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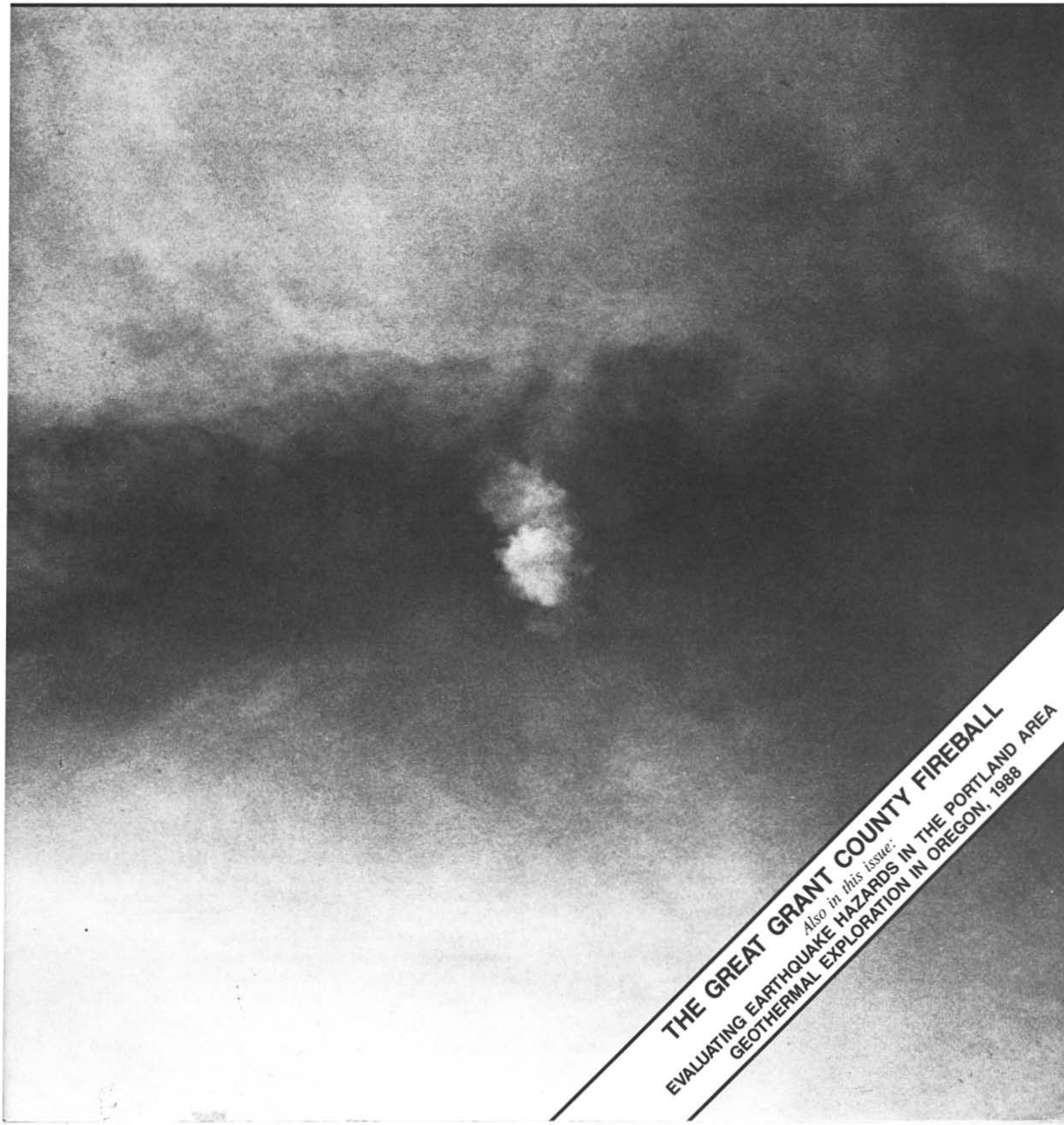

THE GREAT GRANT COUNTY FIREBALL

Also in this issue:

EVALUATING EARTHQUAKE HAZARDS IN THE PORTLAND AREA

GEOTHERMAL EXPLORATION IN OREGON, 1988

OREGON GEOLOGY

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Main Office: 910 State Office Building, 1400 SW Fifth Ave., Portland 97201, phone (503) 229-5580.

Baker Field Office: 1831 First Street, Baker 97814, phone (503) 523-3133 Howard C. Brooks, Resident Geologist

Grants Pass Field Office: 312 SE "H" Street, Grants Pass 97526, phone (503) 476-2496

Mined Land Reclamation Program: 1534 Queen Ave. SE, Albany 97321, phone (503) 967-2039 Gary W. Lynch, Supervisor

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Information for contributors

Oregon Geology is designed to reach a wide spectrum of readers interested in the geology and mineral industry of Oregon. Manuscript contributions are invited on both technical and general-interest subjects relating to Oregon geology. Two copies of the manuscript should be submitted, typed double-spaced throughout (including references) and on one side of the paper only. If manuscript was prepared on common word-processing equipment, a file copy on 5¼-in. diskette may be submitted in addition to the paper copies. Graphic illustrations should be camera-ready; photographs should be black-and-white glossies. All figures should be clearly marked, and all figure captions should be typed together on a separate sheet of paper.

The style to be followed is generally that of U.S. Geological Survey publications (see the USGS manual *Suggestions to Authors,* 6th ed., 1978). The bibliography should be limited to "References Cited." Authors are responsible for the accuracy of the bibliographic references. Names of reviewers should be included in the "Acknowledgments."

Authors will receive 20 complimentary copies of the issue containing their contribution. Manuscripts, news, notices, and meeting announcements should be sent to Beverly F. Vogt, Publications Manager, at the Portland office of DOGAMI.

DOGAMI announces contest for best nontechnical geologic paper

The Oregon Department of Geology and Mineral Industries (DOGAMI) would like for Oregonians and visitors to enjoy more fully the geology of the state. We are announcing a contest for the best nontechnical paper or field trip guide on the geology of the state. The winning papers and possibly some of the runners-up will be printed in *Oregon Geology.* The rules are as follows:

1. The contest is open to anyone knowledgeable about the geology of Oregon except for DOGAMI employees or their families.
2. The subject is some aspect of the geology of the state. Articles or field trip guides are welcome. The paper should be nontechnical and written for the interested lay public, not just for other geologists. Papers should be technically correct and should contain up-to-date information. They will be judged on their readability, interest to the nongeologist, and quality and accuracy of information.
3. The papers should not exceed 15 pages of *Oregon Geology,* including maps, figures, and photos. One typeset page of the magazine with no pictures contains between 1,300 and 1,400 words.
4. Manuscripts should be typed double spaced, and three copies should be submitted. The author's name should not be on the manuscript but should be placed with address, phone number, and title of article on a separate sheet of paper inside the envelope with the manuscript. All artwork should be camera-ready. Only black-and-white photographs can be used.
5. All material should use DOGAMI format, which is similar to that used by the U.S. Geological Survey (USGS). Consult recent issues of *Oregon Geology* or the USGS *Suggestions to Authors* (6th ed.) for specific questions.
6. All entries should be mailed to Beverly F. Vogt, Publications Manager, DOGAMI, 910 State Office Building, Portland, OR 97201, and must be received no later than January 31, 1990. DOGAMI is not responsible for entries lost in the mail. Manuscripts will be returned upon request.
7. Entries will be judged by a panel of three judges. Winners will be announced in the May 1990 issue of *Oregon Geology.* The first prize is $500. Second prize is $300. Third prize is $150. If no suitable manuscripts are entered, no prizes will be awarded. DOGAMI reserves the right to publish manuscripts in *Oregon Geology.*
8. Questions should be addressed to Beverly Vogt at DOGAMI. □

COVER PHOTO

On October 23, 1987, Oregon experienced the largest fireball ever reported in the state during this century. Picture shows "smoke" cloud as seen from Mount Vernon, Grant County, 50 seconds after the sonic boom, 26 km from the fireball's end point. Photo by Mike Burgett. See related article on page 111.

CONTENTS

Geothermal exploration in Oregon, 1988 99
Evaluating earthquake hazards in the Portland area 106
The great Grant County fireball, October 23, 1987 111
Oregon boasts first gas storage site at Mist field 112
Book review by Allen Agnew: Odyssey of Thomas Condon . 113
Mineral-exploration activity 115
Recent DOGAMI publications 116
Additional sources of information on Thundereggs 117
Oil and gas news 117
Thesis abstracts 118

Geothermal exploration in Oregon, 1988

by George R. Priest and Gerald L. Black, Oregon Department of Geology and Mineral Industries

LEVEL OF GEOTHERMAL EXPLORATION

Introduction

Aside from a few shallow temperature-gradient holes drilled by the U.S. Geological Survey (USGS) in the Western Cascades, no significant geothermal exploration occurred in 1988. The amount of leased land declined on both U.S. Bureau of Land Management (USBLM) and USDA Forest Service (USFS) lands. The total amount of federal land leased for geothermal resources has declined annually by small amounts since the peak in 1983.

Drilling activity

Figure 1 shows the number of geothermal wells drilled and geothermal drilling permits issued from 1970-1988. Figure 2 shows the same information for geothermal prospect wells (depths <610 m). Tables 1 and 2 list the Oregon Department of Geology and Mineral Industries (DOGAMI) permits for geothermal drilling that were active in 1988. Five new permits were issued, three for prospect holes and two for geothermal wells. Only four holes were drilled. All were shallow (<152 m) temperature-gradient holes drilled by the USGS in the northern part of the Western Cascades.

Leasing

The consolidation of land holdings continued in 1988 as the total leased acreage of federal lands decreased by about 10 percent (Table 3; Figure 3). This decrease in leased lands was the result of a 53-percent decline in USBLM leases coupled with a 6-percent decrease in USFS leases (Table 3). This decrease marks the fifth straight year of decline since the 1983 peak in total leased acreage.

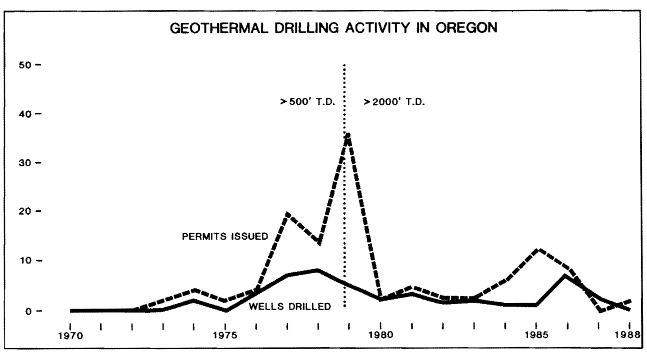


Figure 1. Geothermal well drilling in Oregon. Vertical line indicates time when definition of geothermal well was changed to a depth greater than 610 m.

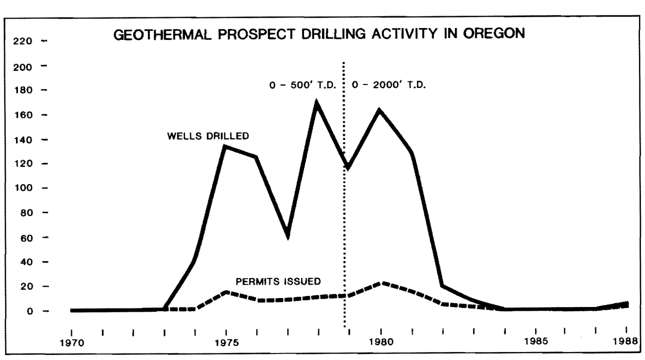


Figure 2. Geothermal prospect-well drilling in Oregon. Vertical line indicates time when definition of prospect well was changed to a depth of less than 610 m.

There are 112 leases pending on Forest Service lands in Oregon. Of these leases, 57 are awaiting preparation of Environmental Assessments or Environmental Impact Statements. The remainder are awaiting reports on adverse effects regarding the National Park Service (NPS). There are no leases pending on USBLM lands in Oregon.

Figure 4 is a graph of the annual total monies received by the federal government from geothermal leasing in Oregon from 1974, when leasing was initiated, to the present. Included in the graph is income from filing fees, rental on competitive and noncompetitive leases, and bonus bids. Income from geothermal leasing peaked in 1980 at $1,701,189 and has declined steadily since then to its present level of about $435,000.

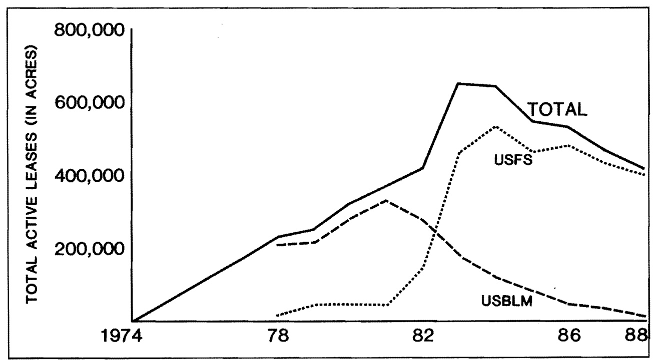


Figure 3. Active geothermal leases on federal lands in Oregon from the inception of leasing in 1974 through December 1988.

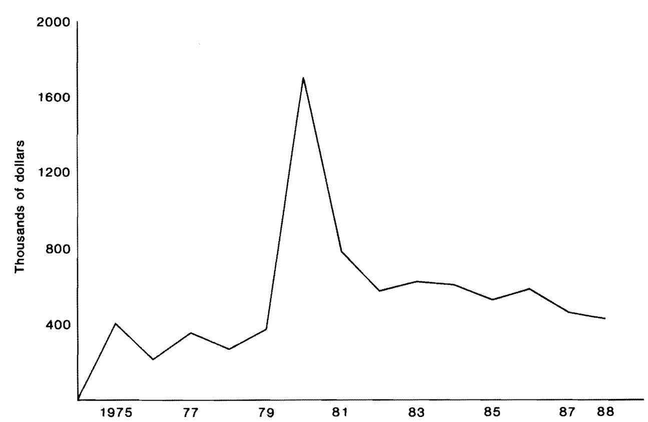


Figure 4. Federal income from geothermal leases in Oregon from the inception of leasing in 1974 to the present.

KNOWN GEOTHERMAL RESOURCE AREA (KGRA) SALES

No KGRA lands were offered for bid in 1988. Some KGRA lands at Newberry volcano will probably be incorporated into a proposed geological monument (see section on regulatory actions).

REGULATORY ACTIONS

In May 1988, Congress ordered the Secretary of the Interior to determine whether or not significant thermal features exist in Crater Lake National Park. The Secretary was required to report within six months (see section on the Mount Mazama area for further information).

Table 1. *Active permits for geothermal drilling in 1988*

Permit no.	Operator, well API number	Location	Status, proposed total depth (m)
116	Calif. Energy Co. MZI-11A 035-90014	SW¼ sec. 10 T. 31 S., R. 7½ E. Klamath County	Suspended; 413.
117	Calif. Energy Co. MZII-1 035-90015	SE¼ sec. 13 T. 32 S., R. 6 E. Klamath County	Suspended; 148.
118	GEO* N-1 36-017-90013	SW¼ sec. 25 T. 22 S., R. 12 E. Deschutes County	Suspended; 1,387.
124	Thermal Power Co. CTGH-1 36-047-90002	SE¼ sec. 28 T. 8. S., R. 8 W. Marion County	Suspended; 1,463.
125	GEO* N-2 36-017-90018	SW¼ sec. 29 T. 21 S., R. 12 E. Deschutes County	Suspended; confidential.
126	GEO* N-3 36-017-90019	NE¼ sec. 24 T. 20 S., R. 12 E. Deschutes County	Suspended; 1,219.
127	Calif. Energy Co. CE-NB-4 36-017-90020	NW¼ sec. 16 T. 22 S., R. 13 E. Deschutes County	Plugged and abandoned.
129	Calif. Energy Co. CE-NB-4 36-017-90022	SE¼ sec. 4 T. 21 S., R. 12 E. Deschutes County	Plugged and abandoned.
131	GEO* N-4 36-017-90023	NE¼ sec. 35 T. 21 S., R. 13 E. Deschutes County	Suspended; confidential.
132	GEO* N-5 36-017-90024	NE¼ sec. 8 T. 22 S., R. 12 E. Deschutes County	Suspended; confidential.
135	GEO* NC88-29 36-017-90027	SE¼ sec. 29 T. 21 S., R. 12 E. Deschutes County	Not drilled.
136	GEO* NC54-5 36-017-90028	NE¼ sec. 5 T. 22 S., R. 12 E. Deschutes County	Not drilled.

