

JULY 1977
VOLUME 39, No. 7

THE ORE BIN



STATE OF OREGON

DEPARTMENT OF GEOLOGY AND MINERAL INDUSTRIES

The Ore Bin

Published Monthly By

STATE OF OREGON
DEPARTMENT OF GEOLOGY AND MINERAL INDUSTRIES
Head Office: 1069 State Office Bldg., Portland, Oregon 97201
Telephone: [503] 229-5580

FIELD OFFICES
2033 First Street 521 N.E. "E" Street
Baker 97814 Grants Pass 97526

Subscription Rates

1 year, \$3.00; 3 years, \$8.00

Available back issues, \$.25 at counter, \$.35 mailed

Second class postage paid at Portland, Oregon

GOVERNING BOARD

R. W. deWeese, Portland, Chairman
Leeanne MacColl, Portland
Robert W. Doty, Talent

STATE GEOLOGIST

Ralph S. Mason

GEOLOGISTS IN CHARGE OF FIELD OFFICES

Howard C. Brooks, Baker Len Ramp, Grants Pass

EDITOR Beverly F. Vogt

Permission is granted to reprint information contained herein.
Credit given the State of Oregon Department of Geology and Mineral Industries
for compiling this information will be appreciated.

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

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

Introduction

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

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

Methods

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

* Oregon Department of Geology and Mineral Industries
** Consulting Geologist, Portland, Oregon
*** Southern Methodist University, Dallas, Texas

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

Heat flow

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

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

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

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

Geothermal phenomena

Natural leakage of hot fluids from geothermal systems within the earth's crust to the earth's surface results in hot springs (springs with a temperature 10°C above ambient temperature) and fumaroles (volcanic vents from which gases and vapors are emitted). An inventory of these phenomena in Oregon was made by Bowen and Peterson (1970). Hot springs and fumaroles are not associated

with all geothermal resources, however; and other search techniques, such as heat-flow measurements, are desirable in geologically favorable areas.

Geologic mapping

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

Geothermal Energy Potential

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

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

Areas of maximum potential, shown as "High" in Figure 2, have regional heat-flow values ranging from 1.9 to more than 2.5 microcalories per cm² sec (heat-flow units or HFU), numerous thermal manifestations in the form of hot springs and fumaroles, and volcanism that occurred within the last 2 million years. Areas of

