbon age of the carbonized wood, and thus Lava Butte and its associated lava fields and plume deposit, is 6,160±65 years B.P. (USGS-107), as determined by Steve W. Robinson, Branch of Isotope Geology, U.S. Geological Survey, Menlo Park, California. Duane Champion, U.S. Geological Survey, who is currently doing a paleomagnetic study of the recent cinder cones and lava flows along the Northwest Rift Zone, arranged for the age determination; and again many geologists are somewhat surprised that such young-looking lava is so old.

The age of Lava Butte is significant because ages of all dated recent eruptions from the Northwest Rift Zone, including that of Lava Butte, are apparently grouped over a short period of a few hundred years. All radiocarbon ages so far lie between 5,800±100 and 6,380±130 years B.P. (Peterson and Groh, 1969).

While Lava Butte is known to be the same age as or younger than the Gas-Line Flows, the appearance of a slight radiocarbon age discrepancy between them is probably of no consequence. The eruptive period along the rift may be even shorter than the radiocarbon dates indicate. The age of recent lava flows or cinder cones is determined by measuring the radioactive carbon-14 content of wood that was carbonized by heat at the time of an eruption (Libby, 1965; Sheppard, 1975). The radioactive carbon-14 available to a growing tree from atmospheric carbon dioxide becomes fixed in the wood of the tree, and half of the carbon-14 decays (changes) to nitrogen-14 in 5,730 years. That is, if only half the amount of carbon-14 normally found in the atmosphere is found in the wood of a tree being tested by the carbon-14 method, the age of the tree is 5,730 years. But the sample of carbonized wood to be used for dating should be taken from the youngest (outer) growth rings if it is to yield an age close to that of the eruption. If older wood is mixed with younger wood, the age that is determined for the wood will be greater than the length of time since the eruption. Therefore, the apparent spread of ages along the Northwest Rift Zone may be the result of this type of sampling error.

Existing evidence thus suggests that the short period of eruptive activity that produced Lava Butte was the final event along the full length of the Northwest Rift Zone. Any future

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64.	MINERAL AND WATER RESOURCES OF OREGON, 1969. [Detailed outline of geology, mineral resources, water resources, and water resources devel. 462 p., 102 figs. and maps, 57 tables.]	$ 3.00_____
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0-76-2 GEOTHERMAL GRADIENT DATA, BROTHERS FAULT ZONE, CENTRAL OREGON, 1975, Hull, Bowen, Blackwell, and Peterson. $ 2.00_____
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[Charts and computer printouts of geothermal gradient data collected by the Department 1975-76. 133 p., with locality map.]

O-77-3 HEAT FLOW STUDY OF THE BROTHERS FAULT ZONE, OREGON, 1977, Hull, Blackwell, Bowen, and Peterson. $ 3.00_____
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[56 p. with map in pocket.]

USGS Map I-902 GEOLOGIC MAP OF OREGON EAST OF THE 121ST MERIDIAN, 1977, G.W. Walker. $ 3.75_____
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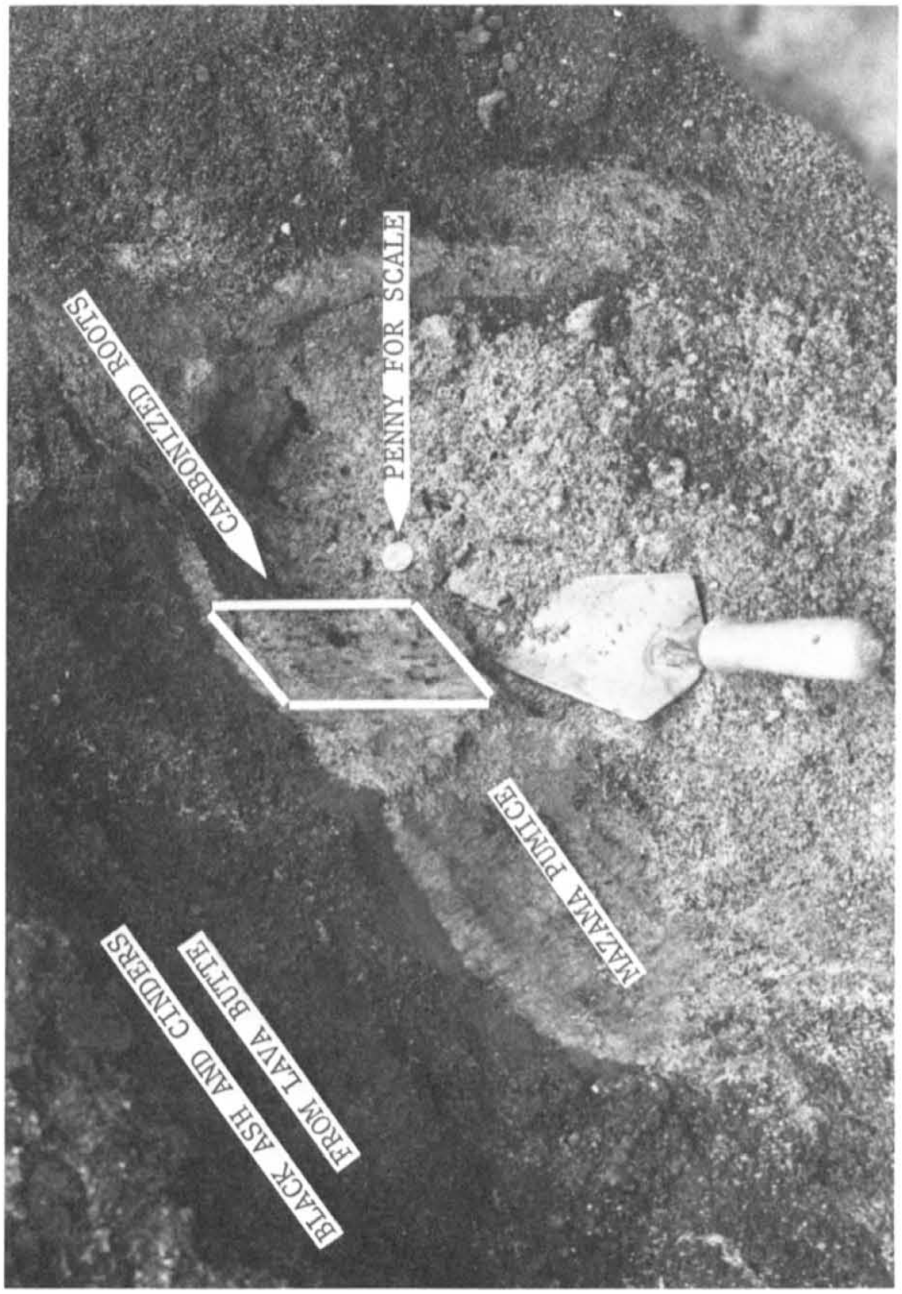

Figure 4. The small black spots above the gardener's trowel are carbonized roots from plants buried 6,160±65 years ago. The roots were found in the top 0 to 6 in (0 to 15 cm) of the 6,600-year-old cream-colored Mazama pumice which underlies the black ash and small cinders of the Lava Butte plume deposit.

volcanism in this part of Oregon would probably follow a similar pattern of multiple events in a relatively short period of time.

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__________, 1957, Reconnaissance geologic map of the central portion of the High Cascade mountains: Oregon Dept. Geol. and Mineral Indus.

EDWARD A. GROH

Ed Groh, co-author of this month's feature article and longtime friend of the Department, died September 15, 1977. His main geologic interest was the volcanic history of Oregon, primarily Holocene volcanic landforms around Bend; and he cooperated with Department geologists in writing Bulletins 57 and 89 as well as numerous Ore Bin articles on volcanic features such as Hole-in-the-Ground, Diamond Craters, Cove Palisades, Crack-in-the-Ground, Newberry Volcano, and Metolius Springs. Recently he had been working in the development of Oregon's geothermal potential and had been consulting in the Newberry Volcano area.


Edward A. Groh

Although never a member of the Department's staff, he had contributed much to the Department's publications. His presence and work will be missed, both by geologists who worked with him personally and by readers who learned about Oregon's volcanic history through his articles.

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COLOR GEOLOGIC MAP OF EASTERN OREGON IS HERE

The U.S. Geological Survey has released its Map I-902, "Geologic Map of Oregon East of the 121st Meridian," a 42x44-inch map of Oregon east of the Cascade Range. The map is lithographed in seven colors and is on a scale of 1:500,000 (1 inch equals about 8 miles).

In addition to serving as an educational tool and giving an overview of part of the State's geology, the map should provide a useful framework for future environmental and geologic studies. The region is currently being explored by industry and federal and state agencies to determine its potential for development of geothermal energy and selected mineral resources, notably uranium and zeolites.

George G. Walker, geologist with the USGS Menlo Park, California, research center, prepared the map as a companion to Map I-325, "Geologic Map of Oregon West of the 121st Meridian," which covers the remainder of Oregon on the same scale.

Copies of both maps are now available from the Department's Portland, Baker, and Grants Pass offices. To order either of the maps by mail, see centerfold, page iii, for Map I-902 and the inside back cover for Map I-325.

* * * * *

MINING ASSOCIATION TO MEET IN SPOKANE

Theme of the Northwest Mining Association 83rd Annual Convention, which meets December 2 and 3 at the Davenport Hotel in Spokane, Washington, is "Mining at the Crossroads." The convention will focus on the effects of government policy on the industry, looming energy shortages, new exploration techniques, changes in commodity markets, and changes in mineral industry education. A short course will precede the convention.

Registration materials for the convention may be obtained from Northwest Mining Association, West 1020 Riverside Avenue, Spokane, Wash. 99201. (Telephone: 509-624-1158).

* * * * *

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SCHWABE APPOINTED TO GOVERNING BOARD

John L. Schwabe, a Portland attorney, has been appointed by Governor Robert W. Straub to serve a four-year term as a member of the Department's Governing Board. Schwabe is a senior partner in the Portland law firm of Souther, Spaulding, Kensey, Williamson, and Schwabe.

* * * * *

DeWEESE RETIRES FROM GOVERNING BOARD

R.W. "Bill" deWeese, Portland businessman, has retired from the Department's Governing Board after serving the two-term maximum. DeWeese was appointed by the then governor, Tom McCall, in April 1969. He owns and operates Odyssey Productions, Inc., a commercial film-making organization. DeWeese has devoted much time and effort while serving on the Board, acting as its chairman for the last five years.

DeWeese's many other public services have included memberships in the Oregon Office of Emergency Planning, the Portland Chamber of Commerce, and Portland Public School District No. 1, often in the role of chairman or director. He has been a director on the boards of over half a dozen industrial or commercial organizations located in the State, as well as National Director of the Association Internationale des Étudients en Sciences Économiques et Commerciales.

* * * * *

STAFF GEOLOGIST HONORED

Herbert G. Schlicker, an engineering geologist for the Department, has been awarded a Certificate of Appreciation by the Association of Engineering Geologists. The award stems from Schlicker's participation on the A.E.G. Geologic Hazards Committee study of the seismic susceptibility of the Auburn Dam on the American River, California. The Committee became concerned over the methodology used in calculating probable earthquake damage to the concrete, thin-arch, 685-foot-high structure.

Because the August 1975 Oroville earthquake, which occurred only 50 miles from the dam site, developed a horizontal acceleration of 0.12 g, committee members believed that the Auburn Dam design should be based on acceleration values greater than this to ensure an acceptable margin of safety. As a direct result of the A.E.G. committee's concern, the U.S. Bureau of Reclamation ordered a restudy of the dam's design, even though construction had already begun.

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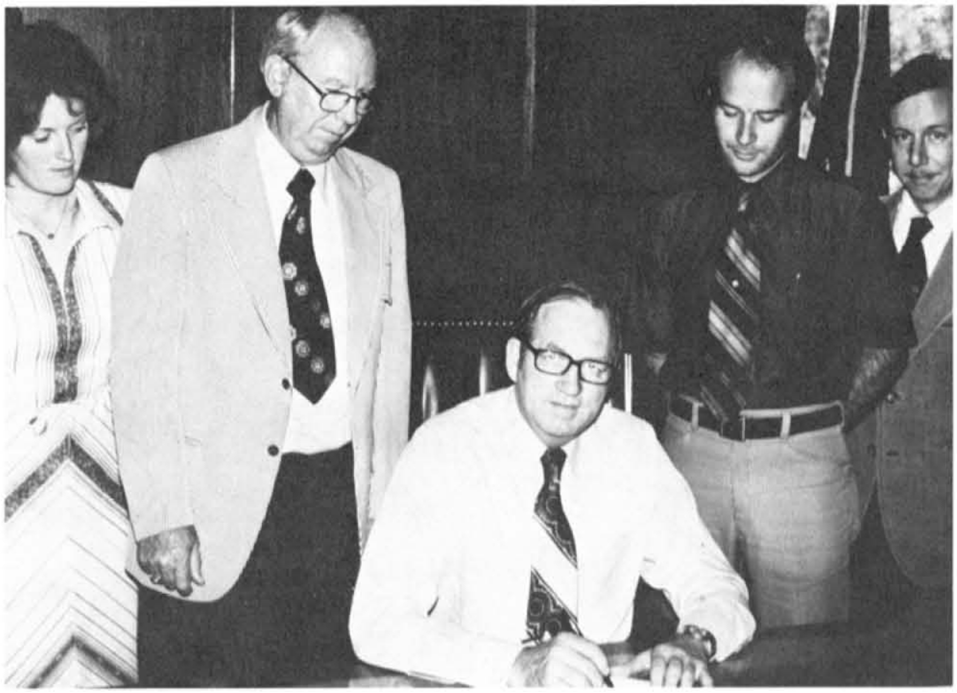

GOVERNOR SIGNS GEOLOGIST REGISTRATION BILL

On July 21, 1977, Governor Bob Straub signed the Geologist Registration Bill (HB 2288). Shown here witnessing the event are geologists Mavis Kent, Herbert Schlicker, John Beaulieu, and Rick Kent, all of whom campaigned long and hard for passage of the bill. This photograph was taken by Senator Walt Brown, who also took a personal interest in the bill.

