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GEOTHERMAL POTENTIAL OF THE CASCADE MOUNTAIN RANGE: EXPLORATION AND DEVELOPMENT

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19-22

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H. D. Pilkington

AMAX Exploration, Inc.

INTRODUCTION

Geothermal exploration consists of measuring geological, geochemical and geophysical parameters at the earth's surface. The measured parameters then must be interpreted in terms of our geothermal model for the Cascades to determine where and how deep we must drill for the geothermal resource. The exploration manager will take the technical data developed for a given prospect and determine whether it can be a business within the constraints imposed by corporate policy.

The ideal geothermal prospect developed from our exploration model should have most of the following technical features (Fig.1 Slide 1): be of greater than 10mi^2 with a heatflow three times background or be greater than 2mi^2 with a heatflow ten times background, exhibit viable hydrothermal alteration, contain recent igneous activity (< 1 m.y.), yield favorable hydrogeochemical geothermometers, i.e., greater than 225°C (450°F), have hot springs with siliceous sinter deposits, have mercury and/or sulphur mineralization and finally the presence of abundant faults.

Technical

1. >10mi^2 3 x background HF
2. >2 mi^2 10 x background HF
3. Viable hydrothermal alteration
4. Recent igenous activity
5. Geothermometers forecast > 225°C (450°F)
6. Siliceous sinter deposits
7. Hg and/or S mineralization
8. Abundant faulting

Business

1. Traversed by major transmission line
2. Private ownership
3. Amiable lessor
4. Easy access
5. Environmentally insensitive
6. Oil is the competing fuel

Figure 1. Characteristics of the Ideal Geothermal Prospect

The ideal geothermal prospect will also have most of the following business features (Fig.1-Slide 2): the prospect will be traversed by a major transmission line, the land will be under private ownership, the lessor will be amiable, access to the prospect will be easy, the property will be in an environmentally insensitive area, and the competing fuel within the market area is oil.

EXPLORATION PHILOSOPHY FOR CASCADES

Geothermal exploration in the Cascades is still in the early stages with the exception of the space heating area at Klammath Falls, Oregon. A flurry of leasing took place following the passage of the Geothermal Steam Act and the designation of Known Geothermal Resource Areas (KGRA's) by the U.S. Geological Survey. Since that time, varying amounts of geothermal exploration and/or applied research has been done by private industry, the federal government and the state government.

Geological Characteristics

The young stratavolcanoes of the Cascades suggests the area must be regarded as being geothermally prospective. The geological characteristics of a geothermally prospective area are shown in Figure 2 (Slide 3). The first characteristic is recent volcanic activity (Slide 4) such as seen at Mt. St. Helens, Washington.

1. Volcanic activity
2. Tensional fractures
3. High heatflow
4. Thermal springs
5. Seismicity (microearthquakes)

Figure 2. Geological Characteristics of Geothermal Areas.

The presence of tensional fractures (Slide 5) provides adequate channelways for fluid migration. The area should exhibit high heatflow. Heatflow data for the Cascades is somewhat sparse (Fig. 3-Slide 6) but does allow one to prepare a contour map (Fig. 4 Slide 7) for the Pacific Northwest. Note that large areas fall between

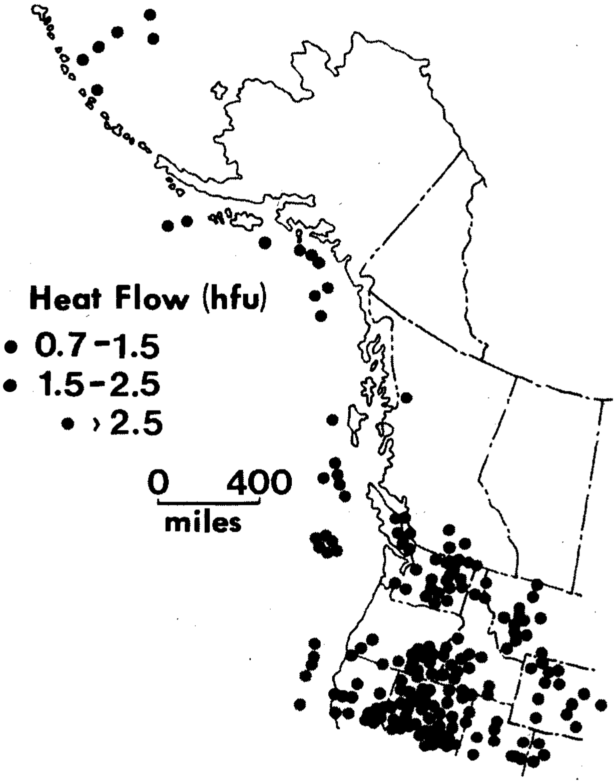

Figure 3. Heatflow Data Points For The Pacific Northwest

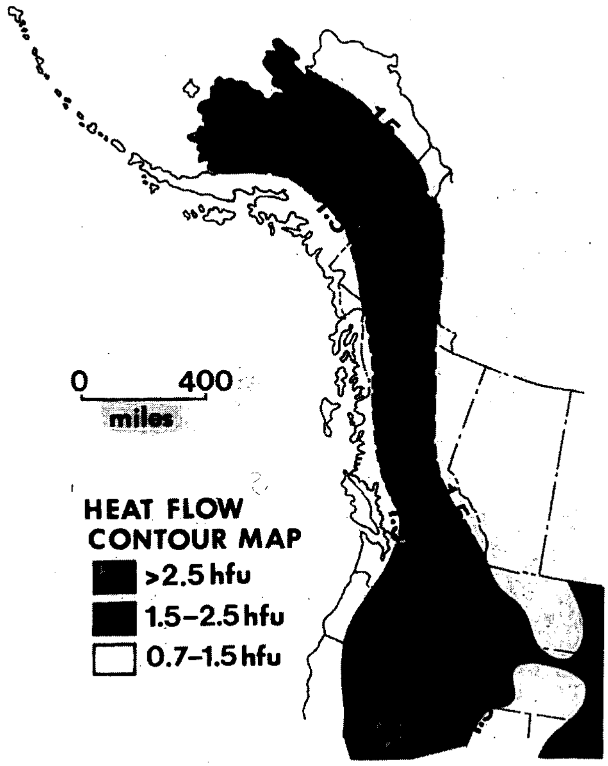

Figure 4. Heatflow Contour Map of The Northwest

the 1.5 and 2.5 HFU contours indicating more than average heat energy is stored in the earth's crust in the Cascades. Superimposed upon the broad general areas of high heatflow are numerous local areas where the heatflow is greater than 2.5 HFU.

Thermal springs (Slide 8) are direct indicators of geothermal systems because they represent escaping fluids from some buried source.

Some idea of the abundance of thermal springs in the Cascades can be seen in Figure 5 (Slide 9) which shows the location of springs with subsurface temperatures greater than 90°C and less than 150°C. Note that within the Cascade region the density of such springs is low. The final characteristic (Slide 10) of geothermal areas is seismicity in the form of microearthquakes.

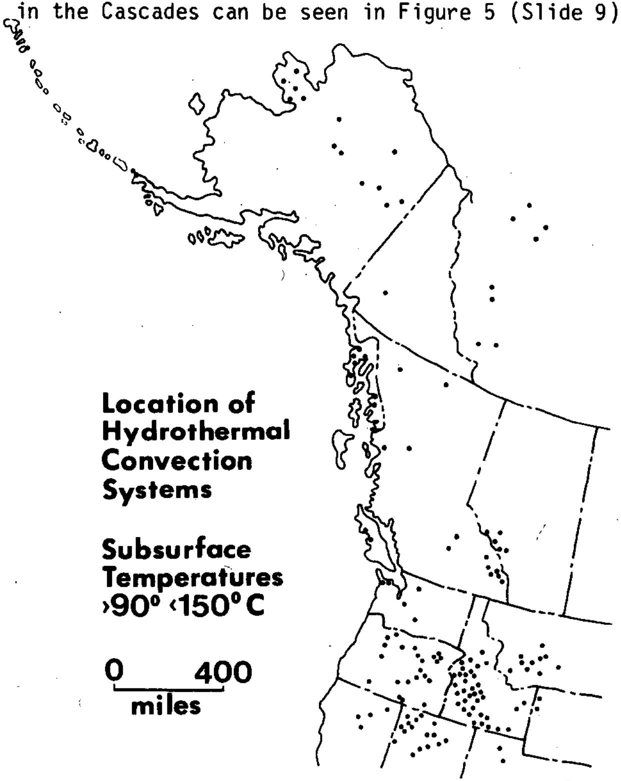

Figure 5. Location of Hydrothermal Convection Systems With Subsurface Temperatures >90°C <150°C

Geothermal Model

It is important to develop a geothermal model early on to guide your exploration program. The geothermal model you build for the Cascades will form the basis of your exploration program. Young mountain belts and modern island areas are associated with seismic and volcanic belts (Fig. 6-Slide 11) along convergent plate boundaries which suggests our model will center upon plate tectonic concepts. The miocene volcanic arc

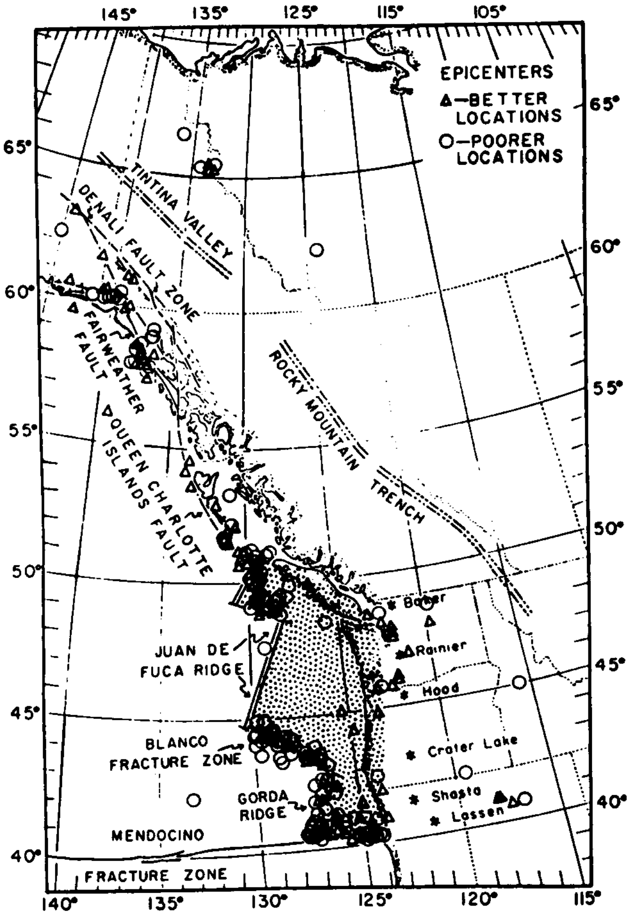

Figure 6. Seismic Belt, Cascade Volcanoes and Juan de Fuca Ridge

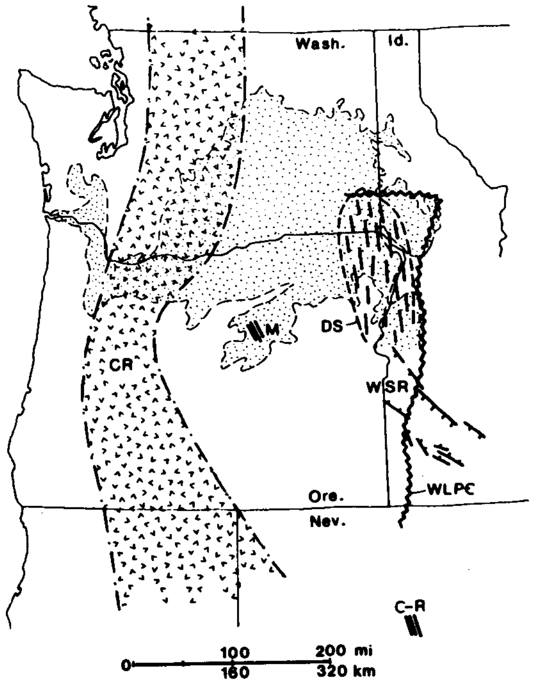

Figure 7. Miocene (20-10 m.y. ago) Volcanic Arc - Pacific Northwest

(Fig. 7-Slide 12) in the Pacific Northwest coincides with the Cascade Range. Most recent workers consider the andesitic volcanism of the Cascades to represent a volcanic arc above the subdusting Farallon-Juan de Fuca plate. The Columbia River basalts are regarded as a back-arc response to the subduction. The back-arc extension was probably triggered by an accelerated rate of plate convergence approximately 20 m.y. ago and the consequent steepening of the Farallon-Juan de Fuca plate. About 10 m.y. ago the triangular shaped Juan de Fuca plate began to move as a separate plate bounded by transformed faults. The construction of the high Cascades and the Coast Range formed in late Pleocene and Pleistocene time. The sedimentary Coast Range represents uplifted trench fill and the Cascades are the associated volcanic arc.

Exploration Methods

The exploration program one develops for the Cascades will be governed by your geothermal model, staff capabilities and budget. Let us discuss a generalized exploration program leading to a wildcat test for discovery (Figure 8). Phase I of the program (Slide 13) includes all those reconnaissance activities which will lead you to prospects with evidence of heat and "plumbing" which gives favorable hydrogeochemistry. In the Cascades, the obvious manifestations of heat are the volcanos and the limited number of thermal springs. The high rainfall and dense vegetative cover makes the preliminary reconnaissance phase very difficult in the Cascades.

In most areas of the western United States we would then proceed into Phase II(Slide 14) of "recce" follow-up. In the Cascades we probably follow A through C with no modification. However, the shallow thermal gradient drilling program should be permitted to include holes from

Phase I <u>Recce</u>

Locate prospects with evidence of heat and "plumbing" with favorable hydrogeochemisty.

Phase II <u>Recce Follow-Up</u>

A. Geological Recon
B. Verify Heat and Chemistry
C. Take Land Position
D. Shallow ΔT Program.

Phase III <u>Targeting</u>

A. Detailed Geologic Mapping
B. Seismic Monitoring.
C. Gravity and Magnetics
D. Electrical Methods(MT? EM? SP?)
E. Supplemental Shallow ΔT Holes
F. Intermediate Depth ΔT Program
G. Title Curative Work.

Figure 8. Geothermal Exploration Program Prior to Wildcat Test

150m (500ft.) to as much as 610m (2,000ft.) because of the problems associated with downward and lateral migration of meteoric waters.

If a prospect survives after Phase II it will the move into the targeting stage of Phase III (Slide 15). An exploration program in the Cascades should give serious consideration to including a hydrogeologic mapping effort perhaps with detailed temperature surveys of the waters. Such information could be helpful in interpreting heatflow studies and might also help delineate the heat source. Seismic monitoring, gravity and magnetic studies should provide much useful data to substantiate or modify the basic geothermal model of the area. What if any electrical method will provide us with data to help target a production test? Probably a magnetotelluric survey carefully located with respect to structure and topography will give us the most information. A self-potential survey could be done in connection with a hydrogeological survey to help our understanding of the near surface water movement. Finally, we will be ready to carry out an intermediate depth thermal gradient drilling program with holes permitted from 610m (2,000 ft.) to as much as 1,220m (4,000 ft.).

Land Positions and Problems

The geothermally prospective area of the Cascades extends from Mount Lassen in northern California to Mount Garabaldi in southern British Columbia. As stated earlier, the ideal geothermal prospect would be located on fee lands and be in the hands of an amiable person. In the Cascades, as elsewhere geothermal prospects are where you find them, not necessarily where you would like them to be. The odds are in favor of the prospect being on federal lands administered by the Forest Service, in total or in part. Even though geothermal exploration in the Cascades is still in the early stages, leases have been taken on most fee lands in those areas deemed to be most prospective.

Forest Service Lands

Lease applications were filed on large areas of Forest Service lands immediately after the passage of the Geothermal Steam Act. Years and years have gone by and only a handful of leases have been issued to date. On the bright side, the Region VI Office in Portland announced in October 1980 that a back log of 500 geothermal lease applications will be processed by the third quarter of 1981, thirty-six more in the first quarter of 1982 and twenty-one in the first quarter of 1983.

The USFS completed, in 1980, the environmental assessment for the non-competitive leasing on 539,600 acres of land within the Fort Rock Ranger District of the Deschutes National Forest. The report showed 308,320 acres available for "standard" lease stipulations and 178,560 acres available for "staged leasing". In 1981, a supplement to the environmental assessment report was issued which is said to pave the way for issuance of geothermal leases. However, the new proposal is more restrictive than the 1980 version (Fig. 9-Slide 16).

	'80 USFS Version	'81 USFS Version
standard leasing	308,320 ac.	267,600 ac.
staged leasing	178,560 ac.	209,490 ac.
no leasing	52,720 ac.	62,820 ac.

Figure 9. USFS Recommendations for Geothermal Leasing in Fort Rock Ranger Dist., Deschutes National Forest.

On March 30, 1981, the Gifford Pinchot National Forest resended their decision of May 15, 1979 regarding geothermal leasing. The decision to adopt alternative No. 4 (Fig. 10-Slide 17) was proven to be too restrictive and was not going to permit adequate geothermal exploration. Therefore, the March 30, 1981 adopted alternative No. 2 with minor modifications.

Fee Lands

Although the bulk of the lands in the Cascades are within the national forests, a surprising amount of private land is present. The private owners may be individuals or large wood and/or paper production companies. The railroads also hold significant tracts of land in the Cascades.

Acquisition of a land position involving the fee lands can be done by leasing from the owner, earn acreage by drilling exploration test wells, or by joint exploration agreements with either the land owner, in case of the wood and/or paper pro- duct companies, or with competitors.