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

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

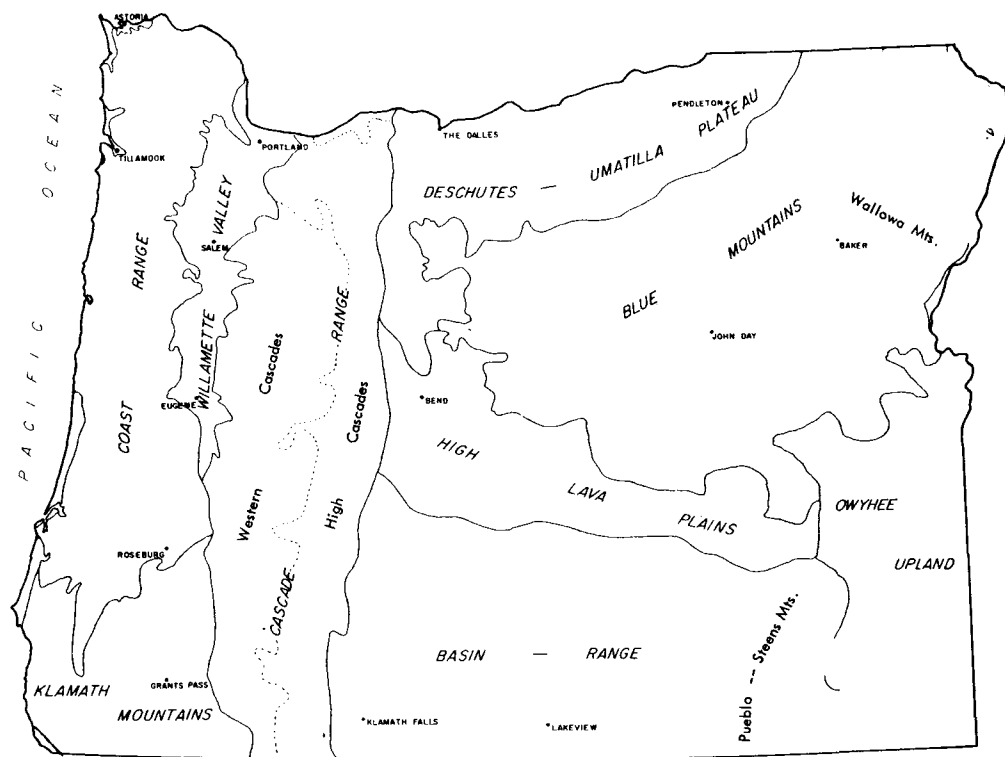


Figure 1. Physiographic provinces of Oregon.