The registration bill becomes law in October and will be administered by the State Department of Commerce, 428 Labor and Industries Building, Salem, Oregon 97310. After the State Board of Geologist Examiners has been appointed, application forms will become available to geologists. The cost of registration will be dependent upon the number of registrants, so it is recommended that each geologist intending to register write immediately to the Department of Commerce and indicate his intention to register.

The registration act contains an engineering geologist specialty, and the Board will entertain requests for additional specialties. A "grandfather" clause will be in effect for one year. Registration may also be by reciprocity.

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BEACH PROFILES OBTAINED WITH AN AMPHIBIOUS DUKW ON THE OREGON AND WASHINGTON COASTS

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Introduction

During 1945 and 1946, a series of U.S. Navy-sponsored studies were conducted on Washington, Oregon, and California beaches. The overall purpose was to develop scientific means for determining beach morphology and characteristics of nearshore waves and currents that would make it difficult for landing craft to approach enemy-held beaches. The project was directed by M.P. O'Brien, Dean of Engineering, University of California, Berkeley, and included other illustrious names such as Willard Bascom, John Isaacs, J.W. Johnson, and Robert Weigel.

Results of the investigations are contained in a series of reports on file in the Water Resources Center Archives, University of California, Berkeley. Titles of some of the more scientifically interesting reports concerning Oregon-Washington beaches are included in the list of references following this paper. The atlases by Johnson and Bascom (1950) and Bascom (1950) contain many ground and aerial photographs that form a valuable source for considerations of long-term coastal changes. Other data, such as the depths of tire impressions left by the DUKW (pronounced "duck") on beaches, are specific to aiding amphibious landings and are of lesser scientific concern.

Of particular interest are beach profiles collected at 15 Washington and Oregon locations during the investigations. These profiles were obtained by using a DUKW (Figure 1), a six-wheeled amphibious vehicle that is 32 ft long and 8 ft wide, whose capabilities made it possible for beach-profile determinations to be made through the entire surf zone to beyond the breakers. Because of high surf conditions prevailing off the coasts of Oregon and Washington, subsequent attempts at obtaining beach profiles have been limited to the inner surf zone. Therefore, the University of California beach profiles are the only profiles available that show the entire offshore bar and trough system. These bars and troughs and their changes are important to an understanding of beach processes and erosion on the Oregon-

Washington coasts. A knowledge of the morphology of this zone is also required for the construction of sewage and industrial waste outfalls (pipes that must extend through the nearshore without being excavated by wave erosion).

Most of the beach profiles obtained by the University of California investigations in Oregon and Washington are included in the reports by Isaacs (1947) and Bascom and McAdam (1947). The purposes of this paper are to summarize and discuss the profiles obtained and to increase the availibility of typical and interesting examples.

Profiling Techniques

The general methods of obtaining the beach profiles are discussed by Isaacs (1947) and Bascom and McAdam (1947). Bascom (1964, p. 173-183) also discusses these techniques and, in addition, describes the excitement of taking a DUKW through the surf.

The general procedure was to obtain the profile above the low-tide water line with a stadia rod and transit. During the following high tide, lead-and-line soundings were taken from the DUKW, starting about 4,000 ft from shore and extending through the breaker zone. The old lead-and-line method was used because echo sounders would not work amid the bubbles and turbulence of the surf zone.

The location of each sounding was determined by turning the interior angle from a point on the base line as the DUKW approached shore on a range (Figure 2). At frequent intervals, the leadsman in the DUKW called "Mark" into a radio transmitter and heaved the lead-weighted sounding line into water off the bow. As the DUKW passed the lead, the leadsman held the line vertical and read the depth of water beneath the wave trough. Upon hearing "Mark" via the radio, the transit man, who was following the progress of the DUKW with a telescope, read the angle. His assistant recorded the angle and the water depth, which had also been called out over the radio by the leadsman. In this way, the depths at a series of points along the range line were determined, establishing the overall beach profile.

In most cases, sand samples were obtained along the profile lengths, from the offshore sections as well as from postions of the profile which were exposed above the low-tide line. Offshore samples were collected by dragging a bucket along the bottom from the DUKW. Examples of grain-size distribution analyses of these sand samples can be found in Isaacs (1947) and Bascom and McAdam (1947).

High surf made DUKW operations difficult and hazardous. Bascom (1964, p. 178) relates that on one occasion a breaker heaved a DUKW onto its side on the beach face, wheels pointing out to sea. Fortunately, the next wave set it back on its wheels with-

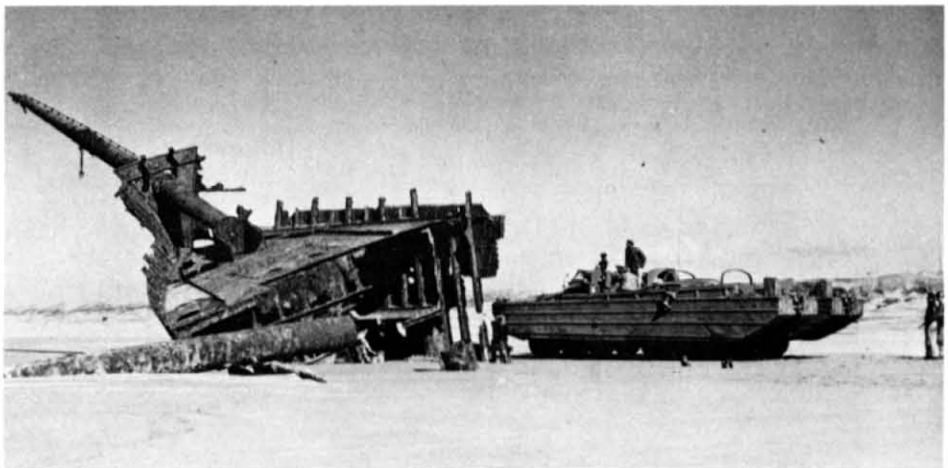

Figure 1. A DUKW, used in beach surveys, next to the wreck of the Peter Iredale, Clatsop Beach, south of the mouth of the Columbia River (18 September 1945).

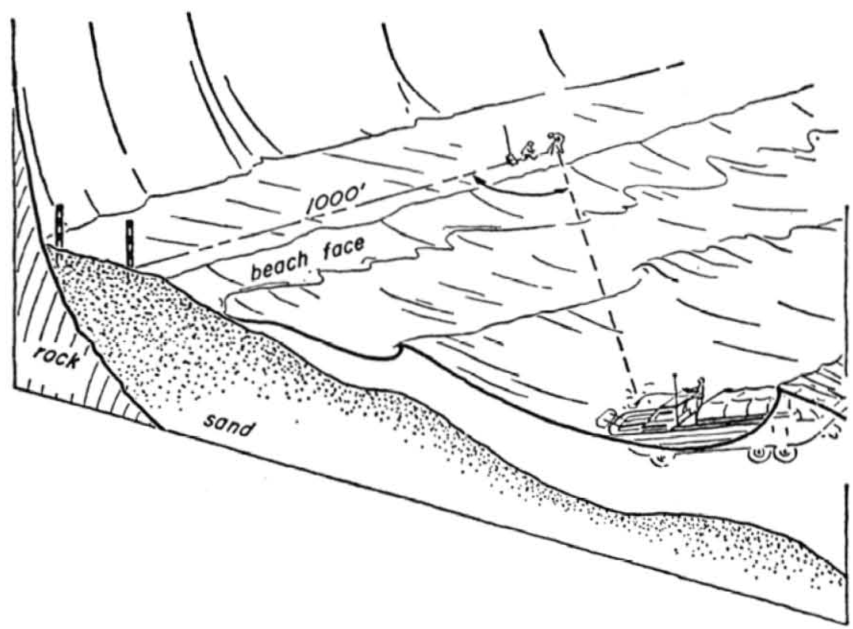

Figure 2. Sketch showing survey techniques used in determination of beach profiles. The DUKW is run shoreward along range defined by two poles on beach, and its position is determined by triangulation from transit located 1,000 ft along beach (from Bascom, 1964).

out damage. Altogether, three DUKW's were lost during the course of the study, two in the surf, and a third that rolled off a mountain cliff in Oregon and plunged 200 ft into the sea. Somehow, no one was ever seriously injured.

Locations of Profiles

Beach profiles were obtained from nine locations on the Washington coast and from six on the Oregon coast. Locations are identified in Figure 3, and data from the sites are summarized in Tables 1 and 2.

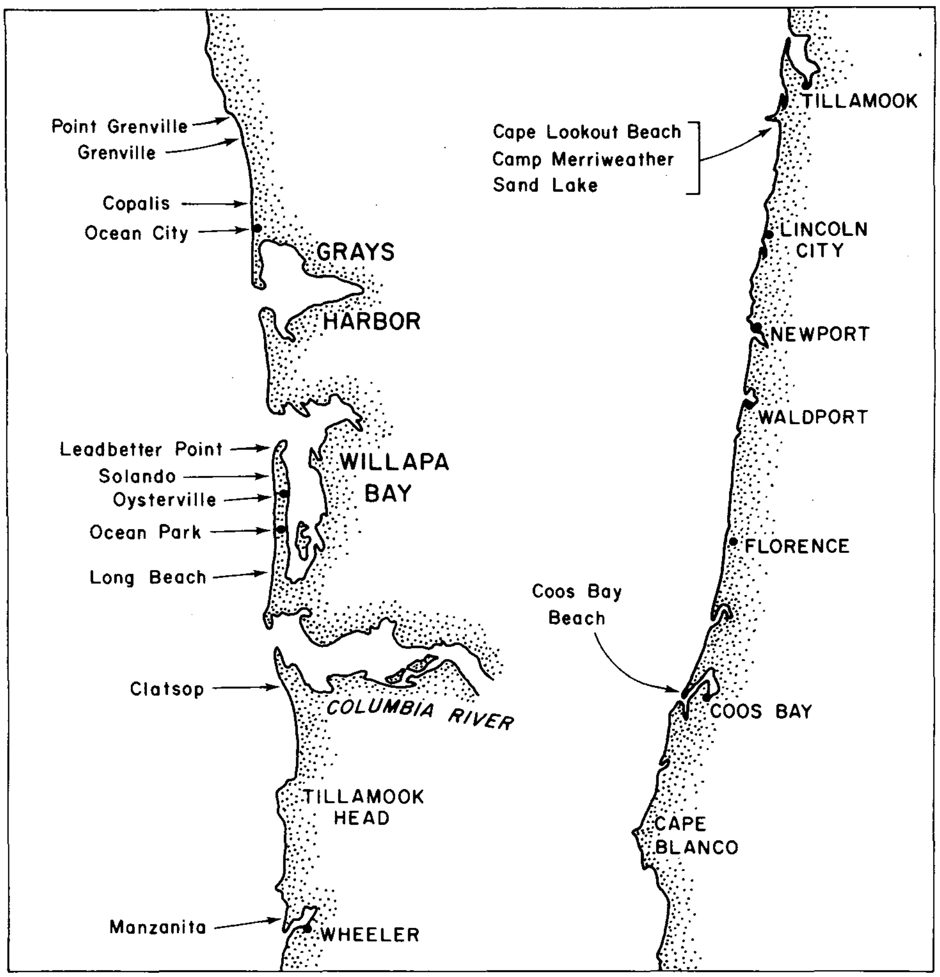

Figure 3. Locations of DUKW surveys along Oregon-Washington coast. Cape Lookout station extended from south base of the cape, Merriweather station was about one mile from the cape, and Sand Lake station was about one mile north of the entrance to Sand Lake. Dates of surveys are given in Tables 1 and 2.