Regulatory Problems

During all phases of your exploration program and especially in Phase II and III you must time your work in order to comply with all the regulations (Figure 11-Slide 18). The federal acreage limitation thus far has probably not been a serious problem in the Cascades, and hopefully the legislation increasing the limitation to 51,200 acres will pass this year. Permitting regulations of the federal government, and in some cases local government require much planning and an orderly progression of work by your permitting people to insure uninterrupted exploration work. Often times permits are required from three different agencies for the same work. In geothermal exploration "casual use" of public lands has almost become a thing of the past.

1. Federal acreage limitation
2. Permitting problems
3. State regulations
4. Local regulations

Figure 11. Regulatory Problems Affecting Geothermal Exploration.

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USFS Leasing Alternatives May 15, 1979

APPROVALS AND CONSTRAINTS	ALTERNATIVES													
	1		2		3		4		Preferred Alternative		5		6	
	Acres	%	Acres	%	Acres	%	Acres	%	Acres	%	Acres	%	Acres	%
A. Leasing Approved: All Surface Development 1. Leasing Approved	295,581	99	215,038	72	65,627	22	117,050	39	105,526	35	59,419	20	0	0
B. Leasing Approved: With No Surface Occupancy Constraints 2. No Surface Occupancy	0	0	7,457	2	17,675	6	74,175	25	86,784	29	5,288	2	0	0
3. NSO -- Conditional (Subject to Waiver)	0	0	71,785	24	146,176	49	0	0	0	0	0	0	0	0
4. NSO: Except Access Roads	0	0	0	0	0	0	10,207	3	0	0	0	0	0	0
5. NSO: Except Access Roads and Transmission Lines	0	0	0	0	31,412	10	55,357	18	0	0	0	0	0	0
6. Total Leasing Approved Area with SOC (2 + 3 + 4 + 5)	0	0	79,242	26	195,263	65	139,739	46	86,784	29	5,288	2	0	0
C. Summary 7. Leasing Approved Total Area (1 + 6)	295,581	99	294,280	98	260,890	87	256,789	84	192,310	64	64,707	22	0	0
8. Leasing Denied	4,027	1	5,328	2	38,718	13	42,819	14	107,298	36	234,901	78	299,608	100
9. Total Study Area (7 + 8)	299,608	100	299,608	100	299,608	100	299,608	100	299,608	100	299,608	100	299,608	100
D. 10. Percent of Leasing Approved Area (7) with SOC (6)		0		27		75		54		45		8		0

NOTES:
1. NSO = No Surface Occupancy; SOC = Surface Occupancy Constraint.
2. Figures are digitized close estimates from the Forest's ½" = 1 mile base map.
3. Acres and percentages are rounded to the nearest unit.

Figure 10. Forest Service Recommendations for Leasing May 1979

TYPES OF GEOTHERMAL RESERVOIRS

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ABSTRACT

Geothermal systems exist in several widely differing types from radiogenically heated sandstones to vapor-dominated hydrothermal systems in fractured granites sitting above cooling magma chambers to geopressured reservoirs. Geochemistry plays a large role in distinguishing among the different types. Some example systems of each type are 1) The Geysers CA-vapor-dominated, 2) Cerro Prieto Mexico-liquid-dominated, high temperature, 3) Klamath Falls OR-liquid -dominated, low to moderate temperature, 4) Fenton Hill NM-hot dry rock, 5) Texas Gulf Coast-geopressured geothermal, 6) Paris Basin France-sedimentary basin, 7) US East Coast-radiogenic.

CHARACTERISTICS

All geothermal systems which are of any practical use must have the following three things: 1) A source of heat, e.g., radioactive rocks, magma chamber, 2) Permeability in the rock-intergranular or fracture or both, and 3) A heat transfer medium-natural pore water or injected water. Beyond these three characteristics the types of systems vary widely. White and Williams (1975) have classified geothermal systems as shown in Table I.

HYDROTHERMAL SYSTEMS

Only hydrothermal systems have been developed commercially to date. Hydrothermal systems can be split into vapor-dominated and liquid-dominated types. See Figures 1-3. Table II shows some of the characteristics and contrasts between the two types. Much of the information in the table is from White et al (1971).

Vapor-Dominated Systems

Vapor-dominated systems are quite rare, probably less than a tenth as common as liquid-dominated systems. They are also quite valuable because they can be used directly for electric power generation. Some of the vapor-dominated areas producing electricity are The Geysers CA, Larderello Italy, and Matsukawa Japan. All vapor-dominated reservoirs are two-phase even though the liquid-vapor interface at The Geysers has not yet been found. Because the density of steam is so low The Geysers source rock would have to be impossibly thick unless a boiling interface existed. The two-phase nature prevents the use of analysis techniques taken from the natural gas industry which has only a single phase system to deal with.

Liquid-Dominated Systems

Liquid dominated systems range in temperature from greater than 150°C for high temperature systems to less than 90°C for low temperature systems. Examples of high temperature systems are Wairakei NZ and Cerro Prieto Mexico; electricity is being generated in both places. The best known low temperature resource in the US is at Klamath Falls where hot water is used to heat homes, pasteurize milk, and melt snow and ice off of highways.

SEDIMENTARY BASINS

Sedimentary basins are found in many parts of the world. They are basins filled with sedimentary rock to depths of 10 km or more. The permeability and depth allow the circulation of ground water which is heated to a useable temperature. Moderate geothermal gradients in the Paris Basin provide warm water which is being used to economically heat thousands of homes. The Madison group carbonate rock sequence in the Dakotas, Wyoming, Montana, and Canada is a similar basin which is being tapped for heating and agricultural use.

GEOPRESSURED GEOTHERMAL

Geopressured geothermal reservoirs are found mainly in the US Gulf Coast. Geopressured zones start at about 3km and go down to perhaps 15km. See Figure 4. They are zones of anomalously high pressure caused by rapid sedimentation and contemporaneous faulting. When these two processes retard water loss from compacting sediment, the interstitial fluid has to support part of the overburden load. This geopressures and superheats the formation water. See Figures 5 and 6 for plots of temperature and pressure vs depth. Paul Jones (1975) has described geopressured zones as "a natural pressure vessel from which superheated water of moderate salinity could be produced through wells, each yielding millions of gallons a day at pressures of several thousands pounds per square inch, and temperatures above 300°F, with considerable amounts of methane gas in solution."

RADIOGENIC RESOURCE

Some areas such as the eastern US have high geothermal gradients caused by heat generated by radioactive rocks. See Figure 7. If water is available in such areas the resource could reasonably be tapped for low to intermediate temperature uses. Exploration and research is being conducted at Virginia Polytechnic Institute and State University.

HOT DRY ROCK

The hot dry rock resource consists of rocks within about 10km of the surface with little permeability and little circulating fluid. Experiments at Los Alamos Scientific Laboratory have succeeded in creating a small geothermal system in such a resource by 1) drilling two adjacent wells, 2) hydraulically fracturing the formation, and 3) injecting cold water into the formation thru one well and producing hot water from the other. See Figure 8.

MOLTEN ROCK

Molten rock utilization is still in the laboratory stages and will probably remain so for quite a while.

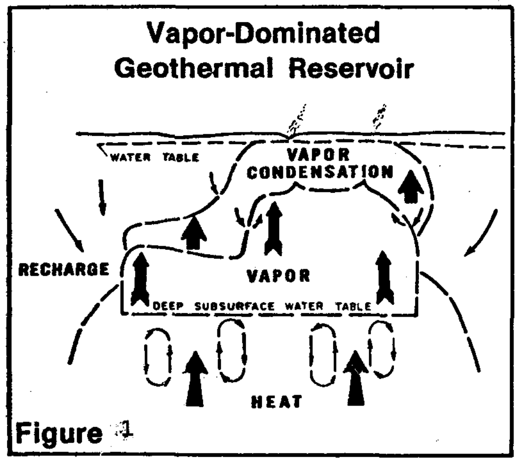

Figure 1

Courtesy of Earth Science Laboratory, University of Utah Research Institute

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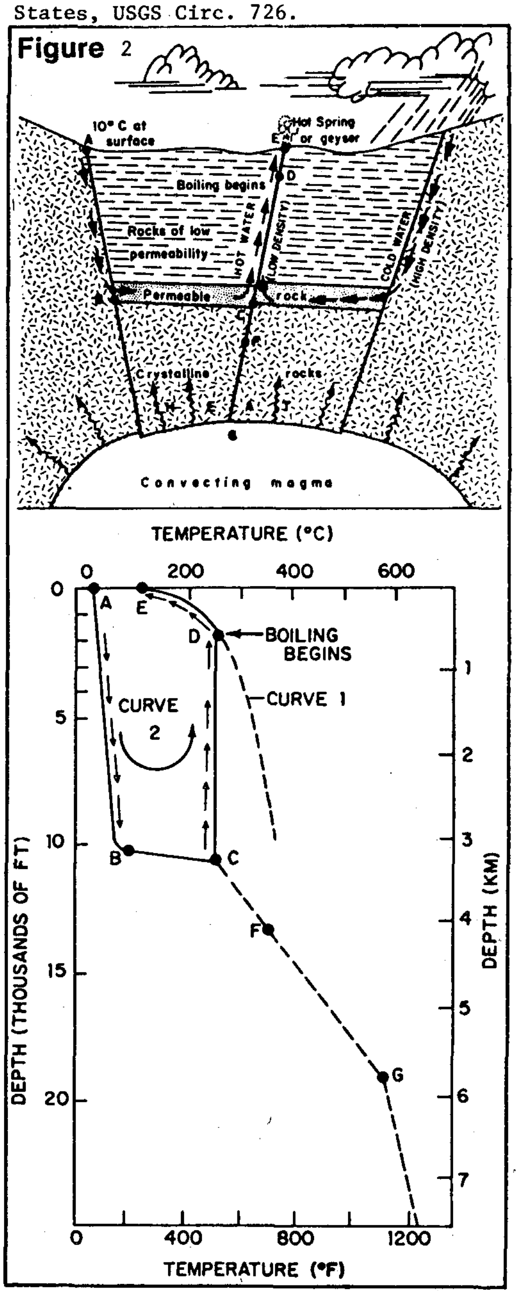
Figure 2



With Permission from Donald E. White, U.S. Geological Survey

Model of a high-temperature hot-water geothermal system with corresponding temperature-depth relations.

WATER DOMINATED GEOTHERMAL SYSTEM

FLOW CONTROLLED BY FRACTURES

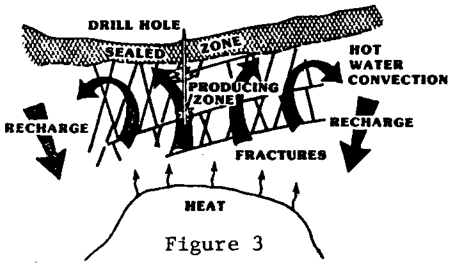
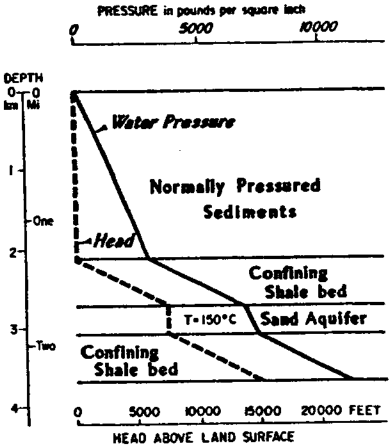


Figure 3

GEOPRESSURED GEOTHERMAL RESOURCE

Figure 4



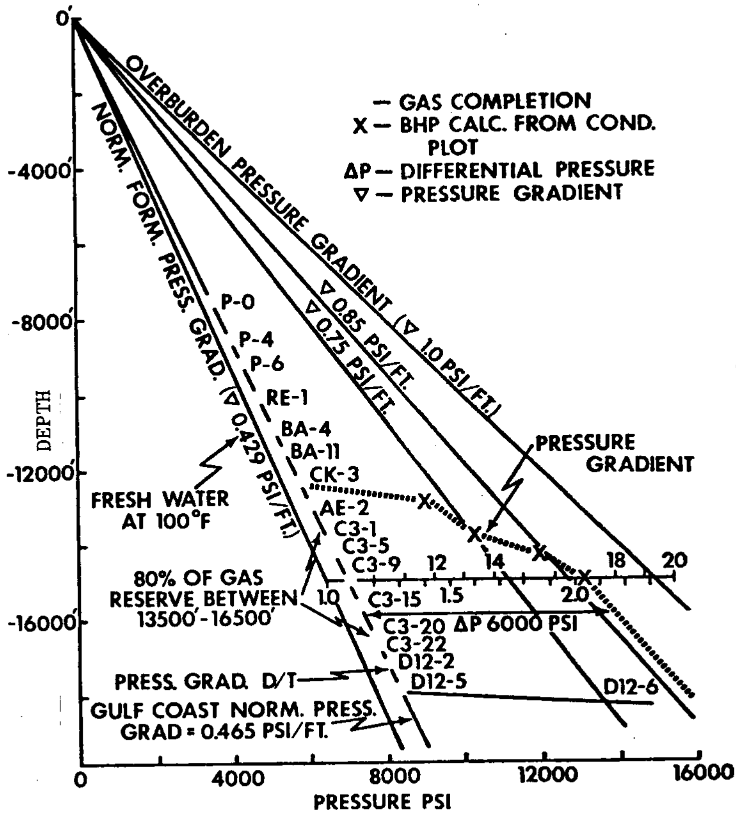


Figure 5. Changes in pressure gradients with depth in deposits penetrated by an offshore Louisiana well (from Meyers, 1968).

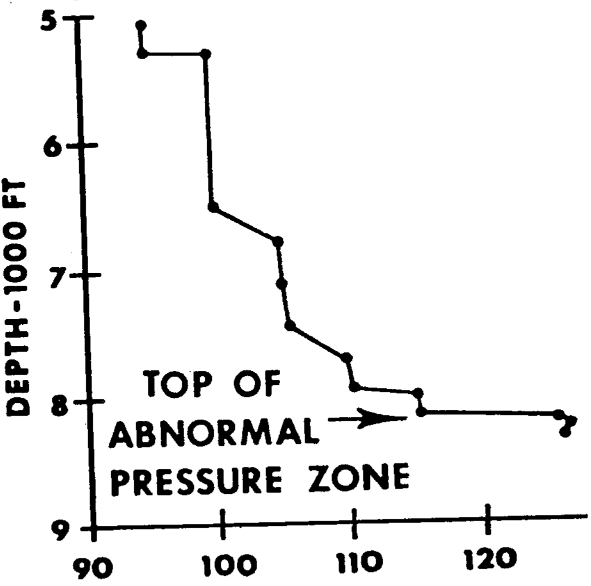


Figure 6. Mud flowline temperature as an indicator of geopressure.

RADIOGENIC GEOTHERMAL RESOURCE

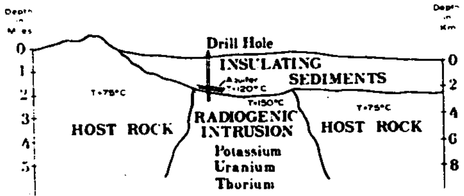


Figure 7

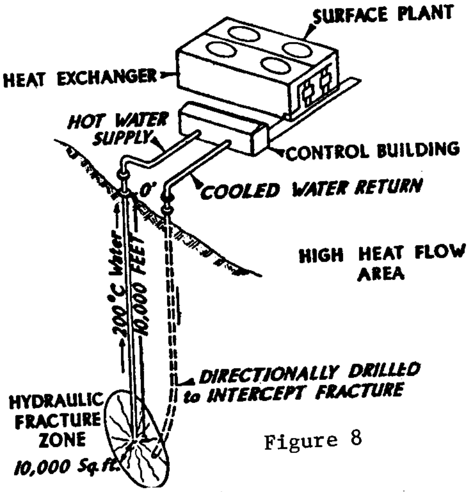


Figure 8

HOT DRY ROCK GEOTHERMAL RESOURCE

TABLE I

Geothermal Resource Classification

Resource Type	Temperature Characteristics
1. Hydrothermal convection resources (heat carried upward from depth by convection of water or steam)	
a. Vapor dominated	about 240°C (464°F)
b. Hot-water dominated	
1. High temperature	150°-350°C+ (300°-660°F)
2. Intermediate temperature	90°-150°C (190°-300°F)
3. Low temperature	less than 90°C
2. Hot igneous resources (rock intruded in molten form from depth)	
a. Part still molten	higher than 650°C (1200°F)
b. Not molten—"hot dry rock"	90°-650°C (190°-1200°F)
3. Conduction dominated resources (heat carried upward by conduction through rock)	
a. Radiogenic (heat generated by radioactive decay)	30°-150°C (86°-300°F)
b. Sedimentary basins (hot fluid in sedimentary rocks)	30°-150°C
c. Geopressured (hot fluid under high pressure)	150°-200°C (300°-390°F)

TABLE II

LIQUID-DOMINATED SYSTEMS VS VAPOR-DOMINATED SYSTEMS

1. Host rock permeability high	1. Host rock permeability low
2. Discharge high (100's to 1000's gpm)	2. Discharge low (c. 25 gpm)
3. High chloride content (greater than 50 ppm)	3. Low chloride content (less than 20 ppm)
4. High pH	4. Low pH (acid)
5. Low sulfate	5. High sulfate
6. Natural geysers	6. No natural geysers
7. Mercury deposits uncommon	7. Mercury deposits characteristic
8. High potential for self sealing with silica	

Factors Which Indicate High-Intensity Systems

1. SiO_2 greater than 240 ppm = 180°C	1. ---
2. Current sinter deposits = 180°C	2. None but if vapor-dominated system exists, temp = 236°C-240°C
3. Natural geysers = 150°C-170°C	3. Fumaroles 236°C-240°C
4. Na/K ratio less than 20 =170°C	4. ___

WHEN THE HOLE IS DRY - THE HDR ALTERNATIVE IN THE CASCADES

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Abstract

The Hot Dry Rock (HDR) method of heat extraction was developed by Los Alamos in silicic plutonic-metamorphic rocks of Precambrian age. Now that the method and mechanisms are better understood, we are looking at other rock types as potential HDR "reservoirs".