* GEO-Newberry Crater, Inc.

USBLM announced on October 17, 1988, that no adverse effect will occur to any significant thermal feature of Crater Lake National Park resulting from leases issued for acreage 70-160 km north of the Park.

Two temperature-gradient holes drilled in 1986 by California Energy Company, Inc. (CECI), near Crater Lake National Park can now be completed, according to a recent decision by the Interior Board of Land Appeals (IBLA). On February 1, 1989, the IBLA turned down a 1988 appeal by the Sierra Club and other environmental groups that questioned USBLM's decision to approve amendments to the CECI drilling permits. The amendments authorize CECI to drill to 1,676 m, with loss of circulation of drilling fluid to the subsurface (see the section on the Mount Mazama area for further information).

Anadarko Petroleum Corporation has yet to obtain permission to drill a proposed 457-m test well in the Alvord Desert area (Table 1). Before the permit is approved, USBLM must determine whether the project might endanger rare fish in nearby Borax Lake. The proposed well would test flow rate and flow temperature of the hydrothermal system. Studies are reportedly underway to determine environmental impacts.

USFS and USBLM officials met with industry and environmental groups in February 1989 to work out a preliminary boundary for a proposed geological monument at Newberry volcano. The area of the monument will reportedly encompass much of the land formerly classified as KGRA. The work was still in progress at the writing of this paper.

The Geothermal Advisory Committee in Klamath Falls is considering engineering and financial alternatives that will help users to comply with the Klamath Falls Geothermal Code. The Code requires that users who discharge effluent to the surface must, by 1990, reinject the fluid.

DIRECT-USE PROJECTS

The direct use of relatively low-temperature geothermal fluids continued in 1988 at about the same level as over the last several years. Most of the activity is centered in Klamath Falls and Vale.

Ashland

Jackson Hot Springs in Ashland, Oregon, is still being run as a resort.

Klamath Falls

The Oregon Institute of Technology (OIT) improved its geothermal heating system, and the City continued to wrestle with the problem of defective piping installed in its district heating system. Improvements in the OIT system resulted in a 27-percent reduction in the amount of geothermal water used (Geo-Heat Center Quarterly Bulletin, 1989). An injection well was also drilled at OIT, but more work will have to be done to achieve an adequate level of reinjection (Paul Lienau and Susan Hartford, personal communication, 1989). In 1988, the City completed engineering plans for the replacement of defective pipe connections in part of its system. Replacement should occur in the near future now that legal action has secured $685,000 from the companies that manufactured and installed the pipe (Geo-Heat Center Quarterly Bulletin, 1989). Further expansion of the system utilizing the Small-Scale Energy Loan Program of the Oregon Department of Energy is planned (Geo-Heat Center Quarterly Bulletin, 1989).

Table 2. *Active permits for geothermal prospect drilling in 1988 (holes less than 610 m)*

Permit no.	Operator, well name	Location	Issue date; status
95	USGS	Mount Hood National Forest	June 1988; drilled two of four sites to 70 and 153 m.
96	USGS	Willamette National Forest	June 1988; drilled two sites to 47 and 91 m.
97	Anadarko Petroleum Corporation Well 25-22A	Alvord Desert area	September 1988; location, one hole.

La Grande

The Hot Lake Recreational Vehicle Resort plans to utilize 85 °C water from the Hot Lake artesian well to heat a pool later this year. The company hopes to eventually use the resource to heat greenhouses.

Lakeview

In Lakeview, the binary-cycle electrical generating station set up several years ago remains idle. The 300-kilowatt (kw) unit had an ouput of 250 kw from 105 °C water in a November 18, 1982, test (Geo-Heat Center Quarterly Bulletin, 1982).

The City of Lakeview terminated its agreement with Brown, Vence, and Associates, the firm that in 1985 won a geothermal franchise in the City. The City is still interested in the development of a district heating system.

Paisley

The Paisley area has one of the best quality but least utilized low-temperature geothermal resources in the state. Thermal wells there reportedly have high flow rates (observations of Gerald L. Black, 1981) and temperatures as high as 111 °C at only 228 m (Peterson and others, 1982). A campground and recreational vehicle park utilizes hot water for a pool, but no other uses are known.

Vale

In Vale, the successful Oregon Trail Mushroom Company, which commenced full-scale operations in 1986, continues to operate using water from a 107 °C aquifer for heating and cooling. Oregon Trail annually produces 2.3 million kilograms of mushrooms, which are marketed in Spokane, Seattle, Salt Lake City, and the Treasure Valley area in Idaho (Geo-Heat Center Quarterly Bulletin, 1987). Other users at Vale include Ag-Dryers (a grain-drying facility) and a greenhouse operation.

Ground-water heat pumps

In the Bend, Redmond, Prineville, and Madras areas of central Oregon and in the Willamette Valley, there was considerable activity in 1988 in the installation of ground-water heat pumps. The Oregon Department of Energy (ODOE) certified 97 residential geothermal tax credits in 1988, most of them for the installation of such systems. At the present time, a tax credit of up to $1,500 is available for each residence. The amount of tax credit is based on energy savings, not the cost of the system.

DOGAMI APPLIED RESEARCH

In 1986, DOGAMI received a grant from the U.S. Department of Energy (USDOE) to complete a geologic and geothermal-resource study of the Breitenbush-Austin Hot Springs hydrothermal area, including a detailed analysis of the Thermal Power drill hole, CTGH-1. The CTGH-1 hole was drilled to 1.46-km depth in the High Cascade Range northwest of Mount Jefferson in 1986 (Figure 5). David Sherrod of the U.S. Geological Survey (USGS) cooperated with DOGAMI to edit an open-file report summarizing data from the drill hole and from the Austin-Breitenbush geothermal area in general. The report, Open-File Report O-88-5, entitled *Geology and Geothermal Resources of the Breitenbush-Austin Hot Springs Area, Clackamas and Marion Counties, Oregon*, is available from DOGAMI. The report discusses two possible models of the geothermal system, utilizing all geological, geophysical, geochemical, and hydrological data from the area. Both models require a deep magmatic heat source to explain heat flow in the area, but one model requires that the magmatic heat source be significantly wider than the High Cascades (Blackwell and others, 1982; Blackwell and Baker, 1988), whereas the other model requires a narrow heat source or sources centered under the High Cascades (Sherrod, 1988; Ingebritsen and others, 1989). The latter model produces the observed high regional heat flow in the Western Cascades by lateral flow of heated ground water. These models were the subject of heated debate in a December 1988 symposium on the Cascades (see USGS activities).

DOGAMI formulated a scientific drilling program in 1987 (Priest and others, 1987) and had planned to drill a 650-m diamond-core hole in the Santiam Pass area in 1988. The project is now planned for the summer of 1989, because of delayed funding. DOGAMI is evaluating four potential sites (Figure 6). A diamond-core hole 600-1,000 m in depth is planned, with total depth depending on the level of support secured. Those interested in participating in the project are encouraged to contact George R. Priest for further information.

Core from four temperature-gradient holes was donated to DOGAMI by UNOCAL. The holes, drilled in the High Cascades near the South Sister and Mount Jefferson (Figure 5), reached depths ranging from 250 to 610 m. No temperature data are publicly available from the holes, but detailed lithologic logs are being produced as part of DOGAMI's scientific drilling program. The core is stored at Oregon State University, with representative samples available for inspection at DOGAMI.

A synthesis of Cascade geology in central Oregon was presented in 1988 at a symposium on the Cascades sponsored by the USGS (Priest, 1989; see next section). The paper presents a geological cross section through the Three Fingered Jack area that shows in excess of 1 km of downward displacement on a complex graben structure. This amount of displacement is consistent with earlier interpretations of Taylor (1981) and preliminary data from the previously mentioned UNOCAL holes (Smith and others, 1989; Gerald L. Black and Platt Bradbury, unpublished data). High permeability and geothermal fluids could occur in fractures and intergranular pore spaces associated with intra-graben faults and fill.

USGS ACTIVITIES

The USGS was involved in several geothermal-related projects in 1988. They also performed a great service to the geothermal and geologic communities by organizing and coordinating efforts to publish new research papers on Newberry volcano and the Cascade Range.

David V. Fitterman of the USGS edited a special issue of the *Journal of Geophysical Research* (JGR) on Newberry volcano (JGR, v. 93, no. B9, 1988). The issue includes articles on geology, hydrology, hydrothermal alteration, transient electromagnetic soundings, magnetotellurics, resistivity, high-resolution seismic imaging, gravity, and magnetics (see section on Newberry volcano for details).

Table 3. *Geothermal leases in Oregon in 1988*

Types of leases	Numbers	Acres
Federal leases in effect:		
Noncompetitive, USFS	223	402,037.95
Noncompetitive, USBLM	2	942.79
KGRA, USFS	1	100.00
KGRA, USBLM	7	16,465.12
Total leases issued:		
Noncompetitive, USFS	344	664,645.18
Noncompetitive, USBLM	266	406,157.79
Total leases relinquished:		
Noncompetitive, USFS	121	262,607.23
Noncompetitive, USBLM	264	405,215.00
KGRA, USFS	7	11,824.61
KGRA, USBLM	55	101,842.73
Lease applications pending	112	———

In December 1988, the USGS sponsored a Red Book conference on the Geological, Geophysical, and Tectonic Setting of the Cascade Range. Thirty-six new papers on the Cascades were presented at the four-day conference. The papers will be published as a USGS open-file report (Muffler and others, 1989). Many of the papers will appear in a special issue of JGR to be published in 1990.

Much debate on the previously mentioned geothermal models for the Cascades occurred at the Red Book conference (see section on DOGAMI activities), and some actions for resolving the debate were proposed. Cleaning out and logging the 2.5-km-deep Sunedco 58-28 hole near Breitenbush Hot Springs was considered a cost-effective means of definitively testing the two competing models. Drilling additional temperature-gradient holes in the High Cascades was also recommended as a means of establishing how much heat is actually available for lateral transfer to the Western Cascades. Additional heat-flow measurements in the Western Cascades would help to test for complex patterns of heat-flow variation that would be produced by lateral flow of heated ground water.

The USGS Water Resources Division (WRD) completed three years of intensive work in the Cascade Range. The program included NaCl surveys, stable-isotope studies, water chemistry, and temperature-gradient work in the central Oregon Cascades between Mount Hood and the Three Sisters. The data are summarized in an open-file report (Ingebritsen and others, 1988) and an interpretive paper (Ingebritsen and others, 1989).

WRD also drilled four shallow (47-153 m) temperature-gradient holes in the Western Cascades in 1988 (Table 2); three provided useful temperature gradients (Figures 5 and 7). The holes were drilled to fill in gaps in the existing heat-flow data base. The temperature gradients (51-66 °C/km; Figure 7) are similar to those previously measured by DOGAMI in nearby areas (e.g., Black and others, 1983).

Compilations of the geologic map of the State of Oregon by George W. Walker and Norman S. MacLeod and the Salem 1° by 2° sheet (Walker and Duncan, 1988) were completed. The geologic map of the state will be printed in 1990 or 1991.

David Sherrod and Jim Smith finished a geologic map of the Cascade Range in Oregon (Sherrod and Smith, 1989). The 1:500,000-scale map shows Quaternary volcanic rocks split into five age divisions and four compositional divisions. Western Cascades rocks, which are not as well known as the younger rocks, are shown in lesser detail.

Terry Keith and Keith Bargar continued their hydrothermal-alteration studies of holes drilled under the USDOE cost-share program. They also contributed hydrothermal-alteration studies to the Breitenbush-Austin geothermal report (see section on DOGAMI activities).

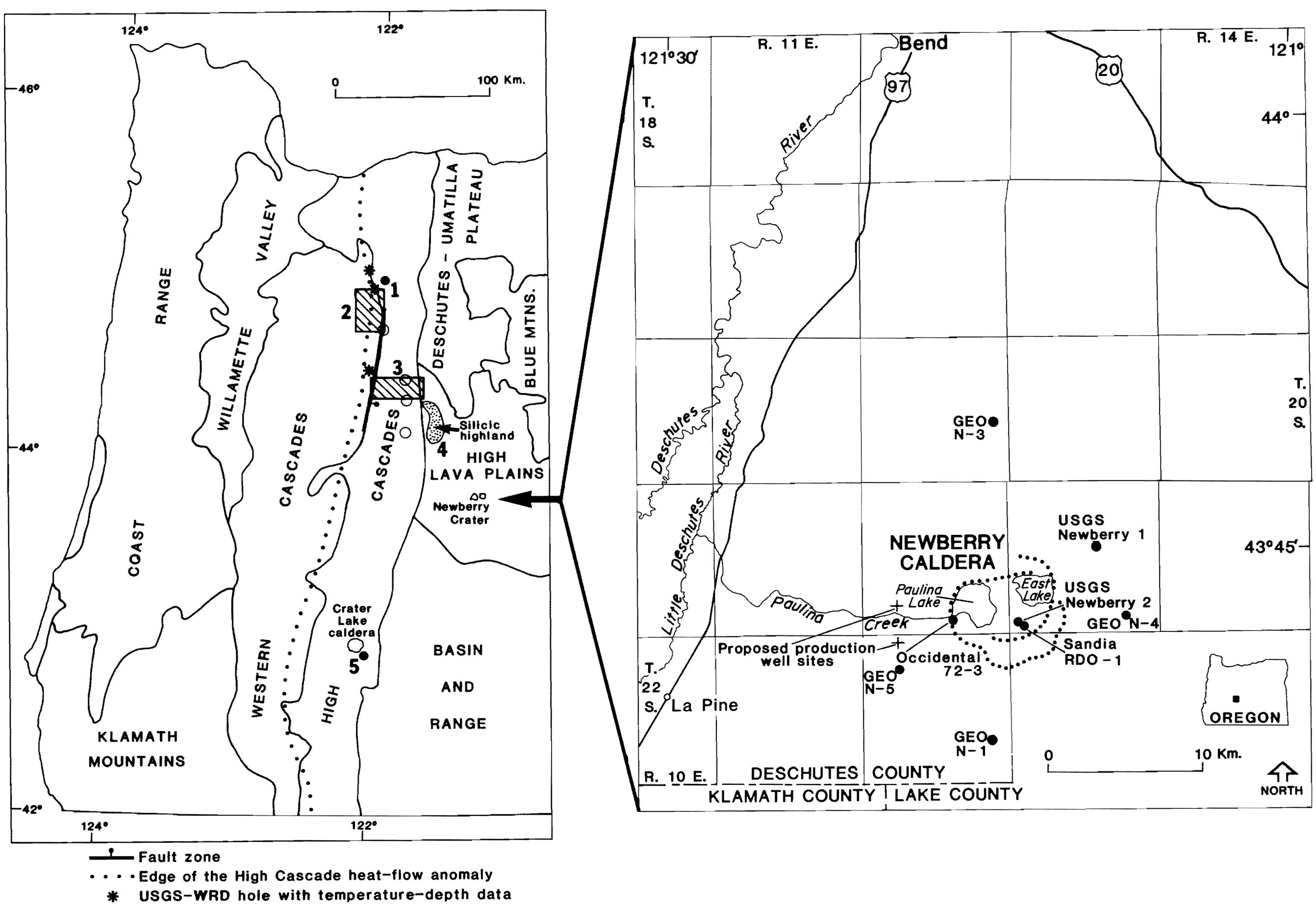


Figure 5. Physiographic provinces of western Oregon (after Dicken, 1950), showing major areas of geothermal activity discussed in text. 1. Location of Thermal Power drill hole CTGH-1. 2. Breitenbush River map area. 3. Santiam Pass study area. 4. Silicic highland. 5. Location of CECI drill hole MZI-11A. Edge of High Cascade heat-flow anomaly after Black and others (1983).

Inset map of Newberry caldera shows locations of temperature-gradient holes discussed in text and GEO permitted production well sites. Dotted lines show ring fractures of Newberry caldera.

Charles Bacon continued his investigation into the volcanic evolution of Mount Mazama, including the study of samples collected from the bottom of Crater Lake during *Alvin* dives. Manuel Nathenson and Michael Thompson presented an interpretation of water chemistry of Crater Lake at the January 1988 Corvallis meeting of the American Association for the Advancement of Science (AAAS).

