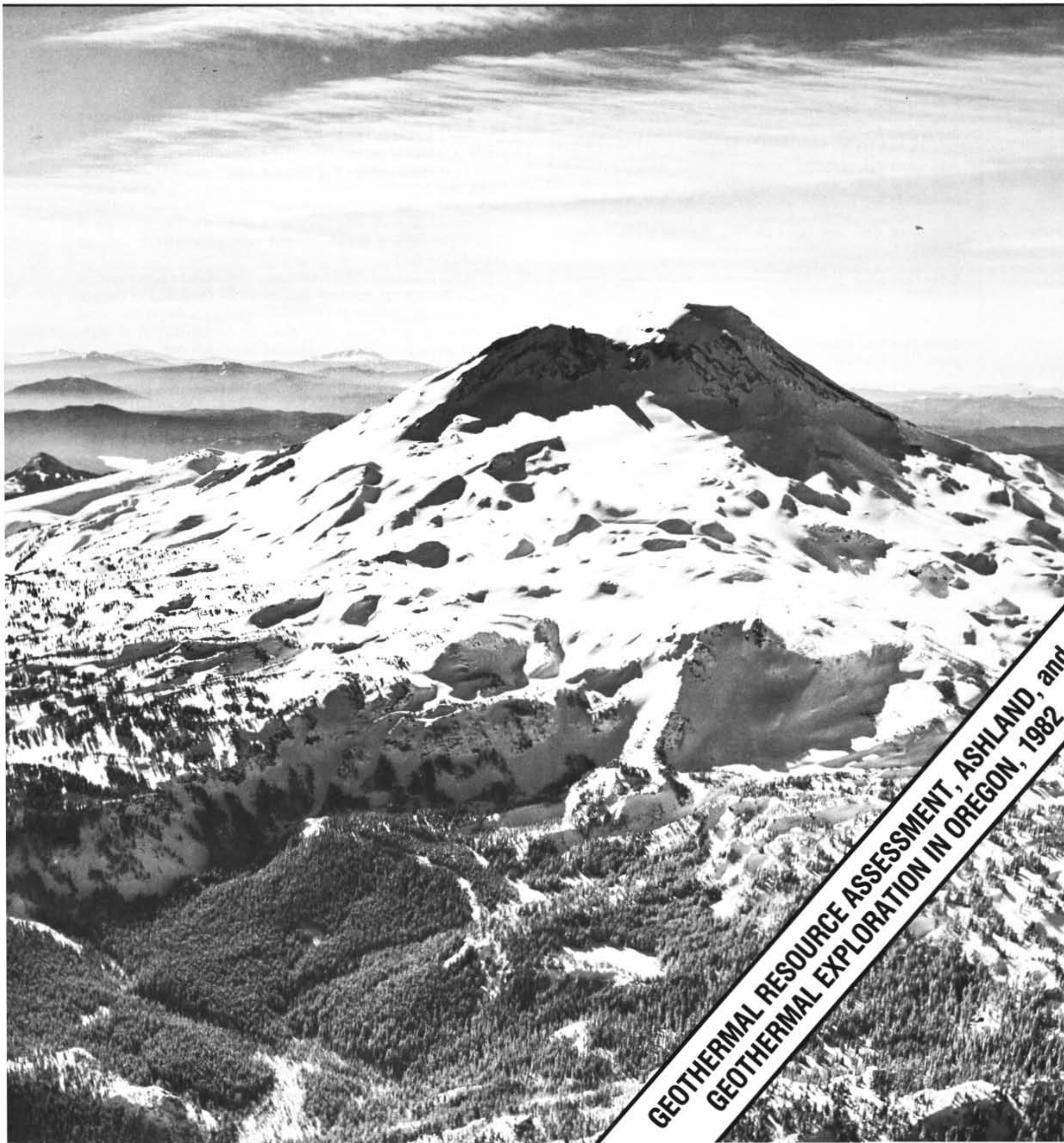
OREGON GEOLOGY

published by the

Oregon Department of Geology and Mineral Industries

VOLUME 45, NUMBER 5

MAY 1983



OREGON GEOLOGY

(ISSN 0164-3304)

VOLUME 45, NUMBER 5 MAY 1983

Published monthly by the State of Oregon Department of Geology and Mineral Industries (Volumes 1 through 40 were entitled *The Ore Bin*).

Main Office: 1005 State Office Building, Portland 97201, phone (503) 229-5580.

Baker Field Office: 2033 First Street, Baker 97814, phone (503) 523-3133.
Howard C. Brooks, Resident Geologist

Grants Pass Field Office: 312 S.E. "H" Street, Grants Pass 97526, phone (503) 476-2496.
Len Ramp, Resident Geologist

Mined Land Reclamation Program: 1129 S.E. Santiam Road, Albany 97321, phone (503) 967-2039.
Paul F. Lawson, Supervisor

Subscription rates: 1 year, $6.00; 3 years, $15.00. Single issues, $.75 at counter, $1.00 mailed.
Available back issues of *The Ore Bin*: $.50 at counter, $1.00 mailed.

Address subscription orders, renewals, and changes of address to *Oregon Geology*, 1005 State Office Building, Portland, OR 97201.

Send news, notices, meeting announcements, articles for publication, and editorial correspondence to the editor, Portland office. The Department encourages author-initiated peer review for technical articles prior to submission. Any review should be noted in the acknowledgments.

Second class postage paid at Portland, Oregon.
Postmaster: Send address changes to *Oregon Geology*, 1005 State Office Building, Portland, OR 97201.

COVER PHOTO

South Sister, one of the Three Sisters in Oregon's central Cascade Range. Volcanoes such as this suggest the possibility of geothermal potential at depth, and the focus of geothermal exploration has shifted from eastern Oregon to this part of the state. See article beginning on p. 56 for summary of 1982 geothermal activity in Oregon. Photo courtesy Oregon State Highway Commission.

OIL AND GAS NEWS

Clatsop County

Drilling permits continue to be applied for in Clatsop County. Diamond Shamrock has filed for a location in sec. 11, T. 6 N., R. 6 W. (see table below). The well, Clatsop County 33-11, has a proposed total depth of 6,000 ft and will probably be the next well to be drilled by the operator in the state. The tract on which this well is to be drilled was offered by Clatsop County at a sealed bid auction on February 9, 1983. The parcel had originally been nominated for leasing by Diamond Shamrock and went for a bonus bid of $338 per acre.

Gas prices at Mist Gas Field

The U.S. Natural Gas Policy Act (NGPA) became effective December 1, 1978. The Federal Energy Regulatory Commission (FERC), which implements the NGPA, determined several categories of gas wells. These categories are used to establish gas prices. FERC is required to compute and publish maximum lawful prices each month. The monthly equivalent of the annual inflation adjustment allows the price to be increased each month. The prices are in dollars per million British thermal units ($/MMBTU) and are published in the Federal Register.

After passage of the act, each state formulated a determination process for natural gas well categories. In Oregon, the Oregon Department of Geology and Mineral Industries is the jurisdictional agency which processes applications for Determination of Maximum Lawful Price under the Natural Gas Policy Act.

Mist Gas Field gas is priced under NGPA Section 102, New Natural Gas, Category B. Following are prices for Mist gas at various selected times: December 1979, $2.336/MMBTU; December 1980, $2.640/MMBTU; December 1981, $2.971/MMBTU; December 1982, $3.274/MMBTU; and April 1983, $3.367/MMBTU.

Oregon Gas Production 1979-1982

The Mist Gas Field first went on production in December 1979, after completion of four wells and construction of a pipeline. The heating value of the gas measures from 890 to 960 Btu per cubic foot, depending on the individual pool and well.