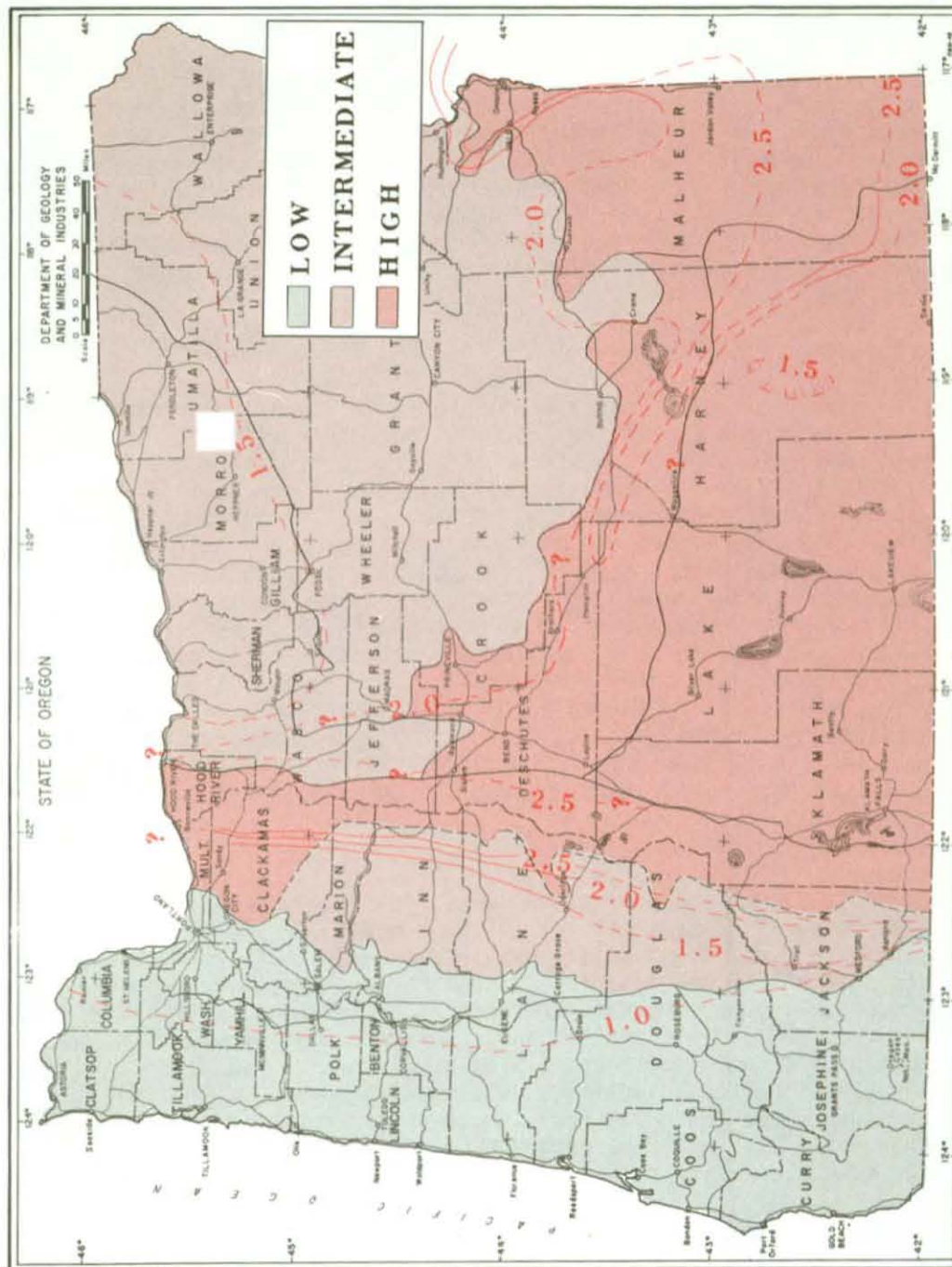


Figure 2. Preliminary heat-flow map of Oregon showing geothermal energy potential of various physiographic provinces. Heat-flow contours indicate heat-flow units of microcalories per $\text{cm}^2 \text{ sec}$.

Coast Range

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

Willamette Valley

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

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

Klamath Mountains

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

Western Cascades

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

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

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

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

High Cascades

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

Deschutes-Umatilla Plateau

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

geothermal gradients of 30° to 40°C per km for the province. The geothermal energy potential of the Deschutes-Umatilla Plateau is considered to be intermediate.

Blue Mountains

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

High Lava Plains

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

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

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



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

Basin and Range

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

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

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



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



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



Figure 6. Lakeview greenhouse heated by geothermal energy.

Owyhee Upland

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

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

Summary

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

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

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

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

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

Acknowledgments

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

had numerous stimulating discussions of Oregon's geothermal resources with Paul Hammond of Portland, Walter Youngquist of Eugene, John Hook of Salem, Paul Lineau and John Lund of Klamath Falls, and Ed Groh and Larry Chitwood of Bend.

References

- Allen, John E., 1975, Volcanoes of the Portland area, Oregon: Ore Bin, v. 37, no. 9, p. 145-157.
- Blackwell, David D., Hull, Donald A., and Bowen, Richard G., 1977, Regional geothermal assessment of Oregon [abs.]: Geol. Assoc. Canada Annual Meeting, Vancouver, B.C.
- Bowen, Richard G., 1972, Geothermal gradient studies in Oregon: Ore Bin, v. 34, no. 4, p. 68-71.
- _____, 1975, Geothermal gradient data: Oregon Dept. Geol. and Mineral Indus. Open-file Report O-75-3, 114 p.
- Bowen, Richard G., and Blackwell, David D., 1973, Progress report on geothermal measurements in Oregon: Ore Bin, v. 35, no. 1, p. 6-7.
- _____, 1975, The Cow Hollow geothermal anomaly: Ore Bin, v. 37, no. 7, p. 109-121.
- Bowen, Richard G., Blackwell, David D., and Hull, Donald A., 1975, Geothermal studies and exploration in Oregon: Oregon Dept. Geol. and Mineral Indus. Open-file Report O-75-7, 65 p.
- _____, 1977, Geothermal exploration studies in Oregon: Oregon Dept. Geol. and Mineral Indus. Misc. Paper 19 (in press).
- Bowen, Richard G., Blackwell, David D., Hull, Donald A., and Peterson, Norman V., 1976, Progress report on heat-flow study of the Brothers fault zone, central Oregon: Ore Bin, v. 38, no. 3, p. 39-46.
- Bowen, Richard G., and Peterson, Norman V., 1970, Thermal springs and wells in Oregon: Oregon Dept. Geol. and Mineral Indus. Misc. Paper 14.
- Brown, C.E., and Thayer, T.P., 1966, Geologic map of the Canyon City quadrangle, northeastern Oregon: U.S. Geol. Survey Map I-447.
- Couch, Richard W., 1977, Analysis of the geophysical data pertaining to the Vale KGRA: Rept. under U.S. Geol. Survey grant, 52 p.
- Diment, W.H., Urban, T.C., Sass, J.H., Marshall, B.V., Munroe, R.J., and Lachenbruch, A.H., 1975, Temperatures and heat contents based on conductive transport of heat, p. 84-103, in White, D.F., and Williams, D.L., eds., Assessment of geothermal resources of the United States: U.S. Geol. Survey Circ. 726, 155 p.
- Groh, Edward A., 1966, Geothermal energy potential in Oregon: Ore Bin, v. 28, no. 7, p. 125-135.
- Hull, Donald A., 1975, Geothermal gradient data, Vale area, Malheur County, Oregon: Oregon Dept. Geol. and Mineral Indus. Open-file Report O-75-4, 18 p.