Table 1. Beach profiles (Isaacs, 1947)

WASHINGTON		
Copalis	8/25/45	(3 ranges)
Point Grenville	8/28/45	(3 ranges)
	8/31/45	(1 range)
Ocean City Beach	8/31/45	(1 range)
Leadbetter	9/07/45	(2 ranges)
Solando Wreck	9/10/45	(4 ranges)
Oysterville	9/14/45	(3 ranges)
Long Beach Portal	9/13/45	(1 range)
Ocean Park Beach	9/14/45	(4 ranges)
OREGON		
Sand Lake	9/27/45	(3 ranges)
Cape Lookout	9/27/45	(2 ranges)
Camp Merriweather	9/27/45	(1 range)

Table 2. Beach profiles (Bascom and McAdam, 1947)

WASHINGTON		
Point Grenville	10/08/46	(1 range)
South Grenville	10/08/46	(1 range)
Copalis	10/09/46	(3 ranges)
Ocean City	10/11/46	(1 range)
Leadbetter	10/16/46	(4 ranges)
	11/08/46	(1 range)
Solando Wreck	10/16/46	(4 ranges)
	11/08/46	(1 range)
Oysterville	10/14/46	(2 ranges)
	10/17/46	(3 ranges)
	11/18/46	(1 range)
OREGON		
Clatsop Beach	11/04/46	(1 range)
	11/07/46	(2 ranges)
Manzanita	10/18/46	(3 ranges)
	11/06/46	(3 ranges)
Cape Lookout	10/28/46	(2 ranges)
Camp Merriweather	11/12/46	(1 range)
Sand Lake	10/26/46	(1 range)
	11/05/46	(1 range)
	11/12/46	(2 ranges)
Coos Bay Beach	11/15/46	(3 ranges)

Profiles which are presented by Isaacs (1947) were obtained in September 1945 and come mainly from the Washington coast (Table 1). Profiles described by Bascom and McAdam (1947) (Table 2) were obtained one year later (October and November 1946) from both Washington and Oregon.

Some profile ranges were surveyed by both field parties, providing some indication of changes that had occurred in profiles after one year. At some locations, profiles that were obtained on the same ranges after only a few days' interval gave some indication of expected short-term changes in beach profiles. Examples will be discussed in the next section. Two or three ranges were surveyed at some locations, the profiles usually being separated by 1,000 ft; this arrangement permitted the determination of longshore variations in the nature of beach profiles, especially of the extent of development of bars and troughs.

The Washington and Oregon beach profiles were determined from September through November, a time of transition during which wave heights are increasing along the coast as the low waves of summer months are giving way to the high waves of winter months (Komar and others, 1976). Lowest waves generally occur during June through August, highest waves during December through February. Details of the wave conditions during the 1945 and 1946 investigations are not known, although some visual estimates of breaker heights and periods are included in the reports. Beach profiles obtained by the study are therefore limited seasonally; no profiles were obtained during December to February, when the maximum amount of beach sand is shifted offshore into bars (Komar and others, 1967; Aguilar-Tunon and Komar, in prep.), or during midsummer, when sand has shifted back onto the exposed beach face.

Examples of Beach Profiles

Figure 4 shows two beach profiles obtained at Solando, Washington, which are typical of the many profiles obtained in the University of California study. Three bars separated by two troughs can be identified in each profile. In the three-week interval between the first profile on 16 October 1946 and the second on 8 November 1946, offshore bars and troughs had developed more relief but had not changed positions significantly. The seawardmost bar is 2,300 to 2,500 ft offshore, depending on the date, and is in 8 to 10 ft of water depth below the mean lower low water (MLLW) tide level. These offshore distances and depths are typical for the outer bar on most Oregon and Washington beaches. The shoreward trough of the 8 November 1946 profile extends to a depth of -17 ft MLLW, so there is a depth difference of some 9 ft from the top of the outer bar. The middle bar is at a water depth of -4 to -5 ft MLLW and so will not become exposed even during the lowest low tides.

A significant inner bar above MLLW appears on the 16 October 1946 profile but has essentially disappeared by 8 November. Such an inner bar with a shoreward trough becomes exposed at normal low tides and is an example of a bar familiar to beach observers. Inner bars are known to develop rapidly, migrate in the on-offshore direction under changing wave conditions, and disappear (Fox and Davis, 1974; Aguilar-Tunon and Komar, in prep.). They appear most commonly in the spring months of decreasing wave conditions, when they are formed by the onshore movement of sand from offshore bars to the exposed beach berm (Hayes and Boothroyd, 1969; Hayes, 1972; Davis and others, 1972). Exposed inner bars are rare from October through February because beach-berm erosion prevails during that period. The appearance of an inner bar on the 16 October 1946 profile (Figure 4) may indicate that a period of storms with accompanying high waves occurred, followed by a quieter time of low waves during which some sand shifted back onshore. Winter occurrences of inner bars were noted on Oregon beaches by Fox and Davis (1974) under such conditions. Between 16 October and 8 November 1946, a storm probably occurred, eroding away the inner bar and shifting sand offshore (Figure 4).

Figure 5 shows a profile obtained from the ocean beach one mile north of the inlet to Sand Lake, Oregon (Figure 3). Three bars are present, and possibly a small fourth bar is centered at 500 ft on the exposed portion of the beach. The small seaward-most bar is not completely transected by the profile but does appear in other profiles from that location. Of special interest is the very pronounced middle bar and trough system. The major bar extends up to the mean lower low water level (MLLW) and so could become exposed at lowest tides. The seaward trough extends to a depth of -18 ft MLLW, and the shoreward trough to -10 ft MLLW. Therefore, there are appreciable water-depth changes across the beach profile.

The majority of the beach profiles are much simpler, with only one or two offshore bars. Figure 6 is a profile from the ocean beach seaward of the spit at Coos Bay, Oregon. Only one relatively small bar is seen, about 1,300 ft offshore at a depth of -10 ft MLLW.

Two beach profiles (Figure 7), taken a week apart at Sand Lake, Oregon, give some indication of short-term changes. There are appreciable shifts in the positions of bars and troughs between the two profiles. Both bars and troughs have migrated in the shoreward direction by some 100 ft during that one-week interval. In the process, the bars and troughs have reached shallower depths. One or two feet of sand has accumulated on the exposed beach above MLLW. The overall shoreward migrations of bars and troughs and deposition above MLLW suggests that a period of reduced wave activity occurred during the time between profile determinations. Such migrations of the inner bar have been demonstrated on Oregon beaches, especially by Fox and Davis (1974). Figure 7 indicates that appreciable migrations and water-depth changes may also occur in the outer and middle bars. These changes could not always be detected by Fox and Davis because their surveys were limited to the inner surf zone.

The University of California investigators generally obtained beach profiles along two or three ranges about 1,000 ft apart at each location to give an indication of longshore vari-

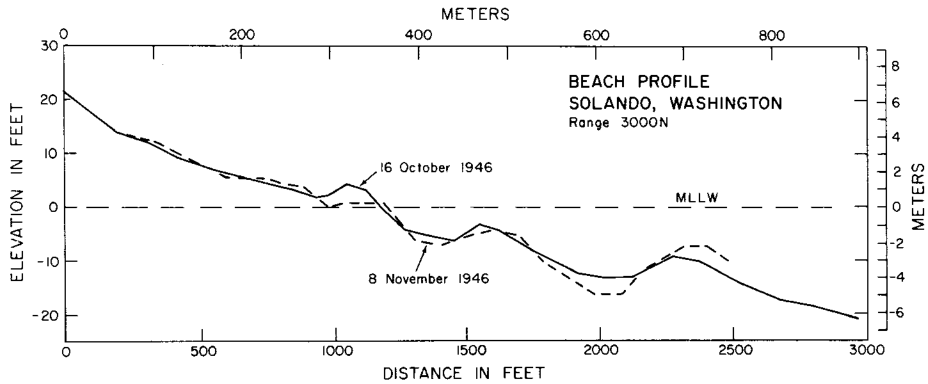

Figure 4. Two profiles from Solando, Washington, showing a system of three offshore bars (after Bascom and McAdam, 1947).

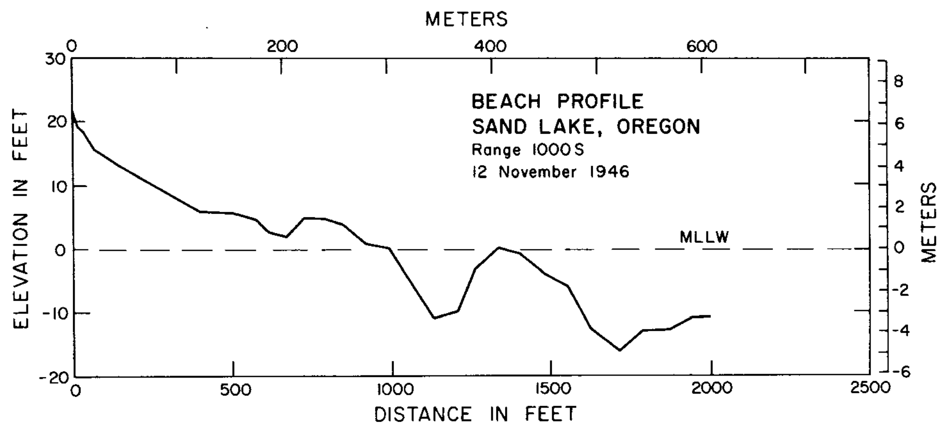

Figure 5. Profile from ocean beach one mile north of entrance to Sand Lake, indicating a very pronounced system of offshore bars and troughs (after Bascom and McAdam, 1947).

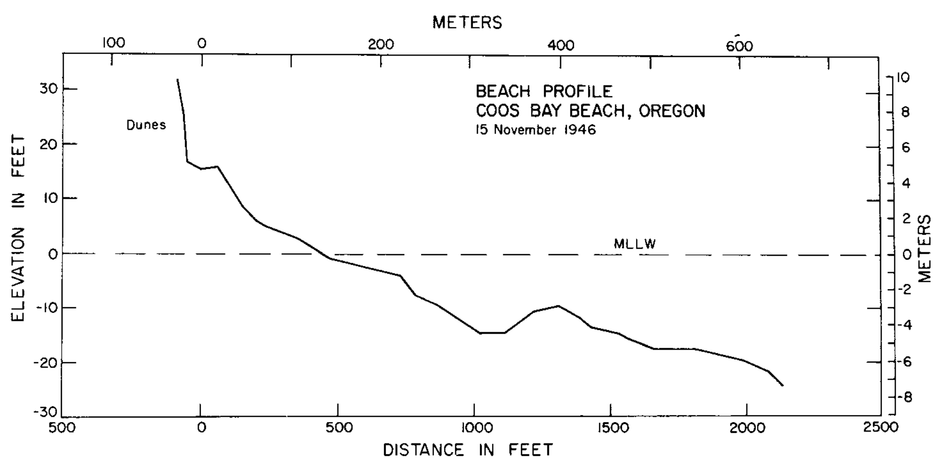

Figure 6. Typical beach profile of Oregon-Washington coast, with only one major offshore bar and perhaps a smaller bar just below MLLW (after Bascom and McAdam, 1947).

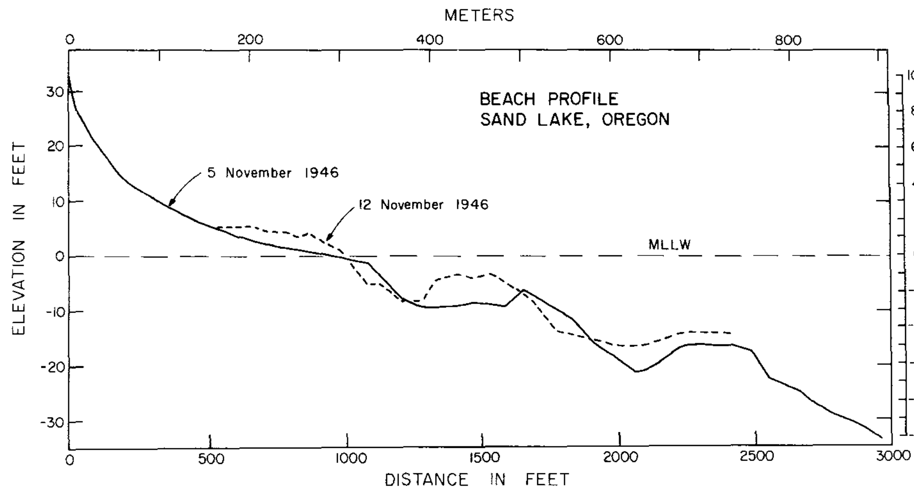

Figure 7. Two Sand Lake ocean-beach profiles. The second profile, taken one week after the first, shows onshore migration of bars and troughs (after Bascom and McAdam, 1947).

ations in the nature of beach profiles at a given time. Figure 8 shows a series of three profiles from the beach along the Clatsop Plains, Oregon (Figure 3). Although profiles from ranges 0 and 1000S were obtained on 7 November 1946 and the profile on range 1000N was obtained three days earlier, the small time difference should not be too significant. It is quite apparent that profiles change appreciably in the longshore direction. The profile on range 1000S is unusually flat, with a sudden increase in depth at 2,500 ft offshore. In marked contrast, the profiles at ranges 0 and 1000N have pronounced bars and troughs. Such longshore variations in beach profiles have been demonstrated for the inner bar of Oregon beaches by Fox and Davis (1974) as well as at coastal locations elsewhere in the world by studies such as those of Hom-ma and Sonu (1963). These variations are usually associated with a system of nearshore currents consisting of longshore currents flowing parallel to shore within the surf zone and feeding rip currents, which are narrow currents that flow seaward from the surf zone to beyond the breakers (Komar, 1976, p. 168-182, p. 263-266, p. 274-280).