The following table gives cumulative production figures for the field at the end of each year of production:

Year	Cumulative production at year's end (Mcf)
1979	15,160
1980	4,947,190
1981	9,867,623
1982	13,266,806

Recent permits

Permit no.	Operator, well, API number	Location	Status, proposed total depth (ft)
233	Diamond Shamrock Clatsop County 33-11 007-00014	SE¼ sec. 11 T. 6 N., R. 6 W. Clatsop County	Application
234	Reichhold Energy Werner 34-21 047-00014	SE¼ sec. 21 T. 5 S., R. 2 W. Marion County	Application

□

CONTENTS

Results of a geothermal resource assessment of the Ashland, Oregon, area, Jackson County

by Gerald L. Black, Oregon Department of Geology and Mineral Industries, and
Monty Elliott, Jad D'Allura, and Bill Purdom, Southern Oregon State College, Ashland, Oregon

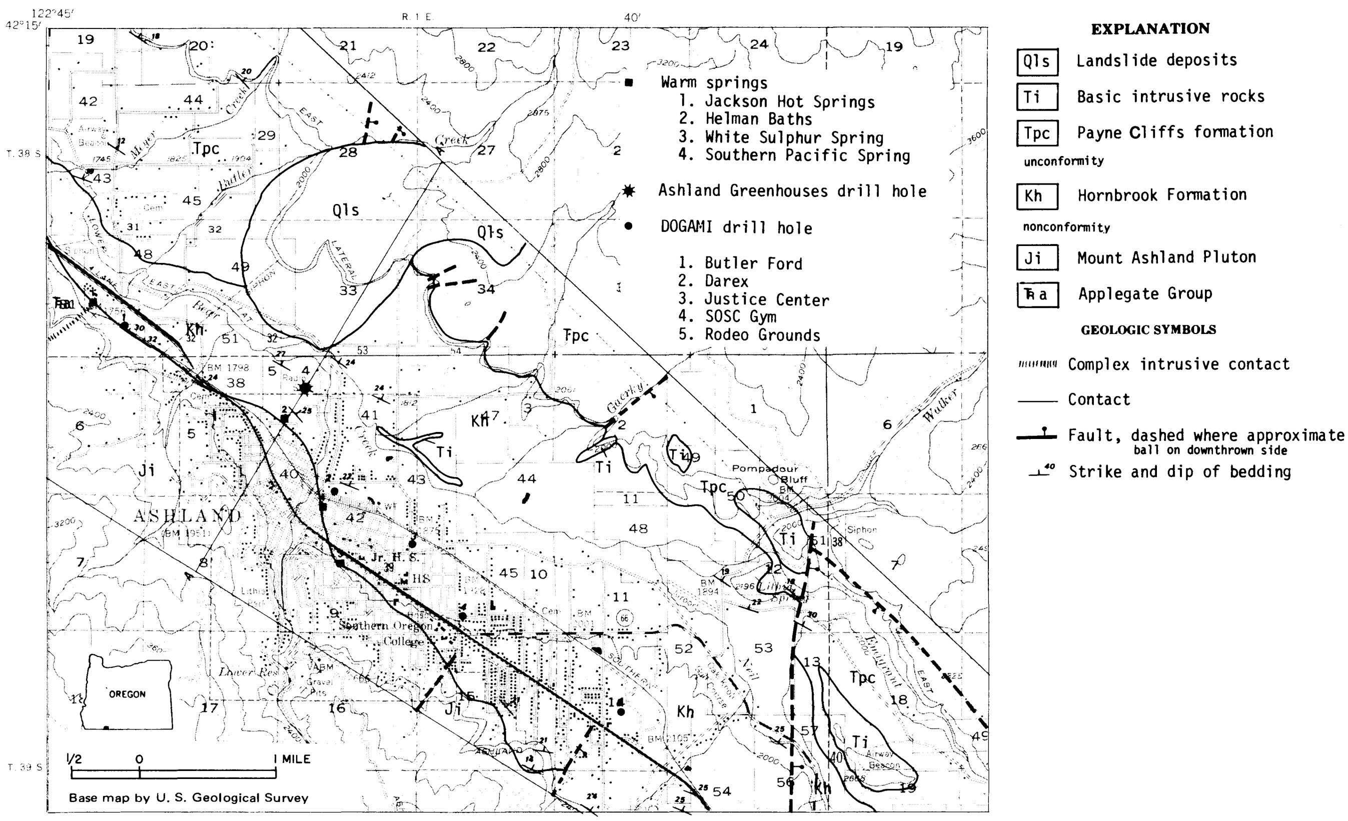


Figure 1. Geologic map of the Ashland, Oregon, area.

INTRODUCTION

As part of its low-temperature geothermal resource assessment program, the Oregon Department of Geology and Mineral Industries (DOGAMI) drilled five temperature-gradient holes in the Ashland, Oregon, area during June of 1982. A sixth hole was drilled in the Cascade Mountains east of Ashland during the same period. This last hole was drilled as part of a continuing evaluation of the geothermal potential of the Cascade Range in Oregon. It was sited to aid in defining the position and/or existence of a transition from lower (~40 milliwatts per square meter [mWm^{-2}]) to higher (>100 mWm^{-2}) heat flow which has been identified in the northern and central Cascade Range in Oregon.

Ashland, a city of 14,975 inhabitants, is located in southwestern Oregon in Jackson County (Figure 1). There are four warm springs located in or near the city (Figure 1). Jackson Hot Springs, the warmest of the four, is located northwest of the city limits (Figure 1). A temperature of 35° C has been reported for Jackson Hot Springs (Berry and others, 1980), but DOGAMI personnel have measured temperatures as high as 43.5° C in the warmest of the approximately ten orifices which occur in the hot springs area. The three other springs lie on a north-northwest-trending line within the city limits (Figure 1). They include Helman Hot Springs (31.5° C), White Sulphur Spring (28.5° C), and the Southern Pacific Spring. A resort located at Jackson Hot Springs represents the only commercial use of geothermal fluids in Ashland.

GEOLOGY

The city of Ashland lies on the boundary between the Klamath Mountains and Western Cascades physiographic provinces. The geology in the immediate vicinity of the city was mapped in 1981 by three of the authors (Elliott, D'Allura, and Purdom) specifically for the low-temperature geothermal resource assessment project. Figure 1 is taken from their map.

Quartz diorites of the Late Jurassic Mount Ashland Pluton dominate the terrain west of the city. The rocks of the pluton were encountered in two of the five temperature-gradient holes drilled for the project (Darex at 93 m [305 ft] and SOSC Gym at 120 m [392 ft]; see Figure 2). In addition, a well drilled at the Ashland Greenhouses (Figure 1) encountered the contact between the pluton and the overlying Hornbrook Formation at a depth of 299 m (982 ft).

Cropping out northwest of the city are rocks of the Late Triassic Applegate Group. These rocks were contact metamorphosed during the emplacement of the Mount Ashland Pluton. The Butler Ford hole encountered Applegate Group rocks at 352 m (115 ft) (Figure 2). The contact between the metamorphic rocks and the pluton is a zone of mixed rocks, where stringers of quartz diorite complexly intrude the Applegate Group. Jackson Hot Springs is located near the contact between the Applegate Group, the Mount Ashland Pluton, and the Hornbrook Formation.

Greenish to gray sandstones and mudstones of the Late Cretaceous Hornbrook Formation nonconformably overlie the Mount Ashland Pluton and the associated metamorphic rocks of the Applegate Group. The Hornbrook Formation, which represents a marine onlap sequence, dips rather uniformly northeastward at about 25° (Figure 1). The four warm springs occurring in the Ashland area are located at the contact of the Hornbrook Formation with the Mount Ashland Pluton, and all five of the temperature-gradient holes drilled in the Ashland area were collared in Hornbrook Formation sediments.

The Hornbrook Formation is in turn unconformably overlain by the Eocene to late Oligocene Payne Cliffs formation which consists of fluvial conglomerates and sandstones. Tertiary intrusions of basaltic composition occur east and southeast of the city, but neither they nor the rocks of the Payne Cliffs formation were encountered in any of the drill holes. Figure 2 shows the lithologies of the five temperature-gradient holes drilled in the Ashland area.

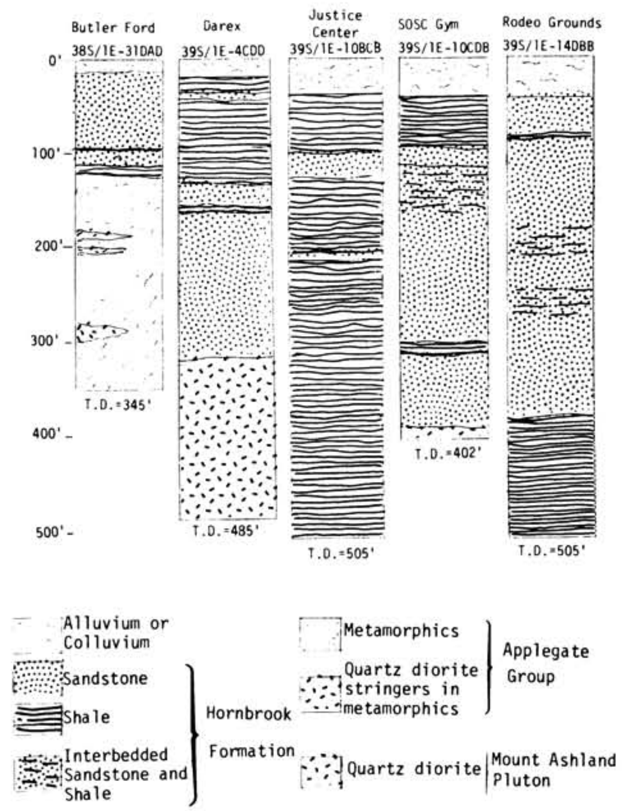


Figure 2. Lithologies of Ashland, Oregon, temperature-gradient holes.