- _____, 1976, Electrical resistivity survey and evaluation of the Glass Buttes geothermal anomaly: Oregon Dept. Geol. and Mineral Indus. Open-file Report O-76-1, 11 p.
- Hull, Donald A., Bowen, Richard G., Blackwell, David D., and Peterson, Norman V., 1976, Geothermal gradient data, Brothers fault zone, central Oregon: Oregon Dept. Geol. and Mineral Indus. Open-file Report O-76-2, 24 p.
- Hull, Donald A., Blackwell, David D., Bowen, Richard G., and Peterson, Norman V., 1977a, Heat-flow study of the Brothers fault zone, Oregon: Oregon Dept. Geology and Mineral Indus. Open-file Report O-77-3, 43 p.
- Hull, Donald A., Blackwell, David D., Bowen, Richard G., Peterson, Norman V., and Black, Gerald L., 1977b, Geothermal gradient data: Oregon Dept. Geol. and Mineral Indus. Open-file Report O-77-2, 134 p.
- Lawrence, Robert D., 1976, Strike-slip faulting terminates the Basin and Range province in Oregon: Geol. Soc. America Bull., v. 87, no. 6, p. 846-850.
- MacLeod, Norman S., Walker, George W., and McKee, Edwin H., 1975, Geothermal significance of eastward increase in age of upper Cenozoic rhyolitic domes in southeastern Oregon: U.S. Geol. Survey Open-file Report 75-348, 22 p.
- Mariner, R.H., Rapp, J.B., Willey, L.M., and Presser, T.S., 1974, The chemical composition and estimated minimum thermal reservoir temperatures of selected hot springs in Oregon: U.S. Geol. Survey open-file report, 27 p.
- Munroe, Robert J., and Sass, J.H., 1974, Basic heat-flow data from the western United States, *in* Sass, J.H., and Munroe, Robert J., Basic heat-flow data from the United States: U.S. Geol. Survey Open-file Report 74-9, p. 3-1 to 3-185.
- Renner, J.L., White, D.E., and Williams, D.L., 1975, Hydrothermal convection systems, p. 5-57, *in* White, D.E., and Williams, D.L., eds., Assessment of geothermal resources of the United States - 1975: U.S. Geol. Survey Circ. 726, 155 p.
- Sass, J.H., Diment, W.H., Lachenbruch, A.H., Marshall, B.V., Munroe, R.J., Moses, T.H., Jr., and Urban, T.C., 1976a, A new heat-flow contour map of the conterminous United States: U.S. Geol. Survey Open-file Report 76-756, 24 p.
- Sass, J.H., Galanis, S.P., Jr., Munroe, R.J., and Urban, T.C., 1976b, Heat-flow data from southeastern Oregon: U.S. Geol. Survey Open-file Report 76-217, 52 p.
- Sass, J.H., Lachenbruch, A.H., Munroe, R.J., Greene, G.W., and Moses, T.H., Jr., 1971, Heat flow in the western United States: Jour. Geophys. Research, v. 76, p. 6376-6413.
- Sass, J.H., and Munroe, R.J., 1973, Temperature gradients in Harney County, Oregon: U.S. Geol. Survey open-file report, 3 p.
- Sass, J.H., and Sammel, E.A., 1976c, Heat-flow data and their relation to observed geothermal phenomena near Klamath Falls, Oregon: Jour. Geophys. Research, v. 81, p. 4863-4868.

White, D.E., and Williams, D.L., eds., 1975, Assessment of geothermal resources of the United States - 1975: U.S. Geol. Survey Circ. 726, 155 p.