Longshore currents are confined mainly to longshore troughs that are shoreward of significant offshore bars such as those that appear in ranges 0 and 1000N of Figure 8. Seaward flow of a rip current will breach the offshore bar, producing a beach profile that is characterized by an even offshore slope with little, if any, bar-and-trough system. A seaward-flowing rip current probably formed the unusual profile at the 1000S range of Figure 8, but because its inner half is so shallow, the profile is not entirely typical of one found in a rip-current position. Instead,

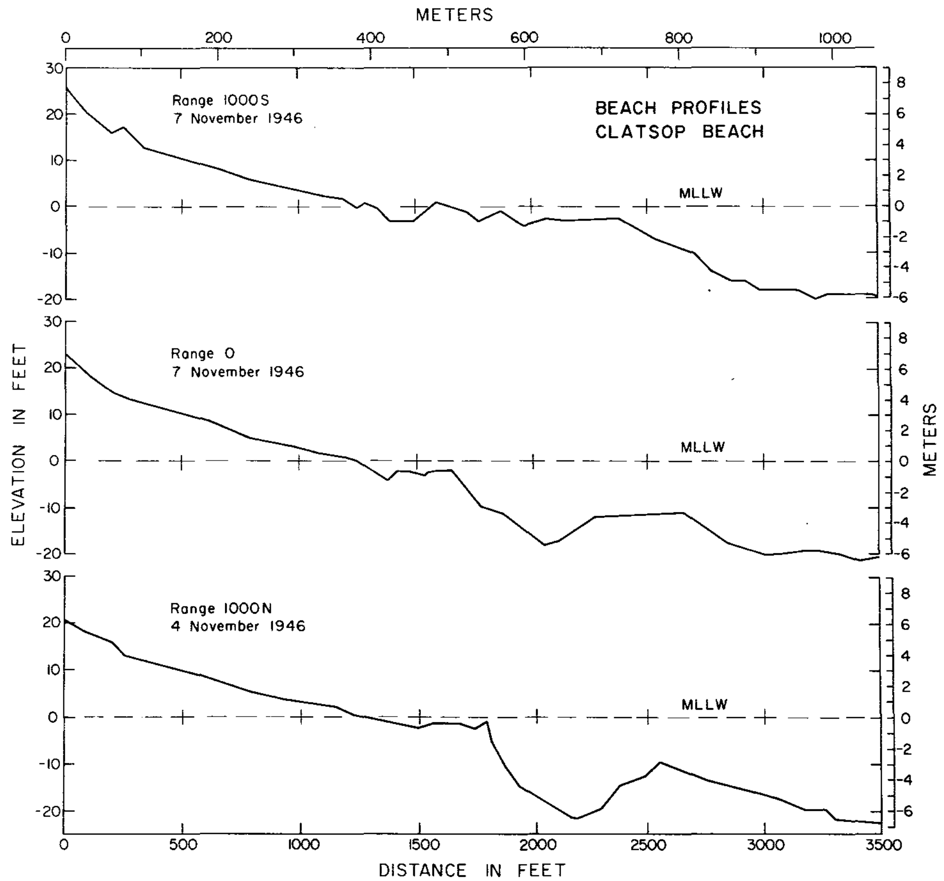

Figure 8. Three Clatsop Beach profiles, separated by 1,000 ft in the longshore direction, showing pronounced changes in development of the offshore bar and trough. Variations were probably produced by a system of longshore currents feeding a rip current (after Bascom and McAdam, 1947).

it is possible that the shoal (shallow portion) is part of a zone of deposition that has formed shoreward of the rip-current position and may even be part of a cusp formed on the shoreline. Another possibility is that the shoal is part of a transverse bar that has built across the surf zone, extending in the seaward direction (Komar, 1976, Figures 10-19). Such bars, which can develop under a rip-current system modified by waves breaking at appreciable angles to the shoreline trend, have been investigated especially by Sonu (1969, 1973).

The beach profiles shown in Figure 8 are rather extreme examples of longshore variations, changing from a profile with an unusually large trough-bar system (range 1000N) to a troughless-barless profile (range 1000S) with a shoreward shoal. More commonly there will be less dramatic longshore changes in profiles, with profiles in rip-current positions becoming flat without offshore bars.

Summary

The beach profiles that were obtained with an amphibious DUKW during University of California investigations show one, two, or three offshore bars at various localities on Oregon and Washington beaches. The seawardmost bar is generally some 2,300-2,500 ft offshore with its shallowest depth reaching -8 to -10 ft MLLW. The middle bar is larger (when present) and may extend to water depths sufficiently shallow to become exposed at lowest tides. At times, a small inner bar may exist on the exposed beach face, even during the winter months, which are generally characterized by beach-face erosion and an offshore shift of sand.

All bars can migrate in the on-offshore direction under changing wave conditions and alter their depths in the process. Horizontal migration distances of some 100 ft are demonstrated by repeated profiles, separated by short time periods, on the same range.

There may be appreciable longshore variations in the nature of the beach profiles. The data include examples where one profile has a pronounced bar-and-trough system, and at the same time, some 1,000 to 2,000 feet in the longshore direction, the beach profile is flat. Such longshore changes in the profiles can be best explained as having been caused by a system of longshore currents feeding offshore-flowing rip currents.

The beach profiles obtained by the University of California study are particularly valuable in that they extend across the entire nearshore zone and include information on the outer bars and troughs. Beach profiles obtained with the conventional stadia rod and transit are confined to the inner surf zone, seldom reaching the middle bar and never the outer bar. Considering the intensity of the surf on Oregon and Washington beaches and the difficulties of measurement in this zone, it is doubtful whether additional profiles that span the entire nearshore to beyond the breakers will be obtained in the near future.

Acknowledgments

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I would like to thank Professor Joe Johnson, University of California, and the librarians of the Water Resources Center Archives for their active help in seeking out the materials upon which this paper is based.

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MINED LAND RECLAMATION OFFICE RELOCATES

In response to a directive from the Governing Board of the State Department of Geology and Mineral Industries, the Albany Mined Land Reclamation staff has moved into new quarters in the Carriage House Plaza, 1129 South Santiam Road, Albany, Oregon 97321. The new offices will house not only the Mined Land Reclamation staff but also the Department's Mineral Resource Survey staff. The purpose of this move is to make the Department even more available and responsive to the needs of the State's mineral industries, public agencies, and general public.

Herbert G. Schlicker, Engineering Geologist, Department of Geology and Mineral Industries, previously stationed on the Oregon State University campus, will also be moving shortly to the new Albany office, making it then the Department's third full-fledged field office in operation. A real advantage to this consolidation will be the immediate availability of top geological expertise to the Mined Land Reclamation staff. The Mined Land Reclamation program involves all aspects of natural resource management, but because of the very nature of the mining industry, geological concerns and problems are among the most prominent ones requiring expert handling. This move will enable the staff to respond to these concerns even more quickly and positively than has been possible in the past.

The Mined Land Reclamation program is having a real, positive impact around the State in spite of the small staff and funding problems that have hampered the program since it was created by the legislature in 1972. Changes by the 1977 legislature in the Mined Land Reclamation Law have improved funding of the program, but at the present time, the staff remains at its previous level of two professional and two clerical employees.

Currently 242 surface mining reclamation plans are in effect around the State. About six new plans are approved each month, for an average net gain of about three plans per month. In addition, the number of "grandfather" or reactivated sites shows a net increase of about three a month.

Inquiries by the score for information and numerous requests for assistance, either in the preparation and development of mining plans or in dealing with on-going mining problems, continue to come to the Mined Land Reclamation staff. Although these requests add to the workload, they are a real measure of the effectiveness and credibility of the Mined Land Reclamation program.

The staff of the Mined Land Reclamation program intends to continue to be available to the general public, industry, and State and local agencies and authorities as all work together to build a growing reclamation and conservation ethic within the mining industry while simultaneously being responsive to the growing needs of the State for mineral resource development.

83RD ANNUAL MINING CONVENTION OPENING SPEAKERS ANNOUNCED

"Mining at the Crossroads," the theme of the Northwest Mining Association's 83rd Annual Convention to be held December 2-3 at the Davenport Hotel in Spokane, Washington, reflects the uncertainty the mining industry feels today. The Opening General Session will feature speakers from the federal government who will talk about the way members of the Senate and House of Representatives view resource exploration and development of public lands and how they see prospective changes in our mining laws. Speakers for the Opening General Session are Michael Harvey, chief counsel for the Senate Committee on Energy and Natural Resources; William Shafer, staff member of the House Committee on Interior and Insular Affairs; and Vincent McKelvey, director of the U.S. Geological Survey.

Other convention sessions and chairmen are:

Geology/Session 1 - New Exploration Techniques: Daniel B. Robertson, Consultant.

Geology/Session 2 - New Deposits: Gerald G. Booth, Cominco American, Inc.

Cost of Environmental Protection/Reclamation: Bruce A. Kennedy, Golder and Associates.

Innovative Techniques in Metallurgy: Rhoshan B. Bhappu, Mountain State Engineers.

Innovative Mining Techniques: Merle W. Emmert, Anaconda Co.

Nontechnical Session: Mrs. Dan Robertson.

Energy in the Northwest: Harold W. Harding, Washington Water Power Co.

Regional Development: Jerry J. Gray, Oregon Department of Geology and Mineral Industries.

Student Session: Joseph Mills, Washington State University.

Money Session: Robert W. Holder, Merrill, Lynch, Pierce, Fenner, and Smith.

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GOVERNOR APPOINTS GEOLOGIST EXAMINER BOARD MEMBERS

Governor Bob Straub has appointed the following persons to the State Board of Geologist Examiners: Herbert Schlicker, State Department of Geology and Mineral Industries; Harold Enlows, Geology Department, Oregon State University; Lloyd W. Staples, Professor Emeritus of Geology, University of Oregon; Robert L. Gamer, Consulting Geologist, Salem; and Emily Schue, Public Member, Eugene.

The Geologists Registration Bill (HB 2288) became law in October and is administered by the State Department of Commerce, 428 Labor and Industries Building, Salem, Oregon 97310. Geologists planning to register should write immediately to the Department of Commerce.

NEW CHIEF GEOLOGIST NAMED

Dallas L. Peck has been named Chief Geologist to head the Geologic Division of the U.S. Geological Survey, Department of the Interior. He succeeds Richard P. Sheldon, who occupied the post since 1972, and who will return to his research in economic geology.

As the Survey's new Chief Geologist, Peck will direct the operations of one of the major divisions of the USGS, representing the largest single group of geologic science professionals in the United States.

Peck is a native of Spokane, Washington. He received formal training in geology at California Institute of Technology, where he received his B.S. degrees with honors in 1951 and his M.S. in 1953. He earned his Ph.D. in geology at Harvard University in 1960, after concentrating on mining geology.

Peck joined the U.S. Geological Survey in 1951. He has become a nationally and internationally recognized authority on a wide variety of geological studies, particularly on geothermal energy and volcanology. His pioneering research on ponded lava flows in Hawaii resulted in a better understanding of the processes of solidification of lava and the physical properties of basalt.

During the earlier part of his USGS career, Peck was assigned to field geological studies in California, Colorado, and Oregon. His studies in Oregon, which led to the publication of a geologic map of western Oregon, unraveled the underlying structure and volcanic stratigraphy of the Cascade Range and yielded an improved understanding of the geologic history of the state.

* * * * *

EXPLORATION GEOCHEMISTS TO MEET IN APRIL

The Association of Exploration Geochemists is sponsoring the 7th International Geochemical Exploration Symposium, to be held in Golden, Colorado, April 16-20, 1978. In addition to technical sessions, a number of geochemically-oriented field trips are planned to various mining districts in the western United States. Spouse/guest activities are also planned.

Further information concerning the Symposium will be sent to those making requests (by AIRMAIL if overseas) to:

M.A. Chaffee, Secretary
Organizing Committee
7th International Geochemical Exploration Symposium
U.S. Geological Survey
5946 McIntyre Street
Golden, Colorado 80401 U.S.A.