HEAT FLOW

Based on data from a U.S. Geological Survey (USGS) hole drilled as part of a regional heat-flow study of southwestern Oregon and northern California (Mase and others, 1982) and on temperature gradients measured by DOGAMI in unused water wells ("free" holes) during the summer of 1981 (Blackwell and others, 1982), the background heat flow in the Ashland area is approximately 42 mWm^{-2}. Typical background-temperature gradients are 16°-18° C/km in the quartz diorite of the Mount Ashland Pluton and 20°-25° C/km in the sedimentary rocks of the Hornbrook Formation. The USGS hole is located near Winburn Camp, about 6.5 km (4 mi) south of Ashland. The DOGAMI "free" holes are scattered around the outskirts of the town, mostly in the valley to the east-northeast.

The heat-flow data for the six holes drilled as part of the Ashland low-temperature assessment project are summarized in Table 1. Also included in Table 1 are heat-flow data for a 344-m (1,130-ft) well drilled at the Ashland Greenhouses (39S/1E-4BBD) during 1981 and 1982. The temperature-depth curves for the six holes are reproduced in Figure 3. The data for the Ashland Greenhouses hole have been published previously (Blackwell and others, 1982) but are reproduced here because information obtained from the hole was invaluable in understanding the nature of the low-temperature resource at Ashland. It should be noted that the thermal conductivities listed in Table 1 for the Ashland Greenhouses hole were determined on cuttings from the Darex hole, the nearest hole for which cutting samples were available. All thermal-conductivity measurements were performed under the direction of David D. Blackwell at Southern Methodist University, using the divided-bar technique of Sass and others (1971).

The temperature-depth curve of the Butler Ford hole (Figure 3) above 70 m (230 ft) is a good example of fluid upflow within the well bore. During drilling of the well, artesian flow was encountered at about 70 m (230 ft). Normally in temperature-gradient wells the intraborehole movement of fluids is prevented by grouting the hole from bottom to top with cement. Since the quantity of fluid encountered in the Butler Ford hole (~100 gallons per minute [gpm]) represented a potential low-temperature resource, the decision was made not to grout the hole in order to preserve it for possible later use. Instead, the well was sealed with a welded-steel plate. Beneath the artesian zone at 70 m (230 ft), the temperature-depth curve appears conductive. The heat-flow value (118 mWm^{-2}) for the lower portion of the hole is high but reasonable, considering the nearness of the hole to Jackson Hot Springs (Figure 1).

The temperature-depth curve for the Darex hole results from variations in thermal conductivity. There are three linear segments with breaks in slope at 50 m (165 ft) and 100 m (330 ft) (Figure 3). The lithology in the hole consists predominantly of shale to 49 m (160 ft), sandstone from 49 m to 94 m (160 to 310 ft), and quartz diorite from 94 m to 148 m (310 to 486 ft)

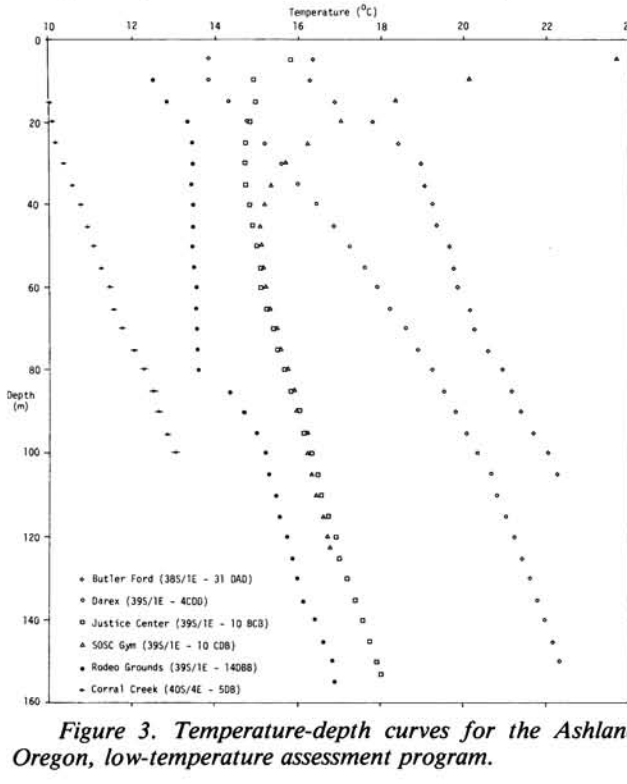


Figure 3. Temperature-depth curves for the Ashland, Oregon, low-temperature assessment program.

(Figure 2). Temperature gradients are typically higher where the thermal conductivities are lower (Table 1). The disparity in heat-flow values between the lower and upper part of the hole (Table 1) most probably reflects the presence of a warm-water aquifer at or near the contact of the Hornbrook Formation with the Mount Ashland Pluton. The difference in heat flow between the upper and lower portions of the Ashland Greenhouses hole is probably due to the same aquifer and will be discussed in more detail in a later section.

The temperature-depth curves for both the Justice Center and SOSC Gym holes are typical of conductive heat flow. The highly convex nature of the curve for the upper part of the SOSC Gym hole (Figure 3) is a microclimatic effect resulting primarily from solar heating. The hole collar is located on the margin of a large parking lot, where evapotranspiration does not effectively moderate the near-surface temperatures. The hole is also adjacent to the Southern Oregon State College steam plant, which may be partly responsible for the high near-surface temperatures. A similar, but smaller, microclimatic effect can be seen in the upper portion of the Justice Center hole (Figure 3) which is located in a large, open, flat field with sparse vegetation.

The temperature-depth profile for the hole at the Rodeo Grounds is typical of intraborehole downflow. The hole was not grouted to prevent intraborehole fluid movement, and as a result it is isothermal to a depth of 80 m (264 ft). Below that depth, the temperature gradient is linear, and the heat flow is conductive.

The hole at Corral Creek, which is located east of the map area of Figure 1, also possesses a linear temperature-depth curve and conductive heat flow.

Based on the above analyses, it appears that the Rodeo Grounds, SOSC Gym, and Justice Center holes all represent "background," or average, heat-flow values for the Ashland area. The heat-flow values for these three holes (50 to 65 mWm^{-2}) are somewhat higher than the background value (42 mWm^{-2}) quoted at the beginning of this section. There are several possible explanations for the discrepancy: (1) The regional heat flow increases from west to east (toward the Cascade Mountains), and the background value of 42 mWm^{-2} was based primarily on a hole located west of the city. It is possible that the regional heat flow in the Ashland area is greater than 42 mWm^{-2}. (2) A warm aquifer located at the Hornbrook Formation-Mount Ashland Pluton contact may underlie the entire Ashland area. The aquifer would not need to be particularly large or particularly warm to produce the required increase in temperature gradient (and hence, heat flow). (3) The lithologies in the upper part of the drill holes consisted mostly of shales and fine siltstones (Figure 2). The in-situ thermal conductivities of shales are nearly always lower than values obtained from laboratory measurements with a divided bar (D.D. Blackwell, personal communication, 1981). The discrepancy is due to the impossibility of preserving the in-situ anisotropic nature of shale in measurements on randomly oriented cuttings fragments. The thermal conductivity values of Table 1 may thus be slightly inflated, resulting in increased heat-flow values. (4) The higher heat flow may be due to thermal refraction at the contact between bodies of higher thermal conductivity (Mount Ashland Pluton) and lower thermal conductivity (Hornbrook Formation), in a manner analogous to many Basin and Range situations (Blackwell and others, 1978). (5) Terrain corrections have not been completed for the holes listed in Table 1.