William Scott and Cynthia Gardner completed their geologic map of the Mount Bachelor area (Scott and Gardner, 1989). The map will be published in color at a scale of 1:50,000.

GEO-HEAT CENTER, OREGON INSTITUTE OF TECHNOLOGY

The Geo-Heat Center at the Oregon Institute of Technology (OIT) specializes in assisting in the development of low-temperature (<90 °C) and moderate-temperature (90-150 °C) geothermal applications for direct use. The Center is under contract with USDOE to provide geothermal services to state and federal agencies who receive requests from engineering consultants, planners, and developers for development assistance on direct-use projects. The assistance can range from answering technical questions and simple consultations on methods, equipment, and applications to providing feasibility studies. The Geo-Heat Center has published over 70 such feasibility studies, which are available as examples. The project period is slated to run through the end of 1992.

The Geo-Heat Center completed a report on geothermal direct use that summarizes applications, regulations, and environmental factors. The report, entitled *Geothermal Direct Use Engineering and Design Guidebook*, is now available (Geo-Heat Center, Oregon Institute of Technology, Klamath Falls, Oregon 97601; phone 503-882-6321).

In 1988, the Geo-Heat Center assembled information on the original design and subsequent performance of a selected group of geothermal district heating systems that have operated at least three years. Specific areas of investigation were (1) customer connect time and disposal and (2) equipment type and materials of construction for production pumps and transmission piping. The operational performance of equipment in each of these areas is described and will serve as a reference for designers of new systems and operators of existing systems. The report will be available from the Geo-Heat Center some time in 1989.

The Geo-Heat Center evaluated downhole heat exchanger performance world wide. A summary of this study should be available sometime in 1989.

The Geo-Heat Center aided OIT in making plans to drill an injection well to eliminate surface discharge from its geothermal system.

The Geo-Heat Center continues to be involved in the evaluation of the Klamath Falls geothermal aquifer. Its staff plays an active role on the Klamath Falls Geothermal Advisory Committee and continues to publish the *Geo-Heat Center Quarterly Bulletin*, which has been in circulation since 1975.

ACTIVITIES OF OREGON WATER RESOURCES DEPARTMENT

The Oregon Water Resources Department (OWRD) continued its low-temperature geothermal program, which includes monitoring of the resources in Vale, the Klamath Falls area, and Lakeview.

The OWRD published a report on the hydrogeology of the developed geothermal aquifer at Vale (Gannett, 1988). The report can be obtained from OWRD.

Monitoring of the geothermal aquifer in Klamath Falls shows that water levels have been declining at a rate of approximately 0.3 m per year since about 1975. In 1985 the City of Klamath Falls passed the Geothermal Management Act in order to eliminate, by 1990, the wasteful geothermal-water discharge that presumably is causing the decline. In November 1987, the Water Resources Commission received a staff report describing the Klamath Falls decline and its implications. The report recommended that OWRD continue to monitor conditions in the geothermal aquifer and track progress toward the elimination of wasteful discharge. If the decline continues after 1990, OWRD will evaluate the situation and may consider administrative action to stabilize water levels.

Water levels fluctuate seasonally in Klamath Falls, with lowest levels occurring during the peak heating season in February. Water levels in February 1988 did not show any decline relative to 1987, probably due to the mild weather and resultant decreased heating demand.

Users in the Klamath Falls area are continuing to move toward total reinjection of pumped thermal water. The OIT Geo-Heat Center is working on a reinjection well for its system. Reinjection wells are already in use at the city jail and museum.

OWRD now has expanded authority to regulate use of low-temperature geothermal resources. State Senate Bill 237 provides the means for OWRD to protect senior users of a resource by controlling water use when alteration of temperature or undue thermal interference between wells is determined to exist.

ACTIVITIES OF ODOE

In 1988, geothermal activities of the Oregon Department of Energy (ODOE) focused on research and support for other agencies. ODOE, in cooperation with the Washington State Energy Office, continued to perform financial evaluations of new geothermal power plants for the Bonneville Power Administration (BPA).

ODOE responds to inquiries on geothermal energy development from the public. Over 140 such responses were provided in 1988. ODOE also certifies geothermal tax credits: 97 residential and 11 business tax credits (all for heat pump applications) were certified in 1988. ODOE continues to participate in the activities of the Pacific Geothermal Resources Council (GRC), publishing articles at the national meetings and being a board member of the local Northwest Section. Finally, ODOE instructed USFS personnel in geothermal energy in February 1988.

RESEARCH BY OSU

Brittain Hill, a doctoral candidate at Oregon State University (OSU), is continuing his work on Quaternary ash flows in the Bend area (Hill, 1985) and the silicic highland west of Bend. Isotopic age data indicate that the Bend Pumice and Tumalo Tuff, a sequence of air-fall ash-flow deposits, may be considerably younger than previously supposed (Sarna-Wojcicki and others, 1987). Hill has also acquired data that support a silicic highland source for the ash flows (Hill, 1985).

Jack Dymond and Robert Collier of the OSU Oceanography Department continued investigations at Crater Lake during the summer of 1988 (Collier and Dymond, 1988). Their objective is to determine whether or not hot springs exist on the floor of the lake (see section on the Mount Mazama area).

RESEARCH BY WASHINGTON STATE UNIVERSITY

Richard Conrey is finishing up a three-year study of the Mount Jefferson area. He found that, for the last 2.5 m.y., about 200 km^2 of the area has been the site of andesitic to rhyodacitic volcanism (Conrey, 1988). He postulates that a granodiorite-tonalite batholith lies at shallow depths beneath the area.

NEWBERRY VOLCANO

As previously mentioned (section on USGS activities), a special issue of JGR summarized current research on Newberry volcano. Of particular interest is the interpretation by Swanberg and others (1988) that the so-called "rain curtain" effect extends to a depth of about 1,000 m in the 1,219-m GEO N-1 hole (south flank of Newberry volcano). Blackwell and Steele (1987) used the same temperature data to infer that the "rain curtain" effect extends to a depth of only 350-400 m. Black and Priest (1988), in a review of all available

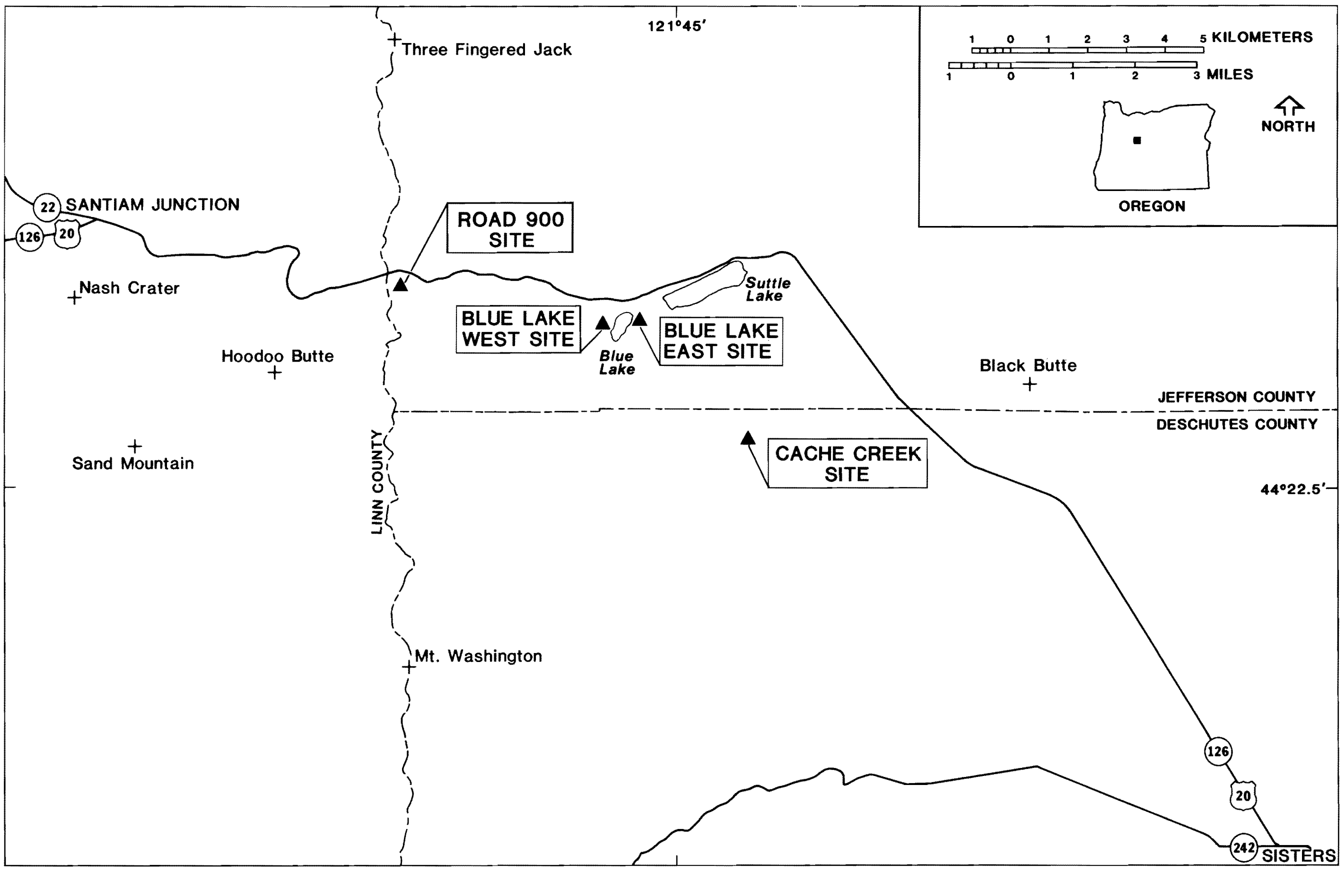


Figure 6. Location of potential scientific drilling sites near Santiam Pass, Oregon.

temperature-depth data at Newberry volcano, concluded that the "rain curtain" extends to a depth of about 450-550 m on the flanks of the volcano. Resolution of this issue is important to those trying to decide on appropriate depths of exploration for temperature-gradient studies of Newberry volcano and other young volcanic areas.

Achauer and others (1988), utilizing high-resolution seismic tomography, identified a low-velocity body at 3 km depth below the summit caldera at Newberry volcano. They interpret the body as "a possible magma chamber a few to a few tens of km³ in volume."

Sammel and others (1988) presented a theoretical model of the hydrothermal system and concluded that (1) elevated temperature gradients in drill holes on the flanks of the volcano are not influenced by any Holocene magma body under the caldera, and (2) the gradients in the lower part of flank drill holes "may be related to the cumulative effect of older intrusions."

Recently released temperature data from the west flank of the volcano tend to support the hypothesis that a very significant heat source exists there. The period of confidentiality on data from the lower portion of a 1,372-m hole drilled on the west flank of Newberry volcano ended in 1988; the data are therefore now available to the public. The hole was spudded in September 1983 by Occidental Geothermal, Inc., in sec. 3, T. 22 S., R. 12 E. (Figure 5, well 72-3). The hole was drilled to a total depth of 1,068 m in the fall of 1983. The hole was reentered in the fall of 1984 and deepened to 1,372 m. Data from the upper 1,068 m were published in last year's geothermal summary (Black and Priest, 1988). The operator of record is now Santa Fe Geothermal, Inc., of Bakersfield, California. The temperature-depth curve for hole 72-3 is essentially isothermal to a depth of approximately 470 m, reflecting the "rain curtain" effect (Black and Priest, 1988). The temperature gradient from 488 m to 1,366 m is 137 °C/km, with a bottom-hole temperature of 155 °C (Arestad and others, 1988). The gradient is linear, indicating conductive heat flow. Arestad and others (1988) argue that available exploration data favor further exploration of the west flank of the volcano for high-temperature geothermal resources.

Geo-Newberry Crater, Inc., reportedly plans to drill a test well on the west flank of Newberry volcano in 1989. DOGAMI in early 1988 granted permits for two sites: SE¼ sec. 29, T. 21 S., R. 12 E., and NE¼ sec. 5, T. 22 S., R. 12 E. (Figure 5). The environmental assessment for the drilling has been approved by USBLM. At this time, it is not known when drilling operations on Newberry will begin.

MOUNT MAZAMA AREA (CRATER LAKE AREA)

The reader is referred to Black and Priest (1988) for a detailed history of geothermal development issues at Mount Mazama prior to July 1988.

On June 21, 1988, the Pacific Division of the American Association for the Advancement of Science sponsored a special session on "The Clarity of Crater Lake, Oregon. An Ecosystem Study." A number of papers on the limnology and geohydrology of the lake were given. Sewage and natural processes were discussed as possible sources for the continued degradation of the clarity of the lake.

Responding to the previously mentioned directive from Congress (section on regulatory actions), the National Park Service granted $225,000 to Jack Dymond and Robert Collier of OSU to study the lake with a number of submarine dives. Temperatures 2-6 °C above the 3.6- °C lake temperature were found in gelatinous bacterial mats on the floor of the lake. These are the highest temperatures measured thus far on the lake bottom. The Park Service convened a panel of experts to review the findings of the OSU team. Additional dives are planned for the summer of 1989 (Jack Dymond, personal communication, 1989).

In 1989, California Energy Company reportedly plans to continue drilling on the Mount Mazama sites permitted by the previously discussed IBLA decision (see section on regulatory actions). In 1986, the MZI-11A site (Table 1) was drilled to 413 m, yielding a bottom-hole temperature of 107 °C and a temperature gradient of 372 °C/km in the lowest 20 m of the hole (Priest and others, 1987).

ACKNOWLEDGMENTS

We acknowledge the cooperation of numerous individuals in government and industry. Jacki Clark of USBLM provided the federal leasing data. Jack Feuer of USBLM and Bob Fujimoto of USFS provided much useful information on regulatory issues. Dennis Olmstead and Dan Wermiel of DOGAMI furnished the data on drilling permits. Alex Sifford of ODOE and Susan Hartford of OWRD provided information on their agencies' activities for the year. Paul Lienau of OIT provided much of the information on direct-use projects around the state. David Sherrod, Terry Keith, and Steve Ingebritsen of USGS supplied accounts of USGS activities in Oregon. Don Hull of DOGAMI, Alex Sifford, and David Sherrod reviewed the paper. Jack Dymond of OSU reviewed the section on his study of Crater Lake.

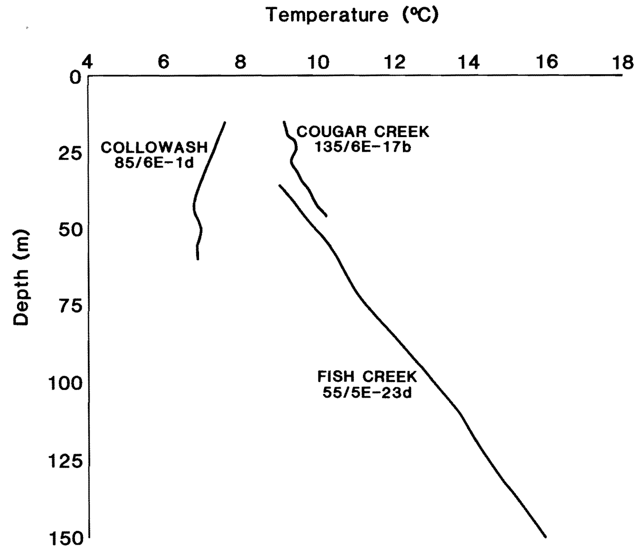


Figure 7. Temperature-depth curves for 1988 USGS drilling program.

REFERENCES CITED

Achauer, U., Evans, J.R., and Stauber, D.A., 1988, High-resolution seismic tomography of compressional wave velocity structure at Newberry volcano, Oregon Cascade Range: Journal of Geophysical Research, v. 93, no. B9, p. 10135-10147.

Arestad, J.F., Potter, J.F., II, and Stewart, G.E., 1988, Stratigraphic test drilling in the Newberry Crater KGRA, Oregon: Geothermal Resources Council Bulletin, v. 17, no. 10, p. 3-8.

Black, G.L., Blackwell, D.D., and Steele, J.L., 1983, Heat flow in the Oregon Cascades, *in* Priest, G.R., and Vogt, B.F., eds., Geology and geothermal resources of the central Oregon Cascade Range: Oregon Department of Geology and Mineral Industries Special Paper 15, p. 69-76.

Black, G.L., and Priest, G.R., 1988, Geothermal exploration in Oregon, 1987: Oregon Geology, v. 50, no. 9/10, p. 107-116.