* * * * *

GEOHERMAL OPEN-FILE REPORT RELEASED

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

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

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

* * * * *

DEPARTMENT PUBLISHES REVISED REGULATIONS

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

* * * * *

USGS PRELIMINARY GEOLOGIC MAP ON OPEN FILE

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

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

* * * * *

HATE TAX WASTE? Call or write to the Department, giving us your change of address, before or when you move. Otherwise, the U.S. Postal Service charges the Department 25¢ for your new address, and you lose an issue of your ORE BIN.

* * * * *

TWO NEW MAP SETS FROM USGS

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

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

* * * * *

COMMITTEE ESTIMATES FUTURE NATURAL GAS POTENTIAL

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

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

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

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

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

AVAILABLE PUBLICATIONS

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

BULLETINS	Price
26. Soil: Its origin, destruction, and preservation, 1944: Twenhofel	\$.45
33. Bibliography (1st suppl.) geology and mineral resources of Oregon, 1947: Allen	1.00
35. Geology of Dallas and Valsetz quadrangles, Oregon, rev. 1964: Baldwin	3.00
36. Papers on Tertiary foraminifera: Cushman, Stewart and Stewart, 1949: v. 2,	1.25
39. Geol. and mineralization of Morning mine region, 1948: Allen and Thayer	1.00
44. Bibliog. (2nd suppl.) geology and mineral resources of Oregon, 1953: Steere	2.00
46. Ferruginous bauxite deposits, Salem Hills, 1956: Corcoran and Libbey	1.25
49. Lode mines, Granite mining district, Grant County, Oregon, 1959: Koch	1.00
53. Bibliog. (3rd suppl.) geology and mineral resources of Oregon, 1962: Steere, Owen	3.00
57. Lunar Geological Field Conf. guidebook, 1965: Peterson and Groh, editors	3.50
61. Gold and silver in Oregon, 1968: Brooks and Ramp	8.00
62. Andesite Conference guidebook, 1968: Dole	3.50
63. Sixteenth biennial report of the Department, 1966-1968	1.00
64. Mineral and water resources of Oregon, 1969: USGS with Department.	3.00
65. Proceedings of Andesite Conference, 1969: [copies]	10.00
67. Bibliog. (4th suppl.) geology and mineral resources of Oregon, 1970: Roberts	3.00
68. Seventeenth biennial report of the Department, 1968-1970	1.00
71. Geology of selected lava tubes in Bend area, Oregon, 1971: Greeley	2.50
72. Geology of Mitchell quadrangle, Wheeler County, 1971: Oles and Enlows	3.00
75. Geology and mineral resources of Douglas County, 1972: Ramp	3.00
76. Eighteenth biennial report of the Department, 1970-1972	1.00
77. Geologic field trips in northern Oregon and southern Washington, 1973	5.00
78. Bibliog. (5th suppl.) geology and mineral resources of Oregon, 1973: Roberts	3.00
79. Environmental geology inland Tillamook and Clatsop Counties, 1973: Beaulieu	7.00
80. Geology and mineral resources of Coos County, 1973: Baldwin and others	6.00
81. Environmental geology of Lincoln County, 1973: Schlicker and others	9.00
82. Geol. hazards of Bull Run Watershed, Mult., Clackamas Counties, 1974: Beaulieu	6.50
83. Eocene stratigraphy of southwestern Oregon, 1974: Baldwin	4.00
84. Environmental geology of western Linn County, 1974: Beaulieu and others	9.00
85. Environmental geology of coastal Lane County, 1974: Schlicker and others	9.00
86. Nineteenth biennial report of the Department, 1972-1974	1.00
87. Environmental geology of western Coos and Douglas Counties, 1975	9.00
88. Geology and mineral resources of upper Chetco River drainage, 1975: Ramp	4.00
89. Geology and mineral resources of Deschutes County, 1976	6.50
90. Land use geology of western Curry County, 1976: Beaulieu	9.00
91. Geologic hazards of parts of northern Hood River, Wasco, and Sherman Counties, Oregon, 1977: Beaulieu	in press