Since temperature gradients lower than those measured in the SOSC Gym, Rodeo Grounds, and Justice Center holes have been measured in "free" holes east of Ashland, it is doubtful that a regional eastward increase in heat flow is the cause of the anomaly. It is also unlikely that a warm aquifer underlies the entire city, as no such aquifer was identified in the three holes mentioned above. Two of the three holes were slightly artesian, but the artesian zones were located within the Hornbrook Formation rather than at the contact between the Hornbrook Formation and the Mount Ashland Pluton. It is also improbable that thermal refraction can account for much, if any, of the anomaly. The contrast in thermal conductivities between the quartz diorites of the Mount Ashland Pluton and the sedimentary rocks of the Hornbrook Formation is not nearly as great as the conductivity contrast between the unconsolidated sediments of the basins and the bedrock of the ranges in the Basin and Range province. The thermal conductivities in the latter situation often differ by a factor of two or more (Blackwell and others, 1978). It is more likely that the higher

Table 1. *Heat-flow information for the Ashland, Oregon, drill holes.*

Hole name	Location	Lat. (N.)	Long. (W.)	Collar elev. (m)	Depth (m)	Depth interval (m)	Thermal conductivity ($Wm^{-1}°K^{-1}$)	Gradient (°K/km)	Heat flow (mWm^{-2})
Butler Ford	38S/1E-31DAD	42°13.10'	122°44.32'	510	107	70-107	1.90	62.0	118
Ashland Greenhouses	39S/1E-4BBD	42°12.72'	122°42.8'	536	344	180-300 310-330	(1.77) (2.07)	53.5 28.7	95 59
Darex	39S/1E-4CDD	42°12.05'	122°42.52'	502	148	10-50 55-90 100-148	1.77 2.64 2.07	84.8 63.1 41.5	149 167 86
Justice Center	39S/1E-10BCB	42°11.70'	122°41.82'	573	154	65-115 125-154	2.06 1.85	29.8 36.5	61 68
SOSC Gym	39S/1E-10CDB	42°11.25'	122°41.45'	603	123	60-123	1.98	25.1	50
Rodeo Grounds	39S/1E-14DBB	42°10.62'	122°40.07'	635	154	100-150	1.85	33.0	61
Corral Creek	40S/4E-5DB	42°07.08'	122°22.5'	1055	99	65-100	1.31	43.5	57

Table 2. *Silica geothermometers for springs and wells in the Ashland, Oregon, area.*

Name	Type of Source	Location	Measured Surface Temp.	Si Conductive	Si Adiabatic	Si Chal	Si Opal
Jackson Springs North	spring	38S/1E-31DBB	43.5	92.8	94.7	62.2	-21.7
Jackson Springs South	spring	38S/1E-31DBD	42.5	92.8	94.7	62.2	-21.7
Jackson Hot Springs Well	well	38S/1E-31DAB	22.5	50.5	57.4	18.1	-56.5
Butler Ford	well	38S/1E-31DAD	18.4	104.5	104.9	74.8	-11.7
Helman Hot Spring	spring	39S/1E-4CBD	31.5	83.4	86.5	52.2	-29.6
White Sulphur Well	well	39S/1E-9BBA	28.5	73.6	78.0	42.0	-37.8
Darex	well	39S/1E-4CDD	21.1	91.7	93.8	61.0	-22.6
Justice Center	well	39S/1E-10BCB	16.8	67.1	72.2	35.1	-43.1
Lithia Spring	spring	39S/1E-12DAD	12.5	85.9	88.7	54.9	-27.5
Lithia Wells	well	39S/2E-7CCA	18.5	100.9	101.7	70.9	-14.8
Buckhorn Mineral Springs	spring	40S/2E-12ADD	5.5	112.9	112.1	83.9	-4.5
Corral Creek	well	40S/4E-5DB	14.5	110.5	110.0	81.25	-6.6

background heat flow measured in the above three holes results from a combination of the effects of errors in the measurement of thermal conductivities of shales and the lack of terrain corrections. The terrain corrections, when completed, can be expected to lower the temperature gradients and, hence, the heat-flow estimates by approximately 5 to 10 percent (D.D. Blackwell, personal communication, 1982). It is interesting to note that the lowest heat-flow value of 50 mWm^{-2} (Table 1) was obtained from a predominantly sandstone section of the SOSC Gym hole, which should be relatively immune to large errors in the measurement of thermal conductivity. A 10-percent decrease in the heat-flow estimate (resulting from the terrain correction) would result in a heat-flow value of 45 mWm^{-2}, which is very close to the USGS estimate of 42 mWm^{-2} at Winburn Camp.

GEOTHERMOMETRY

By making certain basic assumptions, the chemical compositions of thermal waters can be used to estimate the subsurface temperatures of geothermal reservoirs. The assumptions are as follows: (1) Temperature-dependent reactions occur at depth. (2) All of the chemical constituents involved in the temperature-dependent reactions are sufficiently abundant. (3) Water-rock equilibrium occurs at the reservoir temperature. (4) Re-equilibration does not occur at a lower temperature as the water flows from the reservoir to the surface. (5) The thermal water does not mix with cool, shallow ground water (Fournier and Rowe, 1966). While assumptions (1) and (2) are probably valid for most hot spring systems, assumptions (3), (4), and (5) are less often fulfilled, particularly in low-temperature systems. As a result, the temperatures indicated by the chemical geothermometers tend to be minima.

Table 2 is a tabulation of minimum estimated reservoir temperatures calculated from various silica geothermometers. Included in the table are waters from warm and cold springs in the Ashland area and from the DOGAMI temperature-gradient wells. For the ranges in temperature and flow rate involved, the conductive silica geothermometer probably gives the best estimate of minimum reservoir temperature. The sodium/potassium geothermometers were not included in Table 2, because the amount of potassium in the thermal waters was generally less than the minimum detectable concentration.

As can be seen in Table 2, minimum reservoir temperatures in the Ashland area are on the order of 100° C. The low value of 50.5° C for the Jackson Hot Springs well probably results from the mixing of shallow ground water with the deeper thermal water. The minimum estimated reservoir temperature for the Justice Center hole is also low, probably because the hole is located south of the main geothermal anomalies and thus did not encounter geothermal fluids. It is also possible that geothermal fluids were not encountered because the well did not penetrate the Mount Ashland Pluton-Hornbrook Formation contact, the aquifer which carries the fluids in the geothermal areas to the north. This second possibility is considered unlikely because the heat flow in the hole (Table 1) is significantly lower than that in the holes to the north (Darex, Ashland Greenhouses, and Butler Ford).

INTERPRETATION

Figure 4 is a cross section through northwest Ashland along line A-A' of Figure 1. The cross section passes through Helman Hot Springs and the Ashland Greenhouses well.

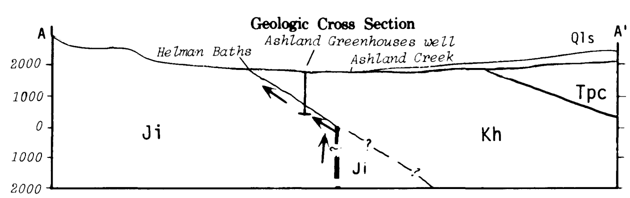


Figure 4. Cross section along line A-A' of Figure 1. Arrows show hypothetical flow of geothermal fluids.

As stated in the introduction, the warm springs in the Ashland area occur on or very close to the mapped contact between the Hornbrook Formation and the underlying Mount Ashland Pluton (Figure 1). It is believed that the positions of the hot springs in the Ashland area are stratigraphically controlled but that the high-temperature geothermal fluids are the result of a forced-convection geothermal system analogous to many known Basin and Range systems.

In a forced-convection system, ground-water recharge in a highland adjacent to a basin penetrates slowly downward to great depths. As the water penetrates downward, it is heated by the natural geothermal gradient. Eventually it reaches a zone of high vertical permeability, such as a fault zone. It then rises rapidly to the surface along the fault zone to emerge at the surface as a spring or series of springs. In effect, the heat is "mined" from beneath the recharge area and is "deposited" in the zone of convective upflow.

In the Ashland area, the geothermal water apparently does not reach the surface along a fault zone. Instead, it appears that as the water moves upward along the postulated fault it encounteres the contact between the Mount Ashland Pluton and the Hornbrook Formation. The water is confined to the contact zone by the impermeable shales of the Hornbrook Formation and is driven up the structural dip by the hydrologic head until it emerges at the surface as a series of warm springs at the contact (Figure 4).

The precise position of the fault zone is unknown, as no surface fault likely to act as a conduit for fluids has been mapped in the area east of the hot-spring line (Figure 1). It must, however, lie between the Ashland Greenhouses well and a "free" well located 3 km (1.8 mi) due east of the Ashland Greenhouses well (Blackwell and others, 1982). This second well is 177 m (581 ft) deep and has a reliable temperature gradient of only 27° C/km. As no warm springs occur in the area east of the Ashland Greenhouses well, it is quite likely that the fault is pre-Hornbrook Formation in age and therefore does not reach the surface.

GEOTHERMAL POTENTIAL

Most of the low-temperature geothermal potential in the Ashland area is confined to the northwestern part of the city. Data from the Rodeo Grounds, SOSC Gym, and Justice Center holes indicate that heat flow is only "background" (50 to 65 mWm^{-2}) in the southeastern area and that fluid temperatures in these areas, even if sufficient fluid volumes could be found, would not much exceed 20° C.