High heat flow over much of the Northwest indicates the potential for geothermal power and heat is great if we could find ways to develop it. Currently we are working with two conceptual models for HDR development in volcanic rocks. Experiments planned for this summer should indicate how the rocks behave and how this behavior compares to existing models.

Introduction

Geothermal heat exists everywhere. In large portions of the Northwest temperatures of 200°C (400°F) exist within 3-4 km of the surface and could be commercially developed for electrical production or space and process heat. Conventional geothermal development requires producible natural hot water and so far this has limited our utilization of the earth's heat.

Original HDR Concept

The HDR concept as developed at Los Alamos and demonstrated at Fenton Hill, on the west flank of the Valles Caldera in northwestern New Mexico, provides a way to extract heat from the earth where no natural hot waters or steam can be produced (Smith et al. 1976).

The original (Phase 1) system (Fig. 1) consists of two boreholes drilled into granitic rock to approximately 3 km (10,000 ft) with an average reservoir temperature of ~185°C (365°F), connected by a system of vertically oriented hydraulically induced fractures. Water is circulated down one borehole, heated by contact with the rock and rises up the second borehole to the surface. The heat is removed from the circulating water by means of an air-cooled heat exchanger (similar to your automobile radiator) and the cooled water is reinjected for recirculation. A 280-day test produced 3-5 MW(t) and resulted in a temperature drawdown of the reservoir of only 5°C. The extracted hot water temperature was 135°C (275°F). The relatively low temperature of the produced fluid resulted from the modest flow rate of 6 ℓ/s (100 gpm) and the temperature drawdown of previous tests. During this 280-day test, <u>some</u> of the superheated water was circulated through a binary fluid generator to produce 60 KW(e) of electric power.

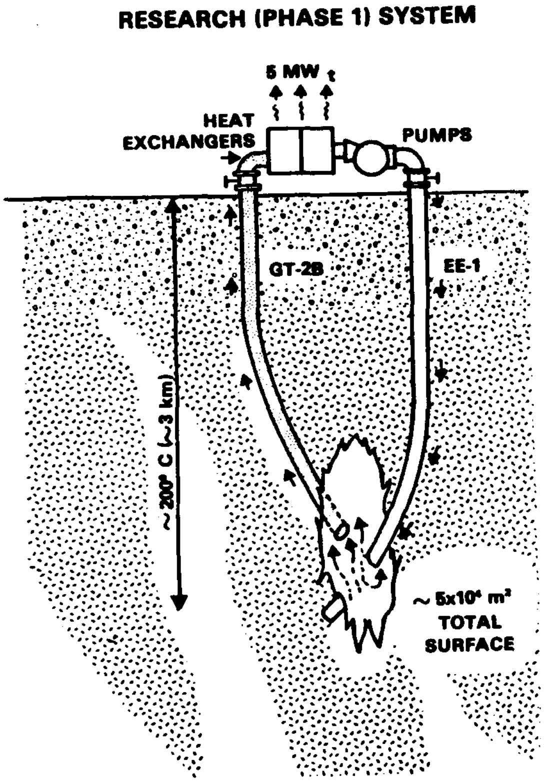

Fig. 1. Phase 1 HDR System, Fenton Hill.

A second-generation (Phase 2) system (Fig. 2) is presently being drilled to 5 km (15,000 ft) and temperatures of 325°C (617°F). Two parallel, inclined (35° from vertical) boreholes, separated by about 400 m, will be connected by multiple parallel vertical fractures. The system could produce 10 MW(e) for 20 years with only 10% thermal drawdown during that time.

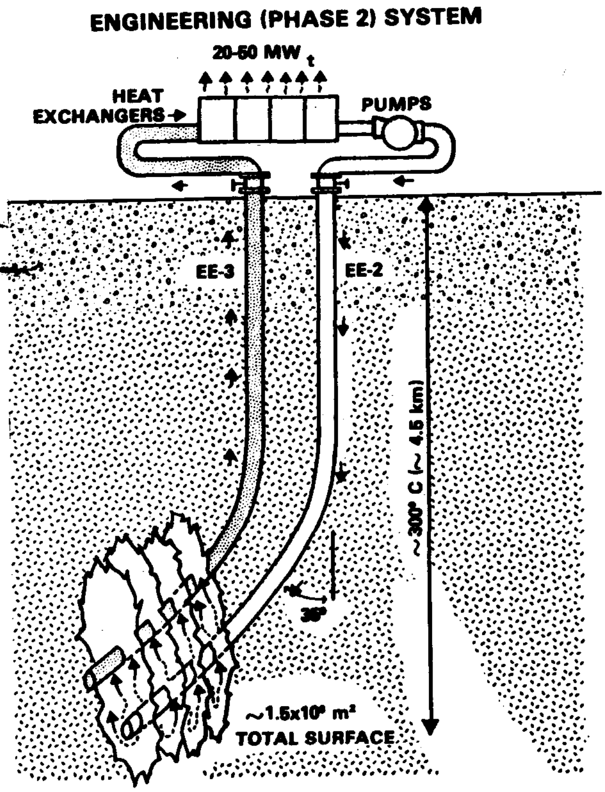

Fig. 2. Phase 2 HDR System, Fenton Hill.

It was originally expected that new fractures would be created by hydraulic fracturing. It is now believed that pre-existing fractures in Precambrian rocks are opened by hydraulic pressure and possible cooling of the rock.

Expanding The Concept

Once the method had been demonstrated at Fenton Hill, consideration was given to other rock types. In 1979 a series of hydrologic tests were done in low-grade meta-volcanic rock below 1625 m (5333 ft) depth in Crisfield, Maryland. The original permeability was 10 microdarcies. The test consisted of hydraulic pressurization resulting in multiple fractures followed by sand propping of the fractures. The results showed that fractures had been opened by the pumping, as the pressure required to produce flows of 1.25 ℓ/sec was less for each successive pressurization (Fig. 3). Well logs indicated that the fractures had been propagating upward (Fig. 4) and with time might break through to the permeable sediments above 1360 m (4461 ft). Unfortunately, our time in the well was limited and there was not the opportunity to see if a single wellbore loop could be established. In a single wellbore loop the water is injected through the insulated center of a double pipe, moves upward through the fractures in the impermeable formation until it intersects a permeable zone. The outer casing of the double pipe is perforated in this zone and the hot water is pumped up through the annulus (Fig. 5).

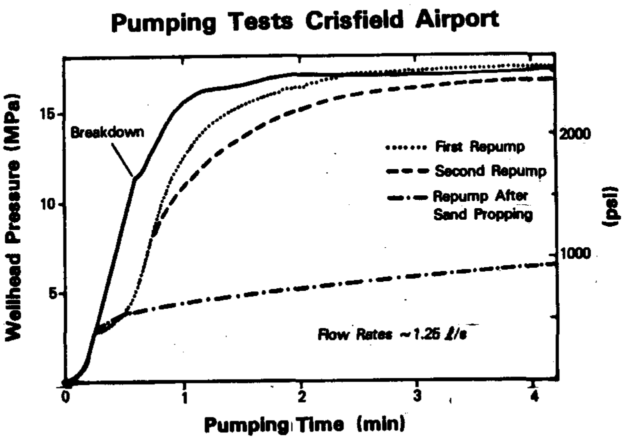

Fig. 3. Pumping tests at Crisfield, Maryland.

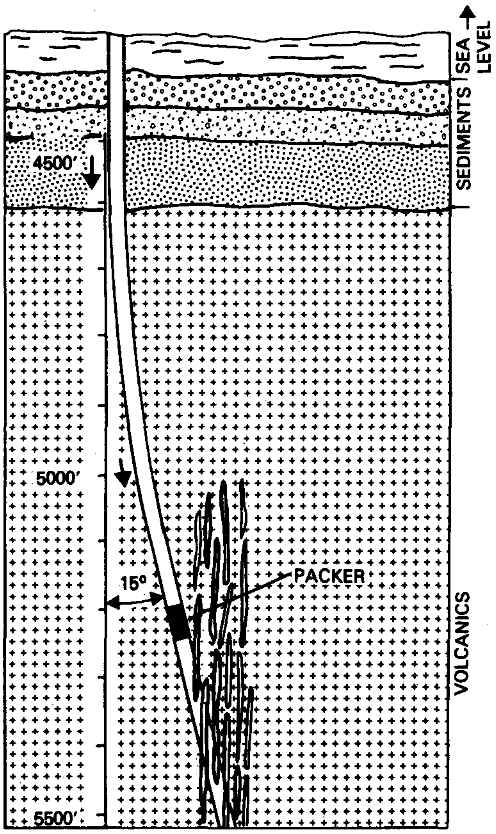

Fig. 4. Well and fracture system at Crisfield, Maryland.

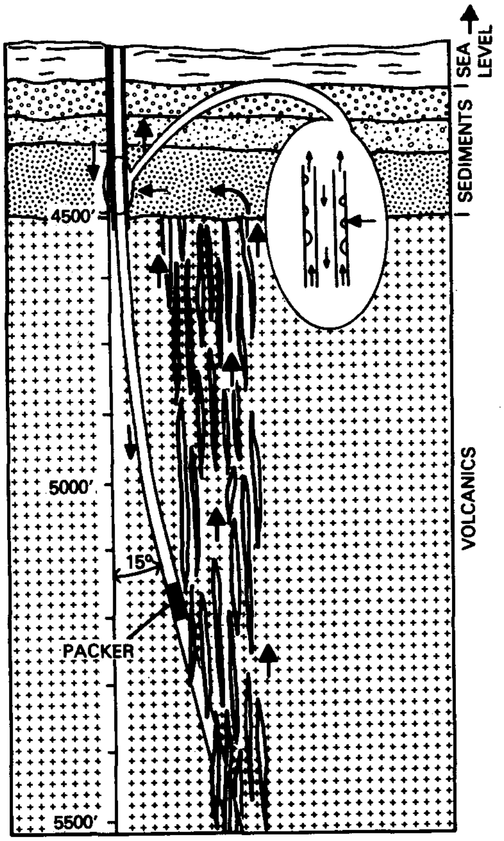

Fig. 5. Single wellbore loop.

We are currently planning hydrologic tests in a number of additional rock types to determine their reservoir characteristics so that suitable HDR extraction techniques can be developed for each. These tests will be done in dry holes loaned to us by industry for testing purposes.

<u>HDR Potential in the Cascades</u>

In many parts of the Cascades temperatures suitable for geothermal development exist within 2-4 km of the surface but hydrothermal reservoirs are not so abundant. For the existing heat to be extracted, HDR techniques will have to be employed.

Under the original HDR concept, we were limited to silicic intrusive rocks for HDR development. Since most of the Northwest lacks a Precambrian basement, this meant intrusive rocks, of Mesozoic to Pliocene age, located mostly in the northern Cascades, or cores of silicic domes.

With the realization that we are not creating new fractures but rather opening old ones with hydraulic pressure, new reservoir configurations are being modeled. One which appears possible in layered volcanic rocks has a flow pattern similar to that shown in Fig. 6, where thick layers of columnar basalts, flow breccias, or fractured tuffs are interbedded with impermeable clay-rich sediments sealed by hydrothermal alteration. In plan view the flow would appear as in Fig. 7, and heat would be flushed from the rock as oil is flushed by water or steam in the oilfields. This is similar to the "forced geoheat recovery" proposed by Bodvarsson (1976) or the flushing of geothermal heat discussed by Andrews et al. (in press).

To test the applicability of this model to volcanic rocks found in the Northwest, two hydrologic tests are planned this year for hot dry wells in Oregon.

The first, which should take place in May, is a multiple pressurization of the Ore-Ida well in Ontario, Oregon. The well is 3065 m (10,054 ft) deep in interlayered sediments, tuffs and basalts and has a bottom hole temperature of 182°C (360°F) (Geothermex Inc., 1980). The lower 588 m (1929 ft) of basalt showed initial fracture permeability which was plugged with mud during drilling. The well produced 1-2 gpm. The test is planned to indicate, by successive pressurizations, whether fractures in the rock can be opened and if their ability to accept and store water is increased during the test. The theory is that if the frac- can be made to accept the water, it could then be recovered from a second well.

Similar testing is tentatively planned for OMF#7a on Old Maid Flat, Mt. Hood, Oregon in August. This well was drilled in a mixed volcanic sequence to a depth of 1838 m (6027 ft) with a maximum recorded temperature of 113°C (235°F) and produced 1/4 gpm from the lower 874 m (2867 ft) (US DOE, Nevada Operations Office, in press). In this well we plan to set packers and isolate the lower basalts and basalt breccia, which seem similar to older more altered basalts found at depth throughout the region.

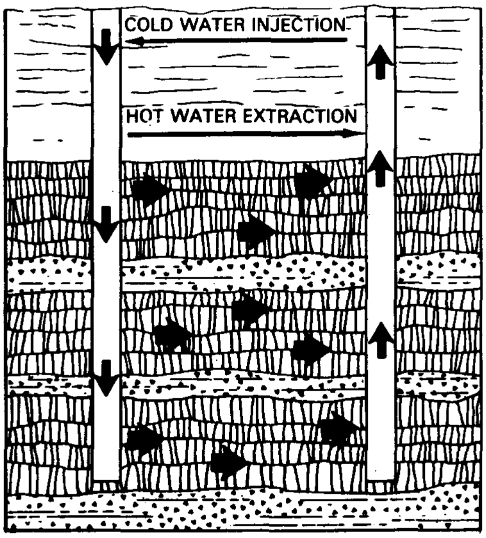

Fig. 6. Two borehole system in volcanic rock.

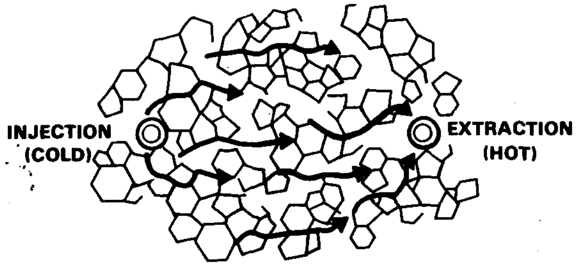

Fig. 7. Plan view of flow patterns for two borehole system shown in Fig. 6.

The results of the tests planned for this summer will show if typical Cascade volcanic rocks are suitable for presently envisioned HDR technology or if new conceptual models must be developed to extract the heat from these rocks with manmade systems.

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MEAGER CREEK GEOTHERMAL PROJECT - AN EXPLORATION CASE HISTORY

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Abstract

The South Reservoir in the Meager Creek Geothermal Area is within crystalline basement rocks on the southern flank of the Pliocene to Recent Meager Mountain Volcanic Complex. Geological, geochemical and resistivity surveys were used to determine targets for temperature gradient diamond drilling. Temperature profiles indicate anomously high temperature gradients in drill holes M2, M3, M4, M6, M7, M8, M10, M11 and M12. Heat flow values of 105-620 mWm^{-2} (2.5-14.8 HFU) have been calculated for drill holes M2, M3, M7, M8, M11 and M12; these values are up to seven times the regional heat flow for the Garibaldi Volcanic Belt. The main South Reservoir thermal anomaly has been defined over an area about 3 km by 1 km in the Meager Creek valley and is open to the north and southeast. Deep drilling and production testing to assess the reservoir as a potential power source will be initiated during 1981.

Introduction

The Meager Creek Geothermal Project area, 160 km northwest of Vancouver, is associated with the Pliocene to Recent Meager Mountain Volcanic Complex (Figure 1). Meager Mountain is the northern most volcano of the Garibaldi Volcanic Belt, (Souther, 1976) an extension of the High Cascade volcanos into Canada. This paper describes the South Reservoir, an area of fractured crystalline and metamorphic basement rocks on the southern flank of the Meager Volcanic Complex.

The project is operated by B.C. Hydro and Power Authority, a provinical government public utility, for which Nevin Sadlier-Brown Goodbrand Ltd. has acted as exploration consultants since the work commenced in 1973 (Nevin and Sadlier-Brown, 1972). The Geological Survey of Canada and Earth Physics Branch of the Department of Energy, Mines and Resources (EMR) have conducted various independent research studies at Meager that generally compliment applied exploration by B.C. Hydro.

Standard exploration techniques have been modified to accommodate the rugged terrain, high precipitation and remoteness of the area. Geological mapping, spring water geothermometry, isotope hydrology, radon and soil mercury, airborne infrared scanning, resistivity, self potential, microseismicity and magneto-telluric techniques have been applied along with temperature gradient drilling utilizing diamond drilling equipment (Nevin et al 1978). Emphasis during the initial exploration phase was on geological and geochemical studies. For detailed evaluation of potential target areas detailed geologic mapping and structural analysis, resistivity surveys, and diamond drilling have proved to be the most useful exploration techniques.

Geology

The volcanic complex and adjacent basement terrane has been mapped by Read (1979). The basement consists mainly of Mesozoic to early Tertiary crystalline and metamorphic rocks of the Coast Plutonic Complex but includes high level, quartz monzonite plutons as young as late Miocene. A post-Miocene erosion surface of high relief separates the basement rocks from the overlying volcanic complex. The volcanic edifice itself is a deeply dissected, glacier-covered complex of overlapping andesite, dacite and rhyodacite piles that become progressively younger from south to north.

The earliest (1.0 Ma) episode of volcanism, which occurred on the south flank of the complex immediately north of current drilling in the South Reservoir, includes an extensive basal breccia of dominantly plutonic blocks overlain successively by porphyritic andesite flows and breccia, porphyritic dacite flows and breccia, and hydrothermally altered rhyodacite tuff, flows, and breccia (Devastator Assemblage). The intense brecciation and alteration indicate that the initial eruption was explosive and that it was followed by prolonged hydrothermal activity. Subsequent, successively younger eruptions form a stratavolcano of andesite, dacite and rhyodacite flows, breccias and subvolcanic intrusions 12 km across. The last volcanic eruption of welded block and ash flows from a vent on the north side of the complex, occurred approximately 2550 years ago. Airfall tephra, the Bridge River ash, from this eruption is similar in morphology and extent to the May 18th St. Helen's ash.