SYMPOSIUM TO STUDY DIRECT UTILIZATION OF GEOTHERMAL ENERGY

To demonstrate the scope, availibility, and economy of low-temperature geothermal resources, a Direct Utilization of Geothermal Energy Symposium, sponsored by the U.S. Energy Research and Development Administration (ERDA) and coordinated by the Geothermal Resources Council, will be held Tuesday, January 31 through Thursday, February 2, 1978, at the Bahia Motor Hotel, 998 West Mission Bay Drive, San Diego, California.

The symposium will focus on the results of 18 ERDA-sponsored Engineering and Economic Studies of Nonelectric Applications of Geothermal Heat and other selected recent work in the area of geoheat utilization. Papers from industry and universities, as well as federal, state, and local agencies, will be included. Emphasis will be placed on current and proposed practical applications of geothermal heat such as for commercial industrial enterprises and municipal district heating systems. The symposium will cover four major areas of direct uses of geothermal resources: space conditioning, agribusiness (agriculture and aquaculture), industrial processing, and integrated applications.

For more information, write:

GEOTHERMAL RESOURCES COUNCIL
P.O. Box 1033
Davis, California 95616

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MINERALIZATION IN THE NORTH-CENTRAL WESTERN CASCADES

R.S. Mason*, J.J. Gray**, and B.F. Vogt***
Oregon Department of Geology and Mineral Industries

This is the second of a series of four articles prepared because of renewed interest by major mining firms in mineralized areas in the north-central Western Cascades; the general public's growing interest in geology, mineral collecting, and mining history; and the need for local planning groups to know what is in their planning units. These articles summarize information that has been published piecemeal concerning mineralization and mining in the area, showing what has been studied and what needs to be studied. This geologic jigsaw puzzle has many scrambled pieces that need to be put together before the picture becomes clear.

The first article, "A Geological Field Trip Guide from Sweet Home, Oregon, to the Quartzville Mining District," appeared in the June 1977 ORE BIN. This article presents an overview of published information on mineralization in the north-central Western Cascades. The third article, scheduled for an early summer 1978 ORE BIN, will provide a closer view of typical mineralization in the Western Cascades and will serve as an introduction to the last article in the series, "A Field Trip Guide to the Bohemia Mining District," to appear in a following ORE BIN.

Location and Geography

Mineralized areas in the north-central Western Cascades have produced approximately $8.9 million worth of metals at today's prices since 1858, when gold was first discovered in this region. Most production took place prior to 1920. The mineralized areas are fairly evenly spaced along a north-south line extending from Clackamas County on the north to the northern part of Douglas County on the south. The mineral deposits are in Tertiary volcanic rocks and are apparently associated with small Tertiary intrusive bodies.

The north-central Western Cascades (Figure 1) are located on the east side of the Willamette Valley. The Western Cascades are composed of old, deeply dissected, Tertiary volcanic rocks lying to the west of the younger High Cascades which, in Oregon, extend from the Columbia River on the north to the California border on the south. Because the

*Acting State Geologist
**Economic Geologist
***Geologist-Editor

High Cascades are composed of younger volcanic rocks, they have not been deeply eroded and have little known mineralization.

Summits in the Western Cascades rise to altitudes of 2,000 to 6,000 ft; relief ranges from 1,000 to 4,000 ft over a horizontal distance of 2 to 4 mi. No original upland surfaces are preserved; divides are sharp and valleys narrow. The stream pattern is dentritic (see Glossary at end of article), and streams drain toward the west. The highest ridges form divides between major drainage systems, and lower ridges slope toward the valleys. Valley walls are generally steep, and cliffs occur in many places. Glaciation has modified the higher summits.

Heavy forest cover of Douglas fir and hemlock is common, and timber productivity is excellent. The climate is generally mild and wet during winter months and dry in summer. The average annual rainfall is from 28 to 110 in, depending on elevation. Precipitation is greatest at higher elevations and is largely in the form of snow.

The location of mineralized areas that will be discussed in this article is shown in Figure 2. Granitoid intrusions are indicated on the same map.

History and Production

The discovery of placer gold in southern Oregon in 1851 stimulated interest in the prospecting of all streams in the Cascade Range. Small amounts of gold panned in the tributaries of Row River led to the discovery of a lode gold deposit at Bohemia in 1858; placer gold in the Molalla and North Santiam Rivers pointed the way to the North Santiam lodes in 1860. The Middle Santiam placers preceded the development of the Quartzville district, and in 1863 the discovery of placer gold in the McKenzie River led to the discovery of the Blue River lodes.

Interest in the Western Cascades languished after the first flurry of discovery until the 1890's, when the Lawler mine at Quartzville and the Musick, Champion, and Noonday mines of the Bohemia district became active. The major producing mine in the Blue River district, the Lucky Boy, reached its peak in the early 1900's. During this period, mining was with hand steel (Figure 3), and crushing was done by stamp mill (Figure 4) or arrastre (Figure 5). Gold was recovered with an amalgamation plate, a copper plate coated with mercury, that trapped any free gold touching it. Only free gold found in near-surface oxidized ore could be recovered by this system; and because this type of ore is never completely oxidized, only 50 percent of the total gold value present was ever recovered by early-day miners. Furthermore, these mining techniques were completely unsuited for recovering values in complex primary (unoxidized) sulfides. Selective flotation had not been developed; and gravity concentration, where tried, produced a complex concentrate of copper, lead, and zinc not desired by smelters.

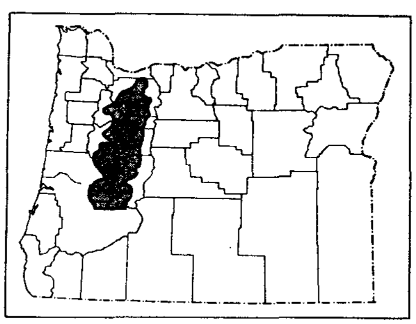

Figure 1. Location map of north-central Western Cascades, Oregon.

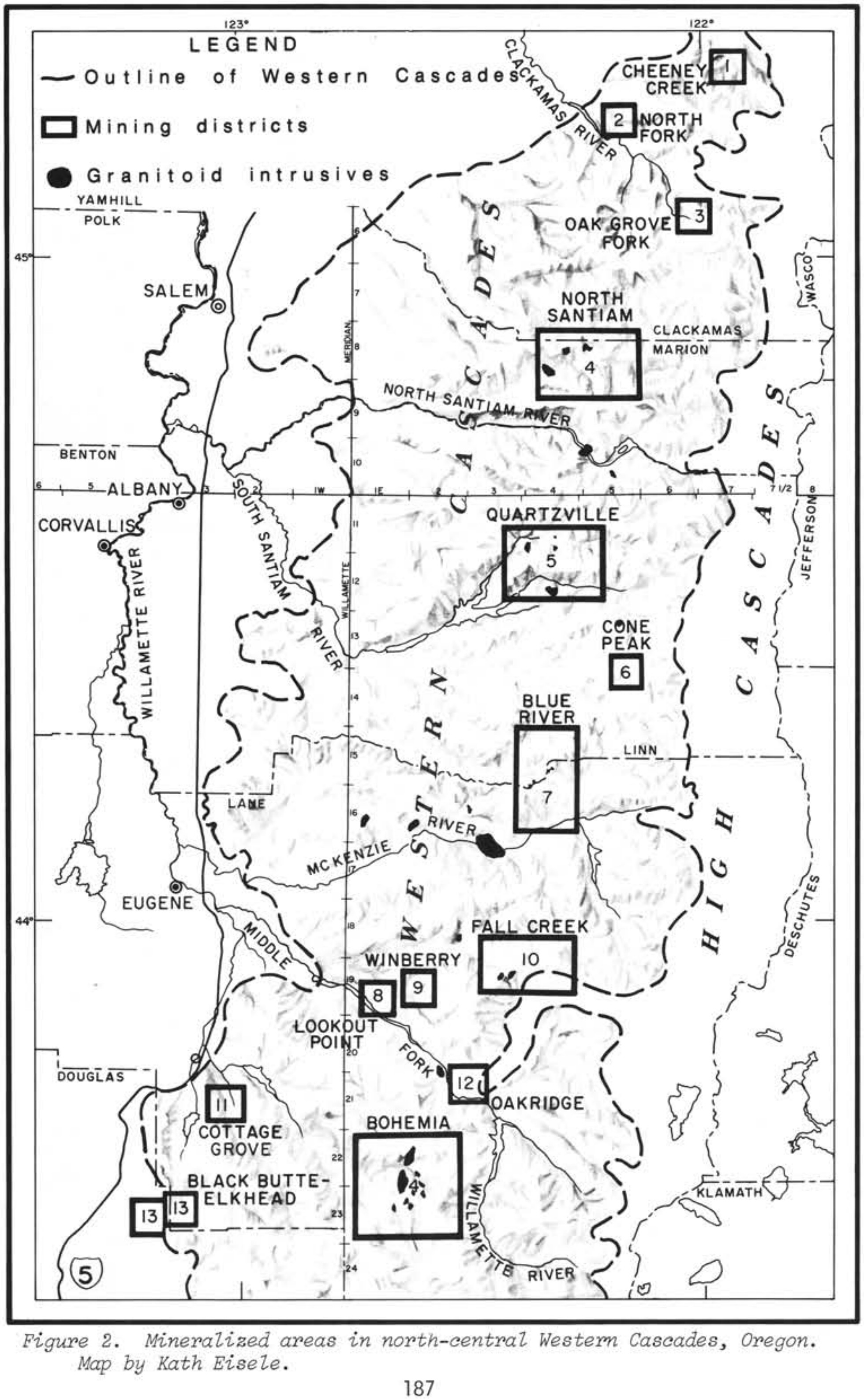

Figure 2. Mineralized areas in north-central Western Cascades, Oregon. Map by Kath Eisele.

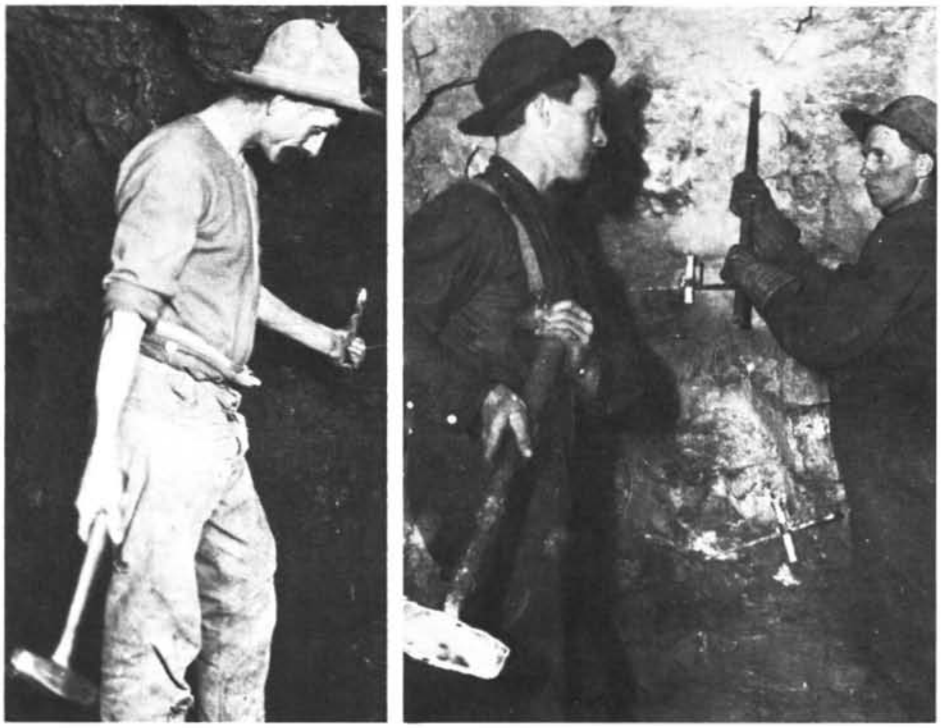

Figure 3. Hand steeling (drilling holes in rock with chisel and hammer). Left: Single jacking. Miner holds steel (chisel) in one hand and swings 6- to 8-lb hammer with other. Right: Double jacking. One miner holds steel; other miner swings 12- to 16-lb hammer. Photos courtesy Oregon Historical Society, Portland, Oregon.