In the northwest part of town, the potential is highest between the existing hot springs and the fault(?) which controls distribution of the fluids. The lateral flow of warm water along the Hornbrook Formation-Mount Ashland Pluton contact makes it possible to find geothermal fluid down the structural dip from the hot-spring line, but the temperature of the water will probably not much exceed the surface temperature of the nearest spring. It is interesting to note that the highest temperature in the Ashland Greenhouses hole was 31.4° C, measured at a depth of 330 m (1,083 ft). The measured surface temperature of Helman Hot Springs, the nearest spring updip from the Greenhouse hole, is 31.5° C (Table 2). In order to encounter fluids at temperatures significantly greater than the temperatures of the springs, drill holes will have to be sited to intersect at depth the faults controlling the distribution of the geothermal fluids. Since neither the precise location nor the dip of the controlling faults is known for certain, the optimum sites for such drill holes are not known. Most probably, however, they lie a short distance east of the Ashland Greenhouse well. In any case, the maximum temperature encountered will not much exceed 100° C and will almost certainly be less.

ACKNOWLEDGMENTS

The authors would like to thank John Fregonese of the City of Ashland Planning Department, Butler Ford, and Darex Industries for their help in obtaining drilling sites. We would also like to thank Jones Well Drilling, the contractor who completed the drilling of the temperature-gradient holes, and John Studebaker of Studebaker Well Drilling, who provided abundant information on local drilling conditions. The project was made possible by funds from the United States Department of Energy (Cooperative Agreement No. DE-FC07-79ID12044).

REFERENCES CITED

Berry, G.W., Grim, P.J., and Ikelman, J.A., 1980, Thermal springs list for the United States. National Oceanic and Atmospheric Administration key to Geophysical Records Documentation No. 12: Boulder, Colo., National Geophysical and Solar-Terrestrial Data Center, 59 p.

Blackwell, D.D., Black, G.L., and Priest, G.R., 1982, Geothermal gradient data (1981): Oregon Department of Geology and Mineral Industries Open-File Report 0-82-4, 430 p.

Blackwell, D.D., Hull, D.A., Bowen, R.G., and Steele, J.L., 1978, Heat flow of Oregon: Oregon Department of Geology and Mineral Industries Special Paper 4, 42 p.

Fournier, R.O., and Rowe, J.J., 1966, Estimation of underground temperatures from the silica content of water from hot springs and wet-steam wells: American Journal of Science, v. 264, no. 9, p. 685-697.

Mase, C.W., Sass, J.H., Lachenbruch, A.H., and Munroe, R.J., 1982, Preliminary heat-flow investigations of the California Cascades: U.S. Geological Survey Open-File Report 82-150, 240 p.

Sass, J.H., Lachenbruch, A.H., and Munroe, R.J., 1971, Thermal conductivity of rocks from measurements on fragments and its application to heat-flow determinations: Journal of Geophysical Research, v. 76, no. 14, p. 3391-3401. □

Geothermal Resources Council calls for papers for October meeting in Portland

The Geothermal Resources Council will hold its annual meeting October 24-27, 1983, at the Red Lion-Jantzen Beach Hotel in Portland. The three-day meeting will include a technical program consisting of oral and poster presentations, commercial and educational exhibits, photo contest winner display, luncheons, special events, guests' program, and field trips. Special sessions scheduled for the meeting will focus on geothermal resource development in the Cascade Range and on industrial geothermal water heat pumps.

The Council's annual meeting is intended to provide a forum for exchange of new and significant information on all aspects of the development and use of geothermal resources. Papers are solicited in the following areas: exploration (geology, geophysics, and geochemistry), drill technology, reservoir engineering, power generation, direct use, legal/institutional aspects, economics/financing, environmental, and case histories. Papers must be submitted by Friday, June 3, 1983. Authors' packets containing detailed instructions and blue-lined sheets to be used for papers may be obtained from the Geothermal Resources Council, P.O. Box 1350, Davis, CA 95617, phone (916) 758-2360.

The Council is holding its fourth annual photograph contest in conjunction with the annual meeting to recognize artistic merit in recording geothermal development and to augment the Geothermal Resources Council's photo library. For information about the photo contest or any other aspect of the meeting, contact the Geothermal Resources Council at the above address. □

Geothermal exploration in Oregon, 1982

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

ABSTRACT

The drilling of six shallow wells as part of a low-temperature geothermal resource assessment conducted by the Oregon Department of Geology and Mineral Industries (DOGAMI) in Ashland and the drilling of five 2,000-ft wells by Union Oil of California in the central Cascade Range were the significant geothermal drilling activities in Oregon in 1982. The total area of leased Federal lands increased by 51,916 acres. Most of the geothermal leases relinquished were in areas outside the Cascades, whereas most of the leases newly acquired were in the Cascades, particularly the eastern slope of the High Cascade Range. There appears to be a general shift on the part of developers from eastern Oregon toward the youthful volcanic terrane of the Cascade Range. This comes as a result of both the discovery by the U.S. Geological Survey (USGS) of high-temperature fluids at Newberry Volcano and the measurement of high-temperature gradients in DOGAMI drill holes in the central and northern Cascade Range.

LEVEL OF GEOTHERMAL EXPLORATION

The general level of geothermal exploration activity in Oregon decreased during the last year. This decline is probably the result of numerous factors, but the recent decreases in oil prices have no doubt had a strong impact on both the availability of oil company capital for exploration and the competitiveness of geothermal energy relative to fossil fuels. In addition, in this region there is currently an electrical power surplus, which has kept power prices low. The geothermal picture in Oregon has one very encouraging trend which may portend extensive development of resources capable of electrical generation: As a result of the success of the USGS drilling program at Newberry Volcano and the delineation by the DOGAMI research program of a regional heat-flow anomaly in the Cascades, there is a greater level of activity—both leasing and exploration—in the Oregon Cascade province than in other geothermal provinces of the State. The Newberry 2 drill hole in the summit caldera of Newberry Volcano conclusively proved that substantial temperatures (i.e. 265° C) can be completely masked by shallow ground-water circulation in the young volcanic rocks characteristic of the High Cascade Range (Sammel, 1981; MacLeod and Sammel, 1982). The Newberry well showed that drilling to intermediate depths (2,000 to 3,500 ft) is necessary to explore for geothermal resources in the young volcanic rocks of the High Cascades. As a result, companies such as Union Oil of California have begun to drill intermediate-depth holes into the young High Cascade rocks. In view of the expense of these holes ($100,000 to $300,000 each), this trend reflects substantial confidence on the part of industry in the potential of the High Cascades-Newberry region. This encouraging trend strengthens the hope that large quantities of electrical energy could be generated from Cascade geothermal systems in the near future (see DOGAMI Open-File Report 0-82-7).

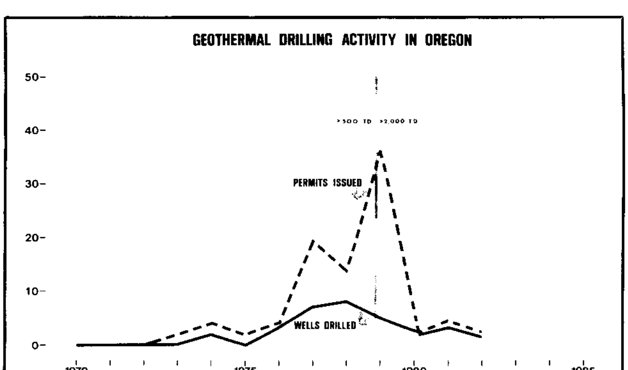


Figure 1. Geothermal well drilling in Oregon. Vertical line indicates time when definition of geothermal well was changed to a depth greater than 2,000 ft.

DRILLING ACTIVITY

In keeping with the general decline in geothermal exploration in 1982, the level of drilling activity was substantially lower than in 1981. No deep wells (greater than 2,000 ft) were drilled, and the number of prospect wells (2,000 ft or less) dropped sharply (Tables 1 and 2).

Table 1. *Permits for geothermal wells (greater than 2,000 ft in depth)*

Permit no.	Operator and well name	Location	Status
85	Sunoco Energy Development Co. Breitenbush 58-28	SE¼ sec. 28 T. 9 S., R. 7 E. Marion County	Abandoned.
86	Union Oil of California Well 47-10	SW¼ sec. 28 T. 19 S., R. 45 E. Malheur County	Suspended.

Table 2. *Permits for geothermal prospect wells (less than 2,000 ft in depth)*

Permit no.	Operator and well name	Location	Issue date and status
91	Renewable Energy, Inc.	Vale Butte, Malheur County	December 1981; drilled one hole to 1,425 ft.
92	Union Oil of California	Western Cascades, Deschutes, Linn, Jefferson, and Klamath Counties	April 1982; drilled five holes to 2,000 ft.
93	DOGAMI	Ashland area, Jackson County	June 1982; drilled six holes to 500 ft.