GEOLOGIC MAPS

Geologic map of Galice quadrangle, Oregon, 1953	1.50
Geologic map of Albany quadrangle, Oregon, 1953	1.00
Reconnaissance geologic map of Lebanon quadrangle, 1956	1.50
Geologic map of Bend quadrangle and portion of High Cascade Mtns., 1957	1.50
Geologic map of Oregon west of 121st meridian, 1961	2.25
Geologic map of Oregon east of 121st meridian, 1977	3.75
Geologic map of Oregon (9 x 12 inches), 196925
GMS-2: Geologic map of Mitchell Butte quadrangle, Oregon, 1962	2.00
GMS-3: Preliminary geologic map of Durkee quadrangle, Oregon, 1967	2.00
GMS-4: Oregon gravity maps, onshore and offshore, 1967 [folded]	3.00
GMS-5: Geologic map of Powers quadrangle, Oregon, 1971	2.00
GMS-6: Prelim. report on geology of part of Snake River Canyon, 1974	6.50
GMS-7: Geology of the Oregon part of the Baker quadrangle, Oregon, 1976	in press

The ORE BIN
1069 State Office Bldg., Portland, Oregon 97201

The Ore Bin

Second Class Matter
POSTMASTER: Form 3579 requested

Available Publications, Continued:

THE ORE BIN		Price
Issued monthly - Subscription	[Annual]	\$ 3.00
	[3-year]	8.00
Single copies of current or back issues	[Over the counter]	.25
	[Mailed]	.35
OIL AND GAS INVESTIGATIONS		
1. Petroleum geology, western Snake River basin, 1963: Newton and Corcoran		3.50
2. Subsurface geology, lower Columbia and Willamette basins, 1969: Newton		3.50
3. Prelim. identifications of foraminifera, General Petroleum Long Bell #1 well.		2.00
4. Prelim. identifications of foraminifera, E.M. Warren Coos Co. 1-7 well, 1973		2.00
5. Prospects for natural gas prod. or underground storage of pipeline gas		5.00
SHORT PAPERS		
18. Radioactive minerals prospectors should know, 1976: White, Schafer, Peterson.75
19. Brick and tile industry in Oregon, 1949: Allen and Mason20
21. Lightweight aggregate industry in Oregon, 1951: Mason25
24. The Almeda mine, Josephine County, Oregon, 1967: Libbey		3.00
25. Petrography, type Rattlesnake Fm., central Oregon, 1976: Enlows		2.00
MISCELLANEOUS PAPERS		
1. A description of some Oregon rocks and minerals, 1950: Dole		1.00
2. Oregon mineral deposits map (22 x 34 inches) and key (reprinted 1973):		1.00
4. Laws relating to oil, gas, & geothermal exploration & development in Oregon		
Part 1. Oil and natural gas rules and regulations, 1977.		1.00
Part 2. Geothermal resources rules and regulations, 1977		1.00
5. Oregon's gold placers (reprints), 195450
6. Oil and gas exploration in Oregon, rev. 1965: Stewart and Newton		3.00
7. Bibliography of theses on Oregon geology, 1959: Schlicker50
Supplement, 1959-1965: Roberts50
8. Available well records of oil and gas exploration in Oregon, rev. 1973: Newton		1.00
11. Collection of articles on meteorites, 1968 (reprints from The ORE BIN)		1.50
12. Index to published geologic mapping in Oregon, 1968: Corcoran50
13. Index to The ORE Bin, 1950-1974		1.50
14. Thermal springs and wells, 1970: Bowen and Peterson (with 1975 suppl.)		1.50
15. Quicksilver deposits in Oregon, 1971: Brooks		1.50
16. Mosaic of Oregon from ERTS-1 imagery, 1973		2.50
18. Proceedings of Citizens' Forum on potential future sources of energy, 1975		2.00
MISCELLANEOUS PUBLICATIONS		
Oregon base map (22 x 30 inches)50
Landforms of Oregon (17 x 22 inches),25
Mining claims (State laws governing quartz and placer claims)50
Geological highway map, Pacific NW region, Oregon-Washington (pub. by AAPG)		3.00
Fifth Gold and Money Session and Gold Technical Session Proceedings, 1975		
(including papers on gold deposits, exploration, history, and production		5.00
Color postcard, GEOLOGY OF OREGON	[each]	.10
	[3]	.25
	[7]	.50
	[15]	1.00