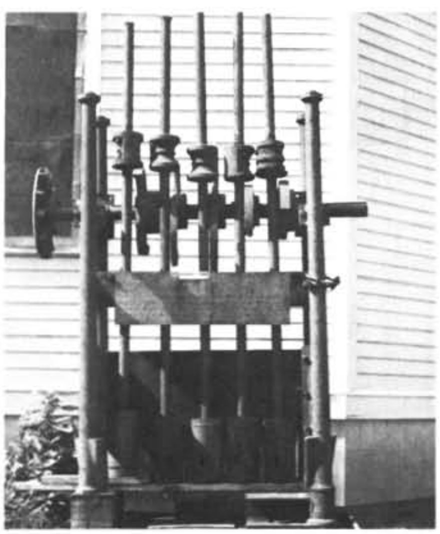

Figure 4. Five-stamp mill, Cottage Grove Historical Museum. These heavy iron stamps (pestles), which rose and fell over a hundred times a minute, were used to crush ore.

Figure 5. Arrastre used to grind friable gold and silver ore. Ore spread on floor was crushed by heavy stones chained to arms pivoting around central shaft. In this drawing, water provides power to turn shaft; in other cases, horses or steam could be used. Gold was then recovered, as it was from a stamp mill, by sluicebox and copper-mercury-coated plate.

The first recorded Western Cascades mercury production was from the Black Butte-Elkhead district in 1882, and production was more or less continuous from then until the 1960's. Mercury was discovered in the Oak Grove Fork area in 1923-1924, first mercury was produced in 1925, and latest production was in 1943.

The nature of the ore, technology, and economics of the times were all important factors determining the intermittent operation of the Western Cascades mining districts. Of the total production from the north-central Western Cascades, 47 percent came from the Bohemia district, 23 percent from Black Butte-Elkhead, 14 percent from Quartzville 13 percent from Blue River, 2 percent from North Santiam, and less than 1 percent from Oak Grove Fork (see Table 1).

Geology

The north-central Western Cascades in Oregon are underlain by a downwarped, 10,000-ft-thick pile of Tertiary volcanic rocks, consisting mainly of andesite with some basalt and rhyolite flow rock, extensive tuff beds, and lenses of lacustrine and fluviatile sediments. The rocks,

Table 1. Summary of production of mining districts of Cascade Range from 1880 to the present [1/]

District	Mercury (flasks)	Gold (oz)	Silver (oz)	Copper (lb)	Lead (lb)	Zinc (lb)	Sept. '77 Value[2/]
Oak Grove Fork........	172	—	—	—	—	—	19,780
North Santiam.....	—	454	1,412	41,172	40,700	110,063	148,487
Quartzville.	—	8,559	2,920	—	—	—	1,253,730[3/]
Blue River..	—	7,727	17,162	267	—	—	1,196,773
Bohemia.....	—	28,285	9,567	14,831	120,816	5,550	4,192,634
Black Butte-Elkhead (est.)	18,000	—	—	—	—	—	2,070,000
Total:	18,172	45,023	31,061	56,260	161,516	115,613	8,881,404

1/ Statistics taken from Brooks and Ramp (1968) and Brooks (1963)

2/ Metal prices: mercury, $115/flask; gold, $145/oz; silver, $4.44/oz; copper, $0.64/lb; lead, $0.31/lb; zinc, $0.34/lb

3/ Unreported production might raise production value another $1,000,000

ranging in age from Eocene to late Miocene (see Figure 6), are folded into a series of anticlines and synclines with north- to northeast-trending axes. Northwest-trending faults occur in many of the mineralized areas of the Western Cascades. To the west, the volcanic rocks overlie or interfinger with Tertiary marine beds. Undeformed Pliocene and Pleistocene fluviatile deposits and andesite and basalt flow rock are locally present. Small late Miocene to Pliocene granitoid intrusions occurring in the mineralized areas are believed to be the sources of mineralizing solutions.

Stratigraphy

The following brief summary of the stratigraphy of the Western and High Cascades is derived largely from the work of Peck and others (1964), Griggs (1969), and Baldwin (1974). The time-rock chart (Figure 6) was developed by John Beaulieu, Oregon Department of Geology and Mineral Industries.

The oldest unit discussed in this article is 3,000 ft of flows, breccias, tuffs, and tuffaceous sandstones of the Eocene Colestin Formation. These nonmarine rocks crop out along the western edge of the Cascade Range, covering the eastern margin of older marine Eocene rocks.

The next oldest exposed unit in the area is the Oligocene and early Miocene Little Butte Volcanic Series, consisting of 3,000 to 15,000 ft of pyroclastic and flow rock. These rocks form the bulk of the Western Cascades south of the McKenzie River and crop out in the foothills and in axes of anticlines to the north. Tuffs, some of them welded, ranging in composition from andesite to rhyodacite, account for more than three-fourths of this unit; basalt and andesite flow rock and breccia make up

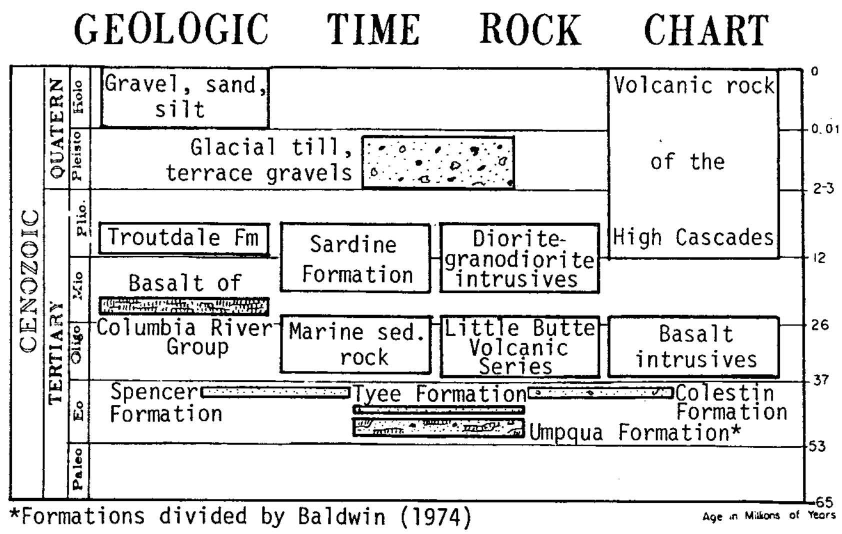

Figure 6. Time-rock chart for Western Cascades, Oregon. Stratigraphy by John Beaulieu, Oregon Department of Geology and Mineral Industries.

much of the remainder. Water-lain tuffs and conglomerate are present locally through the section. The thickest section of the Little Butte Volcanic Series, 15,000 ft, is exposed along the North Umpqua River. In the northern Western Cascades, where the base is not exposed, from 1,500 to 5,000 ft are exposed in eroded anticlinal cores. Intermittent subsidence of the volcanic pile as it accumulated is evident in the central part of the western margin, where the interfingering of marine rocks marks the last eastward incursions of the seas into the Western Cascades. Interbedded stream and lake deposits show that westward-flowing streams that drained the Cascades and the country to the east were dammed by volcanic material from time to time.

In the northern part of the Western Cascades, middle Miocene basalt flow rock of the Columbia River Group crops out along the east and west fringes of the Cascade Range. Basalt of the Columbia River Group laps onto eroded edges of rocks of the older Little Butte Volcanic Series. The section of Columbia River Basalt exposed in the Columbia Gorge is more than 2,000 ft thick, but the flows generally pinch out at about the latitude of the North Santiam River. Basalt of the Columbia River Group is, however, exposed at intervals farther south along both the eastern and western margins.

The Sardine Formation is composed of flow rock, breccia, and tuff, mostly hypersthene andesite in composition, that conformably overlie the Columbia River Group in the northern part of the Western Cascades and unconformably overlie older volcanic rocks to the south. As presently mapped, the Sardine Formation, which is considered to be mostly middle to late Miocene in age, covers most of the northern part of the Western Cascades. Some correlative basalt and basaltic andesite flow rock exposed along the west-central margin of the Cascade Range is included in this unit. Locally along the North Santiam River, as much as 10,000 ft of section is exposed; but in most places, thickness is 3,000 ft or less.

During the middle to late Pliocene, a huge up-arching of the earth's crust, extending from Canada to California, began along the axis of what was presently to become the High Cascades. This great arch disrupted westward-flowing streams originating in eastern Oregon, forcing them eventually to flow northward to join the Columbia River. As the arch increased in height, it also uplifted the volcanic rocks of the Western Cascades, subjecting them to intense erosion and the development of a new drainage system. The ruggedness of the Western Cascades contrasts sharply with the much flatter slopes that are common in the High Cascades promontory upon which the younger Cascade peaks such as Mount Hood, Mount Jefferson, and the Three Sisters rest.

Pliocene conglomerate, mixed with sandstone, shale, tuff, and volcanic rock, is found along both margins of the Cascade Range for 30 to 40 mi to the south. Fluvial and lacustrine rock on the west side comprise the Troutdale Formation; the andesitic debris fan to the east forms the Dalles Formation. These units may be as much as 1,500 ft thick but are generally less.

The High Cascades are predominantly basalt and basaltic andesite, mostly in the form of lava flows that built up the chain of broad volcanoes that cover the eroded eastern margin of the Western Cascades, form the plateau, and underlie the narrow eastern slope of the Range. Eruptions of these rocks began early in the Pliocene and continued into the Holocene. Isolated volcanoes of the High Cascade type also developed in the Western Cascades (Treasher, 1942; Trimble, 1963). Some Western Cascade valleys were filled by many hundreds of feet of intracanyon flows from these Pliocene-Holocene volcanoes.

Quaternary deposits in the Western Cascades consist of gravel, sand, silt, and local glacial till in major stream valleys. Some of these deposits are gold bearing, but none have a history of production.

Intrusive rocks

Small bodies of intrusive rock, ranging in composition from rhyodacite to basalt, cut the volcanic rocks of the Western Cascades. The intrusions are related to the volcanic units and intrude rock ranging in age from Oligocene to late Miocene. Most granitoid rocks (including quartz diorite, granodiorite, and quartz monzonite) associated with mineralized areas are probably Miocene to Pliocene in age. Figure 2 shows their distribution in the Western Cascades. These intrusions are almost uniformly porphyritic in texture and are scattered throughout a narrow north-south belt. Some of the intrusions cover as much as 4 sq mi, but most are less than 1 sq mi. They are usually round to elliptical in plan and have nearly vertical margins.

Country-rock alteration/metamorphism

In the Western Cascades, most Miocene or older volcanic rocks have been partly or completely changed in composition and appearance by the intrusion of molten rock and associated heat and hydrothermal fluids. Three general types of country-rock changes have occurred (see Figure 7): rock farthest from intrusions has undergone zeolite alteration; rock somewhat closer has been altered propylitically; and rock closest to the intrusions has been subjected to contact metamorphism.

Zeolite alteration, the weakest and most widespread type of alteration in the Western Cascades, chemically breaks down (devitrifies) rel-

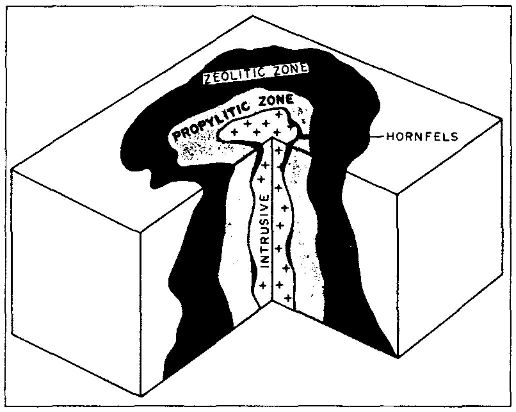

Figure 7. Country-rock alteration/ metamorphism.

atively unstable volcanic glass in pyroclastic and lava flow rock, altering it to green clay and zeolites. Because flow rock does not contain much glass, even after alteration it may remain fresh in appearance. Pyroclastic rock, which contains more glass, is generally much more affected in appearance by alteration.

Propylitic alteration affects country rock more intensely. Propylitically altered rocks are generally greenish-gray in color. As they are altered, they become more brittle; when broken, they often develop a conchoidal fracture. A zone of propylitic alteration surrounding granitoid intrusions forms an apparently discontinuous, north-south trending band in the Western Cascades. Most of the mineralized areas shown in Figure 2 are associated with this alteration zone.

Rock closest to intrusive bodies is affected most profoundly and may be contact metamorphosed into a dark, fine-grained, flinty rock called hornfels. The major effect of this type of alteration is the introduction or remobilization of silica (silification) and the formation of the following mineral assemblages: tourmaline-quartz, epidote-tourmaline, tourmaline-specularite-sericité, epidote-chlorite-magnetite (or pyrite), and quartz-sericite-pyrite. These mineral assemblages may occur in the total rock mass, along rock fractures, or as nodules within the rock mass. Such nodules have been found as far as 4,000 ft away from the intrusive body in the Bohemia mining district.

Within the Western Cascades, another type of metamorphic rock has also been found. Deposits of emery may have been formed as the result of contact metamorphism of ferruginous bauxite by mafic intrusions. Mineral assemblages occurring within the emery deposits include corundum-magnetite, mullite-cristobalite, and hercynite-mullite-crisobalite.