The only significant drilling activity was in the Ashland, Oregon, area and in the central Cascade Range. Union Oil of California drilled five 2,000-ft wells in the central Cascades. Information on the drillings, including locations, is confidential, however. Utilizing USDOE funds, DOGAMI completed five shallow temperature-gradient wells (depths 325-500 ft) in the Ashland, Oregon, area and a sixth well in the Cascade Mountains east of Ashland. Preliminary results indicate the presence of a low-temperature (30° C) thermal aquifer beneath the northwestern portion of the city. The aquifer appears to occur along the eastward-dipping contact between the Mount Ashland pluton and the overlying Hornbrook Formation.

LEASING

The pattern of geothermal leasing has, like the drilling, shifted toward the Cascade Range. This is reflected in Table 3 by a decrease in U.S. Bureau of Land Managment (USBLM) leases and an increase in U.S. Forest Service (USFS) leases (geothermal resource areas on USFS lands are primarily in the Cascade Range).

In addition to this shift in the pattern of leased Federal lands, there was also an increase in the total acreage of leased lands. The

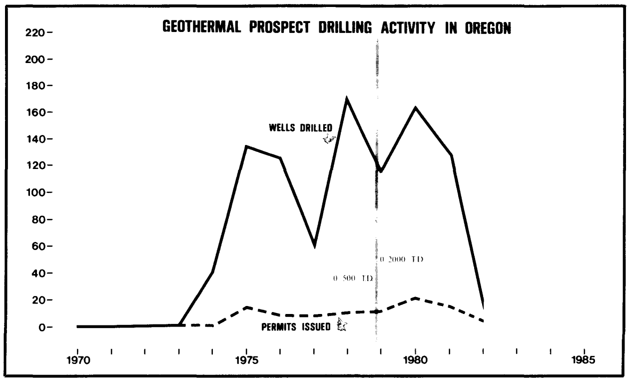


Figure 2. Geothermal prospect-well drilling in Oregon. Vertical line indicates time when definition of prospect well was changed to a depth less than 2,000 ft.

increase in total acreage for 1982 is about the same as in 1981 (51,585 acres in 1981 and 51,916 acres in 1982). This increase was heavily concentrated on the east slope of the High Cascade Range from Green Ridge near Sisters, Oregon, to the Klamath Lake area.

State lands in Klamath and Deschutes Counties will see a particularly sharp rise in total leased acreage in 1983 as a result of this interest in the eastern slope of the High Cascades. 18,369 acres of the 19,649 acres pending on state lands (Table 3) are from this Klamath-Deschutes County area.

The disparity between leasing and drilling activity is probably a reflection of the economy. Whereas developers appear to be optimistic about the geothermal resource potential of the state in general and the Cascade Range in particular, they are not ready to capitalize expensive drilling operations during a period of falling oil prices and electrical energy surpluses. It is clear that, should the utilities offer an economically attractive price for geothermal power, this increasingly large backlog of undrilled leases could result in an explosion of drilling activity.

Table 3. *Geothermal leases in Oregon, 1982*

Types of leases	Numbers	Acres	Relinquished leases Numbers	Relinquished leases Acres
Federal leases (change from 1981)				
Noncompetitive, USBLM	−39	− 50,939	62	85,713
Noncompetitive, USFS	+49	+101,858	13	22,224
KGRA, UŞBLM	− 1	+ 997	No data	No data
KGRA, USFS	0	0	No data	No data
TOTAL	+ 9	+ 51,916	75	107,937
Federal leases pending (total since 1974)				
Noncompetitive, USBLM	11	No new data*		
Noncompetitive, USFS	513	No new data* (est. 1,000,000)		
KGRA, USBLM	No data	No data		
KGRA, USFS	No data	No data		
TOTAL	524			
State (total since 1974)				
Total leases active in 1982	11	7,607		
Total applications pending in 1982	5	19,649		
Private (total since 1974)				
Total leases active (est.)	No data	200,000		

* Last data reported in summary for 1981: *Oregon Geology*, v. 44 (1982), no. 6, p. 67.

KGRA lease sales

Two KGRA lease sales took place in 1982. The first occurred on June 15, 1982, and involved tracts totaling 114,600 acres in the Alvord, Crump Geyser, Klamath Falls, Summer Lake Hot Spring, and Vale Hot Springs KGRA's in Oregon and the Horse Heaven KGRA in Washington. Bids were received on ten tracts totaling 18,718.57 acres in the Alvord, Crump Geyser, Klamath Falls, and Vale Hot Springs KGRA's in Oregon and the Horse Heaven KGRA in Washington. The total bonus was $112,250.06, an average of $6 per acre. The highest bid was $26.05 per acre by Hunt Oil for a tract of 2,605.24 acres in the Alvord KGRA.

The second sale took place on November 16, 1982, and involved two units in the Belknap-Foley Hot Springs KGRA. A total of 4,706.21 acres were involved. Hunt Oil was the only bidder and paid a total bonus of $9,611.23, an average of $2.04 per acre.

Two units totaling 3,658.6 acres in the McCredie Hot Springs KGRA were withdrawn from the November sale due to a lawsuit by the Sierra Club. The suit has since been dropped, and it is assumed that the units will be offered for sale at a later date.

DOGAMI GEOTHERMAL PUBLICATIONS

Several geothermal and geophysical publications were released by DOGAMI in 1982 (Table 4).

Table 4. *DOGAMI geothermal publications, 1982*

Special Papers

14 Geology and geothermal resources of the Mount Hood area, Oregon, ed. by G.R. Priest and B.F. Vogt, 100 p.

Geological Map Series

GMS-20 Map showing geology and geothermal resources of the southern half of the Burns 15′ quadrangle, Oregon, by D.E. Brown, scale 1:24,000.

GMS-21 Map showing geology and geothermal resources of the Vale East 7½′ quadrangle, Oregon, by D.E. Brown, scale 1:24,000.

GMS-26 Residual gravity maps of the northern, central, and southern Cascade Range, Oregon, 121°00′ to 121°30′ W. by 42°00′ to 45°45′ N., by R.W. Couch and others, 3 sheets, scale 1:250,000.

Open-File Reports

0-82-4 Geothermal gradient data (1981), by D.D. Blackwell and others, 430 p.

0-84-5 Oregon low-temperature resource assessment program. Final technical report, by G.R. Priest and others, 53 p.

0-82-7 Geology and geothermal resources of the Cascades, Oregon, ed. by G.R. Priest and B.F. Vogt, 205 p.

0-82-8 Gravity and aeromagnetic maps of the Powell Buttes area, Crook, Deschutes, and Jefferson Counties, Oregon, by Oregon State University Geophysics Group, 4 sheets, scale 1:62,500.

0-82-9 Gravity anomalies in the Cascade Range in Oregon: Structural and thermal implications, by R.W. Couch and others, 66 p.

Released by DOGAMI

Geothermal resources of Oregon, 1982, map by DOGAMI and National Oceanic and Atmospheric Administration, scale 1:500,000.

Articles in Oregon Geology, *v. 44 (1982)*

Thermal springs near Madras, Oregon, by M.S. Ashwill: No. 1, p. 8-9.

An estimate of the geothermal potential of Newberry Volcano, Oregon, by G.L. Black: No. 4, p. 44-46, and no. 5, p. 57.

Newberry Volcano, Oregon: A Cascade Range geothermal prospect, by N.S. MacLeod and E.A. Sammel: No. 11, p. 123-131.

The Open-File Report 0-82-7 was a preliminary version of a Special Paper on the geology and geothermal resources of the central Oregon Cascade Range. The Special Paper will be released in the fall of 1983 and will include a summary of approximately five years of geologic mapping and temperature gradient measurements in the Oregon Cascades. Estimates of the electrical power production potential for the entire province will be included. Publication of this paper will bring to a close the Department's USDOE-funded Cascade geothermal assessment program.

One of the most important products of the Cascade geothermal assessment is a series of gravity and aeromagnetic maps completed by the Oregon State University Geophysics Group (GMS-8, 9, 15, 16, 17, and 26). Gravity data for the entire Oregon Cascade Range are summarized and interpreted in Open-File Report 0-82-8.

The Department's USDOE-sponsored low-temperature geothermal resource assessment project ended in the spring of 1982 with the publication of detailed geologic maps of the Vale quadrangle (GMS-21) and part of the Burns quadrangle (GMS-20) and the completion of a final summary report to USDOE (Open-File Report 0-82-5).

The DOGAMI geothermal group, in cooperation with Andrew Griscom of the USGS and David Blackwell of Southern Methodist University, are preparing a survey of potential geothermal exploration sites at Newberry Volcano under sponsorship of the Bonneville Power Administration (BPA). Preliminary results of a soil-mercury survey completed in 1982 as a part of the Newberry project have been released by DOGAMI under the title *Preliminary Soil-Mercury Survey of Newberry Volcano, Deschutes County, Oregon*.