The South Reservoir area is underlain by weakly-foliated Cretaceous quartz diorite containing tabular and wedge-shaped pendants of banded amphibolite, migmatite, greenstone and quartzofeldspathic gneiss. Intrusive contacts are gradational. Quartz diorite and metamorphic rocks are affected by pervasive propylitic (chlorite, epidote, carbonate and albite) alteration and local silicification.

Hypabyssal dikes of light green, dacitic, feldspar porphyry and milky-white aphanitic rhyolite correlated with volcanics on Pylon Peak cut basement rocks. Most of them display a strong pervasive clay-carbonate-quartz-chlorite alteration that partially obscures original textures.

Mineral precipitates in fractures include silica, kaolinite and other clays, calcite, dolomite, gypsum and barite. A crude zoning of precipitated minerals upward and outward from the near-surface thermal anomaly appears to exist. Silica precipitates occupy a central position surrounded by peripheral zones of clay-carbonate, carbonate and gypsum.

Structural control of the reservoir configuration is provided mainly by faults and fractures along which hydrothermal fluids are localized. Of particular importance are the Carbonate Fault, striking 160° and dipping 60° southwest near the western boundary of the near-surface thermal anomaly (Figure 3), and the Meager Creek Fault striking east-west along Meager Creek and dipping approximately 40° north (Figure 4). The Meager Creek Fault is a relatively young extensional feature with about 500 m of normal dip-slip movement possibly related to subsidence. In addition, young volcanic dikes, intersected in drill holes, are commonly emplaced along faults and/or zones of weakness with evidence of post-dike movement. Faulted and/or broken, permeable zones associated with hypabyssal dikes are up to 20 m in width.

The dominant joint attitudes in the South Reservoir area are 130°/60° SW (parallel to foliation attitudes and the Carbonate Fault) and 020°/vertical. Various other attitudes are important over smaller areas within the South Reservoir area. Fractures striking east-west and dipping 40° N (parallel to the Meager Creek Fault) occur in exposures along Meager Creek and on the slope of the Meager Creek valley between No Good and Angel Creek and are of particular interest with respect to the reservoir configuration (refer to "Reservoir Model"). The generally regular joint pattern breaks down and becomes random in the area of the north-south trending No Good Discontinuity (Figure 3) where one set of north-south near vertical fractures is prevalent.

Geochemistry

In early assessment work, spring water chemistry was used to obtain reservoir temperature estimates of 59 to 166°C using the silica geothermometer (Fournier and Rowe, 1966) and 96 to 250°C using the Na-K-Ca geothermometer (Fournier and Truesdell, 1973). A stable isotopes study of oxygen isotope fractionation between $SO_4^=$ in solution and water similarly indicates a low temperature ($<150°C$) shallow origin for most of the waters studied (Fritz et al, 1980). A study at Meager by Hammerstrom and Brown (1978) determined that the spring waters are in equilibrium with near-surface rock alteration assemblages. Water chemistry is complicated by mixing relationships between reservoir fluids and volumous but variable surface runoff. Thermal water at the Meager Creek main hot springs is believed to have migrated up to 5 km from the source area within crudely stratified colluvium greather than 250 m deep in the Meager Creek channel. Thus the calculated temperatures must be viewed with discretion.

The stable isotopes study also indicates that the waters samples have a residence time of at least 25 years (Fritz et al, 1980).

The majority of springs are dilute Cl dominated waters with 200 to 2000 ppm total dissolved solids (TDS). Two drill holes yielded artesian flows which had TDS of 6000 to 10,400 ppm and high boron contents of 22 to 28 ppm. These two samples were obtained from the deepest part of the system and are the best candidates obtained to date for a representative geothermal fluid.

Pilot radon gas (Track-Etch) and mercury soil surveys conducted in 1978 detected local anomalies but deep groundwater saturated overburden effectively suppresses response over most of the area and reduces the applicability of these surveys as a reconnaissance tool in the Meager environment. Mercury content was found to be dependent on soil type (proportional to organic content); however, soils are extremely variable and consistent sampling becomes a limited factor in survey design. Radon is associated with thermal water at the Meager Creek main springs.

Resistivity

Resistivity surveys of two types, dipole-dipole and pole-pole, have been conducted (Figure 1)(Shore, 1975, 1978). For dipole-dipole surveys, dipole spacings ("A") of 300 m and dipole separations ("NA") of N = 1 to 8 are currently used. Because of the rugged terrain and inability to lay out straight lines of suitable lengths, dipole-dipole work was confined mainly to the valleys or to slopes parallel to valleys. The pole-pole resistivity technique, with one each of the current and potential electrode pairs placed at electrical infinity and corresponding active current and potential electrodes positioned in the survey area, has been used to overcome terrain restrictions (Shore, 1978).

Interpretation of resistivity data must take into account water-saturated conductive overburden and significant topographic effects. The coincidence of resistivity anomalies along line K and line D with the high temperature zone determined by drilling (Figure 1 and 3) is striking. Apparent resistivities between 14 and 50 Ω·m are measured across the thermal anomaly against a background of 250 to 1000 Ω·m. Absolute resistivity values of 50 Ω·m in the anomalous zone and 500 Ω·m background (10:1 ratio) are interpreted from apparent values. Pole-pole results confirm that the resistivity anomaly extends northward toward Pylon Peak up to the point where deep response is masked by conductive volcanic units at surface. East and west of the shallow thermal anomaly shown in Figure 1, the subsurface is relatively non-conductive (> 500 Ω·m).

Drilling

Fourteen diamond drill holes have been drilled in the South Reservoir area (Lewis and Souther 1978, NSBG.1974-1981). Helicopters were utilized for mobilization and camp support until road access was established in late 1978. Holes are drilled with HQ and/or NQ bits for a hole diameter of 96 and/or 76 mm respectively and depths are routinely between 300 and 600 m. Blowout prevention equipment is installed whenever temperatures are encountered over 100°C.

Holes are drilled primarily for temperature profiles. Temperatures are measured daily on bottom following an 8 hour static period between shifts and additional temperature traverses are run following hole completion. The continuous core sample recovered in diamond drilling is extremely useful in determining lithological distribution, interpreting, alteration and mineral precipitate patterns, and in obtaining rock samples for geochemical and other studies.

A near surface thermal anomaly has been detected by drilling as shown on Figure 1. The eastern "tail" of the anomaly is interpreted as an outflow plume from the main reservoir. Temperature profiles (Figure 2) indicate anomalously high temperature gradients in M2, M3, M4, M6, M7, M8, M10, M11 and M12. Heat flow values of 105-620 mWm^{-2} (2.5-14.8 HFU) have been calculated for M2, M3, M7, M8, M11 and M12 (NSBG, 1981); these values are up to seven times the regional heat flow determined for the Garibaldi Volcanic Belt (Lewis and Jessop, 1981). Calculated heat flow values of 1150 and 1730 mWm^{-2} (27.5-41.3 HFU) for M6 and the upper part of M7 are considered to be strongly influenced by convective heat transfer. Drill holes M5 (entirely in overburden) and M1 have temperature inversions due to lateral hot fluid movement within the overburden. At M1, hot water is produced under artesian conditions from a confined aquifer between two varved clay horizons.

The highest temperature recorded to date is from hole M7 (Figure 5) which was 192.7°C at a total depth of 367 m eight hours after completion and 202.2°C following a two-week static period. Minor hot water in-flows are suggested by the temperature profile and rock alteration at depths of 230 m, 295 m and 330 m corresponding to temperatures of 160°C, 175°C and 185°C respectively. These zones are coincident with fractured and broken intervals as indicated on the rock quality log (Figure 5). Temperatures in the bottom section of M7 are increasing at a rate of 330°C/km. In the fall of 1980, an attempt was made to flow the well and although it flashed, production was not sustained. Efforts were further thwarted by cold water in-flows below the casing in the upper part of the hole.

Reservoir Model

A shallow thermal anomaly has been defined by drilling over an accessible area of about 3 km by 1 km in the Meager Creek valley. The west boundary of the thermal anomaly and possibly the reservoir is coincident with and influenced by the Carbonate Fault (Hole M8, Figure 3) and/or the No Good structural discontinuity (Figure 3). The nature of the east boundary is unknown and the north boundary is open into the mountain. Work is currently underway to assess areas southeast of the known shallow thermal anomaly (Figure 3).

The South Reservoir is believed to be roughly tabular and dipping into the mountain towards Pylon Peak with the Meager Creek Fault and parallel fractures acting as major controls (Figure 4). This general pattern may be distorted by other dominant fracture directions and/or major faults.

In conclusion, temperatures adequate for electric power generation from a water dominated reservoir are apparent, however, the degree of fracture permeability at depth and recharge to enable sustained production are yet to be determined. At shallow depths penetrated so far by drilling, permeable zones associated with volcanic dikes, fractures, and faults are common. Warm and hot fluid migration along discrete structural zones and convective heat transport on a larger scale have been documented by the temperature profiles and geologic logs in drill holes. Deep drilling and production testing to assess the reservoir as a potential power source will be initiated during 1981.

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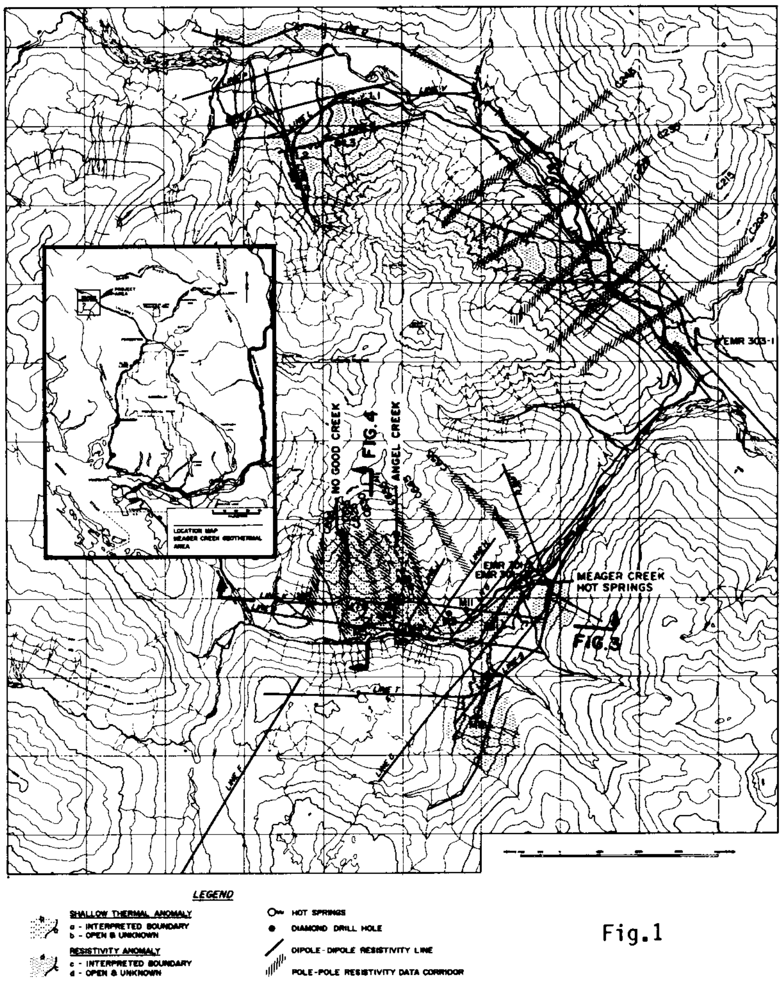


Fig.1

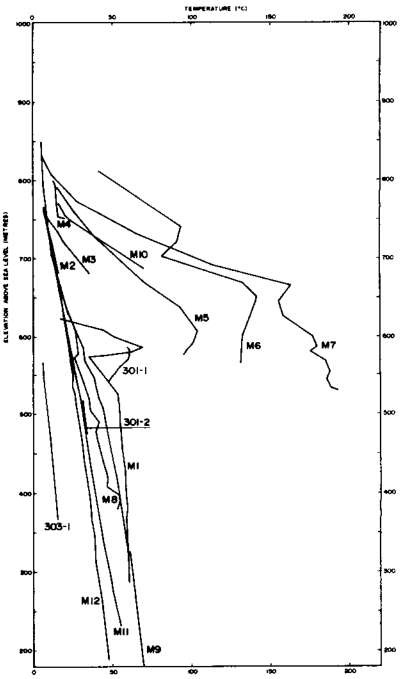


Fig.2

Fig.1 Location Map and Summary of Resistivity & Diamond Drill Coverage

Fig.2 Temperature Profiles - South Reservoir

Fig.3 Longitudinal Section Through South Reservoir

Fig.4 Cross-Section Through South Reservoir

Fig.5 Temperature Profile and Graphic Log - M7-79D

Fig.3

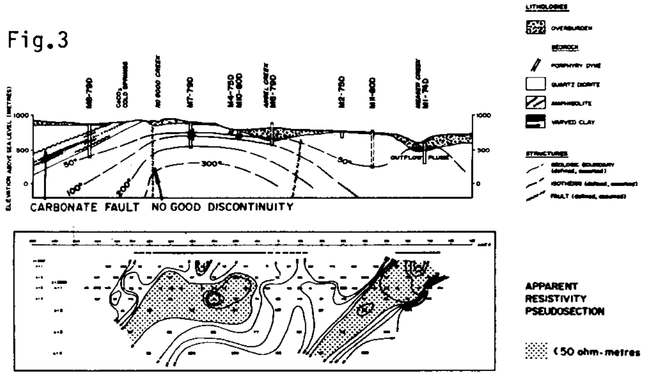
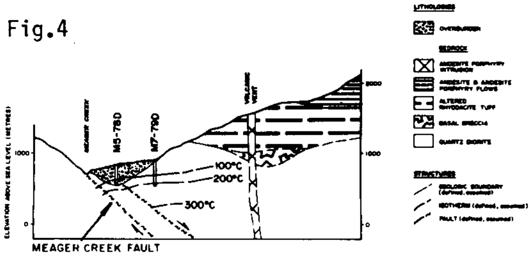


Fig.4



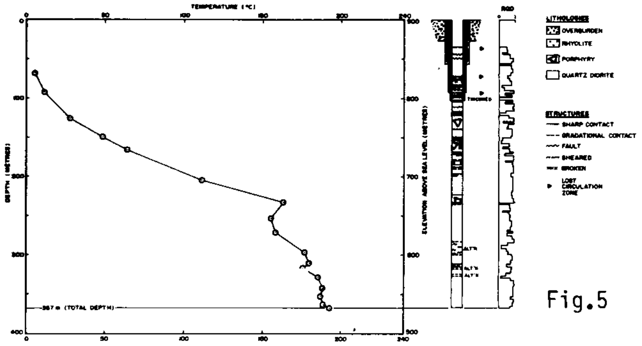


Fig.5

MOUNT HOOD EXPLORATION, OREGON - A CASE HISTORY

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ABSTRACT

An assesment program of Mount Hood is giving information useful for geothermal development in the area and is expected to characterize and aid in exploration of other Cascade volcanoes. These studies have shown the presence of thermal waters coming to the surface around the south flank of the mountain and subsurface flow in other areas. Geothermal gradient drilling show the average heat flow in the area to be about two times normal increasing toward the summit. Two commercial exploration programs resulting in drilling are underway; Northwest Natural Gas is exploring the west side for direct utilization in the Portland area, and Wy'East is exploring near Timberline Lodge on the south flank. On the west side adequate temperatures have been found but the wells have not found enough permeability to be useful. At Timberline Lodge a 4000'well appears to have sufficient temperature, but it has not yet been tested. Further exploration and testing will continue this summer.

INTRODUCTION

Mount Hood gives more clues that geothermal fires burn within its heart than do most of the other Cascade volcanoes, at least prior to March 27, 1980 when Mount Saint Helens, its neighbor to the north, took center stage.

Fumaroles, warm springs and a record of late Holocene eruptions indicate the presence of geothermal heat within the Mountain. The most impressive of these manifestations is the Mount Hood Fumaroles. These are located on the south side of the peak, just a few hundred feet below the summit. Occasionally, on a clear windless day, the fumaroles form a steam cloud that can be seen from Portland rising over the top of the Mountain. The fumaroles consist of several hundred vents at temperatures of 90 to 95°C scattered over a few acres in the Crater Rock area. The conductive heat loss from the fumarole area measured by infrared radiation and reported by Friedman and Frank, 1977, amounts to 4 megawatts. Additional heat discharge by fumarolic mass transfer of vapor and advective heat loss from runoff and ice melt increases the total heat loss an unknown amount but probably makes the Mount Hood fumaroles Oregon's largest natural thermal manifestation. Other evidence of geothermal systems is the two warm springs at lower elevations on the Mountain, one near Government Camp and another at Mount Hood Meadows.

Indian legends and more recently geologic mapping indicate there have been several major eruptions on Mount Hood during the last few thousand years and since the recording of historical events in the area, there have been two minor eruptions in 1859 and 1865.

The fact that Mount Hood is only 50 miles east of Oregon's major industrial, population and energy use center, Portland, makes the area an attractive exploration target.

On the other side of the coin are the complications; in a normal winter twenty feet of snow covers the slopes and above the timberline, snow and ice storms that can cause severe problems with any construction operations can devastate the Mountain from August through May. Mount Hood's proximity to Portland has also made it a year-round recreation center and it is the most climbed hiked over and skied on of any of the Cascade volcanoes. In many other areas these divergent demands of recreation and exploration have created a great deal of conflict thereby delaying any geothermal exploration. On Mount Hood this conflict has never developed even though all of the lands discussed here lie within the Mount Hood National Forest. This lack of conflict can be attributed to a spirit of cooperation and a lot of effort on the part of developers, the groups doing exploration and the Forest Service.