Blackwell, D.D, and Baker, S.L., 1988, Thermal analysis of the Austin and Breitenbush geothermal systems, Western Cascades, Oregon, *in* Sherrod, D.R., ed., 1988, Geology and geothermal resources of the Breitenbush-Austin Hot Springs area, Clackamas and Marion Counties, Oregon: Oregon Department of Geology and Mineral Industries Open-File Report O-88-5, p. 47-62.

Blackwell, D.D., Bowen, R.G., Hull, D.A., Riccio, J.F., and Steele, J.L., 1982, Heat flow, arc volcanism, and subduction in northern Oregon: Journal of Geophysical Research, v. 87, no. B10, p. 8735-8754.

Blackwell, D.D., and Steele, J.L., 1987, Geothermal data from deep holes in the Oregon Cascade Range: Transactions of the Geothermal Resources Council, v. 11, p. 317-322.

Collier, J.W., and Dymond, J., 1988, Observations of bacterial mats associated with thermal springs at 450 m depth at Crater Lake, Oregon: EOS, v. 69, p. 1138.

Conrey, R.M., 1988, Mt. Jefferson area, Oregon High Cascade Range: a long-lived locus of andesitic and dacitic volcanism and plutonism [abs.]: Geological Society of America Abstracts with Programs, v. 20, no. 7, p. A196.

Dicken, S.N., 1950, Oregon geography: Eugene, Oreg., University of Oregon Cooperative Bookstore, 104 p.

Gannett, M., 1988, Hydrogeologic assessment of the developed geothermal aquifer near Vale, Oregon: Oregon Department of Water Resources Open-File Report 88-04, 33 p.

Geo-Heat Center Quarterly Bulletin, 1982, Low temperature geothermal power production in Lakeview, Oregon: Geo-Heat Center Quarterly Bulletin, v. 7, no. 3, p. 19-20.

———1987, Geothermal pipeline: Geo-Heat Center Quarterly Bulletin, v. 10, no. 1, p. 17-19.

———1989, Geothermal pipeline: Geo-Heat Center Quarterly Bulletin, v. 11, no. 3, p. 26.

Hill, B.D., 1985, Petrology of the Bend pumice and Tumalo tuff, a Pleistocene Cascade eruption involving magma mixing: Corvallis, Oreg., Oregon State University master's thesis, 101 p.

Ingebritsen, S.E., Mariner, R.H., Casidy, D.E., Shepherd, L.D., Presser, T.S., Pringle, M.K.W., and White, L.D., 1988, Heat-flow and water-chemistry data from the Cascade Range and adjacent areas in north-central Oregon: U.S. Geological Survey Open-File Report 88-702, 205 p.

Ingebritsen, S.E., Sherrod, D.R., and Mariner, R.H., 1989, Heat flow and hydrothermal circulation in the Cascade Range, north-central Oregon: Science, v. 243, p. 1458-1462.

Muffler, L.J.P., Blackwell, D.D., and Weaver, C.S., eds., 1989, Geology, geophysics, and tectonic setting of the Cascade Range: U.S. Geological Survey Open-File Report 89-178, in press.

Peterson, N.V., Priest, G.R., Black, G.L., Brown, D.E., Woller, N.M., Blackwell, D.D., Steele, J.L., and Justus, D., compilers, 1982, Geothermal resources of Oregon: Oregon Department of Geology and Mineral Industries and National Oceanic and Atmospheric Administration, scale 1:500,000.

Priest, G.R., 1989, Volcanic and tectonic evolution of the Cascade volcanic arc, 44° 00" to 44° 52' 30", *in* Muffler, L.J.P., Blackwell, D.D., and Weaver, C.S., eds., Geology, geophysics, and tectonic setting of the Cascade Range: U.S. Geological Survey Open-File Report 89-178, in press.

Priest, G.R., Bargar, K.E., Black, G.L., Blackwell, D.D., Couch, R.W., Collier, R., Duncan, R.A., Dymond, J., Evans, J., Goldstein, N., Haimson, B.C., Hughes, S., Iyer, M., Keith, T.E.C., Korosec, M.A., Laul, J.C., Levi S., Mariner, R.H., Mooney, W.D., Rowley, J., Sherrod, D.R., Smith, M., Waibel, A., Weaver, C.S., Woller, N.M., and Wright, P.M., 1987, Investigation of the thermal regime and geologic history of the Cascade volcanic arc: First phase of a program for scientific drilling in the Cascade Range: Oregon Department of Geology and Mineral Industries Open-File Report O-86-3, 120 p.

Sammel, E.A., Ingebritsen, S.E., and Mariner, R.H., 1988, The hydrothermal system at Newberry volcano, Oregon: Journal of Geophysical Research, v. 93, no. B9, p. 10149-10162.

Sarna-Wojcicki, A.M., Morrison, S.D., Meyer, C.E., and Hillhouse, J.W., 1987, Correlation of upper Cenozoic tephra layers between sediments of the western United States and eastern Pacific Ocean and comparison with biostratigraphic and magnetostratigraphic age data: Geological Society of America Bulletin, v. 98, no. 2, p. 207-223.

Scott, W.E., and Gardner, C.A., 1989, Geologic map of the Mount Bachelor volcanic chain and surrounding area, Cascade Range, Oregon: U.S. Geological Survey Miscellaneous Investigations Series Map I-1967, scale 1:50,000.

*(Continued on page 117, **Geothermal**)*

Evaluating earthquake hazards in the Portland, Oregon, metropolitan area: Mapping potentially hazardous soils

by Ian P. Madin, Seismic Hazard Geologist, Oregon Department of Geology and Mineral Industries

ABSTRACT

The scientific perception of earthquake hazards in Oregon is rapidly evolving, with the advent of new research that suggests that Oregon may be susceptible to earthquakes much more damaging than any in the state's short recorded history. Unfortunately, this new research does not provide the kind of well-constrained estimates of earthquake magnitude and epicentral location that are possible in areas such as Los Angeles or Salt Lake City.

Faced with the lack of good data about potential earthquake sources, the Oregon Department of Geology and Mineral Industries (DOGAMI) is attempting to approach the problem of earthquake design parameters by mapping surficial geology that may enhance earthquake-related hazards. The program centers on the production of 1:24,000-scale geologic maps that depict the distribution and thickness of Quaternary sediments that may cause amplification of ground shaking or lead to liquefaction during earthquakes. The mapping incorporates both surface geologic data and subsurface data collected from over 10,000 water-well, highway, and foundation-boring logs. DOGAMI anticipates that other workers will use these detailed geologic data to produce a variety of products of use to the engineering and planning communities. Among the planned and proposed uses are the following: (1) A regional map of spectral amplification zones in three period bands, based on surficial-unit thickness, measured and extrapolated shear-wave velocity profiles, and measured low-strain amplification factors; (2) a catalog of synthetic response spectra for a variety of sites and earthquake sources; and (3) liquefaction potential maps.

INTRODUCTION

Recent seismological and geological research suggests that the Portland metropolitan area may be faced with significant earthquake hazards from several different sources and that the area may be susceptible to earthquakes far larger than any in local history. The level of concern is such that the Portland metropolitan area, along with the Puget Sound region, is now the first priority for research funded by the National Earthquake Hazard Reduction Program (NEHRP).

Traditionally, the magnitude, frequency, and location of potential earthquakes is evaluated by studying the rate and distribution of instrumental or historic seismicity and by analysis of the prehistoric activity of the surface traces of active faults. Neither of these approaches serves Oregon well, because the state has a short historic record, a poor instrumental net, and thick soil and vegetative cover in most of the densely populated areas. These problems and the nature of the regional tectonic setting mean that earthquake hazard is currently best understood in terms of geologic source zones that are capable of producing earthquakes.

A geologic understanding of earthquake source zones does not help the professional who is trying to update a Uniform Building Code (UBC)-type seismic zone map or who is selecting a design earthquake for a specific structure in Portland. Unfortunately, there is little hope that the data needed for more specific evaluations of potential earthquake characteristics will be available in the next few years. The Oregon Department of Geology and Mineral Industries (DOGAMI) has therefore chosen to study something for which there are abundant data: potentially responsive or liquefiable soils. Although we may not be able to predict how large an earthquake we may be faced with, through careful mapping of soils we can predict which sites could expect significant ground motion amplification or liquefaction in any given earthquake. To this end, DOGAMI initiated a program of detailed mapping of the thickness and distribution of fine-grained unconsolidated sediments in the Portland metropolitan area, which will be largely completed in mid-1990. The detailed data provided by this program will be made available to the public and to other researchers for site-specific and regional studies of soils-dependent earthquake hazards.

EARTHQUAKE SOURCE ZONES

Earthquake hazards in the Pacific Northwest stem from tectonic activity associated with the subduction of the Juan de Fuca oceanic plate beneath the North American continental plate in Oregon and Washington (Figure 1). The Juan de Fuca Plate converges on, and thrusts beneath, the North American Plate along the Cascadia Subduction Zone. Active seismicity along the southwestern and western margins of the Juan de Fuca Plate indicate that the subduction process is active, with a long-term convergence rate of several centimeters per year in a generally north-northeast direction. Convergence along the Cascadia Subduction Zone implies, for the Portland area, three types of earthquakes, each originating in a different zone (Figure

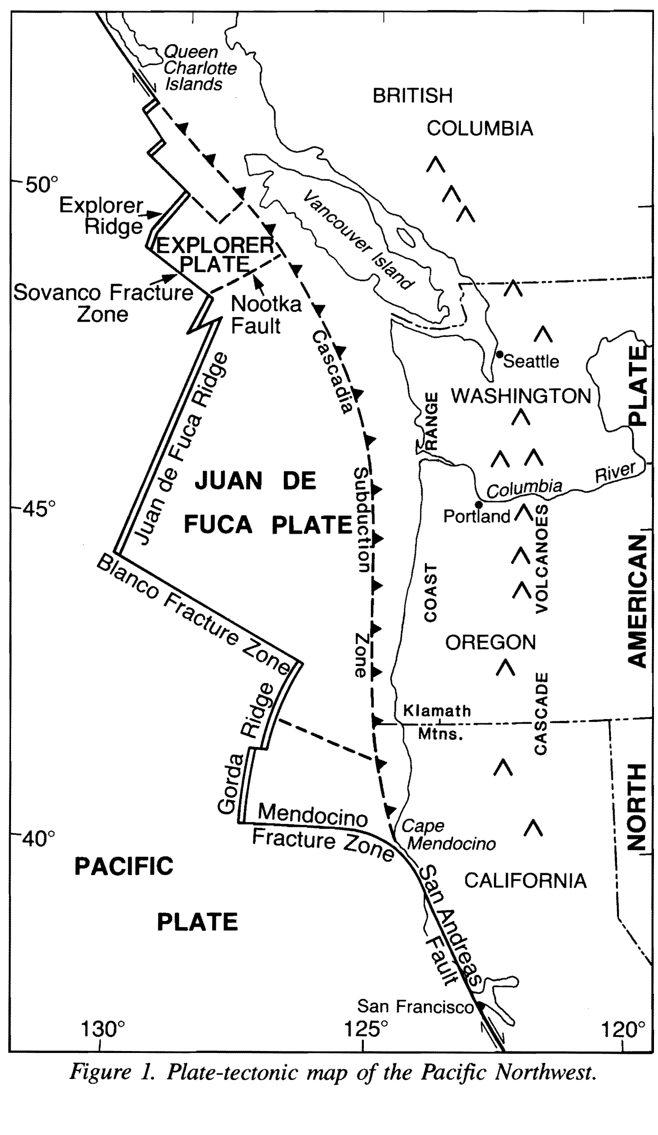


Figure 1. Plate-tectonic map of the Pacific Northwest.

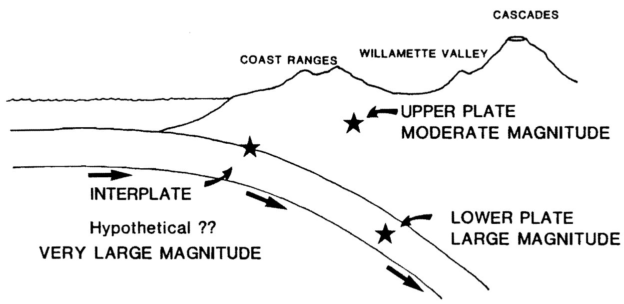


Figure 2. Schematic cross section through the Portland metropolitan area, showing the location of potential earthquake source zones.

2). These types of earthquakes are (1) shallow crustal earthquakes generated by faults in the immediate vicinity of Portland, (2) deep earthquakes originating in the subducted Juan de Fuca Plate beneath Portland, and (3) large earthquakes that may occur during periodic slip along the interface between the Juan De Fuca and North American Plates.

All of the historical earthquakes in Portland are considered to be crustal events. To date, no causative faults have been identified, but recent geologic mapping (Beeson and others, 1989) has demonstrated that the Portland Hills are part of a complex fault zone and that other faults are common within the area. This suggests the possibility of a repeat of the magnitude (M)-5.1 Portland earthquake of 1962 almost anywhere in the region. The current state of fault mapping and the short record of historical earthquakes probably precludes an accurate estimate of the maximum possible crustal earthquake in the area.

Large earthquakes in the Puget Sound region originate at depths of 40-60 km within the subducted Juan de Fuca Plate. A small number of well-located deep earthquakes (Figure 3) indicates that the potentially seismogenic portion of the Juan de Fuca Plate exists beneath northwestern and southwestern Oregon (Weaver and Baker, 1988; Weaver and Shedlock, 1989). This suggests that the Portland area is underlain by an earthquake source zone capable of generating events similar in size to the 1949 Olympia earthquake (M 7.1),

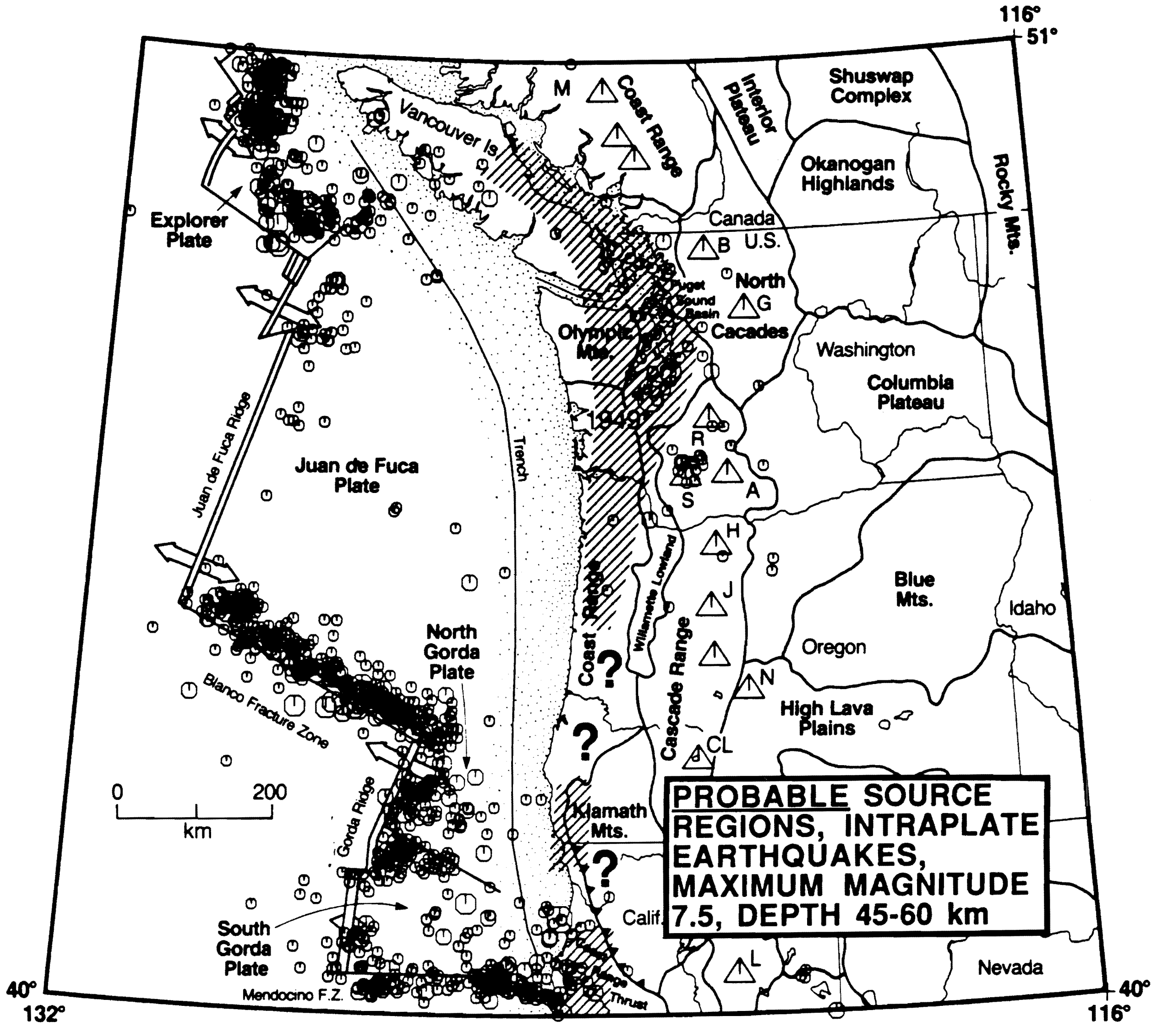


Figure 3. Schematic of probable source zones (hachured area) for deep earthquakes within the subducted Juan de Fuca Plate. Question marks indicate areas where there are no earthquakes located in the Juan de Fuca Plate. After Weaver and Shedlock, 1989.