FUTURE OF THE DOGAMI GEOTHERMAL RESEARCH PROGRAM

The future of the DOGAMI geothermal research program is bleak. The program, since its inception about 15 years ago, has grown to be one of the most active in the United States. A significant portion of the program's support, however, has come from Federal funds. This Federal support for geothermal research (and for other forms of alternative-energy research) has dwindled away. As a result of the loss of Federal support, the ability of the Department to pursue field work and generate new data on the location of geothermal resources in Oregon, using existing contracts, essentially came to an end as of November 1982.

OREGON INSTITUTE OF TECHNOLOGY

The Oregon Institute of Technology (OIT) continues to operate the Geo-Heat Utilization Center to aid geothermal developers. The Center has, however, sharply curtailed its free services, owing to a loss of USDOE support. Their valuable information dissemination service came to a halt in March of 1983, and free consulting to Oregon developers has not been offered since the fall of 1982. They continue to offer consulting services and have aided the cities of Ashland and Klamath Falls on specific contracts. They have also offered some advice and help to the City of La Grande. Aside from time-limited contract work with private developers, such as Wood and Associates in the Lakeview area, this is the extent of their Oregon work. Until additional Federal or State support becomes available, this low level of activity in Oregon will characterize their program.

OREGON DEPARTMENT OF ENERGY

The Renewable Resource Division of the Oregon Department of Energy (ODOE) had two grants with funds for geothermal development during 1982. The first was a USDOE grant of $150,000. This money was earmarked primarily for exploration and, according to David Brown, ODOE's geothermal program manager, has been essentially used up at this time.

The second grant ($750,000) is a BPA grant to the Renewable Resource Division of ODOE and is intended for technical assistance in the development of all forms of alternative energy, including conservation. Of the $750,000, $30,000 is earmarked for geothermal development. With this money, ODOE sponsors OIT, through a letter of agreement, to do district heating studies. Under the terms of this grant, the ODOE geothermal program manager is also allowed to provide some of his time to aid local governments. Most of this aid is in the form of designing exploration programs and overcoming institutional barriers.

Local governments which received aid under the auspices of these grants in 1982 included Malheur, Harney, Deschutes, Lane, Clackamas, Union, Klamath, and Marion Counties, the cities of Vale, Ontario, Nyssa, Little Valley, Burns, Hines, Oakridge, Bend, Klamath Falls, Albany, and Portland, and the Umatilla and Warm Springs Indian Reservations.

ODOE also has available a Small Energy Loan Program (SELP) which provides low-interest loans (up to a maximum of $15 million) for small-scale energy development projects.

USGS–NEW RESULTS FROM NEWBERRY VOLCANO

Although there was no additional field work accomplished in the USGS geothermal program in 1982 because of curtailment of Federal support, the results from their study of Newberry Volcano were published. In 1981, a USGS drill hole encountered a temperature of about 265° C (509° F) at a depth of 3,058 ft in the caldera at Newberry Volcano (Sammel, 1981). The hole produced steam and noncondensible gases from the lower 6.6 ft of the well in a 20-hour flow test (Sammel, 1981). Fluids recovered in this flow test were at first thought to represent injected drilling water (MacLeod and Sammel, 1982), but recent chemical data indicate that they are formation fluids (Sammel, 1983, personal communication).

This discovery well has had a very significant impact on the focus of drilling and leasing activity in Oregon and probably accounts for part of the upsurge in geothermal leasing activity along the eastern side of the High Cascade Range.

Newberry Volcano will probably be the primary focus of exploration for high-temperature geothermal resources in the next several years. The development will be greatly aided by the excellent geologic map for the area recently published by the USGS (MacLeod and others, 1982) and by finalization of the USFS geothermal leasing plan for the Deschutes National Forest.

REFERENCES CITED

MacLeod, N.S., and Sammel, E.A., 1982, Newberry Volcano, Oregon: A Cascade Range geothermal prospect: Oregon Department of Geology and Mineral Industries, Oregon Geology, v. 44, no. 11, p. 123-131.

MacLeod, N.S., Sherrod, D.R., and Chitwood, L.A., 1982, Geologic map of Newberry Volcano, Deschutes, Klamath, and Lake Counties, Oregon: U.S. Geological Survey Open-File Report 82-847, 27 p., map scale 1:62,500.

Sammel, E.A., 1981, Results of test drilling at Newberry Volcano, Oregon: Geothermal Resources Council Bulletin, v. 10, no. 11, p. 3-8. □

Fireballs sighted in Oregon

Pat Merrill reported a fireball at 9:00 p.m., April 4, 1983, in the Aloha area (lat. 45°27′ N., long. 123°5′30″ W.) going from east to west in the southern sky and descending at an angle of 5°. The duration of the flight was 1.5 seconds. The fireball was one-fifth the size of a full moon and orange-white in color, with a very long white-orange tail. The fireball cast a shadow. No sound was heard, and no breakup was reported.

Cole Gardiner sighted a fireball at 8:58 p.m., April 7, in northeast Portland (lat. 45°37′ N., long. 123°16′30″ W.) going from east to west in the southern sky on a path that was almost parallel to the earth's surface. Duration of the flight was 3.5 seconds; angle of descent was 2°. The fireball was one-third the size of a full moon and blue to blue-white in color, with no tail. No sound, breakup, smoke trail, or shadow accompanied the flight. The fireball dimmed and went out quickly.

John Kellogg sighted the same fireball at 8:58 p.m., April 7, in the Clackamas area (lat. 45°27′ N., long. 123°16′30″ W.) in the southwest sky at about 50° above the horizon. The fireball seemed to hang in the sky for about 1 second. The fireball was about one-eighth the size of a full moon and red-white in color.

These sightings have been reported to the Scientific Event Alert Network, Smithsonian Institution. Anyone with any additional information about these or other meteorite sightings should contact Dick Pugh, Cleveland High School, 3400 SE 26th Ave., Portland, OR 97202, phone (503) 233-6441. □

Available publications

BULLETINS	Price	No. Copies	Amount
33. Bibliography (1st supplement) geology and mineral resources of Oregon, 1947: Allen	$ 3.00		
36. Papers on Tertiary foraminifera: Cushman, Stewart, and Stewart, 1949: v. 2	3.00		
44. Bibliography (2nd supplement) geology and mineral resources of Oregon, 1953: Steere	3.00		
46. Ferruginous bauxite deposits, Salem Hills, 1956: Corcoran and Libbey	3.00		
49. Lode mines, Granite mining district, Grant County, Oregon, 1959: Koch	3.00		
53. Bibliography (3rd supplement) geology and mineral resources of Oregon, 1962: Steere and Owen	3.00		
62. Andesite Conference guidebook, 1968: Dole	3.50		
65. Proceedings of the Andesite Conference, 1969: (copies)	10.00		
67. Bibliography (4th supplement) geology and mineral resources of Oregon, 1970: Roberts	3.00		
77. Geologic field trips in northern Oregon and southern Washington, 1973	5.00		
78. Bibliography (5th supplement) geology and mineral resources of Oregon, 1973: Roberts	3.00		
81. Environmental geology of Lincoln County, 1973: Schlicker and others	9.00		
82. Geologic hazards of Bull Run Watershed, Multnomah, Clackamas Counties, 1974: Beaulieu	6.50		
83. Eocene stratigraphy of southwestern Oregon, 1974: Baldwin	4.00		
84. Environmental geology of western Linn County, 1974: Beaulieu and others	9.00		
85. Environmental geology of coastal Lane County, 1974: Schlicker and others	9.00		
87. Environmental geology of western Coos and Douglas Counties, 1975	9.00		
88. Geology and mineral resources of upper Chetco River drainage, 1975: Ramp	4.00		
89. Geology and mineral resources of Deschutes County, 1976: Peterson and others	6.50		
90. Land use geology of western Curry County, 1976: Beaulieu	9.00		
91. Geologic hazards of parts of northern Hood River, Wasco, and Sherman Counties, Oregon, 1977: Beaulieu	8.00		
92. Fossils in Oregon (reprinted from *The Ore Bin*), 1977	4.00		
93. Geology, mineral resources, and rock material of Curry County, Oregon, 1977	7.00		
94. Land use geology of central Jackson County, Oregon, 1977: Beaulieu	9.00		
95. North American ophiolites, 1977	7.00		
96. Magma genesis: AGU Chapman Conference on Partial Melting, 1977	12.50		
97. Bibliography (6th supplement) geology and mineral resources of Oregon, 1971-75, 1978	3.00		
98. Geologic hazards of eastern Benton County, Oregon, 1979: Bela	9.00		
99. Geologic hazards of northwestern Clackamas County, Oregon, 1979: Schlicker and Finlayson	10.00		
100. Geology and mineral resources of Josephine County, Oregon, 1979: Ramp and Peterson	9.00		
101. Geologic field trips in western Oregon and southwestern Washington, 1980	9.00		
102. Bibliography (7th supplement) geology and mineral resources of Oregon, 1976-1979, 1981	4.00		