In this report, the term "wall rock" is applied to country rock that surrounds a mineralized vein or other mineralized zone. The alteration of wall rock by hydrothermal fluids will be discussed in the following section.

Ore Deposits

Base- and precious-metals mineralization

Areas of mineralization are more or less evenly distributed along a north-south line running through the center of the Western Cascade Tertiary volcanic rocks. Most of the sulfide mineralized areas are associated with small granitoid intrusive bodies that are believed to be genetically related to the mineral deposits. Sulfide minerals found in mineralized zones and veins in the Western Cascades include pyrite, sphalerite, chalcopyrite, and galena. The common noneconomic (gangue) minerals include quartz, calcite, and, in places, barite. The veins,

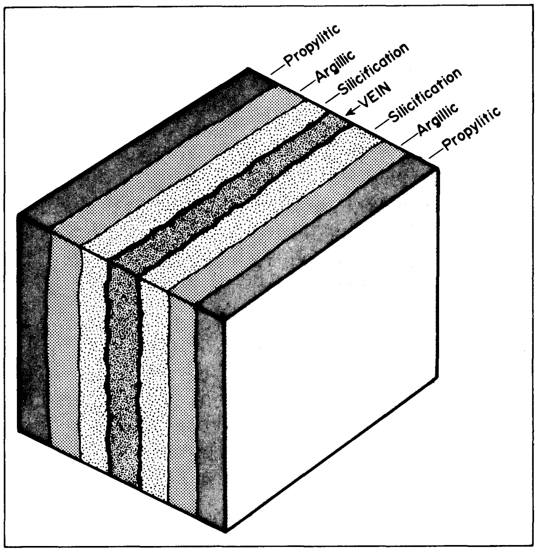

Figure 8. Stages of zoning in wall-rock alteration.

which cut across virtually all rock types including intrusions, generally strike northwest to west and dip steeply. Some veins found in the Bohemia district are more than 0.5 mi long and 20 ft wide.

In general, ore-bearing fluids change gradually in composition as they migrate from their sources. The spatial distribution of mineral deposition is known as zoning. Zoning patterns are shown by changes in mineralogy over a distance in both vertical and horizontal directions in mineralized areas. Most mineralized areas are zoned, both in wall-rock alteration and and in vein minerals. Figure 8 shows the stages of zoning in wall-rock alteration, starting with the closest to the source: silica flooding (silicification), clay mineral (argillic), and propylitic.

Zoning is also shown by minerals in veins. Figure 9 is a generalized picture of vein—mineral zoning in both vertical and horizontal directions. Theoretically, the porphyritic-copper-molybdenum zone is the closest to or part of the granitoid intrusion, followed by copper vein minerals, followed by lead-zinc vein minerals, followed by iron-gold vein minerals, all surrounded by veins of gangue minerals. Figure 9 also shows a pipe-shaped body, called a breccia pipe, filled with fragmental rock, which can be a favorable locale for mineralization.

Veins within mineralized areas in the Western Cascades show this type of zoning. In the North Santiam district, a central zone of chalcopyrite veins is surrounded by a zone of complex-sulfide veins, which in turn is surrounded by carbonate veins. In the Quartzville district, a center zone of gold veins have lead-zinc veins around the periphery; in the Bohemia district, a central zone of large veins with abundant sulfides is surrounded by a zone of veins containing minor amounts of sulfides, and this zone in turn is surrounded by one with stibnite veins.

All past prospecting, mining, and geological studies in this region have concentrated on the veining systems of the districts. The economics of today call instead for the mining of massive orebodies. Evidence from the north-central Western Cascades suggests that copper-molybdenum porphyry-type orebodies such as that shown in Figure 9 may lie at depth. Because the mineralogy of veins is generally related to proximity to the copper-molybdenum-porphyry heart below, the targets for exploration companies should be zoning centers, zones of disseminated copper minerals, geochemical molybdenum anomalies, and breccia pipes (see Figure 9).

<u>Other mineralization</u>

Other types of mineralization occurring in the north-central Western

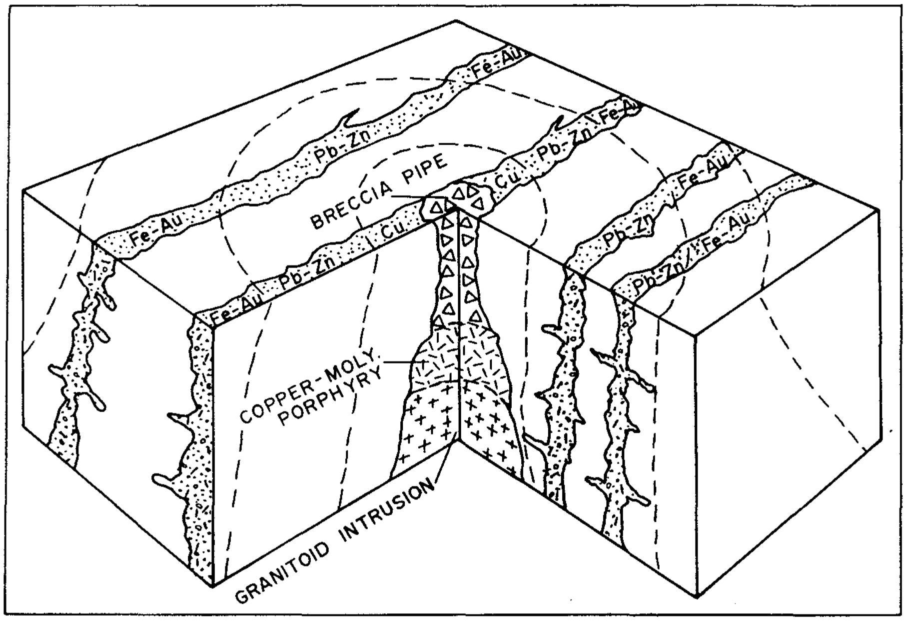

Figure 9. Vein-mineral zoning. Fe=iron; Au=gold; Pb=lead; Zn=zinc; Cu=copper; Moly=molybdenum.

Cascades are discussed later in this article in the sections describing the areas in which they occur. Native copper is found at Cottage Grove; mercury mineralization occurs in the North Fork, Oak Grove Fork, and Black Butte-Elkhead areas. Emery is found in the Cone Peak area, and barite occurs at both Lookout Point and Oakridge.

Mineralized Areas (see Figure 1)

Cheeney Creek, area 1

The Cheeney Creek area is located in Clackamas County, sec. 20, T. 3 S., R. 7 E. One hundred claims were staked by 1903, with workings totaling 87 ft of shaft and 400 ft of adit. Total reported production is 48 oz of gold. Mineralization appears as narrow gouge seams and thin seams of vein matter consisting of fragments of country rock altered to an aggregate of quartz and clay minerals on which are crusts of galena and sphalerite with quartz and dolomite. The country rock is a light-gray andesite that is only slightly altered (Callaghan and Buddington, 1938).

North Fork, area 2

The North Fork area is located in Clackamas County, secs. 7 and 8, T. 4 S., R. 5 E. Traces of mercury mineralization in the form of cinnabar are found in agglomerate and tuff of the Sardine Formation. Development consisted of a 30-ft adit and scattered open cuts. No production has been reported (Brooks, 1963).

Figure 10a. Oak Grove Fork. Country rock is brecciated basalt, cut by vein surrounded with alteration.

Figure 10b. Oak Grove Fork. Mine adit shows typical mine conditions today in this district.

Oak Grove Fork, area 3

The Oak Grove Fork area is located in Clackamas County, secs. 4 and 5, T. 6 S., R. 7 E. The mercury mineralization occurs as cinnabar in fissure veins of banded calcite and zeolite and as narrow fracture filling in the basalt adjacent to the veins. The country rock, basalt of the Columbia River Group, has been brecciated near the veins and altered by hydrothermal solutions to a dark, gray-green rock containing considerable clay and showing some limonite stains (Figure 10a). Reported mercury production from 1923 to 1943 was 71 flasks. The mining was through several adits (Figure 10b), with the ore transferred across the river by tramline (Brooks, 1963).

North Santiam, area 4

The North Santiam mining district (Figure 11) is located in Clackamas and Marion Counties, Ts. 7, 8, and 9 S., Rs. 3, 4, 5, and 6 E. Production of this complex-sulfide mineralized area is given in Table 1. Country rock of the Little Butte Volcanic Series has been intruded by small dacite-porphyry dikes and plugs. One quartz-diorite body is exposed at the Crown mine. Large areas of contact metamorphic alteration and zoning of the vein mineralization indicate the possibility of large, unexposed intrusive bodies. Zoning of vein mineralization appears to be better developed in the North Santiam district than anywhere else in the Western Cascades. Chalcopyrite-bearing veins from the Crown mine to and along the Little North Fork of the Santiam River form a central high-temperature zone that is succeeded in the section by pyrite-bearing veins

Figure 11. Ruth mill, North Santiam district, built and operated in early 1930's. This mill, which had a very small production run, is no longer standing. Photo courtesy George Atiyeh.

on Gold Creek that, in turn, give way to complex-sulfide veins in the Blende Oro mine and, farther east, in the Ruth mine. These complex-sulfide veins contain sphalerite with variable amounts of galena and chalcopyrite. An outer low-temperature zone is represented by a calcite vein on lower Elkhorn Creek and at the Ogle Mountain mine.

Reported development totals 16,344 ft of crosscuts, drifts, winzes, raises, and stopes. Twenty-five different mines and claims groups have been described (Oregon Department of Geology and Mineral Industries, 1951). Because of recent interest by major mining firms, most of the district has been staked with mining claims (Callaghan and Buddington, 1938; Brooks and Ramp, 1968).

Quartzville, area 5

The Quartzville district (Figure 12) is in Linn County, Ts. 11 and 12 S., R. 4 E. See Table 1 for production from this district. Mineralization has occurred in rocks of the Sardine Formation. Scattered dikes and plugs of dacite porphyry are also found in this district. Most of the veins contain mixed sulfides; pyritization (Fe-Au zoning, Figure 8) is widespread; and propylitic alteration is common.

Reported development of drifts, open cuts, shafts, crosscuts, and raises totals 10,688 ft. Twenty-five different mines and claims groups have been described (Callaghan and Buddington, 1938; Brooks and Ramp, 1968). Recently a large mining firm has developed a land base by claim staking. The Oregon Department of Geology and Mineral Industries has published a field trip guide to this district (Gray, 1977).

Figure 12. Small-scale weekend placer mining in Quartzville mining district. Children in foreground are panning for gold; child in background is using mechanical rocker. Photo courtesy Albany Democrat Herald.

Cone Peak, area 6

The Cone Peak emery deposit is located in Linn County, sec. 30, T. 13 S., R. 6 E. The mineralogy of the emery is reported by White and others (1968). Emery is a high-temperature, contact-metamorphic rock (Figure 13a) that is used as an abrasive. Some assays show as much as 70 percent Al_2O_3. Along with the aluminum, every sample assayed shows anomalous values in one or more of the following: copper, zinc, nickel, chromium, vanadium, and silver.

These rocks appear to lie at the contact between the Western and High Cascades. Bauxitic material overlying the Western Cascade rocks may have been fused into emery by a High Cascade feeder dike. Development has been limited and consists of discovery shafts and one open pit from which less than 300 tons of hand-sorted emery have been mined (Figure 13b).

Blue River, area 7

The Blue River mining district (Figure 14) is located in Linn and Lane Counties, Ts. 15 and 16 S., R. 4 E. Production is given in Table 1. The complex-sulfide mineralization occurs in volcanic rock of the Sardine Formation. Two groups of dioritic dikes and plugs surrounded by narrow contact metamorphic rock (hornfels) occur, one northeast of Gold Hill and the other on the south fork of Tid Bit Creek.

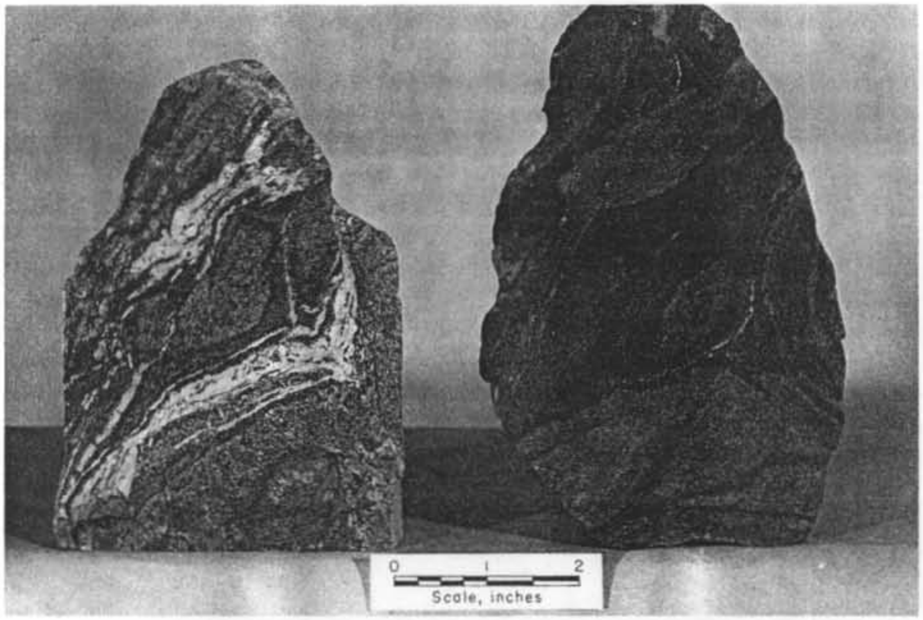

Figure 13a. Flow banding in Cone Peak contact-metamorphosed emery.