As a result of this interest and cooperation there has been far more geothermal exploration on Mount Hood than anywhere else in the Cascade Mountains. To date, there has been one six-thousand and two four-thousand foot tests and about 30 gradient holes drilled ranging from 500 to 2000 feet deep. Additionally, seismic, gravity, magnetic, electrical, geochemical, petrographic, thermal imagery and structural and stratigraphic geologic studies have been concentrated on and around the Mountain.

GEOLOGY

Mount Hood is a composite andesitic stratavolcano rising about 7000' above the surrounding area. The main body of the cone was constructed prior to the onset of Fraser Glaciation, about 20,000 years ago (Wise, 1968). It is built on an earlier volcanic center within a terrane of middle to early Tertiary volcanic and volcaniclastic rocks. The Mountain appears to be within a graben which on the east has a well defined bounding fault, the Hood River Fault. To the west, the edge of the graben is not as defined, but there appears to be a major discontinuity in the subsurface that could represent a fault or monoclinal folding. Superimposed on this graben are sets of northwest trending faults and possibly a series of northeast trending folds.

The present edifice of Mount Hood has been largely formed from central vent eruptions, with only a few minor parasitic centers around the flanks. Three major post-formation eruption periods have been described by Crandell (1980) and dated as about 12,000, 1600 and 220 years old. Historic eruptions, probably small phreatic explosions, were reported in the Oregonian in 1859 and in 1865 by observers in the Portland area.

GEOPHYSICAL STUDIES

There has been a program of geophysical studies of the Mount Hood Volcano carried out under the DOE assessment program. Some of these studies have been published: Friedman and Frank, 1977; Goldstein and Mozley, 1978; Riccio, 1979; and Couch, et al, 1981. A compendium of these geophysical studies is scheduled to be published as an American Geophysical Union Special issue later in 1981.

Heat flow studies, a cooperative project between Southern Methodist University, the Oregon Department of Geology and Mineral Industries and the USGS, have resulted in about 30 measurements around the lower flanks and peripheral to the cone. Conductive gradients have ranged between 20 and 100°C/km with an average of about 60°C/km which gives a regional heat flow of about 105-110 mW/m^2. Within the older rocks surrounding the edifice of the volcano, drilling has been relatively uncomplicated with a gradient of around 60oC/km. In a few cases a fault zone or a subsurface flow of warm water has produced very high gradients locally. Where intrusive rocks of the Laurel Hill-Still Creek Pluton have been intersected, a very low geothermal gradient in the range of 20°C/km is found. This low gradient seems to be caused by the fractured intrusives forming a zone of down-flowing water thereby depressing the subsurface temperatures within the intrusive. Drilling on the upper flanks of the cone has presented numerous problems because it is largely composed of unconsolidated volcanic debris from the avalanches and mud flows from the central vent eruptions that have characterized the building of the Mountain. Within this debris there are large flows of water from the accumulation of snows on the upper part of the mountain. Where these rubble zones have been successfully penetrated and measurements made in the underlying more consolidated rocks, the geothermal gradients have been higher than around the lower flanks, often in the range of 70 to 150°C/km.

GEOCHEMICAL STUDIES

A cooperative study with Lawrence Berkeley Laboratory and Oregon Department of Geology and Mineral Industries has been made and the results presented in Wollenberg, et al (1979).

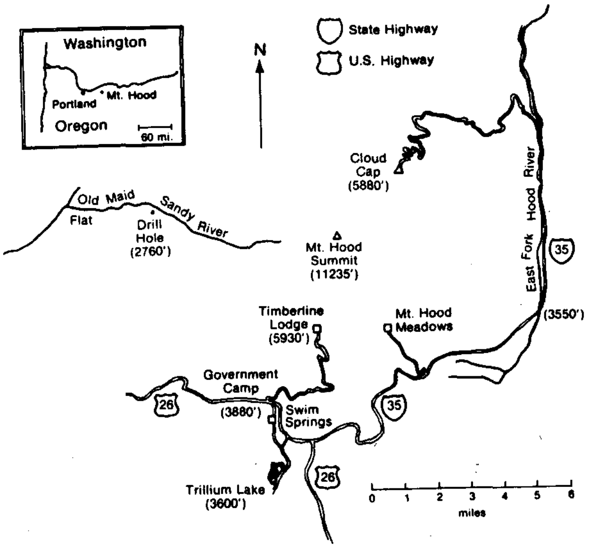
As a part of this study warm and cold spring waters, water from wells, and fumarolic gases and rocks have been collected and analyzed. The first phase of this study was to obtain a sampling of accessable springs on and around the base of the Mountain to identify zones where thermal waters could be mixing with the run-off. Known thermal waters were sampled over a two year interval to see if there were seasonal variations. A few springs were sampled from the older rocks on the margins of the Mountain.

A pattern of mixing of deeper and possibly thermal waters was detected on the south flank of the Mountain near Government Camp. Here, several springs contained field detectable amounts of chloride and had specific conductivities above background. Wells in the area all contained larger amounts of chloride and higher specific conductivity than those of similar depths at other areas.

Swim Warm Springs near Government Camp and Mount Hood Meadows Warm Spring were the only thermal waters found in the survey. Swim Springs consists of an area of four or five acres where numerous seeps and several springs discharge waters from 10 to 26°C. Chemical geothermometers indicate reservoir temperatures in the range of 100 to 140°C. Mixing models indicate the Springs are about 90% near surface runoff with the geothermal component 190 to 240°C water. A very minor seep at 10°C, about 6° over ambient temperature of the area, was located at Mount Hood Meadows.

Gasses from the Mount Hood Fumaroles were collected and analyzed. These tests showed that water vapor amounted to about 90% while the other components were dominately carbon dioxide with lesser amounts of hydrogen sulfide, helium, hydrogen, argon, methane and ammonia.

Wollenberg, et al (1979), proposed a model to explain the presence of thermal waters as a component of meteoric water falling high up on the mountain moving down through the high temperature central vent areas then dispersing and mixing with near surface runoff as it travels down the mountain. Another possibility proposed by Couch (1980), is that Swim Springs represents an outlet along a west-northwest fault zone in the Government Camp area.



COMMERCIAL EXPLOITATION PROGRAMS

There are three commercial exploitation programs underway on and in the area of Mount Hood. Portland General Electric has applied for geothermal leases on the northeast side of the area and have done some preliminary geological and geophysical studies. PGE's interest is in obtaining high temperature geothermal fluids for a source of electric power production. The two other programs are both attempting to develop hot water for space and industrial heating.

Northwest Natural Gas Company has been participating with DOE in an evaluation of the western side of the Mountain to locate a large flow of water in the +80°C range that could be transported to the Portland area for space heating and for industrial process uses. As a part of this program several wells to 2000' have been drilled with one to 4000' and another to 6000'. The deep tests, Old Maid Flats 1 and Old Maid Flats 7A, both located high enough temperatures to be of interest but neither were able to produce sufficient water to be of value. Another possible drill site has been located by the heat flow and linement studies just to the north of Old Maid Flats in the McGee Creek area. A 2000' gradient test here has a bottom hole temperature of 60°C and a gradient of 83°C/km near the bottom of the hole. This well will be deepened in 1981 to see if the Columbia River Basalt, anticipated to be at the 2200' to 2400' level, will provide a reservoir (Hook, 1980).

At Timberline Lodge, Oregon's best known and largest ski resort, Wy'East Exploration and Development Company (Wy'East is the American Indian name for Mount Hood) has obtained a Federal Geothermal lease and is attempting to develop hot water to supplement the oil fired heating system of the several buildings of the Lodge complex. Three wells have been drilled in the Lodge area. Well #1, drilled as a part of the State of Oregon funded Cascade Geothermal assessment, about a quarter of a mile east of the Lodge, was completed to a depth of 380' (115 meters). This well was isothermal at 2.5°C to 100 meters where a gradient of 40 to 50°C/km was recorded in the last 15 meters of the hole. After completion of drilling but prior to setting observation pipe a bottom hole temperature of 10°C was measured in this well. This would indicate a geothermal gradient of 150°C/km for the lower part of the hole, but this could not be confirmed by later measurements as the hole caved in at 115 meters when observation pipe was set.

Another test, funded by DOE, was drilled about a quarter of a mile below the Lodge. The plan was to take this test to 2000' but, again, drilling problems forced termination at a shallower depth, 1380', and a twist off gave usable hole to only 738' (225 M). A pattern similar to No. 1 was measured in this well with it being essentially isotthermal at 3°C to 574' (175 M) where at the bottom, 728', a gradient of 180°C/km was present.

A third test was drilled about 3/4ths of a mile below the Lodge to 2000' in 1979 and deepened to 4000' in 1980. This well generally repeated the pattern of the two earlier tests: isothermal at 3°C to 500' (150 M). For the next 500' the gradient was about 100°C/km decreasing to about 70°C/km at the bottom of the hole at 2000'. In anticipation of this gradient continuing, the Pucci hole was deepened to 4000' in 1980. A stable temperature log has not been made to total depth and the winter storms closed in on the mountain before pumping tests could be run on this well, but electric logs give indications that it will be able to produce water in the 70-80°C range. Testing of this well is scheduled to begin in June, 1981.

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GEOTHERMAL POTENTIAL OF THE CASCADES

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ABSTRACT

The Cascades are a Pacific Rim andesitic volcanic plate junction chain exhibiting recent volcanism and large volumes of young volcanics. Fractures are abundant. Ample water and heat are demonstrated to be present to form geothermal systems. Geophysical anomalies in the Cascades are analogous to other areas of known commercial geothermal resources. Application of reasonable exploration logic clearly indicates that geothermal resources of substantial size will eventually be found in this region. A figure in the vicinity of 6000 megawatts electric equivalent is suggested as a minimum expected resource.

INTRODUCTION

There is a growing general concensus that the geothermal potential of large areas of the Cascades in Oregon, and selected areas of that Range in Washington, and California is large. Muffler, et al., (1978, p. 33) state "Although no large hydrothermal convection systems have been identified in the Cascade Mountains, the abundance of young volcanic rocks and the isolated occurrences of hot water along the range suggest that a large resource may exist." They add (op. cit.) "Primarily because of the favorable geologic setting, we estimate the undiscovered access-resource base in the Cascade Mountains to be twenty times the identified, and recognize that it may be even greater." Blackwell, et al., (1978, p. iii) state in regard to the Oregon Cascade Range ". . . based on the heat flow data along the northwestern boundary, the young volcanism, and the existence of many hot springs along the western boundary, the geothermal potential of this province is undoubtedly large." I also cite, annonymously, an offhand statement but significant because it was from 15 years of experience in geothermal exploration, during an informal discussion of the Cascades geothermal potential. This source said simply "Everywhere we have looked in these plate-junction andesite volcanic areas, we find they are 'stuffed' with geothermal resources."

These general statements, however, have no deep drilling to verify them. The Cascades are unknown by drilling except very surficially. The complexity of the geology, and the thick blanket of relatively porous water-laden volcanics which covers much of the young High Cascades, presumably the prime target for geothermal exploration, precludes drawing very definite conclusions from surface studies. Also, what we are actually measuring in the Cascades by various geophysical methods has yet to be precisely determined, although some interesting results and anomalies have been found.

Two approaches are used here to obtain some estimate of the geothermal potential of the Cascades. The first is to inventory what is known about the region in regard to factors which are significant in the origination of geothermal resources, and then, by analogy with other areas, reach some conclusions. The second approach is to view the problem as a theoretical and statistical matter, and derive some conclusions based in part, at least on the exploration histories of other earth resources--for purposes of this paper, petroleum and uranium are cited.

WHAT IS KNOWN ABOUT THE CASCADES

Volume and age of volcanics: The Cascades of Oregon and Washington are divided into the High, or young, Cascades, and the Western, or older, Cascades. The High Cascades involve the area of relatively young volcanics, late Pliocene, and more generally Pleistocene and younger, which region in Oregon is about 50 kilometers wide, by some 350 kilometers long. The area of High or young Cascades in Washington is somewhat less but encompasses the regions around the major peaks of St. Helens, Adams, and Rainier in the south, and a zone immediately adjacent to Mount Baker in the north. Large volumes of volcanics with ages as young as May 19, 1980 (Mount St.

Helens) are evident. Some of these are basaltic, others are andesitic, a few rhyolites are known. There are many volcanics in the Cascades less than 10,000 years old. The total volume of these young volcanics is very large--a larger volume of young volcanics than any other area in the 48-adjacent states.

Structure and fractures: The major peaks of the Cascades in Oregon are aligned north-south. In Washington a cross-faulting alignment is somewhat more evident. In Oregon, there are three principal fault trends: the major north-south trend just noted, a northwest-southeast trend, and a northeast-southwest trend. This has been generally known for many years, but has recently been nicely put in map form by Venkatakrishnan et al., (1980). Fractures are both abundant and large in the Cascades. Also, there is considerable evidence to indicate that at least a portion of the Oregon High Cascades, from the vicinity of McKenzie Pass up to and beyond the Breitenbush area,is located in a graben. This is analogous to the graben structures in which the geothermal resources of Dixie Valley, Nevada, the Imperial Valley of California and adjacent northern Mexico, the New Zealand resources, and the the geothermal resources of the great Rift Valley of Africa are located. This presumed graben area, of the north-central Cascades of Oregon also is an area where large quantities of volcanics have flooded out from what is apparently a major or several major rift zones.

Water: As the water in any geothermal system must for the most part be derived from surface sources, a water supply is important, and the Cascades surely present such a situation. Indeed, it is this abundant supply of groundwater which has probably succeeded in masking from surface observation the geothermal systems which are present. Annual precipitation in much of the High Cascades is 80 to 100 inches and more. Over the centuries the supply of water to potential geothermal-hydrologic systems has almost certainly been large.

Water analyses: Water analyses of hot springs along the Western/High Cascade boundary appear to indicate that all the waters are more or less the same family, and the reservoir temperatures are moderate, and probably not of electric quality. However, there are, in fact (with one minor possible exception), no water samples known from hot springs in the High Cascades proper as there are no hot springs in that region coming through the cold water-saturated young volcanic debris. The one possible exception is a very small spring, Swim Hot Springs, on the south flank of Mount Hood. Wollenberg et al., (1979) have estimated that the spring water is approximately 90 percent cold surface water. When the silica mixing model is calculated to a temperature of the unmixed hot water, the subsurface temperature is estimated to be between 192 and 240°C, with the note that this is questionable because it is a low-flowing system.

For all practical purposes we have identified no waters coming from geothermal reservoirs within the High Cascades. It is a reasonable assumption held by many geologists that the waters which we have been able to sample in the hot springs along the High Cascade/Western Cascade boundary are related to local fault systems and do not represent geothermal waters within the High Cascades.

Heat and magma chambers: The Cascades of Oregon show a marked change of heat flow at the boundary of the Western with the High Cascades (Blackwell, et al., 1978). Along the western boundary of the High Cascades the average heat flow is 2.5 ± 0.2 HFU, and the average gradient is 61 ± 3°C/km, which figures are about twice the continental averages. It should be noted that these figures are only for the boundary between the Western ahd High Cascades. To date, no reliable heat flow values have been obtained from the High Cascades proper. Blackwell et al., (op. cit., fig. 7, p. 23) further indicate that on the average a temperature of about 200°C is reached in the High Cascades at a depth of about 2.5 kilometers. This would be a marginal target for economic geothermal resources with present drilling and heat transfer technology, but it is important to consider that this is the averge depth/temperature relationship. It is reasonable to assume that there are number of places where such a temperature or higher could be reached at a lesser depth, given the varied and large area which is the Cascades. Furthermore, this is merely an estimate, without any firm heat flow data from the High Cascades. Blackwell (1978) has also published a map of possible contemporary magma chambers in western United States. He estimates there are 14 in Oregon and five in Washington. Other geophysical studies by Couch (1979) indicate that the Curie point in certain portions of the Cascades which have been studied to date is probably in the vicinity of six kilometers, although the complexity of the geology makes it difficult to interpret the data. However, these data are in good agreement with data obtained by Blackwell, and also agree with proprietary studies which have been made. Again, it may be assumed that there are places where this quality of heat lies at shallower depth. Blackwell (1978, p. 15) has commented that "a striking feature of the data is the great variation of heat flow over relatively small distances within certain provinces. The scatter is greatest in the youngest geologic provinces: the High Cascade Range, High Lava Plains, Basin and Range, Owyhee Uplands, and Western Snake River Basin." Such geothermal systems shallow enough to have surface expression in the high Cascades are buried beneath the thick blanket of porous young volcanic which is thoroughly saturated with cold meteoric waters. To one who has done gradient drilling in these higher younger portions of the Cascades, the effectiveness of this wet cinder, ash and ä ä lava blanket in masking the subsurface solid bedrock is painfully apparent. Even Old Faithful would not make it through such a cover.

Gravity studies: Studies conducted by Pitts and Couch (1978), Couch (1979), and Couch et al., (1981) of the gravity of the Cascades show marked gravity lows throughout the length of this range, such lows being characteristic of other areas of known geothermal resources (e. g., The Geysers).

Other geophysical studies: The majority of these are proprietary and cannot be cited in detail. However, it may be said in general in comparing the anomalies found in the Cascades by various geophysical methods, with those known and drilled (and producing economic geothermal resources) in other areas of the world, that if we are measuring the same things in the Cascades by these tools as we are measuring in other regions, the Cascades have just as promising prospects, just as large (if not larger) anomalies, and just as great if not greater anomaly contrasts as those known from geothermal areas elsewhere.

THEORETICAL AND STATISTICAL APPROACH

Analogy with other areas: There are a number of arguments to be made for the Cascade geothermal potential using this approach. Everywhere across the world where these andesitic volcanic plate junctions have been adequately tested, economic geothermal resoures have been found, or are known to exist. Around the Pacific these include the Kamchatka Peninsula of the USSR, Japan, the Philippines, Indonesia, New Zealand, Chile, Mexico, and California. Indeed, the only gap in this ring of geothermal successes is the Cascade Range, which has yet to be explored by deep drilling. It seems reasonable to conclude that when the Cascades are tested that commercial geothermal resources wil be found.