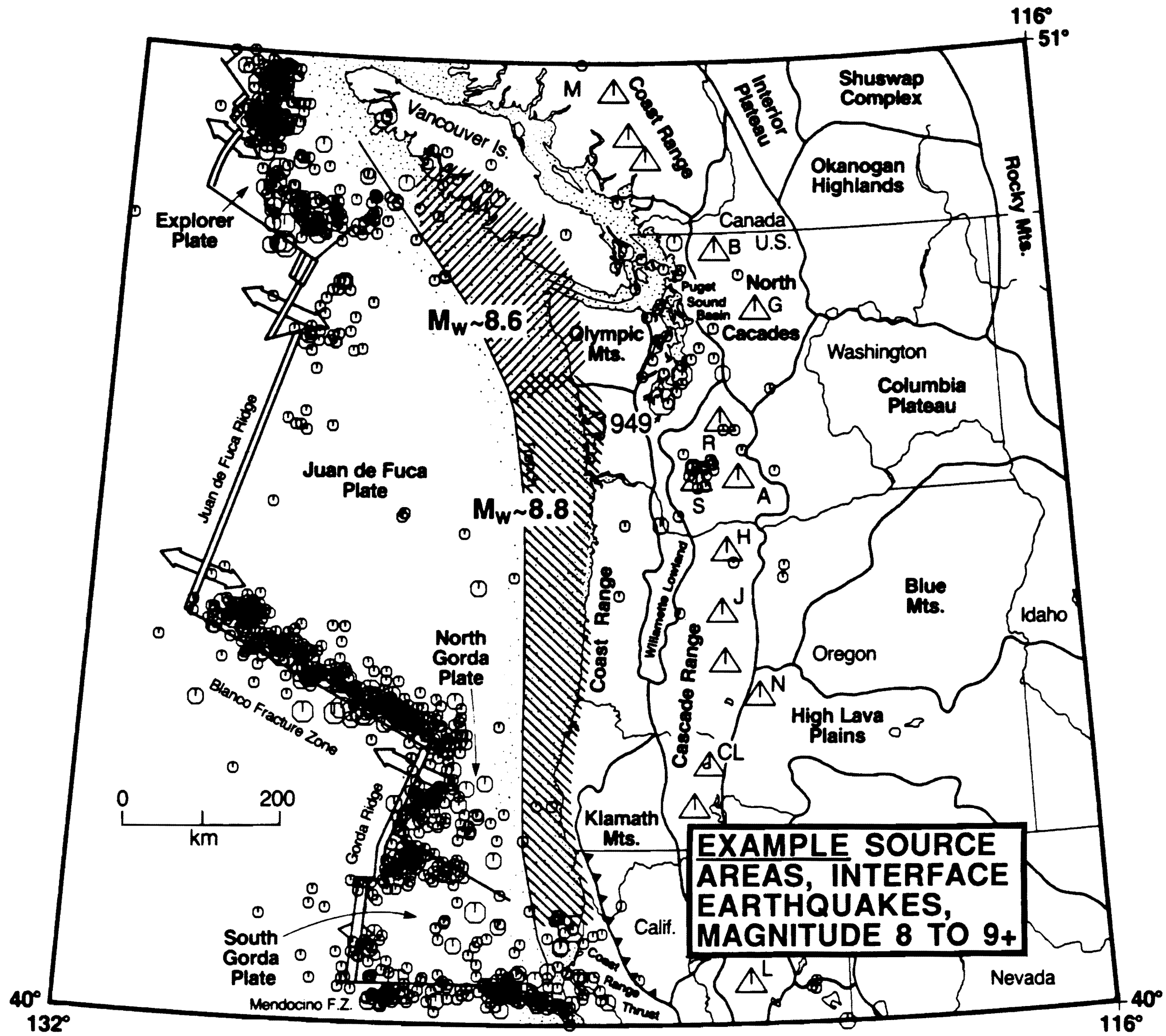
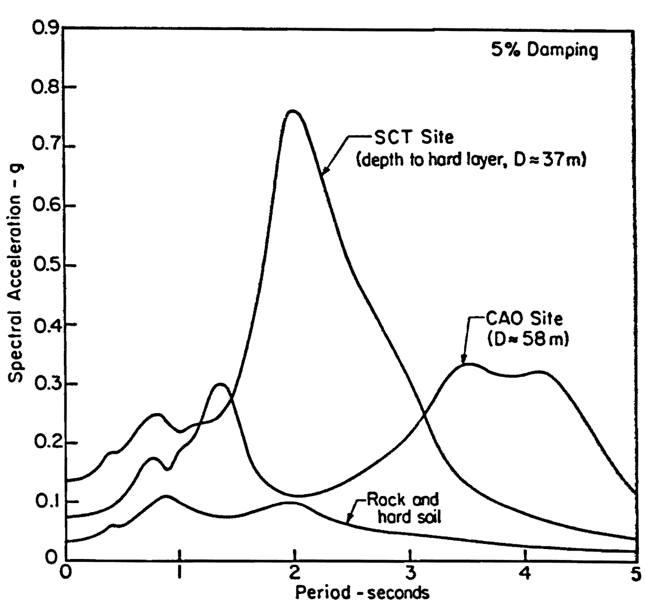


Figure 4. Schematic diagram showing examples of source zones and associated estimated magnitudes for hypothetical subduction interface earthquakes. Other combinations are possible. After Weaver and Shedlock, 1989.



although the overall rate of deep seismicity is orders of magnitude lower in Oregon than in Washington.

Finally, the suggestions of Heaton and Hartzell (1986) and observations of Atwater (1987) have triggered an intense scientific debate over the possibility that the Cascadia subduction zone may experience very large earthquakes due to periodic slip along the Juan de Fuca-North American Plate interface. Seismological data indicate that this interface is currently aseismic, which may mean that slip on the interface is always aseismic or that the interface is temporarily locked and accumulating strain between slip events. Geologic data provide strong evidence for repeated events of abrupt land-level changes and tsunamis that are very similar to those observed during the great earthquakes in Chile in 1960 and in Alaska in 1964. Conservatively, the entire coastal zone from northern California to British Columbia could be considered a potential source zone for large earthquakes (Figure 4).

← *Figure 5. Average acceleration response spectra for motions recorded on rock and hard-soil sites vs. soft-soil sites during the September 19, 1985, earthquake in Mexico City. SCT and CAO sites are soft-soil sites. After Seed and others, 1988.*

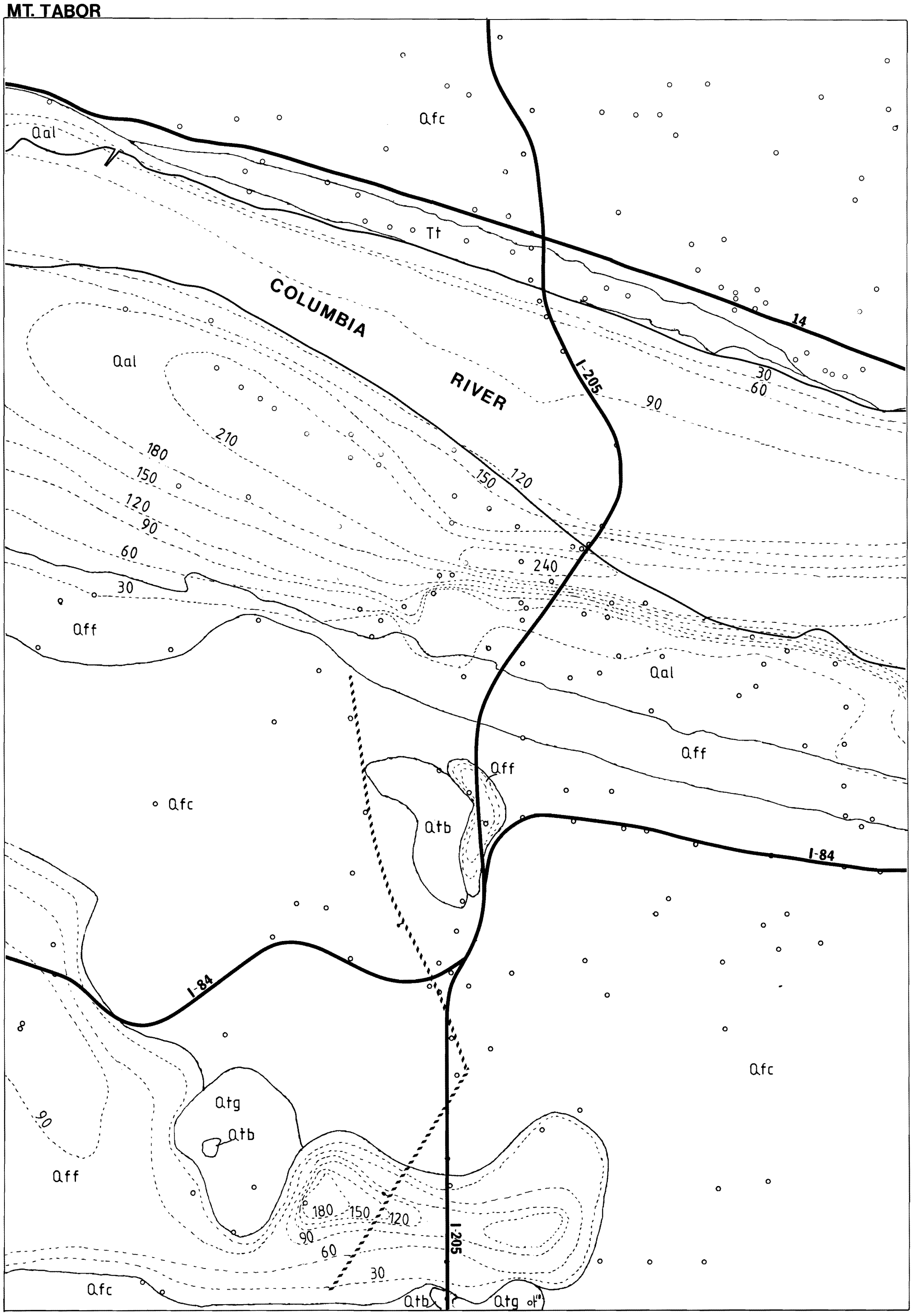


Figure 6. Preliminary geologic map of the Mount Tabor Quadrangle, Portland, Oregon. Small open circles are drill-hole data points. Qal = Recent alluvial sand and silt; Qff = outburst-flood silt of late Pleistocene age; Qfc = outburst-flood gravel of late Pleistocene age; Qtg = Pliocene-Pleistocene gravels; QTb = Pliocene-Pleistocene basaltic lava flows; Tt = Pliocene gravels. Dashed lines are 30-ft isopachs on units Qal and Qff combined. Diagonal dashed lines are inferred buried faults. Heavy black lines are highways.

The three potential earthquake source zones outlined for Portland are similar in two important respects: (1) All indicate a significant possibility of maximum possible ground motions larger than any in the historical record, and (2) it is currently not possible to accurately predict probable maximum ground motions or earthquake return times from any of these sources.

This implies that for many years to come, engineers may be faced with increased concern about potential seismic hazards in Portland without any new quantitative ground-motion data on which to base designs. What is possible, however, is to generate quantitative data on soils and site-dependent shaking amplification and liquefaction potential for a postulated design earthquake.

GROUND-MOTION AND LIQUEFACTION-POTENTIAL MAPPING

In any given earthquake, different sites at similar epicentral distances will experience ground shaking of different amplitude and spectral content due to the amplifying or attenuating effects of the surficial soil profile. Such amplification was, of course, dramatically demonstrated during the Mexico City earthquake of 1985 (Figure 5). Of particular concern are soft or cohesionless soils, which are widespread in the Portland area.

Ideally, one could map amplification due to soils empirically by comparing strong-motion records from a variety of sites. Unfortunately, earthquakes are not common in Portland, and there is only one strong-motion instrument in the area. This requires an approach to ground-response mapping based on an understanding of the density and shear-wave velocity profile at a great number of sites. Although these data can be obtained easily by measurements in a borehole, it is prohibitively expensive to collect data directly for the entire region. This means that we must couple a few direct measurements with an understanding of the local surficial geology in order to extrapolate data for a regional map. For this reason, the U.S. Geological Survey (USGS) and DOGAMI began a joint effort in 1987 to produce geologic maps on which to base evaluations of amplification potential.

DOGAMI's mapping program, which will be largely complete in mid-1990, will depict the thickness and distribution of young, fine-grained sediments and soils and the depth to bed rock throughout the developed portions of the Portland metropolitan area at a scale of 1:24,000. The mapping is based on field examination of surface exposures and topography and on the examination and interpretation of more than 10,000 foundation, highway, and water-well borehole logs. Figure 6, a map of the Mount Tabor Quadrangle, is an example of such a map.

Currently three uses have been proposed for the geologic data that DOGAMI has produced. A team of USGS scientists led by John Tinsley is planning to produce a series of ground-response maps for the area, using a technique that has been developed and refined in the Los Angeles, San Francisco, Salt Lake City, Seattle, and Olympia areas. Ivan Wong of Woodward Clyde Associates is proposing to produce a catalog of synthetic response spectra for a variety of characteristic sites. Finally, DOGAMI staff members are proposing to produce a series of liquefaction-potential maps for the area. It is crucial to note that none of these programs currently has firm funding.

GROUND-RESPONSE MAPS

The USGS team uses an approach in which a series of data layers is used to map spectral amplification factors for three period bands. Recordings of relative ground motion are made at a variety of sites using quarry blasts, nuclear tests, or natural earthquakes. Boreholes are then drilled at the recording sites to measure the thickness, density, and shear-wave velocity of the unconsolidated sediments. The relations between the recorded spectral amplifications and the measured soil profile data are calculated and then extrapolated to the entire region, using data layers for the thickness of unconsolidated sediment, depth to basement, and sediment density. The resultant maps depict zones of similar spectral amplification in the 0.5- to 1.0-, 1.0- to 3.0-, and 3.0- to 10.0-second period bands.

Many workers have questioned the validity of this technique, particularly the linear extrapolation of low-strain spectral-amplification measurements to the high strains expected in earthquakes. However, preliminary results from Olympia (Ken King, personal communication, 1989) indicate that spectral-amplification zones mapped through recordings of quarry blasts correspond closely to mapped intensity anomalies from historical Puget Sound earthquakes.

SYNTHETIC RESPONSE SPECTRA

Workers at Woodward Clyde Consultants have developed a technique for generating synthetic response spectra for sites using the Band-Limited-White-Noise model with Random Vibration Theory (Darragh and others, 1989). Analysis of strong-motion records worldwide indicates that ground motions are controlled by the seismic moment of the earthquake and the rock properties (density, thickness, and shear-wave velocity) beneath the site. Comparisons of calculated spectra with strong-motion record derived spectra for historical Puget Sound earthquakes show excellent agreement (Figure 7). Ivan Wong of Woodward Clyde has proposed to generate a catalog of synthetic-response spectra for a variety of sites in the Portland area. The spectra would be based on site geology and shear-wave velocity data provided by DOGAMI and would model representative earthquakes from each of the potential source zones.