Figure 13b. Small-scale mining operation at Cone Peak emery deposit. Only mechanical equipment used is gasoline-driven conveyer and dump truck.

Figure 14. Blue River. Typical early-day miner and adit. Photo courtesy Oregon Historical Society, Portland, Oregon.

Some vein zoning is present. The vein in the center of the district, the Lucky Boy, contains pyrite, sphalerite, galena, chalcopyrite, and tetrahedrite, with quartz the dominant gangue mineral. Calcite is predominant in a few veins on the edges of the district. Pyrite veins without other sulfides occur between the other two zones. All of the veins in the area strike north to northwest and generally dip steeply. Reported development work for the district totals 15,400 ft (Callaghan and Buddington, 1938; Brooks and Ramp, 1968).

Lookout Point, area 8

The Lookout Point barite, pyrite, and quartz mineralized area (Figure 15) is located in Lane County, secs. 20, 21, and 27, T. 20 S., R. 2 E.

Figure 15. Lookout Point. Note size of barite crystals lining vug that is large enough to accommodate man. Photo courtesy Leo Paschelki.

North of the Lookout Point Reservoir, a small open vein of barite, with crystals up to 6 in across, occurs in rocks of the Little Butte Volcanic Series. The vein has been mined for crystals from an open pit and from a 60-ft adit driven 30 ft below the open pit.

A group of pits on a steep hillside about 600 ft above the south bank of the Middle Fork of the Willamette River at Black Canyon exposes a seam containing a small lens of quartz that has been brecciated and cemented with comb quartz. Pyrite occurs both disseminated and in bands in the quartz lens. No production has been reported (Callaghan and Buddington, 1938; Leo Paschelki, personal communication, November 1, 1977).

Winberry, area 9

The Winberry area is located in Lane County, T. 19 S., R. 2 E. Pyrite and gold mineralization occurring in Little Butte Volcanic Series rocks does not appear to have been very intense, but a small gold content has been reported. The country rock contains limonite and other oxidized iron minerals, and unconfirmed reports suggest the presence of some copper mineralization. Reported development totals 50 ft of adit (Smith, 1938).

Fall Creek, area 10

The Fall Creek mining district is located in Lane County, T. 19 S., Rs. 3 and 4 E. Gold and pyrite mineralization was discovered in 1901, and one mine was worked in a small way for several years. Ore was ground in a five-stamp mill, but the amount recovered was not recorded. Little Butte Volcanic Series rocks have been intruded and mineralized by diorite and dacite-porphyry plugs and dikes. Gold occurs in quartz veins and in zones without any apparent structure. Gold in quartz veins is associated with comb and cockade quartz. Pyrite is apparently the only sulfide present in the district. A total of 1,040 ft of adit has been driven (Callaghan and Buddington, 1938; Brooks and Ramp, 1968).

Cottage Grove, area 11

The Cottage Grove native copper deposit, located in Lane County, sec. 19, T. 21 S., R. 2 W., was discovered in 1940. Mineralization occurs as thin sheets of native copper occurring along fractures in rocks of the Colestin Formation. The sheets of copper are rarely more than 0.04 in (1 mm) thick and 0.4 to 0.8 in (1 to 2 cm) in diameter; commonly they have been altered to malachite. This deposit has had no reported production. Development work included 244 ft of drill hole, 53 ft of shaft, and two or three open pits (Smith, 1938).

Oakridge, area 12

The Oakridge pyrite and barite mineralized area is located in Lane County, secs. 5 and 6, T. 21 S., R. 3 E. Pyrite is the only sulfide present, and no gold values have been reported. The Little Butte Volcanic Series country rock has been extensively altered; some alteration zones have been silicified and pyritized, and others have been altered to aggregates of clay minerals and cherty quartz. Quartz vugs are filled with barite crystals averaging 0.4 in (1 cm) in length (Callaghan and Buddington, 1938).

Black Butte-Elkhead, area 13

The Black Butte-Elkhead mercury mineralized area (Figure 16), located in Douglas and Lane Counties, T. 23 S., Rs. 3 and 4 W., occurs in rocks of

Figure 16. Black Butte mercury retort. Tramline in upper left transported ore downhill from mine to retort. Cinnabar containing mercury and sulfur was heated in rotary kiln to drive off sulfur. Free mercury left behind was condensed as quicksilver. Photo courtesy Daniel Mills.

the Colestin Formation. Production is described in Table 1. The principal ore zone lies along a normal fault. Subordinate faults are distributed through a wide zone both above and below the main fault, and the intervening rocks are extensively brecciated and altered. Veinlets of quartz, calcite, and dolomite are thickly massed in the fault zone; as they are more erosion resistant than the surrounding rock, they are responsible for the butte's standing above the surrounding countryside. Cinnabar occurs as irregular veinlets and disseminations scattered throughout most of the brecciated and altered country rock. The grade of ore is highest in material that was silicified and brecciated prior to the introduction of cinnabar.

The Black Butte mine was developed with adits distributed over a vertical interval of about 1,300 ft. The principal ore shoot has been worked from surface outcrops to the 1,100-adit level, a vertical distance of about 850 ft. Average recovery from the ore has been about 3.5 lb mercury/ton.

Mercury mineralization at the Elkhead deposit occurs in amygdaloidal basalt overlain by a series of interbedded sandstones and shales of the Colestin Formation. The higher grade mineralization lies along the northeastward-trending contact of basalt and an overlying layer of tuffaceous sandstone. Both the basalt and the sandstone are intensely fractured, hydrothermally altered, and cut by numerous thin iron ribs. Alteration has been more intense in the sandstone, and limonite veinlets are more abundantly developed in the sandstone than in the basalt. The veinlets appear to have been originally composed of intermixed silica and siderite, but, because of oxidation of the siderite, only limonite and silica generally remain. A little cinnabar occurs within 25 to 30 ft of the mined-out contact as disseminations and occasional veinlets in the altered sandstone, which assays less than 1 lb mercury/ton. Development work for both mines totals an estimated 6,000 ft of drifts, crosscuts, raises, and stopes (Brooks, 1963).

Figure 17. Bohemia Mountain, with Bohemia City in lower right-hand corner. One Musick mine dump is to left of the city; another is in center of photo. Photo courtesy Ray Nelson.

Bohemia, area 14

A description of the Bohemia mining district (Figure 17) will be published in the early summer of 1978, and a field trip guide to Bohemia will appear in a following ORE BIN. Production figures from the Bohemia district are given in Table 1.

Acknowledgments

The authors thank all the people who helped in the preparation of this series of articles. Special thanks are extended to Harold Barton of Cottage Grove, who served as guide and source of invaluable information.

Glossary

(This glossary defines geological terms that may be unfamiliar to the reader. For information on minerals discussed in this article, readers are urged to consult any standard mineralogy text.)

adit - mine entrance.
amygdaloidal basalt - basalt in which small holes called vesicles have been filled with secondary minerals such as zeolites, calcite, or forms of silica.
breccia - angular rock fragments; rock composed of angular fragments.
cockade quartz - quartz deposited in successive crusts around vein breccia fragments.
comb quartz - quartz crystals growing perpendicular to vein walls.
country rock - the rock into which a mineral deposit or intrusion is emplaced.
crosscut - small passageway driven at right angles to direction of main workings in a mine.
dendritic - branching.
drift - horizontal underground passage in a mine.
extrusive rock - igneous rock that has cooled rapidly on the surface of the earth.
ferruginous - containing iron.
flotation - method of mineral separation in which froth created in water floats some finely crushed minerals and allows others to sink.
fluviatile - produced by action of a stream or river.
friable - said of rock or mineral that crumbles naturally or is easily broken or pulverized.
granitoid - a textural term applied to rock that has cooled underground slowly enough to have formed relatively large crystals.
hydrothermal fluids - hot-water solutions circulating within the earth.
intrusive rock - igneous rock that has cooled slowly under the earth's surface.
lacustrine - produced by lakes.
lode - a narrow fissure, crack, or vein in country rock filled with a mineral deposit.
placer mine - mine operation that extracts free gold from river deposits.
porphyritic - crystalline rock containing some crystals that are larger than the rest.
pyritized - converted to pyrite by simple replacement or alteration or both.
pyroclastic - produced by explosion or aerial ejection of material from a volcanic vent.
raise - a vertical or inclined opening driven upward in a mine.
riffle - the lining in the bottom of a sluicebox, made of blocks or slats of wood, or stones, arranged in such a way that spaces are left between them.
rocker - a sluicebox in which a mixture of water and gold-bearing sand and gravel are agitated in such a way that the gold is separated from the sand and gravel.
sluicebox - long, inclined trough containing riffles in the bottom to provide a lodging place for heavy minerals as water and mineral-bearing river sand and gravel flow through the box.
stope - an excavation from which ore has been removed in a series of steps by working horizontally in a sequence of workings, one on top of another.

tuff - rock composed of very small particles of compacted pyroclastic material.

vug - small cavity in rock, usually lined with mineral incrustation.

winze - a vertical or inclined opening that has been sunk downward, connecting two levels in a mine.

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REPRINTS OF OUT-OF-PRINT PUBS NOW AVAILABLE

The following publications, once out-of-print, have been reprinted and are now available from the American Trading Company; P.O. Box 1312; Bellevue, Washington 98009; phone (206) 747-1764: USGS Professional Paper 73, "Tertiary Gravels of the Sierra Nevada of California," by Waldemar Lindgren ($15.00). "Oregon Metal Mines Handbooks": Bulletin 14A, Baker, Union, and Wallowa Counties ($9.00); Bulletin 14B, Grant, Morrow, and Umatilla Counties ($9.00); Bulletin 14C, vol. 1, Coos, Curry, and Douglas Counties ($9.00); Bulletin 14C, vol. 2, sec. 1, Josephine County ($10.00); Bulletin 14C, vol. 2, sec. 2, Jackson County ($10.00); Bulletin 14D, Northwest Oregon (including Bohemia mining district) ($9.00). All prices include postage and handling.

ALL ABOUT FOSSILS

"Fossils in Oregon," for which the Department has received numerous requests, is now available as Bulletin 92.

The book is a 227-page compilation of 22 ORE BIN articles, many of which have long been out of print, on fossils, written by a number of specialists and categorized as Fossil Plants, Fossil Animals, and Fossil Localities. It is richly illustrated.

Measuring 6 x 9 inches and selling for $4.00, "Fossils in Oregon" will make a readily-wrapped and welcome gift for all of your friends who are fossil fans. Orders will be filled promptly.

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JACKSON COUNTY LAND USE STUDY PUBLISHED

Deputy State Geologist John D. Beaulieu and Consulting Geologist Paul W. Hughes collaborated to produce the Department's Bulletin 94, "Land Use Geology of Central Jackson County, Oregon.

Among the topics covered in the 87-page publication are geography, geologic units, mineral resources, and geologic hazards. Twenty-nine pictures enhance the text, and a convenient glossary is appended.

With the book come geologic and geologic hazard maps of Ashland and Lake Creek quadrangles, Gold Hill quadrangle (in part), parts of Ruch and Wimer quadrangles, Medford quadrangle, and parts of Trail and Talent quadrangles.

Together, the bulletin and 10 maps are priced at $9.00.

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BAKER QUADRANGLE GEOLOGIC MAP AND TEXT NOW AVAILABLE

GMS-7, "Geology of the Oregon Part of the Baker 1° by 2° Quadrangle," is a package comprising a geologic map and text of 25 pages which is now available from the Department.

Howard C. Brooks, Oregon Department of Geology and Mineral Industries; James R. McIntyre, Cousulting Geologist; and George W. Walker, U.S. Geological Survey are the authors. S.R. Renoud was their cartographer.

The text describes pre-Cenozoic rocks, tectonic evolution, Cenozoic rocks, and structural history, along with geography and geologic setting.

Information from prior work by Ashley, Prostka, Bateman, Vallier, Wolff, Corcoran, Wagner, Imlay, Carlat, and Calkins was incorporated into the mapping.

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INDEX TO THE ORE BIN
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