Analogy of histories of exploration: One may also draw an analogy with the histories of exploration for other earth resources. Petroleum is a good example. The procedure is to locate a basin of favorable sediments, apply a general world-wide figure of barrels of oil found per cubic mile of such favorable rocks. Then the exploration program proceeds on the firm assumption that petroleum is there; it is only a question of precisely where. And oil and gas have invariably been found in such a setting and with that exploration philosophy. The key to successful exploration in a given area may take some time to find as in the case of the Overthrust Belt in the American Rockies, but sooner or later petroleum is located. The same principle surely can be reasonably applied to geothermal resources in the Cascades.

It is a geologically favorable area of large extent, fully comparable to other areas of the world where economic geothermal resources have been found. It is, however, a more hostile and challenging terrain in terms of access for exploration and ease of exploration because of weather, vegetative cover, and topography. But the basics for the occurrence of substantial geothermal resources are surely there. Furthermore, worldwide, geothermal resources are now found to be more widespread than was first determined from surface observations. The Desert Peak field of western Nevada was such a "blind" geothermal discovery. Similarly, at one time uranium was regarded as a relatively rare element with only a limited distribution. The intense search for uranium during and after World War II brought new exploration methods to bear (airborne scintillometer, etc.) and new concepts which ultimately made the Colorado Plateau and basins in Wyoming, and many other areas viable and ultimately productive targets of exploration. Similarly, geothermal resources, when we have come to understand in a given province (e. g., the Cascades) how they occur, and what tools are valid for exploration there, will almost surely prove to be more common than we had originally supposed.

Finally, with so large an area to potentially contain geothermal resources, and with very young volcanic rocks in such large quantities, it is only a reasonable statistical expectation that in an area of 30,000 square kilometers or more which is the prospective area of the Cascades of Oregon, Washington, and California, geothermal resources of substantial size and various qualities will be found.

KINDS OF GEOTHERMAL RESOURCES EXPECTED

It is also important to define what a "geothermal resource" is. Warm waters are already being utilized in space heating at Breitenbush Hot Springs and at Belknap Hot

Springs in the Oregon Cascades. There is also evidence there are hot dry rock targets in the Cascades. The abundant silica in surface Cascade waters, and the large volumes of high temperature volcanic ash particles available to yield silica to solution throughout the geologic section of the Cascades suggest that silica seals may be present in places which could produce areas of high temperature dry steam reservoirs. It is possible, then, that nearly all forms of geothermal resources are present in the Cascades--hot water, wet steam, dry steam, and hot dry rocks.

SUMMARY AND CONCLUSIONS

Basic favorable geologic setting: The Cascades are a very large area of young volcanics. Fractures are numerous, and water to charge geothermal systems is abundant. Heat flow studies give evidence of ample heat in the region to supply geothermal systems. Recent eruption of Mount St. Helens, and the relatively recent (1914-1916) eruption of Mount Lassen testify to the active nature of this volcanic chain, as does the presence of very large volumes of volcanics less than 10,000 years old. Gravity and other geophysical studies show anomalies which are similar to those in other known and producing geothermal areas. There is clear indication that all andesitic volcanic plate junctions and rifts, when adequately tested, ultimately produce economic geothermal resources. In the case of the Pacific Rim, the Cascades are the only blank spot, explained simply by the fact that this region has not been drilled. The exploration surprise would be that the Cascades did not produce geothermal resources in quantity. All reasonable exploration logic and analogies with other histories of earth resource explorations such as petroleum and uranium dictate otherwise. With as favorable and as large a geologic setting as are the Cascades for geothermal resources, major economic discoveries will eventually be made. However, the Cascades are a relatively more difficult terrain in which to explore than are many other areas, and the asset of young volcanics and abundant waters also becomes a liability in this regard, as exploration through this mask becomes more challenging.

However, there is abundant actual and theoretical evidence that geothermal resources in quantity do exist in the Cascades. Warm to electrical quality waters can be expected to occur. Blackwell (1978, p. 25) states "If heat flow values typical of the High Cascade Range are 100mW/m^2 (2.4 HFU), and the regional gradients are 60± 10°C/km, then the conditions should certainly be favorable for the existence of geothermal systems of temperature high enough for electrical power generation..." There is also evidence that hot dry rocks exist. A dry steam reservoir is not beyond the realm of possibility.

Some figures. All my seasoned exploration colleagues know it is rash at this stage of our information to suggest a figure for the geothermal resources of the Cascades which might now be developed economically. Yet some people might feel after all this discussion that at least some sort of estimate should be made. If my professional associates will be charitable, let me propose some figures, and if they do not like such numbers, may they feel free to crawl out on their own limb.

Early in the consideration of the Cascades as a geothermal target there was one among us who somehow derived the figure of 20,000 megawatts electric equivalent for the Oregon Cascade geothermal resources. His faith in this figure was reaffirmed to me only recently, although it has generally been met with disbelief, but without any substitute figure being publicly proposed. But at least give the gentleman credit for courage. More recently, after certain studies had been done, quite a different source advised me that to his surprise a figure of 10,000 megawatts was not unreasonable. In making my own estimate I have identified some 4000 km^2 (1544 square miles) chiefly in Oregon, which appear highly prospective. Assuming that only five percent of even this choice area proves to be productive, and applying the figure of 30 megawatts per square kilometer (approximately 80 megawatts/square mile), a 6000 megawatt potential emerges. This may be unjustified positive thinking, but historically in other exploration endeavors this is the sort of thinking which has made the discoveries, and more often than not, ultimately proved actually to be conservative. The three figures cited are all from different sources, they are really not that far apart, and, more importantly, they are all large.

There is one caveat, however. All assumptions must be based on the belief that explorationists will have access to these prime geothermal target areas. Access to such areas is largely a political matter, so, as in the case of development of nearly all earth resources, geology is only part of the problem. Much of the answer to the geothermal future of the Cascades lies with our political and administative decision makers. It is not unduly unkind to point out again that in the Cascades of Oregon there are many geothermal lease applications which have now been on file with the federal government for more than seven years, on which the applicants have received no final decision. With interest rates as they have been, this means that the cost of the application and the first year's rental required to be tendered, has already, in effect, doubled for the applicant. The rather unrealistic 20,000 acre limitation on geothermal leases held by any one individual or organization in any one state was set up to encourage the smaller operator. But the delay in lease decisions has been very costly for the very individual for whom the regulation was designed to protect.

Explorationists have been ready to begin their work for a long time, but they have been at the mercy of other forces. Given a reasonable political, and regulatory climate for exploration, the evidence even at this early stage of our information, appears to amply warrant the conclusion that the Cascades can and will be a major producer of economic geothermal resources.

ACKNOWLEDGMENTS

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UTILIZATION OF GEOTHERMAL ENERGY FOR POWER PRODUCTION

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ABSTRACT

This paper discusses the preparation of electric utility peak and energy demand forecasts and the steps used to prepare supply forecasts to satisfy the demand forecasts. It discusses the selection of new power plant alternatives and the lack of data on binary and flash power plants which inhibits their selection. Attributes which, in the future, could favor geothermal power plants are identified.

INTRODUCTION

The electric utility industry is starting to make some preliminary, and tentative, commitments to geothermal power plants that could lead to the development of the nation's hydrothermal resources. Persons who are not familiar with the industry's financial and regulatory constraints and its opportunities are sometimes frustrated by its apparent unwillingness to make major commercial commitments to hydrothermal reservoir development. Some insights into the industry's planning goals and procedures may explain the situation.

DEMAND FORECAST

Many utilities use econometric models to prepare their peak and energy forecasts. A great many variables are considered which could affect the forecast. For instance:

1. Changes in population
2. Geographic shifts in population
3. Real wages/worker productivity
4. Changes in employment
5. Effects of weather
6. Mix of electrical appliances, especially air conditioners
7. Changes in the rate of inflation

Figures 1 and 2 are typical forecasts.

Figure 1

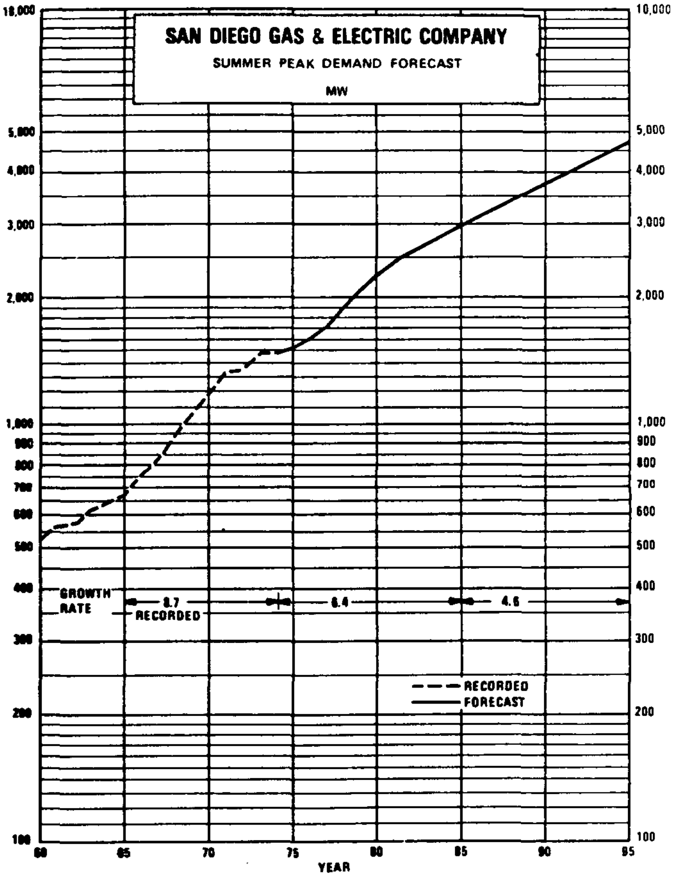
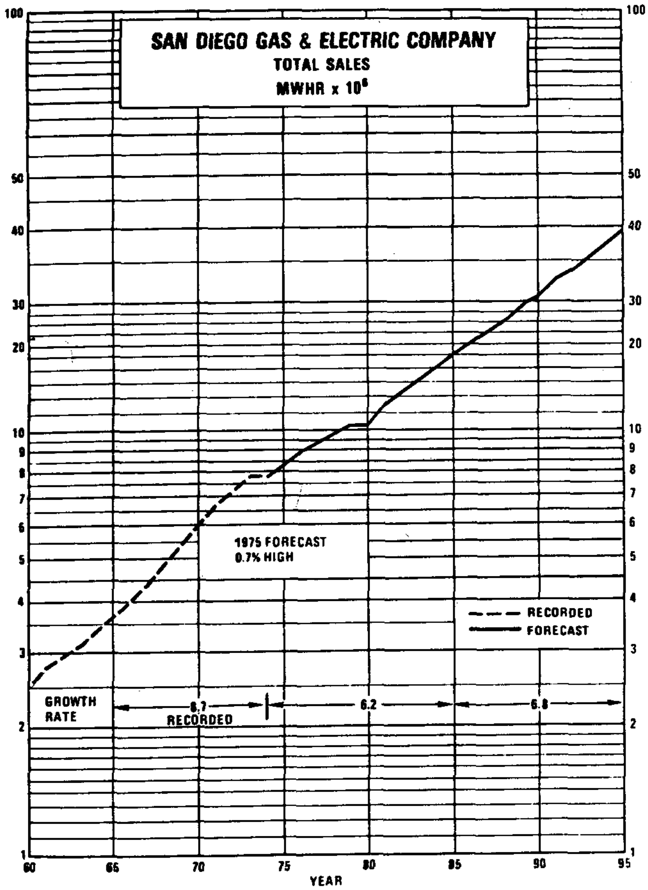


Figure 2



SUPPLY FORECAST

Once the demand forecast is complete, the utility must plan to meet the demand by considering power plant additions which best fit with the existing generating system. The selection of these new additions is also subject to the following criteria:

1. Power plant additions should help reduce the Company's dependence on expensive foreign fuel oil.

2. The financing of new additions must not violate existing corporate financial goals.

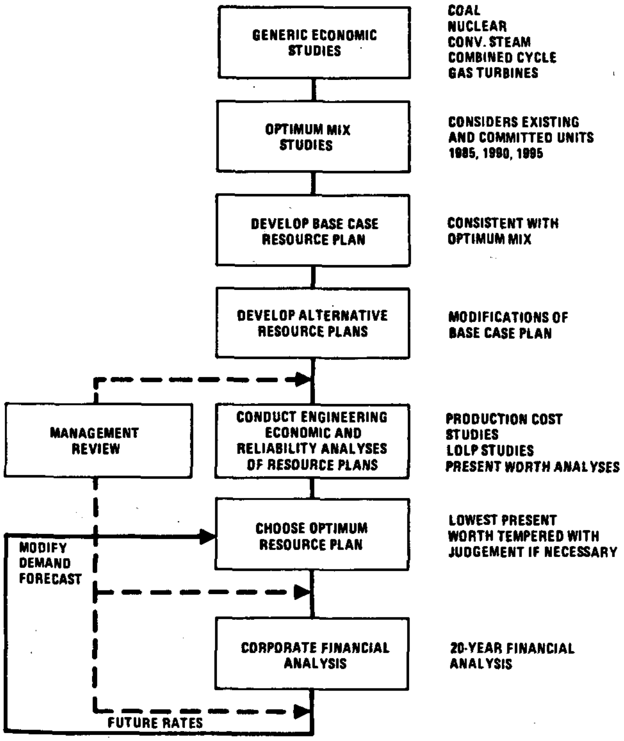
3. Power plant additions should provide a more secure and wider diversity of fuels and technologies.

4. The risks associated with both financing and operation of the new power plants should be held to a minimum.

Figure 3 is a flow diagram which shows the steps in the preparation of a supply forecast.

Figure 3

GENERAL PROCEDURE - SUPPLY FORECAST



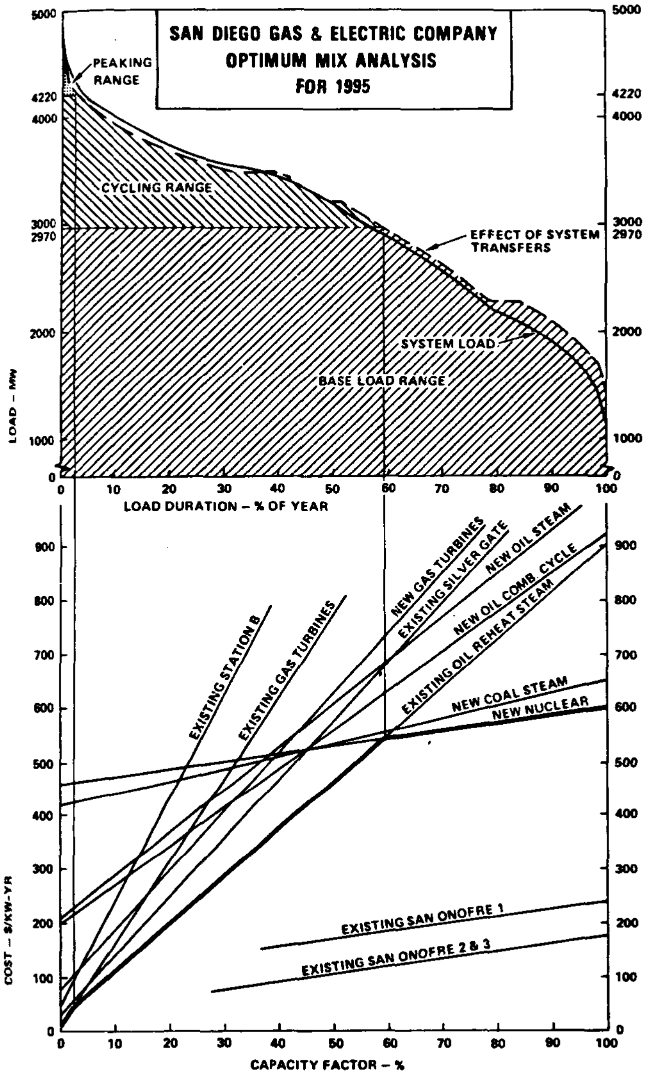
The first step in the development of a supply forecast is the selection of generic (non-site-specific) alternatives which best meet the above stated criteria. Alternatives might include coal, nuclear, oil- or gas-fired steam, combined cycle, gas turbines, and geothermal. With the notable exception of The Geysers, most utilities are not including geothermal in their studies of new generation alternatives because there is no reliable economic and risk data available. To the extent utilities are including geothermal capacity from hydrothermal reservoirs in their resource plans, they are hedging their commitment based on the performance of plants scheduled for operation in the 1980's.

The next step in the supply forecast is usually the preparation of optimum mix studies which evaluate the cost of adding various alternatives. These studies must be performed in the context of generating units that already exist, planned retirements, and long-term purchases from other utilities of capacity and energy. The product of optimum mix studies is a shopping list of new generation alternatives, including their cost.

Utilities are concerned about the reliability of the generating system to meet the forecasted load growth. This concern can be removed by providing sufficient generating capacity above the expected peak demands to compensate for power plants which may be unavailable during these peak periods and for uncertainty in the load forecast. SDG&E utilizes a 20% reserve margin minimum at time of the annual peak to provide this reliability.

Figure 4 shows a typical optimum mix analysis.

Figure 4



Base and alternative resource plans are then prepared, consistent with the results of the optimum mix studies and the reserve criterion. These plans are subjected to further economic and reliability review. Production cost studies generate annual costs for each plan and evaluate each plan's ability to meet customers needs. Loss-of-load studies are conducted to measure the reliability of each plan. Based on the outcome of the economic and reliability reviews, an optimum resource plan is selected. The optimum plan may be altered by judgement considerations which are difficult to quantify. For instance, given today's (and tomorrow's) institutional constraints, can the plan be carried out? A financial analysis is conducted to determine if the capital necessary to carry out the plan can obtained at reasonable cost and without violating corporate financial goals.