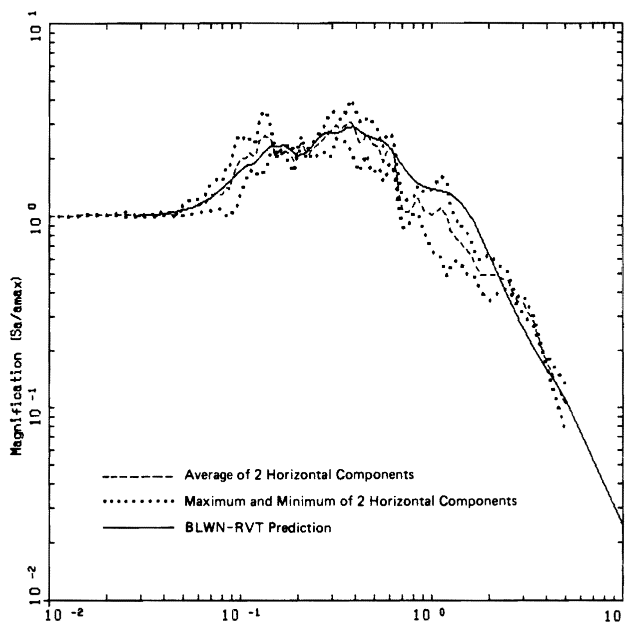


Figure 7. Observed and predicted acceleration response spectra of the earthquake at Olympia, Washington, on April 13, 1949, as recorded at the Highway Test Laboratory site in Olympia. After Darragh and others, 1989.

LIQUEFACTION-POTENTIAL MAPPING

Fine-grained, cohesionless saturated soils are common in the Portland metropolitan area, particularly along the Willamette and Columbia River flood plains and in much of Washington County. Analysis and mapping of the liquefaction potential of these sediments have been proposed by DOGAMI staff in conjunction with Les Youd of Brigham Young University and will make use of the existing borehole and geologic database. Preliminary liquefaction-potential mapping of part of the Portland area is being carried out by the

*(Continued on page 118, **Earthquake**)*

The great Grant County fireball, October 23, 1987

by Richard N. Pugh, Science Teacher, Cleveland High School, Portland, Oregon; Daniel J. Kraus, Former Chief Research Assistant/Deputy Director, Pine Mountain Observatory, University of Oregon; and Blain A. Schmeer, Professional Land Surveyor

The largest fireball ever reported in Oregon during this century occurred October 23, 1987, at 2:36 p.m., Pacific Daylight Time. This daylight fireball was seen from Wenatchee, Chelan County, Washington, on the north, to Burns, Harney County, Oregon, on the south. In Oregon, it was seen from Banks, Washington County, on the west, to Nyssa, Malheur County, on the east. This area covers 180,000 km^2.

The following report is the result of over 250 interviews of eyewitnesses in Oregon of the event and over 1,000 hours in the field.

The fireball entered the atmosphere above the Cascade Mountains north of Mount Adams in Washington State. It moved southeast to Grant County, Oregon, where it exploded. The angle of descent was from 30° in Washington State to 90° at the end point. When it crossed the Columbia River near Celilo, Oregon, the angle of descent was about 35°.

The fireball was very bright. Those people who were in front of it reported that it was too bright to look at. Many reported it to be brighter than the sun and several times the diameter of the sun in the Dayville-Mount Vernon area of Grant County, Oregon.

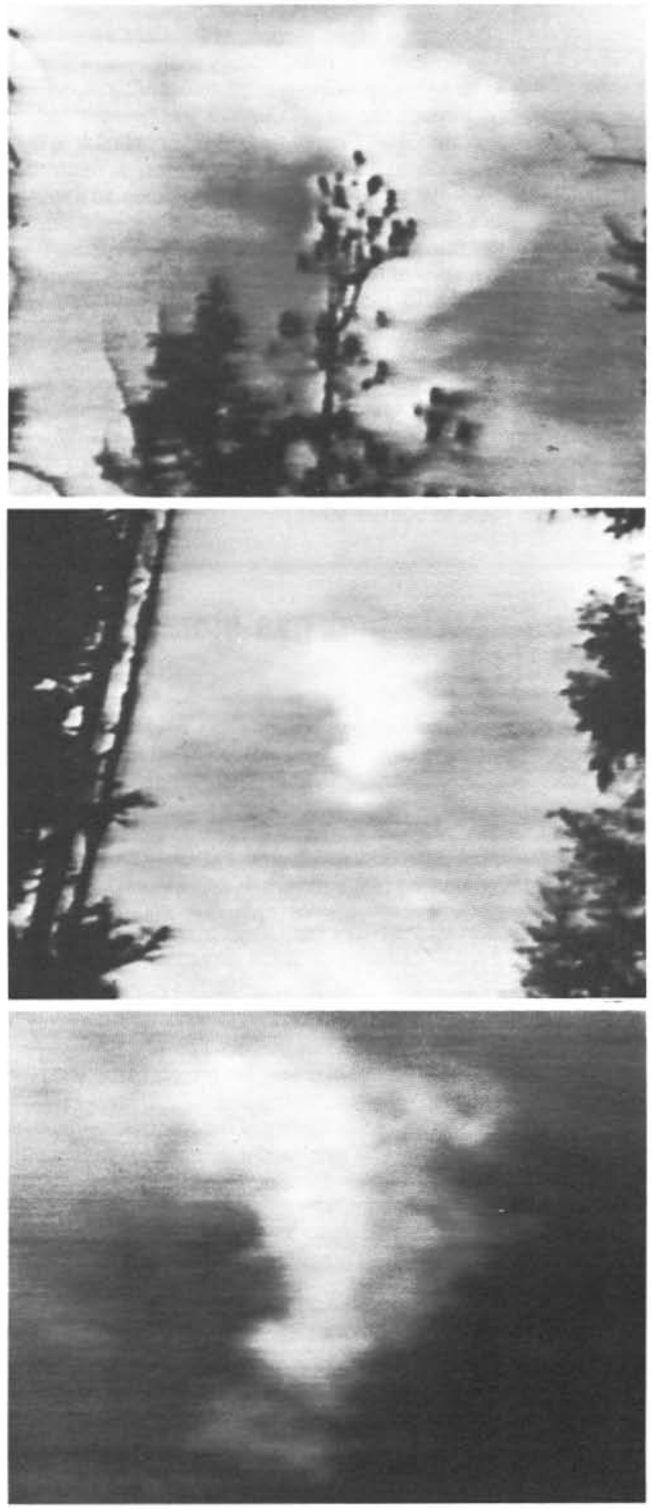
Most observers reported a round to teardrop-shaped fireball. All colors were reported, with orange and red being the most common. Most observers saw a long, white tail. Flames, sparks, and "smoke" were seen with the tail. The end point of the fireball's traverse occurred at an altitude of 29 km over sec. 24, T. 11 S., R. 27 E., W.M., at Grizzly Flats in the Blue Mountains of Grant County. Fragmentation near the end point was reported by some observers.

The fireball finally exploded, producing a large, columnar dust cloud. The dust cloud appears to have penetrated a thin overcast that was at an elevation of about 6,000 m. Most observers saw a blue-white cloud; many reported a black or brown center in the cloud. One person who was positioned almost directly under the cloud saw dark shapes falling out of the cloud. However, no one heard anything hit the ground. The cloud persisted for over 30 minutes.

Rumblings and sonic booms associated with the fireball were heard over an area extending north to the mouth of the Deschutes River in Sherman County, south to Seneca in Grant County, west to Mitchell in Wheeler County, and east to Prairie City in Grant County. Those in front of the fireball heard up to three heavy sonic booms that "caused the ground to move," rattled dishes, and flexed buildings. Those heavy booms were followed by up to 35 pops or cracks like a string of large firecrackers or a machine gun. Those under the fireball's path heard "wamp-wamp" sounds like a helicopter's blade. Swishing sounds were also reported. One to three heavy booms and five to 35 pops or cracks and rumblings lasting up to two minutes were reported by most people.

Within an hour of the event, the smell of sulfur was reported at Clarno in Wheeler County and the odor of hot metal at Canyon City in Grant County.

Anomalous sounds (sounds heard at the same time the fireball was seen) were reported from 6 km southwest of Cornelius in Washington County, over 300 km from the end point of the fireball. A hissing, whistling sound caused one person who was standing near TV and CB antennas on the roof of a house to look up and see the fireball. An observer traveling in an automobile near Boring in Clackamas County about 250 km from the end point heard a swishing sound and a faint boom at the same time he saw the fireball. A person located 8 km southeast of Oregon City in Clackamas County, approximately 260 km from the end point, heard a whooshing sound that caused him to look up and see the fireball. He was standing next to a patio with a metal roof.



VCR photos taken from 20 km southeast of Dale, Grant County, 48 km from the fireball's end point. The pictures were taken two seconds, three minutes, and five minutes after the sonic boom was heard. Photos courtesy of Pat Youmans.

At Kimberly in Grant County, a saddle horse started acting up for no reason, and then a strange sound caused the rider to look up and see the fireball descend. A "wamp-wamp" sound was heard as buildings quivered and the fireball exploded.

About 16 km east of Dayville, Grant County, 25 km from the fireball's end point, two sleeping dogs awoke, jumped up, and ran to the north window of a mobile home. Four or five seconds later, sonic booms hit the home. Loggers working at Pismire Camp, Grant County, 5 km from the end point heard a heavy sonic boom followed a short time later by a "wamp-wamp-wamp" sound of an object going end-over-end through the air. No impact was heard.

The behavior of the Grant County fireball is very similar to that of the fireball that produced the Pasamonte, New Mexico, meteorite, which fell March 24, 1933. The Pasamonte fireball produced a strewn field of meteorites that was 45 km long and 8 km wide (Nininger, 1936). Nearly a hundred small stony meteorites, none weighing over 300 grams, were recovered (Graham and others, 1985). Similarities between the two fireballs indicate that meteorites could be found anywhere along a line from Kimberly to Mount Vernon, Grant County.

Although the area over which the meteorite exploded is very rough terrain, the authors have been searching for pieces that fell to earth. The elevation is around 1,500 m, and the area is covered by a Ponderosa pine forest. Recovery of meteorite specimens is expected to be very difficult, and the authors urge anyone who may have found a piece to contact them.

Photo of "smoke" cloud taken from 110 km west of fireball's end point one minute after the sonic boom. Photo by Dave Corliss.

REFERENCES

Graham, A.L., Bevan, A.W.R., and Hutchison, R., 1985, Catalog of meteorites, 4th ed.: Tucson, Ariz., University of Arizona Press.

Nininger, H.H., 1936, The Pasamonte, New Mexico, meteorite: Popular Astronomy, v. 44, no. 6, p. 331-338. □

Oregon boasts first gas storage site at Mist field

Energy demands on Northwest Natural Gas Company next winter will be met, at least in part, with natural gas from the company's new Columbia County storage field at Mist, the first gas storage site in Oregon.

When it is filled, the storage field will hold 7.5 Bcf of gas, sufficient peaking supplies for "the coldest 60-100 days of winter." The storage field is comprised of the Flora and Bruer pools, the largest pools discovered in the 10-year-old Mist Gas Field. Northwest Natural Gas began pumping gas back into the depleted pools in 1987, after they were taken out of production in 1984.

The distribution system of Northwest Natural Gas will be connected to the storage field by a new $59,200,000 pipeline, which is expected to be ready for use in October. The 49-mi job began May 8 and is the largest capital construction project in the 130-year history of the Portland, Oregon, utility.

Because of the ancient Indian history of the Northwest, management of Northwest Natural Gas gave careful attention to the possibility that any right-of-way chosen for a new pipeline could disturb, or possibly destroy, Indian artifacts.

As it happened, the first route choice had to be abandoned because archeologists found "a heavy concentration of Indian artifact sites" and, because of that, a crew of experienced archeologists "walked every mile" of the route finally used, before trenching of the line was even begun.

This careful attention was rewarded when in the path of the pipeline were found 20 prehistoric Indian sites and seven historic sites, where discoveries have included small Stone Age tools such as mortars, pestles, chopping implements, and small flakes. Such finds indicate, according to the experts, that these sites had been used periodically over the last 6,000-8,000 years.

While the Mist storage field is a first for Oregon, natural-gas storage began in Canada in 1915. The Zoar field near Buffalo, New York, where storage was begun in 1916, remains the oldest continuously used gas storage field in the United States.

Construction of Northwest Natural Gas Company feeder pipeline just east of Mist.

Commenting in the company's annual report for 1988, Robert L. Ridgley, president, said that the storage facility "will allow the company to capitalize on the opportunities provided by open-access pipeline transportation," including summertime purchase of low-cost gas and realization of "substantial savings from reduced payments for peaking gas supplies."

Construction of the 16-in. line is expected to be completed by this fall.

—Reprinted with permission from Oil and Gas Journal, *v. 87, no. 25 (June 19, 1989), p. 59.*

BOOK REVIEW

by Allen F. Agnew, Courtesy Professor of Geology, Oregon State University, Corvallis, Oregon 97331

The Odyssey of Thomas Condon: Irish Immigrant, Frontier Missionary, Oregon Geologist, by Robert D. Clark. Oregon Historical Society Press, 1989, 569 p., illust., $29.95.

Condon, the teacher, minister, searcher for geologic answers

Thomas Condon (1822-1907) was a teacher, a master teacher who broke with tradition in the middle and later 1800's by introducing his students to what was later to be called the "laboratory" method: learning by observation and analysis, rather than by memorization and regurgitation.

Condon was also a minister of the Congregational Church who had received his theological upbringing in a Presbyterian Seminary in Auburn, New York, in the 1840's. His belief in God as creator of the world and of all its natural wonders did not get in the way of his scientific observation and objectivity. Rather, by constantly adapting the biblical story of creation as he was assimilating new evidence and new knowledge, he wedded the two in his personal philosophy and in his teaching, which was especially evident during his many lectures and conversations on evolution. He was part of several decades of debate on the "evolution controversy," his lectures being widely reported in the newspapers. His opponents were not only those speaking for the "established" theology of the various Protestant missionary churches but also some of his professorial colleagues in biology at the University of Oregon.

Condon's inquisitiveness was whetted by the books available to him from his earliest days in the United States. When he arrived in New York from Ireland in 1833, he was an 11-year-old Cork County native with no more than the basic elements of an education. He was fortunate to become a house boy and office boy for a physician who possessed a library. This search for knowledge continued to be fed during his three years of working on a farm in the Finger Lakes area of upstate New York, because the farmer there also had a library.

Condon's powers of observation outdoors and his joy in collecting rocks and fossils were stimulated by the geologic wonders of that beautiful Finger Lakes region, where he attended the Cazenovia Academy for a year and then for three years more engaged in what was to be his ultimate profession—teaching.

In 1849, Condon decided to enter the ministry, enrolling at the Presbyterian Seminary in Auburn, New York. The Presbyterians and Congregationalists in the middle 1800's had joint operations in upstate New York and Ohio, he found. He also learned that the issue of slavery and attendant conservatism had split the Presbyterians in 1837, as it had the Methodists and Baptists. Condon himself was an abolitionist.

While at seminary for three years, Condon taught 200 inmates at the nearby prison, who, as author Clark describes, "were overjoyed with the program—the only minutes in the week . . . when they were permitted human discourse" (p. 69). Condon empathized with them and was glad as a teacher to provide them with such a humanitarian release.

Upon graduation in 1852, Condon was appointed a missionary to the West by the American Home Mission Society. He learned that not only did the Society (of Presbyterians and Congregationalists) stipulate that the new missionaries be ordained but also expected them to be married. Condon was fortunate to have met Cornelia Holt that summer. She was a school teacher in a town near Buffalo, and they were married on October 31. With seven other missionaries and their families, they sailed from New York City on November 12 on a clipper ship for San Francisco. After 102 days and 17,000 miles on the ocean, the Condons and fellow missionary Obed Dickinson and his wife took another ship and, after five more days at sea, arrived in the small settlement of Portland on March 3, 1853.

Thomas Condon. Frontispiece in The Odyssey of Thomas Condon. *Photo from archives of Oregon Historical Society, negative no. ORHI 55652.*

For the next 54 years, Condon was to serve churches (as a missionary and minister), teach school (at both pre-college and college levels), and collect fossils and observe the geology around him. Condon's inquisitive nature, his powers of observation and analysis, and his strong religious foundation together enabled him to make his mark on the people of Oregon in the latter half of the 19th century. He was to be a lucid exponent of Darwin's modified evolutionary theory, which was to put him at odds with many of his religious counterparts in Oregon.