GEOLOGIC MAPS	Price	No. Copies	Amount
Reconnaissance geologic map of Lebanon quadrangle, 1956	3.00		
Geologic map of Bend quadrangle and portion of High Cascade Mountains, 1957	3.00		
Geologic map of Oregon west of 121st meridian (USGS I-325), 1961	3.50		
Geologic map of Oregon east of 121st meridian (USGS I-902), 1977	5.00		
GMS-4: Oregon gravity maps, onshore and offshore, 1967 (folded)	3.00		
GMS-5: Geologic map of Powers quadrangle, Oregon, 1971	3.00		
GMS-6: Preliminary report on geology of part of Snake River Canyon, 1974	6.50		
GMS-7: Geology of the Oregon part of the Baker quadrangle, Oregon, 1976	3.00		
GMS-8: Complete Bouguer gravity anomaly map, Cascade Mountain Range, central Oregon, 1978	3.00		
GMS-9: Total field aeromagnetic anomaly map, Cascade Mountain Range, central Oregon, 1978	3.00		
GMS-10: Low- to intermediate-temperature thermal springs and wells in Oregon, 1978	3.00		
GMS-12: Geologic map of the Oregon part of the Mineral quadrangle, 1978	3.00		
GMS-13: Geologic map of the Huntington and part of the Olds Ferry quadrangles, Oregon, 1979	3.00		
GMS-14: Index to published geologic mapping in Oregon, 1898-1979, 1981	7.00		
GMS-15: Free-air gravity anomaly map and complete Bouguer gravity anomaly map, Cascade Mountain Range, northern Oregon, 1981	3.00		
GMS-16: Free-air gravity anomaly map and complete Bouguer gravity anomaly map, Cascade Mountain Range, southern Oregon, 1981	3.00		
GMS-17: Total-field aeromagnetic anomaly map, Cascade Mountain Range, southern Oregon, 1981	3.00		
GMS-18: Geology of the Rickreall, Salem West, Monmouth, and Sidney 7½-minute quadrangles, Marion, Polk, and Linn Counties, Oregon, 1981	5.00		
GMS-19: Geology and gold deposits map of the Bourne quadrangle, Baker and Grant Counties, Oregon, 1982	5.00		
GMS-20: Map showing geology and geothermal resources of the southern half of the Burns 15-minute quadrangle, Oregon, 1982	5.00		
GMS-21: Geology and geothermal resources map of the Vale East 7½-minute quadrangle, Oregon, 1982	5.00		
GMS-22: Geology and mineral resources map of the Mt. Ireland quadrangle, Baker and Grant Counties, Oregon, 1982	5.00		
GMS-23: Geologic map of the Sheridan quadrangle, Polk and Yamhill Counties, Oregon, 1982	5.00		
GMS-24: Geologic map of the Grand Ronde quadrangle, Polk and Yamhill Counties, Oregon, 1982	5.00		
GMS-26: Residual gravity maps of the northern, central, and southern Cascade Range, Oregon, 1982	5.00		
GMS-27: Geologic and neotectonic evaluation of north-central Oregon: The Dalles 1° by 2° quadrangle, 1982	6.00		

OIL AND GAS INVESTIGATIONS	Price	No. Copies	Amount
3. Preliminary identifications of foraminifera, General Petroleum Long Bell #1 well	3.00		
4. Preliminary identifications of foraminifera, E.M. Warren Coos County 1-7 well, 1973	3.00		
5. Prospects for natural gas production or underground storage of pipeline gas, upper Nehalem River Basin, Columbia-Clatsop Counties, Oregon, 1976	5.00		
6. Prospects for oil and gas in the Coos Basin, western Coos, Douglas, and Lane Counties, Oregon, 1980: Newton and others	9.00		

ORDER FORM — CUT ON DASHED LINE

Available publications (continued)

SHORT PAPERS	Price	No. Copies	Amount
21. Lightweight aggregate industry in Oregon, 1951: Mason	1.00	______	______
24. The Almeda Mine, Josephine County, Oregon, 1967: Libbey	3.00	______	______
25. Petrography, type Rattlesnake Formation, central Oregon, 1976: Enlows	3.00	______	______
27. Rock material resources of Benton County, 1978: Schlicker and others	4.00	______	______
MISCELLANEOUS PAPERS			
1. A description of some Oregon rocks and minerals, 1950: Dole	1.00	______	______
5. Oregon's gold placers (reprints), 1954	1.00	______	______
8. Available well records of oil and gas exploration in Oregon, rev. 1982: King, Olmstead, and Newton	4.00	______	______
11. Collection of articles on meteorites, 1968 (reprints from *The Ore Bin*)	3.00	______	______
13. Index to *The Ore Bin*, 1950-1974	3.00	______	______
15. Quicksilver deposits in Oregon, 1971: Brooks	3.00	______	______
17. Geologic hazards inventory of the Oregon coastal zone, 1974: Beaulieu, Hughes, and Mathiot	5.00	______	______
18. Proceedings of Citizens' Forum on potential future sources of energy, 1975	3.00	______	______
19. Geothermal exploration studies in Oregon – 1976, 1977	3.00	______	______
20. Investigations of nickel in Oregon, 1978: Ramp	5.00	______	______
SPECIAL PAPERS			
1. Mission, goals, and programs of Oregon Department of Geology and Mineral Industries, 1978	3.00	______	______
2. Field geology of SW Broken Top quadrangle, Oregon, 1978: Taylor	3.50	______	______
3. Rock material resources of Clackamas, Columbia, Multnomah, and Washington Counties, Oregon, 1978: Gray and others	7.00	______	______
4. Heat flow of Oregon, 1978: Blackwell, Hull, Bowen, and Steele	3.00	______	______
5. Analysis and forecasts of the demand for rock materials in Oregon, 1979: Friedman and others	3.00	______	______
6. Geology of the La Grande area, Oregon, 1980: Barrash and others	5.00	______	______
7. Pluvial Fort Rock Lake, Lake County, Oregon, 1979: Allison	4.00	______	______
8. Geology and geochemistry of the Mt. Hood volcano, 1980: White	3.00	______	______
9. Geology of the Breitenbush Hot Springs quadrangle, Oregon, 1980: White	4.00	______	______
10. Tectonic rotation of the Oregon Western Cascades, 1980: Magill and Cox	3.00	______	______
11. Theses and dissertations on the geology of Oregon: Bibliography and index, 1899-1982, 1982: Neuendorf and others	6.00	______	______
12. Geologic linears of the northern part of the Cascade Range, Oregon, 1980: Venkatakrishnan, Bond, and Kauffman	3.00	______	______
13. Faults and lineaments of the southern Cascades, Oregon, 1981: Kienle, Nelson, and Lawrence	4.00	______	______
14. Geology and geothermal resources of the Mount Hood area, Oregon, 1982: Priest and Vogt	7.00	______	______
MISCELLANEOUS PUBLICATIONS			
Landforms of Oregon (17 × 12 inches)	1.00	______	______
Mining claims (State laws governing quartz and placer claims)	1.00	______	______
Geological highway map, Pacific NW region, Oregon-Washington (published by AAPG)	5.00	______	______
Geothermal resources of Oregon map, 1982 (published by NOAA)	3.00	______	______
Fifth Gold and Money Session and Gold Technical Session Proceedings, 1975	5.00	______	______
Sixth Gold and Money Session and Gold Technical Session Proceedings, 1978	6.50	______	______
Back issues of *The Ore Bin*	50¢ over the counter; $1.00 mailed	______	______
Back issues of *Oregon Geology*	75¢ over the counter; $1.00 mailed	______	______
Colored postcard, *Geology of Oregon*	10¢ each; 3 for 25¢; 7 for 50¢; 15 for $1.00	______	______
NEW! Oregon Landsat mosaic map, 1983 (published by ERSAL, OSU)	$8.00 over the counter; $11.00 mailed	______	______

OREGON GEOLOGY

1005 State Office Building, Portland, Oregon 97201

Second Class Matter
POSTMASTER: Form 3579 requested

PUBLICATIONS ORDER

Minimum mail order $1.00. All sales are final. Publications are sent postpaid. Payment must accompany orders of less than $50.00. Foreign orders: please remit in U.S. dollars.

Fill in appropriate blanks and send sheet to Department.

YOUR NAME ______________________________

ADDRESS ______________________________

______________________________ Zip __________

Amount enclosed $__________

OREGON GEOLOGY

____ Renewal ____ New Subscription ____ Gift

____ 1 Year ($6.00) ____ 3 Years ($15.00)

NAME ______________________________

ADDRESS ______________________________

______________________________ ZIP __________

(If Gift, From: ______________________________)