GEOTHERMAL AS AN ALTERNATIVE

As discussed earlier, most utilities are not making firm commitments to commercial geothermal power plants located on hydrothermal reservoirs. Information necessary to make informed commercial decisions is not available, therefore, early plants being proposed or pursued are important. When information from these plants is available, utilities will be able to evaluate, and perhaps commit to, geothermal power plants. A notable exception to this constraint is The Geysers where a long history of succcessful operation is available. PG&E and other Northern California utilities are committed to expansion at The Geysers.

Given the lack of hard data, some predictions can be made of how both binary and flash power plants located on hydrothermal reservoirs might fit into a utility's resource plan. We do know that because of reservoir constraints, these plants will be base loaded with some limited load following capability. This means they will have to compete with coal, nuclear, and efficient oil- and gas-fired steam plants. The major factors that will determine their ability to compete are installed cost, operating cost, and reliability.

1. Installed Cost. It appears now that the installed cost ($/kw) of flash and binary plants will be fairly high. The cost will be significantly greater than oil- and gas-fired steam plants. One factor which penalizes both binary and flash plant installed costs is economy of scale. If the plants could be built in the 300-500 Mw size range, rather than 50-100 Mw, the cost in $/kw, could be reduced considerably.

2. Operating Cost. The major part of a flash or binary plant's operating cost is the cost of fuel, or heat. The heat supplier must make a significant investment in reservoir development which is recovered through the sale of heat to the plant. There is very little data available for hydrothermal reservoirs that the utilities can use to make their heat cost projections. It does appear, however, that heat for both binary and flash plants should be considerably more expensive than nuclear and less expensive than oil--perhaps closer to coal.

3. Reliability. Because both binary and flash plants are capital intensive and may have relatively high heat costs, reliability or hours-on-the-line is essential to achieve low unit costs for the energy produced. Unfortunately, we do not know how reliable these plants will be. It is clear, however, that the geothermal alternatives must be reliable if they are to produce electric energy at competitive costs.

With the unknowns mentioned above, it is difficult to say now where the binary and flash geothermal alternatives will fit into utilities' resource plans. This underscores the vital importance of the early projects to follow-on decisions.

TIPPING THE SCALE

When cost and reliability data are available, other considerations could make commitments by the utility industry to geothermal power plants very attractive. Some of these are:

1. Geothermal power plants today enjoy acceptance for the most part by utility regulators and the public at large. As a result of this acceptance, we find it relatively easy to obtain permits for geothermal power plants. If history is a teacher, this acceptance will disappear with time. Industry experience with nuclear and PG&E's experience at The Geysers are two examples.
2. Because geothermal power plants are small, utilities can plan their additions to more closely match load growth than for other base load alternatives. This eliminates the problem of installing capacity earlier than it is needed.
3. The schedules for geothermal power plants are fairly short (about four years, not counting front-end reservoir exploration and evaluation). This permits the utility to make commitments to these plants later than for other alternatives. It also means that the utility does not tie up its capital over a long time period. Normally a utility cannot earn a return on its investment in a new power plant until the plant is placed in service.
4. Geothermal power plants are alternatives which permit the utility to spread its risks. All other things being equal, it is better not to have all of a utility's generation resources tied up in one alternative.
5. As the cost of other fuels go up, particularly oil, the costs of geothermal energy should look relatively better.
6. As emission regulations get more stringent, geothermal will look relatively more attractive.
7. If we can produce electric energy from geothermal resources at a low enough cost, utilities would then be in a position to use it in order to displace energy being supplied by oil to meet existing customer demand. The addition of geothermal power plants would then not be dependent on demand forecasts.

CONCLUSION

Information on the cost and reliability of geothermal power plants on hydrothermal reservoirs is needed to permit utilities to make informed commercial decisions. The installation and operation of flash and binary power plants in the early 1980's is essential in order to supply this information. If geothermal power plants are demonstrated to be competitive, there are very persuasive factors which favor major commitments to this alternative.

GEOTHERMAL HEAT UTILIZATION IN A WOOD FIRED ELECTRIC POWER PLANT

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ABSTRACT

Throughout the Western United States there are a significant number of sites with low to moderate temperature geothermal resources. In many areas coincident with this geothermal resource are some of the nation's prime timberlands (Figure 1). In the production of electric power considerable operating savings can result with a combination of these two resources compared to a conventional wood fired facility. This paper examines an ongoing attempt to develop and utilize this resource combination.

INTRODUCTION

The Honey Lake Hybrid Geothermal Wood Residue Power project is being developed by the GeoProducts Corporation; the California Department of Water Resources; the United States Forest Service, Region 5; and the United States Department of Energy (San Francisco; Idaho Falls). A $2.8 million feasibility study effort begun in 1979 is nearing completion. Four critical areas dealing with wood residue availability and cost, economic and technical feasibility, geothermal resource definition, and environmental aspects of the proposed project are being examined in the feasibility study stage.

FEASIBILITY STUDY

In evaluating any project of this type, several questions must be asked. Are sufficient volumes of wood residue available within an economic haul distance of the proposed project site? Is the geothermal resource sufficient to provide the required dehydration? Are there any major environmental concerns that will have to be overcome if the project is to be developed? Is it economically feasible?

A sophisticated systems analysis has been developed to answer these questions for the project. A comprehensive inventory of a fifteen million acre timbershed in a 100 mile radius of the project site was evaluated in detail. Operating scenarios, management strategies and estimated costs and availability of wood fuel were determined as part of this study.

GEOTHERMAL ENERGY RESOURCES AND COMMERCIAL FOREST LANDS

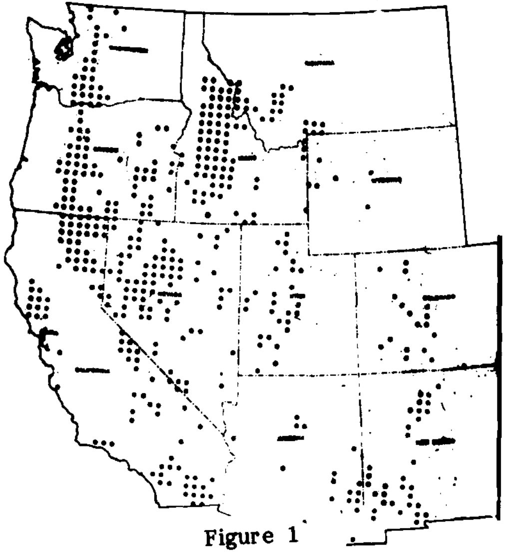


Figure 1

This analysis, to be completed in July 1981, indicates that substantial forest management benefits can result in the collection and utilization of wood residue in the project area. This collection and utilization of residue can be accomplished given proper contracting arrangements at approximately $25/delivered ton (O.D. basis, 1980 dollars). The timbershed was stratified by decade considering the variables such as slope, terrain, species, annual yield, haul distance, cover type, fuel loading per acre, ownership, etc. Available yields of wood residue within the two and three trips/day isobar indicate that during the first decade approximately 2.5 times the required annual amount of wood fuel for the power plant is available each year in the project area. This general oversupply condition in the project study area increases in the subsequent decades.

Geothermal resource definition has begun. Thermal gradient wells were drilled on the prospect in 1980. Two deep (5000') resource definition wells will be drilled this year under the Department of Energy's User Coupled Confirmation Drilling Program. Data from this effort will provide final geothermal resource parameters for design and construction.

Preliminary indications suggest that the liquid dominated reservoir will be in the range of 275°F. However, to allow for timing differences between the engineering and economic studies and geothermal field development, the viability of geothermal termperatures at 230°F, 275°F, 330°F are being examined. This analysis will allow other potential hybrid projects to be evaluated in a preliminary fashion.

Completion of the preliminary environmental study has indicated that no significant environmental constraints exist.

The engineering and economic analysis being conducted by Morrison Knudsen/IECO for GeoProducts Corporation has been developed to investigate in detail the economic and technical feasibility of the project. A complete system analysis and cycle optimization study is being conducted. Where the overall study will examine the above referenced temperatures to achieve various reductions in moisture content and thereby wood fuel, the balance of this paper examines the economic viability of achieving reductions in moisture content given a constant geothermal temperature. Typical savings and marginal cost curves will be displayed to indicate the general area of optimal dehydration.

ECONOMIC ANALYSIS

The assumed power generation cycle is a conventional wood fired boiler utilizing a traveling grate stoker. The analysis is based on the following assumptions for each dehydration case.

Table 1

	Base	1	2	3
MC of Wood Received (%)	50.8	50.8	50.8	50.8
MC after dehydration (%)	50.8	45.0	30.9	15.0
Change in MC (%)	-	5	20	35
Geothermal Temp(°F)		275	275	275
Geothermal Vol.(gpm)		843	1686	2529
Cost of Fuel Delivered(O.D. ton)	$25	$25	$25	$25
Plant Capacity Factor	.85	.85	.85	.85
Electrical Generation (MW)	50	50	50	50

Differential analysis will be used as the basis for determining the marginal costs associated with different levels of dehydration. The minimum point on the marginal cost curve will indicate the general area of optimum dehydration. This approach can also use an internal rate of return or net present value basis for determining alternatives.

Variations in costs and savings are examined with respect to a base case. This focuses the analysis on the relevant issue of dehydration. No consideration has been given to the increase in available power generated by a system utilizing dehydrated wood. This would have a significant impact on the system's marginal costs (rate of return) since the savings would not be measured by a cost reduction but a revenue increase. That is, instead of comparing costs at a low value added stage of power production; costs would be compared at the high value end - the sale of commercial power.

Capital Costs

Variations in capital costs between a wood fuel plant and a hybrid plant are assumed to be limited to the dehydration, boiler feedwater and geothermal equipment necessary to support the indicated level of dehydration. Installed capital costs are shown in Table 2.

Table 2
Capital Costs ($000's)

	Base	1	2	3
Change in MC (%)	0	5	20	35
Dehydration		604.0	2863.20	6152.80
Feedwater/Air		192.0	192.00	192.00
Geothermal		1209.8	1898.96	2642.32

The wood dehydration and feedwater/air preheating cost categories include all required pumps, piping, valving and installation net of investment tax credits at 20%. The dehydration category assumes a standard rotary drum dryer configuration. As the table indicates, the marginal costs of the project are extremely sensitive to dehydration capital costs.

The geothermal category includes wells, pumps, supply and injection lines, and power supply equipment to the well head (transmission lines and starters).

Savings

Each level of dehydration yields a corresponding decrease in annual wood fuel cost as shown in Table 3. Geothermal utilization in three major areas, wood fuel dehydration, preheating boiler feedwater and preheating the combustion air, contributes to an increase in overall boiler efficiency, thereby reducing the amount of fuel needed for a given heat output.

The decreasing feedwater and air preheating savings indicate that as boiler efficiency is increased the economic value of the geothermal heat contribution decreases. This effect tends to levelize the total savings curve over all cases.

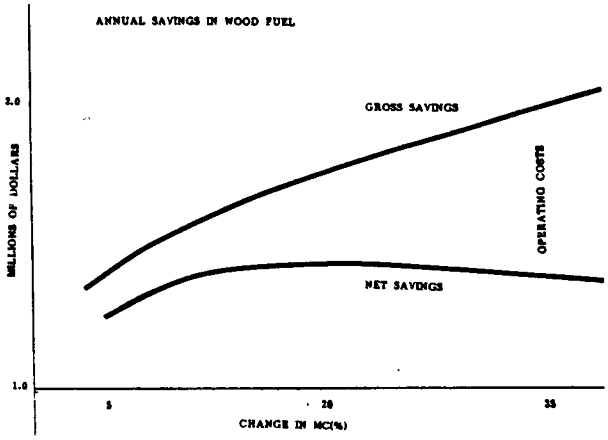
Table 3

Annual Savings ($000's)

Case	Base	1	2	3
Change in MC (%)	-	5	20	35
Savings Due to:				
Dehydration	-	384	801	1034
Feedwater heating	-	761	705	674
Air heating	-	267	249	239

Operating Costs are calculated for each case. The effect of increasing operating cost or reduction in savings is shown in Figure 2.

Figure 2



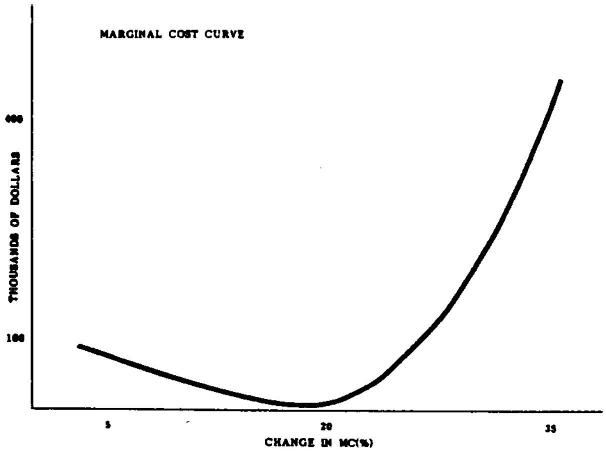
Marginal Costs

A marginal cost curve can be calculated for each area of savings. For illustrative purposes a typical marginal cost curve is presented in Figure 3. The minimum point indicates a level of optimum dehydration. To determine the marginal costs associated with each level of dehydration, the annual wood fuel cost under each case is added to a capital recovery factor and direct operating costs. The change in costs between each case yields the marginal cost.

CONCLUSION

Substantial savings in the cost of power production can be achieved by dehydrating the wood fuel, and preheating the combustion air and boiler feedwater. As can be seen in Figures 2 and 3 the general area of optimal dehydration is approximately a 20% reduction, i.e. wood fuel combustion at 30% MC (wet basis). The marginal cost and net savings figures are highly dependent on the capital costs of dehydration equipment. This indicates that the engineering analysis must focus closely on this area.

Figure 3



UTILIZATION OF GEOTHERMAL ENERGY IN A HYBRID WOOD WASTE/GEOTHERMAL POWER PLANT: ENGINEERING

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ABSTRACT

The implementation of heat from geothermal hot water into a 50 MW wood-fired electrical generating plant is investigated. Plant performance and fuel consumption parameters are compared for various system alternatives to establish the incentives for employing geothermal heat into the power generation process. Several areas for geothermal heat use are investigated and general conclusions are drawn in regard to the overall feasibility of each.

INTRODUCTION

The increasing cost of basic energy such as petroleum, gas, and coal has led to various efforts to conserve all energy forms including electricity. Conservation through improvement in power plant efficiency has become an important aspect of power plant equipment selection. The integration of low temperature geothermal heat into a power plant electrical generation process can cause substantial reductions in the plant fuel consumed. Basically, heat that is normally supplied from plant fuel is augmented with geothermal heat to cause an improvement in power produced in relation to fuel consumed.

The purpose of this paper is to investigate the implementation of geothermal heat in a 50 MW wood-fired power plant by developing the relative improvements in plant performance and fuel saved. The emphasis of the paper is on the thermal affects of geothermal energy utilization and does not address the economics or geothermal field aspects.

Integration of geothermal heat into the power plant is analyzed for the following applications: 1) feedwater heating, 2) combustion air heating, and 3) wood-drying. Geothermal heat used for feedwater heating reduces the amount of steam that must be extracted from the turbine for the same purpose thereby reducing fuel consumption.

The use of geothermal heat for heating boiler combustion air causes air at an elevated temperature to enter the boiler, which in turn saves fuel normally required to heat the air. Geothermal heat for wood-drying reduces the moisture content of the wood by evaporating and discharging the moisture before the wood enters the boiler. Boiler efficiency is improved and fuel consumption reduced. Plant performance and fuel consumption are predicted for each of the above alternates for three variations in geothermal water temperature. The alternates are then combined for each geothermal temperature and the associated results analyzed.

DESIGN BASES

The bases used for the analyses discussed are presented in this section.

The power generation cycle is a configuration consistent with conventional equipment and established design. A conventional wood-fired boiler system using a traveling-grate stoker discharges steam to the turbine for the generation of electricity. Steam expands through the turbine where a portion of the steam energy is absorbed to provide motive force to spin the generator. Steam exhausts from the turbine to the condenser where cooling water condenses the steam to water before its return trip through the extraction feedwater heaters, deaerator, and subsequently to the boiler. The turbine cycle configuration illustrated in Figure 1, is essentially the same for each analysis.

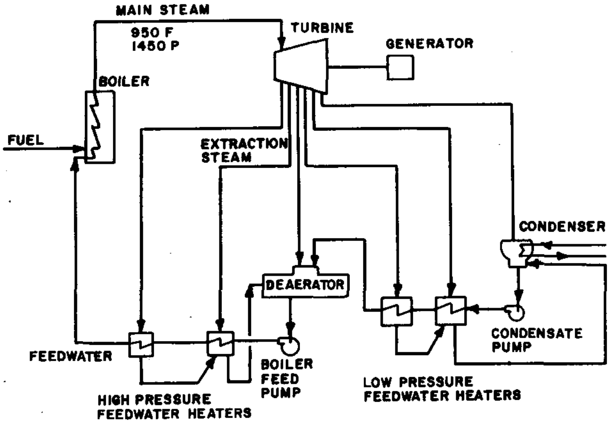

Fig. 1 Turbine Cycle Configuration

The analyses are predicated on the following assumptions:

- 50 MW of electrical generation
- Wood fuel to plant is at 50.8% moisture with a heating value of 4,502 btu per pound
- Three geothermal temperatures considered are 225 F, 275 F, and 340 F
- Turbine throttle conditions are 1450 psig at 950 F, nonreheat
- Plant capacity factor is 85%

GEOTHERMAL FEEDWATER HEATING

Using a feedwater cycle as outlined in the design bases, the location of the geothermal feedwater heater is chosen. Since this analysis considers variations in the geothermal water temperature from 225 F to 340 F, the location chosen for the heater, regardless of geothermal temperature, is downstream of the condensate pump. This allows maximum benefit to be derived from the geothermal fluids, since they can be cooled to a low temperature by the relatively cool condensate.