However, his continued discovery of fossils and his attempts to fit them into the evolutionary scheme of life brought him to the attention of the famous vertebrate paleontologists of the eastern United States. His collections and his thoughtful analysis of how they came to be there fueled the ambitions and abilities of two great movers and shakers during that period, Othniel C. Marsh of Yale University and Edward D. Cope of the Philadelphia Museum of Natural History. Joseph Leidy of the Smithsonian Institution likewise enabled that great museum to thrive on Condon's discoveries. By contributing to Condon's library in return for his fossil collecting, they helped Condon to grow intellectually and make his outstanding impact on Oregon.

Condon was not caught up in what we today call "publish or perish". Rather, partly because of his lack of formal training in geology and paleontology, but also because of his personal characteristic of searching for evidence and then seeking introspectively for the ultimate causes, he published only half a dozen articles on his researches. And those publications, he did not hesitate to state, were not intended as scientific discourses but were written for the general public.

Thus he carried out his lifelong bent of sharing his knowledge with those less tutored in those subjects than he—the great number of people in pioneer Oregon who were seeking to establish themselves in this frontier land and at the same time attempting to understand the world in which they were living. Condon's two larger published works—his Report as State Geologist in 1867, and his magnum opus, "Two Islands—and What Came of Them" in 1902, were both directed toward the general public. It was part of his duty, and his joy, to pass along his knowledge, while at the same time he extended his own comprehension by responding to the questions addressed to him by his audiences and through the mail.

Condon's wife Cornelia may have lived to see him complete his book in 1901, but she was unable to share his triumph in its publication a year later. She was ill during much of the summer of 1901 at the cottage on Yaquina Bay and contracted typhoid fever in August. She died on September 2, 1901, at almost 70 years of age. Condon mourned, "The light of my life has gone out."

Condon flowered in The Dalles, where he had gone in March 1862 as a missionary. It was a lively settlement, with trade not only up and down the Columbia River but also into the gold-mining country to the southeast in the Shoshone (Blue) Mountains. This was the first of his missionary posts that could be called financially successful and thus made the "bringing of the word" and the saving of lives even more satisfying to such a very human person.

But more than that, The Dalles opened up the fantastic fossil-bearing strata of the John Day country to Condon's gaze and collecting acumen. He accompanied U.S. Cavalry there on some assignments to protect the white settlers from the "marauding" Indians who objected to the invasion of their lands in the 1860's.

Oregonians can mark Condon's 11 years in The Dalles as providing the nurturing environment for his greatest contributions—to geology, to his students, and to the general public.

Condon's huge capability at communicating his new knowledge, with newspaper accounts reporting his several series of lectures in The Dalles and in Portland, brought him to the attention of university administrators. Thus, in August 1873, he was attracted, with his collections, to Pacific University in Forest Grove as lecturer. Two years later, the budding University of Oregon offered Condon a professorship in Eugene, and his acceptance inaugurated the final and most significant segment of Thomas Condon's 85 years on earth.

In his first summer after going to the University of Oregon, Condon took his family on a trip of many days to the beach at Newport. Finding an unoccupied cabin on Nye Beach, they settled in and for the next thirty years were regular summer residents of the Newport area. Condon collected fossils, conducted "geological picnics," and recharged his batteries—just as U of O faculty do today, both in the Newport area and along other parts of the Oregon coast.

Condon was good for the University of Oregon, and the university was good to him. Clark's history of Condon's tenure at the U of O is as much a history of that institution as it is a history of the man. Condon was able to collect and study and contemplate the geology of new parts of the state—the coast, the Siskiyou (Klamath) Mountains in southwestern Oregon, and the Fossil Lake collecting grounds of east-central Oregon (east of the Cascade Mountains but south of the John Day country).

All the while, Condon was sharing his knowledge with his students, his fellow faculty members, and the townspeople—the latter two groups not always agreeing with him. The students, however, flourished under his "laboratory" method of instruction with which he replaced the traditional dull reading of textbooks or lecture notes, followed by recitation. His faculty colleagues did not take kindly to his nontraditional pedagogy, and they and some of the townspeople did not agree with him on his evolutionary theory or his accommodation of science and religion.

Nevertheless, they appreciated Condon so much that they named the campus oak trees for him, and they celebrated his birthdays—the 75th, the 80th, and annually thereafter. In June 1903, Condon requested that his teaching load be lightened and his salary reduced to $1,000, with the rest of the money going to an assistant. In 1905 he resigned, "due to the disabilities of old age," and the Regents regretfully elected him Professor Emeritus—at age 83. In January 1907, Condon became ill with influenza and could not get rid of a troublesome cough. Daughter Nellie C. McCornack brought him to her farmhouse about two miles west of Eugene to look after him. He lived for about three weeks and died on February 11, within three weeks of his 85th birthday.

In his old age, Condon had become a legend. Henry F. Osborn is said to have remarked candidly: "Professor Condon deserves the entire credit of the discovery of the upper Oligocene horses in the John Day."

Clark, the chronicler, the historian

Robert D. Clark, President Emeritus of the University of Oregon, taught speech, rhetoric, and public address for many years there. He wrote an article on Thomas Condon, "From Genesis to Darwin: The Metamorphosis of Thomas Condon," which was published by the Oregon Historical Society in *The Western Shore* in 1975. Clark was also an author, along with Dorothy Velasco, of "An Evening with Thomas Condon," one of two pieces of history theater that toured eastern Oregon in 1981 and western Oregon in 1981-82 as part of Chautauqua 1981, a project of the Oregon Committee for the Humanities.

In the book being reviewed here, *The Odyssey of Thomas Condon*, author Clark enables us to live Condon's life along with him, sitting, as it were, in an adjoining chair as he talks or thinks. To some readers, used to speed-reading to the end of an account while hurrying over its details, such "extraneous" matter may constitute an impediment. To others, however, interested more in what made Condon "tick" and how he arrived at various decision points in his career and then made those decisions that constituted his life's history, this wealth of detail is most welcome—and makes Condon "come alive." Clark, a supreme chronicler, has done his job well.

For the geologist, Clark's book provides an interesting and exciting walk through the geological controversy surrounding the earth's origin and later development—uniformitarianism and catastrophism. And, for the geologist and the biologist, the Darwinian controversy and its effects on scientists and on the preservers of church doctrine ("as God wrote it") constitutes a thread that continues throughout the book. Condon's theological bent, coupled with his inquisitive mind and willingness to search for the truth and analyze it as a scientist does, enabled him to be an outstanding teacher—which he considered his main life calling.

Clark's book is very rewarding for a geologist such as this reviewer to read, because it enabled me to re-live my own professional life through the various stages that Condon himself had experienced a century earlier.

Clark's book is amazingly free from errors. Only three seem worth noting here:

(1) Along the Middle Fork of the Willamette River, Condon is said to have proceeded "southwest" from Eugene, whereas he really must have gone southeasterly (p.301).

(2) Sam Williston would have preferred that his name be spelled this way rather than "Willitson" (p. 512, footnote 19).

(3) Likewise, Henry Fairfield Osborn would have preferred this middle name rather than "Fairchild" (p. 435 and 563).

But, you won't wish to nitpick, anymore than I did as I was caught up in Clark's gripping account. Rather, you too will want to re-live Condon's Odyssey. I did—and I enjoyed it very much.

Yes, you should read Clark's *The Odyssey of Thomas Condon*. But you may also want to go to your library and check out the other biography of Thomas Condon, published by his daughter Nellie C. McCornack in 1928, *Thomas Condon: Pioneer Geologist of Oregon* (University of Oregon Press, 355 pages). Hers is full of correspondence between her father and the great names of vertebrate paleontology in the latter half of the 19th century—Cope, Marsh, and Leidy.

Ellen T. Drake gave an interesting account ("Horse genealogy: The Oregon connection," *Geology*, v. 6, no. 10, 1978, p. 587-591) of the Marsh/Cope feud, and of Marsh fending off other vertebrate paleontologists while grabbing for the line himself. She tells the story of Marsh (and his successors Charles Schuchert and Richard S. Lull), who claimed that Marsh himself had discovered the important Miocene horse link in the equine evolutionary tree—whereas the record shows that it was Condon who did so and who knew the significance of what he had found in 1871 when he sent his first collection to Marsh.

Shortly after Condon's death, the geological community recognized the value of his imprint upon vertebrate paleontology and geology in a memorial by Chester W. Washburne of the University of Chicago ("Thomas Condon," Journal of Geology, v. 15, 1907, p. 280-282), who wrote:

> . . . a life little known among scientists, yet a life of considerable service to geology.
>
> Professor Condon was an unusual man in that he seemed to have no desire to publish the results of his study . . . But the writings of the scientists of his day . . . are full of references to Dr. Condon, and all of them acknowledge his contribution to science by exploration and theory.
>
> Condon discovered the famous John Day beds . . . Here he found some of the specimens of three-toed horses on which Marsh based his theory of the evolution of that animal. In this instance, Marsh gave the discoverer scant credit for his work, and the type-specimens remained in Yale Museum until after Marsh died. The same thing happened to many other valuable specimens loaned to Marsh, Cope, Gabb, and others . . . it was unjust to Condon not to acknowledge more fully his services and not to return his specimens . . .
>
> Condon was one of those rare men that study science from an inherent love of nature, not merely for self-advancement, or for the praise of men.

Clark's book is thoroughly footnoted and has a very complete index, making it easy for one who wishes to retrieve information to do so. Index maps of towns mentioned and a number of good photographs complement this very readable text. □

MINERAL EXPLORATION ACTIVITY

Rules for exploration permit to be drafted

The passage of House Bill 2088 requires persons conducting exploration in Oregon who disturb more than one acre or conduct drilling in excess of 50 ft to have an Exploration Permit from the Mined Land Reclamation Program (MLR) of the Oregon Department of Geology and Mineral Industries. MLR is currently drafting rules and will conduct public hearings on those rules in the fall of this year.

The intent of the Exploration Permit is to tailor environmental regulation to the proposed activity. Therefore, in brief, the Exploration Permit will have a lower fee than the operating permit and will require a location map, a reclamation plan including drill-hole abandonment procedures, and a bond.

Until Exploration Permit rules are administratively approved, the term "Exploration" in the "Major metal-mining activity" table refers to the operating permit that is currently issued for exploration activities.

Readers who have questions or comments should contact Gary Lynch or Allen Throop at the MLR office in Albany, phone (503) 967-2039.

Major metal-mining activity

Date	Project name, company	Project location	Metal	Status
April 1983	Susanville Kappes Cassiday and Associates	Tps. 9, 10 S. Rs. 32, 33 E. Grant County	Gold	Expl
May 1988	Quartz Mountain Wavecrest Resources, Inc.	T. 37 S. R. 16 E. Lake County	Gold	Expl
June 1988	Noonday Ridge Bond Gold	T. 22 S. Rs. 1, 2 E. Lane County	Gold, silver	Expl
September 1988	Angel Camp Wavecrest Resources, Inc.	T. 37 S. R. 16 E. Lake County	Gold	Expl
September 1988	Glass Butte Galactic Services, Inc.	T. 23, 24 S. R. 23 E. Lake County	Gold	Expl
September 1988	Grassy Mountain Atlas Precious Metals, Inc.	T. 22 S. R. 44 E. Malheur County	Gold	Expl, com
September 1988	Kerby Malheur Mining	T. 15 S. R. 45 E. Malheur County	Gold	Expl, Com
September 1988	QM Chevron Resources Co.	T. 25 S. R. 43 E. Malheur County	Gold	Expl
October 1988	Bear Creek Freeport McMoRan Gold Co.	Tps. 18, 19 S. R. 18 E. Crook County	Gold	Expl
December 1988	Harper Basin American Copper and Nickel Co.	T. 21 S. R. 42 E. Malheur County	Gold	Expl
January 1989	Silver Peak Formosa Exploration, Inc.	T. 31 S. R. 6 W. Douglas County	Copper, zinc	App, com
May 1989	Hope Butte Chevron Resources Co.	T. 17 S. R. 43 E. Malheur County	Gold	Expl

Explanations: App=application being processed. Expl=Exploration permit issued. Com=Interagency coordinating committee formed, baseline data collection started. Date=Date application was received or permit issued. □

Recent DOGAMI publications

REPORTS ON GORDA RIDGE STUDIES
(Released July 3, 1989)

The Oregon Department of Geology and Mineral Industries (DOGAMI) has released two reports presenting results of research on the Gorda Ridge, a sea-floor spreading region off the coast of southern Oregon and northern California. The reports, published as DOGAMI open-file reports, add more information to the ongoing research into the extent, nature, and effects of the hydrothermal venting that occurs along the mid-ocean ridge.

Both reports contain analyses of samples taken from the sea floor during dives of the submersible vessel *Sea Cliff* that were undertaken in 1988 and resulted in the discovery of the Sea Cliff Hydrothermal Field at the northern end of the Gorda Ridge. The findings confirm the existence of hydrothermal vents and hydrothermal activity in this field.

Mineral Deposits Recovered from Northern Gorda Ridge: Mineralogy and Chemistry (DOGAMI Open-File Report O-89-09, $5) was prepared by Martin R. Fisk and Katherine J. Howard of the Oregon State University College of Oceanography. The 26-page report presents and discusses analyses of samples taken from site GR-14 and analyzed by X-ray diffraction and atomic absorption.

Preliminary Analysis of Four SESCA Samples from the Gorda Ridge (DOGAMI Open-File Report O-89-11, $4) was prepared by John Wiltshire, Gary McMurtry, and Ned Murphy of the Hawaii Institute of Geophysics, University of Hawaii. The 6-page report presents and discusses analyses of samples from the SESCA site located in the Escanaba Trough.

GEOLOGIC QUADRANGLE MAP FOR OWYHEE REGION
(Released July 12, 1989)

A new geologic map describes in detail the geology and mineral potential of a part of the Owyhee region in eastern Oregon. The identified potentially valuable mineral resources include geothermal energy, gold, and semiprecious gemstones.

Geology and Mineral Resources Map of the Owyhee Dam Quadrangle, Malheur County, Oregon, by DOGAMI geologist Mark L. Ferns, has been released in DOGAMI's Geological Map Series as map GMS-55. The price is $4.

The publication, resulting from an ongoing study of southeastern Oregon areas with a potential for mineral resources, was prepared in cooperation with the U.S. Geological Survey (USGS) and partially funded by the COGEOMAP program of the USGS.

The Owyhee Dam 7½-minute quadrangle covers approximately 48 square miles along the Owyhee River, approximately from below Owyhee Dam in the southwest to the city of Owyhee in the northeast. The new two-color map of the quadrangle (scale 1:24,000) identifies 16 rock units, the oldest of which may date back 25 million years before the present. Geologic structure is described both on the map and in two accompanying cross sections. The approximately 28- by 40-inch map sheet also includes a discussion of the area's mineral-resource potential and tables showing whole-rock and trace-element analyses of rock samples.

A variety of valuable and potentially valuable mineral resources were found or indicated by the study, including hot-spring systems at Deer Butte Spring and Snively Hot Spring, indicators for gold in areas of hot-spring-type alteration, silica sand, and semiprecious gemstones in the form of agate and jasper. Except for casual collecting of various types of chalcedony, no mineral-resource production has occurred in the quadrangle.

GEOLOGIC QUADRANGLE MAP FOR LAKE OSWEGO AREA (Released August 16, 1989)

The Lake Oswego Quadrangle covers an area just south of the center of Portland, Oregon. A new geologic map of the quadrangle is intended to serve as an important basic tool for earthquake hazard reduction in the Portland area.

Geologic Map of the Lake Oswego Quadrangle, Clackamas, Multnomah, and Washington Counties, Oregon, by Marvin H. Beeson and Terry L. Tolan of the Portland State University Geology Department and DOGAMI geologist Ian P. Madin, has been released in DOGAMI's Geological Map Series as map GMS-59. The price is $6.

The map was produced and published as part of an earthquake hazard study in the Portland metropolitan area and funded by the U.S. Geological Survey (USGS) and the National Earthquake Hazard Reduction Program.

The new map depicts an area in which several basalt layers of the Columbia River Basalt Group can be identified and mapped individually. This allowed the researchers to map faults with an unprecedented degree of confidence and accuracy. The map is the most detailed and up-to-date geologic map of the Portland area that is currently available.

The full-color map (scale 1:24,000) is printed on a sheet approximately 28 by 40 inches in size. It identifies and describes 16 rock units ranging from 40-million-year-old basement rock to the deposits from late Ice Age catastrophic floods. The map sheet also includes three geologic cross sections and a table of compositional averages of samples from the basaltic units of the map area.

EXPLORATION AND LITERATURE ON OIL AND GAS IN OREGON (Released August 21, 1989)

After nearly 90 years of oil and gas exploration, Oregon today has over 350 wells and a producing natural-gas field. Exploration efforts and published studies during those years have been summarized and listed in two new publications from DOGAMI.

Hydrocarbon Exploration and Occurrences in Oregon, by DOGAMI Petroleum Engineer Dennis L. Olmstead, has been published as DOGAMI Oil and Gas Investigation 15 (OGI-15). The 78-page publication contains introductory discussions of the history of oil and gas exploration in Oregon, the sedimentary basins of the state, and the Mist Gas Field, Oregon's only producing field.

These texts are followed by two tables listing available information about all known oil and gas wells and hydrocarbon occurrences in the state and in federal waters offshore. Grouped by county, the individual wells list names of the wells and of their present and past operators, locations, and drilling dates and depths, and notes that may include information on the method of drilling, the geology, hydrocarbon shows, and references in the literature. Two additional tables present gas analyses from certain wells and water analyses made on samples from exploratory wells.

While OGI-15 lists, in its bibliography, only the references mentioned in the text and tables, a comprehensive bibliography by the same author is contained in DOGAMI Open-File Report O-89-10. This report, **Bibliography of Oil and Gas Exploration and Development in Oregon, 1896-1989**, is intended to serve as a supplement to OGI-15. Comprising 33 pages, its author list includes approximately 750 citations and is followed by a county index listing cross-references for citations associated with a particular county.

Oil and Gas Investigation 15 sells for $7, Open-File Report O-89-10 for $5.

All new publications are available at the Oregon Department of Geology and Mineral Industries, 910 State Office Building, 1400 SW Fifth Avenue, Portland, OR 97201-5528. Orders may be charged to credit cards by mail, FAX, or phone. FAX number is (503) 229-5639. Orders under $50 require prepayment except for credit-card orders. □

Additional sources of information on Thundereggs

The July issue of *Oregon Geology* (v. 51, no. 4, p. 87-89) contained a short article on Thundereggs in Oregon that has also been made available to the public as a colored brochure. A list of references containing additional information about Thundereggs for those readers who would like to learn more about them is printed below.

Brown, R.W., 1957, Plantlike features in thunder-eggs and geodes: Washington, D.C., Smithsonian Institution Report for 1956, p. 329-339.

Crippen, R.A., 1948, Unusual concretions from Templeton, San Luis Obispo County, California: California Journal of Mines and Geology, v. 44, no. 3, p. 249-252.

Dake, H.C., 1951, The agate book: Portland, Oreg., Mineralogist Publishing Company, 64 p.

Dake, H.C., Fleener, F.L., and Wilson, B.H., 1938, Quartz family minerals: New York, Whittlesey House, 304 p.

Dake, H.C., and MacLachlan, D., 1962, Northwest gem trails (3rd ed.): Mentone, Calif., Gembooks, 95 p.

Farrington, O.C., 1927, Agate: Physical properties and origin: Chicago, Ill., Field Museum of Natural History Leaflet 8, p. 105-123.

Foshag, W.F., 1926, The minerals of Obsidian Cliff, Yellowstone National Park, and their origin: Washington, D.C., Proceedings of the United States National Museum, v. 68, art. 17, p. 1-18.

Gaertner, H., 1971, Achate, steinerne Wunder der Natur: Friedrichsdorf, Germany, Alles + Brillant, 71 p.

Highland Rock and Gift Shop, 1982, The rockhound's map of Oregon: Bend, Oreg., map with text on reverse side.

Kunz, G.F., 1893, Precious stones, *in* Day, D.T., geologist-in-charge, Mineral resources of the United States, 1892: U.S. Geological Survey, p. 776.

Leiper, H., ed., 1966, The agates of North America: The Lapidary Journal, 95 p.

McMullen, D.E., 1975, Oregon under foot: Portland, Oreg., Oregon Museum of Science and Industry Press, 60 p.

Oregon Agate and Mineral Society, 1978, Map of Oregon gem locations: Portland, Oreg., map with text on reverse side.

Oregon Department of Geology and Mineral Industries, 1965, Thunderegg: Oregon's state rock: Oregon Department of Geology and Mineral Industries, Ore Bin, v. 27, no. 10, p. 189-194.

Oregon Department of Transportation, Highway Division, (n.d.), Oregon rocks, fossils, and minerals and where to find them: Salem, Oreg., brochure with map, text, and photos.

Quick, L., 1963, The book of agates: Philadelphia, Chilton Books, 232 p.

Rieman, H.M., 1971, Thunder eggs: The Lapidary Journal, v. 24, no. 10, p. 1328-1335.

Rodgers, J.R., 1969, The rockhound's map of Oregon: Portland, Oreg., map with text on reverse side.

Rodgers, P.R., 1975, Agate collecting in Britain: London, B.T. Batsford, Ltd., 96 p.

Ross, C.S., 1941, Origin and geometric form of chalcedony-filled spherulites from Oregon: American Mineralogist, v. 26, no. 12, p. 727-732.

Sinkankas, J., 1959, Gemstones of North America: New York, Van Nostrand Reinhold Company, p. 115, 309-311.

———1976, Gemstones of North America, v. II: New York, Van Nostrand Reinhold Company, p. 52, 53, 235-237.

Smith, K.L., 1988, Opals from Opal Butte, Oregon: Gems and Mineralogy, v. 24, no. 4, p. 229-236.

Staples, L.W., 1965, Origin and history of the thunder egg: Oregon Department of Geology and Mineral Industries, Ore Bin, v. 27, no. 10, p. 195-204.

USDA Forest Service, in cooperation with the U.S. Bureau of Land Management and the Prineville-Crook County Chamber of Commerce, 1969, Central Oregon rockhound guide: Map with photos and text on back.

Wheeley, H., 1976, Take your pick to Agate Creek: Melbourne, Australia, Gemcraft Publications, Ltd., 72 p.

Wright, B., 1984, Native silica: London, England, Wyman and Sons, 263 p.

—*Paul F. Lawson*

OIL AND GAS NEWS

Drilling begins at Mist Gas Field

Drilling began at the Mist Gas Field during July, when DY Oil spudded its well Neverstill 33-30. The well is located on the west side of the field in SE¼ sec. 30, T. 6 N., R. 5 W., Columbia County. Proposed total depth is 3,000 ft. DY Oil has permits for two additional locations at Mist Gas Field. Taylor Drilling Company, Chehalis, Wash., is the contractor.

Mist production for 1989

Through June, 16 gas wells were producing at Mist Gas Field. Cumulative production from January through June was about 1.1 billion cubic feet (Bcf) of gas. In addition, eight gas wells were completed at the field and are shut in, awaiting pipeline connection.

A report containing complete production figures for Mist Gas Field, from its discovery in 1979 through 1988, is available at the Oregon Department of Geology and Mineral Industries (DOGAMI). For each well, the report contains data on monthly and cumulative production, tubing and casing pressures, Btu values, and revenue generated from gas sales. The report will be sold together with the Mist Gas Field Map (Open-File Report O-89-2), which shows the locations of all wells drilled and permitted, as well as dates and depths of drilled wells and names of their operators. Both the map and the production report will be updated annually and sell for $7.

Recent permits

Permit no.	Operator, well, API number	Location	Status, proposed total depth (ft)
431	Northwest Fuel Hammerberg 32-14-65 36-009-00260	NE¼ sec. 14 T. 6 N., R. 5 W. Columbia County	Permitted; 2,700.
432	ARCO Columbia Co. 34-8-75 36-009-00261	SE¼ sec. 8 T. 7 N., R. 5 W. Columbia County	Permitted; 2,760.
433	ARCO Meridian 34-31-65 36-009-00262	SE¼ sec. 31 T. 6 N., R. 5 W. Columbia County	Application withdrawn.

□

***(Geothermal**, continued from page 105)*

Sherrod, D.R., 1988, Geologic and geothermal summary of the Breitenbush-Austin Hot Springs area, Clackamas and Marion Counties, Oregon, *in* Sherrod D.R., ed., 1988, Geology and geothermal resources of the Breitenbush-Austin Hot Springs area, Clackamas and Marion Counties, Oregon: Oregon Department of Geology and Mineral Industries Open-File Report O-88-5, p. 63-67.

Sherrod, D.R., and Smith, J.G., 1989, Preliminary map showing upper Eocene to Holocene volcanic and related rocks of the Cascade Range in Oregon: U.S. Geological Survey Open-File Report 89-14, scale 1:500,000.

Smith, G.,A., Vincent, K.R., and Snee, L.W., 1989, An isostatic model for basin formation in and adjacent to the central Oregon High Cascade Range, *in* Muffler, L.J.P., Blackwell, D.D., and Weaver, C.S., eds., Geology, geophysics, and tectonic setting of the Cascade Range: U.S. Geological Survey Open-File Report 89-178, in press.

Swanberg, C.A., Walkey, W.C., and Combs, J., 1988, Core hole drilling and the "rain curtain" phenomenon at Newberry volcano, Oregon: Journal of Geophysical Research, v. 93, no. B9, p. 10163-10173.

Taylor, E.M., 1981, Central High Cascade roadside geology—Bend, Sisters, McKenzie Pass, and Santiam Pass, Oregon, *in* Johnston, D.A., and Donnelly-Nolan, J., eds., Guides to some volcanic terranes in Washington, Idaho, Oregon, and northern California: U.S. Geological Survey Circular 838, p. 55-58.

Walker, G.W., and Duncan, R.A., 1988, Geologic map of the Salem 1° x 2° sheet, Oregon: U.S. Geological Survey Miscellaneous Investigations Series Map I-1893, scale 1:250,000. □

ABSTRACTS

The Department maintains a collection of theses and dissertations on Oregon geology. From time to time, we print abstracts of new acquisitions that, we feel, are of general interest to our readers.

A SEISMIC-REFRACTION STUDY OF A PORTION OF THE NORTHEASTERN MARGIN OF THE TUALATIN VALLEY, OREGON, by David J. Nazy (M.S., Portland State University, 1987), 81 p.

The Tualatin Valley is a well-defined elliptical basin centered at Hillsboro, with a major axis trending roughly N. 65x W. The valley is bordered on the northeast by the Tualatin Mountains (Portland Hills), which are a faulted, northwest-trending asymmetrical anticline. Topographic and geophysical evidence have defined the Portland Hills fault, which occurs along the northeast side of the Tualatin Mountains. The possibility that a fault or fault zone occurs along the southwest side of the Tualatin Mountains was investigated in this study.

Boring Lavas, occurring on the southwest side of the Tualatin Mountains and having been erupted through the Columbia River basalt, may define zones of fracture or faulting in the Columbia River basalt. An exposed "window" of sediment is located near the town of Bonny Slope on the southwest side of the Tualatin Mountains. This sedimentary unit is presumed to be marine in origin, stratigraphically below the Columbia River basalt. Exposure of this unit at this location may be the result of landsliding, faulting, or paleotopographic highs during the deposition of the Columbia River basalt.

Seismic-refraction methods were used to produce shallow (0-50-m) geologic models near the areas of the proposed fault zone. The refraction models indicate that Columbia River basalt roughly parallels the surface topography at an average depth of 15 m and is overlain by a weathered zone ranging in thickness from 5 to 15 m. The basalt is broken up into blocks, mainly in the southeastern half of the study area. Data collected through this study indicate that the sedimentary unit at Bonny Slope is not underlain by Columbia River basalt. This provides further evidence that this unit is part of the Scappoose Formation, although it is uncertain as to whether this feature is related to faulting or paleotopographic highs.

A MAGNETOTELLURIC INVESTIGATION OF THE LOOKOUT MOUNTAIN AREA IN THE CENTRAL OREGON HIGH CASCADES, by William W. Clingman (M.S., University of Oregon, 1988), 81 p.

A large gravity anomaly and numerous north-trending volcanic lineaments suggest that the area around Lookout Mountain in the central Oregon High Cascades should provide a significant test of the magnetotelluric sounding method in identifying and characterizing subsurface structures in young volcanic areas. Data from 34 wide-band magnetotelluric sites in the area were analyzed; the results are discussed in terms of the known and inferred surficial and subsurface geology of the area.

As in other areas of the Cascade Range, the electrical profile of the crust in the study area consists of shallow and deep conductive layers separated by a thick resistor. Resistivities in the surface layer show excellent correlation with surface geology. Low-frequency electrical strikes trend northeast, roughly parallel to the strike of the gravity anomaly and to other large-scale features of the region. North-trending volcanic lineaments do not appear to exert significant control over resistivity distribution in the area.

THE GEOLOGY, GEOCHEMISTRY, AND ALTERATION OF RED BUTTE, OREGON; A PRECIOUS-METAL-BEARING PALEO HOT SPRING SYSTEM, by C. Susan Evans (M.S., Portland State University, 1986), 133 p.

Red Butte is located 60 km south of Vale, Oregon, about 20 km west of the Oregon/Idaho border. The butte is within eastern Oregon's Owyhee Upland physiographic province, at the intersection of the Western Snake River Plain, the High Lava Plains, and the Northern Basin and Range provinces.

The butte is composed of Miocene to Pliocene lacustrine and fluvial volcaniclastic sediments. The topography of the butte is controlled by silicification of the sandstones and mudstones that cap it. Silicification and hydrothermal alteration are both structurally and stratigraphically controlled. North-trending normal faults dominate the area and show progressively less offset in younger units. Strong northwest and minor northeast faults also cut the area. □

*(**Earthquake**, continued from page 110)*
Portland Water Bureau and Leon Wang of Old Dominion University as part of an NEHRP-funded analysis of the seismic resistance of the Portland water system.

CONCLUSION

The understanding of earthquake hazards in Portland is rapidly improving and suggests that the threat is greater than previously considered. Although it will still be many years before it will be possible to produce accurate probabilistic acceleration maps for the area, it is currently possible to assess relative ground-motion or ground-failure effects for a given earthquake using the detailed surficial geologic maps being produced by DOGAMI. Several studies have been proposed to turn these data into products useful to the engineering and planning communities, and more are encouraged. It is easy to be complacent about earthquakes in Oregon, and there is no question that the risk in adjacent states is far greater. Still, the writing of this paper was interrupted by the Camas earthquake of August 1, 1989, a reminder that the Portland area is tectonically active. We must continue to make use of all available resources to ensure that our community is earthquake-safe.

REFERENCES

Atwater, B.F., 1987, Evidence for great Holocene earthquakes along the outer coast of Washington State: Science, v. 236, p. 942-944.

Beeson, M.H., Tolan, T.L., and Madin, I.P., 1989, Geologic map of the Lake Oswego Quadrangle, Clackamas, Multnomah, and Washington Counties, Oregon: Oregon Department of Geology and Mineral Industries Geological Map Series GMS-59.

Darragh, R., Wong, I., and Silva, W., 1989, Engineering characterization of earthquake strong ground motions with applications to the Pacific Northwest, *in* Hays, W.W., ed., Proceedings of the Third NEHRP Workshop on earthquake hazards in the Puget Sound/Portland region, March 1989, Portland, Oreg.: U.S. Geological Survey open-file report, in press.

Heaton, T.H., and Hartzell, S.H., 1986, Earthquake hazards on the Cascadia Subduction Zone: Science, v. 236, p. 162-168.

Seed, H.B., Romo, R.P., Sun, J.I., Jaime, A., and Lysmer, J., 1988, The Mexico earthquake of September 19, 1985: Relationships between soil conditions and earthquake ground motions: Earthquake Spectra, v. 4, no. 4, p. 687-729.

Weaver, C.S., and Baker, G.E., 1988, Geometry of the Juan de Fuca Plate beneath Washington and northern Oregon from seismicity: Bulletin of the Seismological Society of America, v. 78, p. 264-275.

Weaver, C.S., and Shedlock, K.M., 1989, Potential subduction, probable intraplate and known crustal earthquake source zones in the Cascadia subduction zone, *in* Hays, W.W., ed., Proceedings of the Third NEHRP Workshop on earthquake hazards in the Puget Sound/Portland region, March 1989, Portland, Oreg.: U.S. Geological Survey open-file report, in press. □

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