The optimum number of low-pressure heaters must be analyzed for each geothermal temperature. Geothermal heaters in the 340 and 275 F cases can effectively replace the two low-pressure heaters as shown in Figure 2; however, the 225 F case is sufficiently low in temperature to require the installation of an extraction heater downstream of the geothermal heater to prevent excessive degradation of cycle efficiency.

The addition of a geothermal heater causes improvements in cycle performance, because steam that is normally required to heat the condensate remains in the turbine to release its energy for power generation. This effect is reflected in a reduced fuel consumption, still able to produce the required electrical generation.

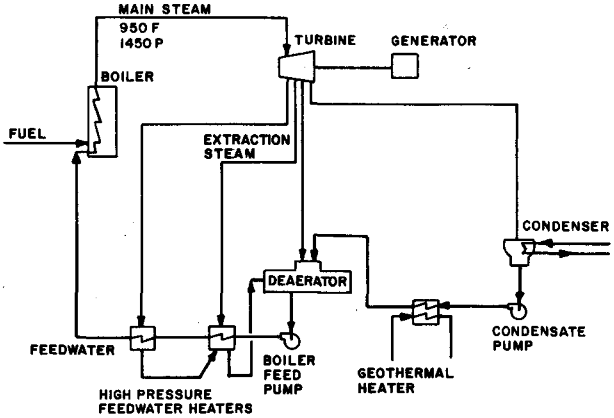

Fig. 2 Turbine Cycle Configuration With Geothermal Feedwater Heater

It is assumed for the purposes of this comparison that the geothermal heater has a temperature difference between the outlet feedwater and inlet geothermal water of 10 F. The difference between the geothermal water outlet temperature and the feedwater inlet temperature (approach temperature) is specified at 35 F. To determine the optimum size geothermal heater or performance and outlet temperatures for final design a detailed analysis of all influential factors must be considered. The nature of this discussion does not warrant such a study, since the emphasis here is to establish adequate estimates for thermal and fuel advantages in relation to the use of geothermal heat.

Relative performance comparisons of the geothermal heating cycles are depicted in Table 1. Using the Morrison-Knudsen heat balance computer program, overall turbine and cycle thermodynamic computations of cycle performance for each alternate were established. For comparative purposes a base case which has no geothermal heating is also developed. Wood fuel quantities are given on a wet basis.

TABLE 1 - PERFORMANCE GAINS FROM GEOTHERMAL FEEDWATER HEATING

Geo. Temp., F	No Geo. Htg.	225	275	340
Differential Plant Heat Rate, Btu/KwH	Base	-281	-506	-936
Geo. Flow, Gpm	0	1127	1006	986
Geo. Heat, MM Btu/Hr	0	35.652	54.533	80.275
% Geo. Heat	0	5.4	8.1	11.9
Fuel Saved, Tons/Yr	0	11,619	20,922	38,702
% Fuel Saved	0	2.2	3.9	7.3

Table 1 shows that plant heat rate improves significantly with the addition of geothermal heat, particularly as the geothermal water temperature increases. Corresponding savings in fuel consumed are equally significant with up to 38,700 tons per year saved when 340 F water is used. The percent of fuel saved over that required when no geothermal heat is incorporated ranges from 2.2% at 225 F to 7.3% at 340 F water.

The amount of geothermal heat supplied, as noted in Table 1, increases with the availability of heat or water temperature. The geothermal water flow rate is approximately equal to that available from a single geothermal production well. The percent of geothermal heat supplied in relation to the total supplied to the plant ranges from 5.4% to 11.9%, depending on geothermal temperature. These percentages are somewhat higher than the corresponding percent of fuel savings because geothermal heat is relatively low-grade and cannot directly offset the fuel consumed in the same proportions as heat supplied.

GEOTHERMAL AIR HEATING

The geothermal air heater is located immediately downstream of the forced draft fan, as shown in Figure 3, followed by the flue-gas air heater. Hot geothermal water flows to a fin-tubed, water-to-air heat exchanger where heat is extracted from the water to raise the air temperature. Flue gas from the boiler flows to the economizer for feedwater heating and then to the flue-gas air heater.

A 350 F flue-gas air heater exhaust temperature is selected and maintained for the alternates examined. It is necessary that this temperature not be allowed to increase as the inlet air temperature increases due to geothermal heating. If flue-gases are exhausted at higher than 350 F, additional heat is lost up the stack and no effective fuel savings can be realized from the corresponding geothermal heat. In this case heat is supplied from the geothermal source but other heat is discharged up the stack.

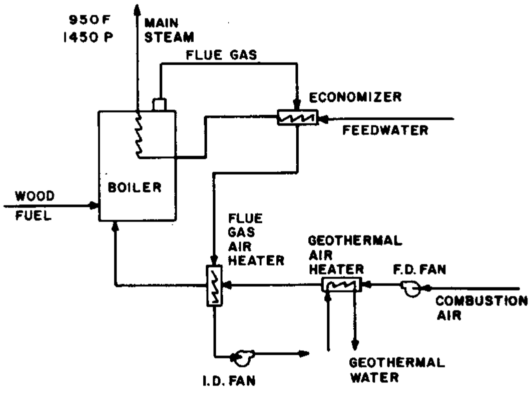

Fig. 3 Boiler Configuration With Geothermal Air Heater

Heat added in the geothermal air heater causes the flue-gas air heater to receive a corresponding higher air temperature. If the air temperature from the flue-gas heater is kept relatively constant heat normally picked up by the air is shifted to the economizer, where the feedwater is heated to a higher temperature before entering the boiler. No attempt is made to address the proration of heat between the boiler, economizer and flue-gas air heater. Suitable adjustments can be implemented into the boiler design to produce the desired heating affects which allow geothermal air heating to occur over the range of temperatures without an increase in flue-gas exhaust temperature.

Geothermal air heating effectively replaces the fuel that is required to heat the air from ambient temperature to the heater exhaust temperature. Since a reduction in fuel is realized, a concomitant reduction in combustion air flow occurs; consequently, the addition of heat to the air has a compounding performance improvement affect. Total heat supplied to the plant does not change with the addition of air heat except for the effects of auxilliary power; however, fuel requirements are less since some of the heat is supplied from the geothermal source.

The geothermal air heater is selected to give performance consistent with good engineering practice. The performance and size has not been optimized; however, for the purpose of this paper a detailed heater analysis is not warranted. The heater approach (temperature difference between entering air and exiting water) and terminal difference (temperature difference between exit air and entering water) are selected as 50 F and 30 F respectively and are the same for each of the three alternates examined. The effect of lowering the approach is to increase heater size and reduce geothermal water flow, while the effect of lowering the terminal difference is to increase the heat supplied to the air (since the air temperature increases) with a corresponding increase in water flow.

The relative performance comparisons between the alternates are depicted in Table 2. As compared to no use of geothermal heat, the fuel savings are substantial amounting to over 40,000 tons per year for a geothermal air heater supplied with 340 F water. The fuel saved, relative to the fuel required with no geothermal air heating, is 4.6%, 6.1%, and 7.9% for the geothermal temperatures of 225 F, 275 F, and 340 F, respectively. The geothermal heat used in comparison to the total gross heat supplied to the plant is 3.2%, 4.2%, and 5.5% for the three geothermal temperatures. The geothermal flow required is about 300 gpm or approximately equivalent to one-third of that available from a single geothermal well.

TABLE 2 - PERFORMANCE GAINS FROM GEOTHERMAL COMBUSTION AIR HEATING

Geo. Temp.,F	No Geo. Htg.	225	275	340
Geo. Flow, gpm	0	333	313	298
Geo. Heat, MM Btu/Hr	0	20.860	27.482	35.886
% Geo. Heat	0	3.2	4.2	5.5
Fuel Saved, Tons/Yr	0	24,695	32,728	42,705
% Fuel Saved	0	4.6	6.1	7.9

GEOTHERMAL WOOD DRYING

Drying of wood before it is combusted in the boiler offers several thermal performance benefits, including an improvement in boiler efficiency, a reduction in combustion air, and more stable combustion control. Boiler efficiency, the major advantage realized from wood-drying, increases because less fuel is required to evaporate the moisture in the wood during the combustion process. Since less wood is required to produce an equivalent amount of net heat, less combustion air is required, resulting in a reduction in boiler fan power. Still there are some offsetting energy penalties experienced including the additional power required for geothermal water pumping and dryer fans.

The dryer system employed for this analysis is a rotary drum type where feed fuel and hot air enter one end of the drum, allowing a direct contact mix of the air and wood. A portion of the water is evaporated and discharged from the dryer, leaving the wood at a lower moisture percentage. Moisture-laden air exiting from the dryer contains wood fines, picked up in the dryer, which are removed in cyclone collectors. Computations for this analyses are based on an approximate exit air temperature from the dryer of 25 F above the dew point temperature. Figure 4 shows a schematic diagram of the dryer system.

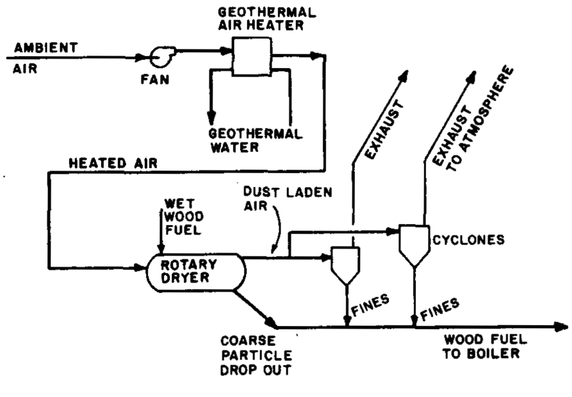

Fig. 4 Wood Drying System with Geothermal Heat

Hot air to the dryer is created by using geothermal hot water in a fin-tubed water-to-air heat exchanger to heat air flowing through it to an elevated temperature. The air is heated to within 35 F of the inlet hot water temperature and the discharge water is cooled to 50 F of the inlet air temperature.

For this comparison it is assumed that the wood is dryed from the design wood moisture of 50.8% down to 35%. A moisture of 35% is selected as a typical value; however, the actual moisture removed as a function of geothermal temperature must be determined from an optimization study where influential factors such as capital costs, operation and maintenance costs, fuel savings, and technical feasibility are integrated into the analysis. The optimization is beyond the scope of this paper.

Table 3 shows a comparison of plant performance parameters for the alternate without wood-drying and alternates with wood-drying at various water temperatures. Boiler efficiency, specified at 69.2% at the design wood moisture, increases to 76.5% at 35% moisture and manifests itself as a reduction in plant fuel of about 50,300 tons per year at 340 F inlet water. The percent of fuel saved compared to that required with no drying is about 9.4% at 340 F. The geothermal heat supplied as a percentage of the total heat required by the plant is 9.1%. The number of geothermal production wells required varies between two-thirds of a well and two wells, depending upon the water temperature.

TABLE 3 - PERFORMANCE GAINS FROM GEOTHERMAL WOOD DRYING

Geo. Temp., F	No Geo. Htg.	225	275	340
Dryer Inlet % M	N.A.	50.8	50.8	50.8
%M to Boiler	50.8	35	35	35
Differential Plant Heat Rate, Btu/Kwh	Base	-921	-1071	-1140
Boiler Eff., %	69.2	76.5	76.5	76.5
Geo. Flow, gpm	0	1457	834	546
Geo. Heat, MM Btu/Hr	0	87.569	68.401	59.082
% Geo. Heat	0	12.7	10.3	9.1
Fuel Saved, Tons/Yr	0	41,297	47,415	50,293
% Fuel Saved	0	7.7	8.8	9.4

COMBINATION OF GEOTHERMAL HEAT APPLICATIONS

Each of the three previous techniques of employing geothermal heat in the power plant are developed separately as if no geothermal heat is used elsewhere in the cycle. To combine all three into one cycle requires an iterative process in which all techniques are balanced to have the correct impact upon each other. This paper is not intended to delve into such a rigorous cycle analysis; however, a straight combination of each of the performance parameters as developed on a singular basis can approximate a refined treatment of the combination and is sufficient to establish the relative performance incentives for geothermal heat utilization.

Table 4 shows the plant effects on performance of a combined utilization of geothermal feedwater heating, air heating, and wood-drying. All performance parameters vary significantly with geothermal water temperature and the cumulative affects of geothermal applications provide a substantial savings in fuel consumption; about 24% (at 340 F geothermal water) is saved over that required with no geothermal heat. The geothermal heat supplied as a percentage of gross plant heat varies from 21.3% to 26.5% at 225 F and 340 F geothermal water temperature, respectively.

TABLE 4 - PERFORMANCE GAINS FROM GEOTHERMAL FEEDWATER HEATING, COMBUSTION AIR HEATING, AND WOOD DRYING

Geo. Temp, F	No Geo. Htg.	225	275	340
%M to Boiler	50.8	35	35	35
Geo. Flow, gpm	0	2917	2153	1830
Geo. Heat, MM Btu/Hr	0	144.081	150.416	175.243
% Geo. Heat	0	21.3	22.6	26.5
Fuel Saved, Tons/Yr	0	77,806	101,066	131,700
% Fuel Saved	0	14.5	18.8	24.6

CONCLUSION

Each of the previously described methods of integrating geothermal heat into the plant energy requirement enhances the overall plant efficiency and produces substantial fuel savings. The higher geothermal temperatures are more effective at replacing boiler fuel since more heat can be extracted because of the greater temperature differences involved. It is apparent that geothermal feedwater heating and combustion air heating can provide substantial savings in fuel at nominal capital outlays for installed equipment. Geothermal wood-drying, also favorable in terms of fuel savings, requires greater initial expense for equipment and suggests the need for more careful attention during final analysis.

ACKNOWLEDGEMENTS

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THE HONEY LAKE HYBRID GEOTHERMAL WOOD RESIDUE POWER PROJECT

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ABSTRACT

Despite some optimistic reports and forecasts, reliable projections show fossil fuels will continue to become scarce. Strong efforts are needed to develop alternative energy sources for states such as California, which is a heavy importer of energy. The Honey Lake Hybrid Geothermal Wood Residue Power Project with a planned output of 50 MW is undergoing feasibility studies funded by GeoProducts Corporation, Department of Water Resources, State of California, U.S. Department of Energy and the Forest Service, USDA. The outlook is optimistic. It is reliably estimated that the required volume of woody biomass can be made available without environmental degradation.

THE HONEY LAKE HYBRID GEOTHERMAL WOOD RESIDUE POWER PROJECT U.S. FOREST SERVICE VIEWPOINT

Little did Georgius Agricola of Saxony realize in 1553, when he authored a book on substances in the ground, that the term he invented called "petroleum" would become perhaps the most significant word in any language in the late 20th century. (De Re Metallica, translated by H. Hoover, 1912.)

Petroleum, then in limited use for heating and lighting, went on to fuel modern civilization in almost every facet of life. Four hundred twenty years later - (1973), the world awoke to the realization of the "petroleum crisis."

Throughout the history of human civilization, mankind has shown a remarkable ability to paint itself into a corner. The resulting crisis, whether it be famine, war, economic peril, or some other circumstance, traditionally brings the world to a crossroad. When it does this, two options usually emerge from the Nations of the world.

The first option is a strong tendency to become nationalistic or really isolationistic. In ancient times, this meant retreat to the castle, pull up the drawbridge and fight the enemy from the ramparts. All actions were governed by the law of survival. In fact, it was difficult to keep the castle population organized and functioning for the common good. The danger of anarchy - every man for himself was ever present.

The second option, more rarely invoked, is to cope with the crisis by motivating the entire population to join forces. Conceivably, the energy crisis could unite the four billion citizens of this planet in recognizing that what is best for the world may also be best for the individual nations.

This may be overly optimistic given the current political state of the world today. In any case, those nations who must import energy - non OPEC nations - certainly have a strong motivation to cooperate in research and development of alternative energy sources. Although each country must organize and attack the energy issue, there is still a strong need to concommitantly work with other countries. Here in the United States, the response to the energy crisis has finally reached the point where one can dare to be optimistic. We are a long way from energy self-sufficiency, but there are many encouraging indicators.

1. A concerted National energy policy is developing in practice - not just on paper. The current administration may have changed priorities, but many efforts are well underway.

2. Energy conservation is finally understood by every citizen and stringent efforts to reduce consumption are becoming a way of life. Candidly, only a modest amount of this conservation effort is attributable to casual motivation; most is due to one factor - Cost! However, we will cheerfully accept the composite result which is a well-defined energy conservation effort showing dramatic reductions in energy consumption.

3. We have awakened to the realization that no single entity can solve the problem - not Government, not industry, not labor, not some other country. Rather, we observe a concerted effort evolving to confront the crisis and tackle the solution with less shouting, hair pulling and accusations of who caused the problem.

Realistically, any cooperative progress at this stage may be best described as embryonic, but encouraging, nonetheless.

The issue, here, is merely to remind you of the need for continued and expanded mutual cooperation in energy development. There is a need to look calmly and cooperatively at the achievable rather than dwell upon the dimension of the catastrophy.

The world does not lack the resources, only the technology to utilize what already exists. As the world supply of petroleum and natural gas diminishes and the price escalates, we must turn to other energy sources.

The seriousness of the situation can be graphically illustrated by a quick look at the energy situation in the State of California. California consumes more energy than any other State and depends upon fossil fuels for 90 per cent of the State's total energy needs. Of that total, 54 per cent must now be imported from other States and Countries. (Edward Teller, 2/9/81, Commonwealth Club Speech.) The State and the Nation need to develop alternative energy sources.

The Use of Wood for Energy.
In the near term, wood combustion is one of the more promising alternative fuel technologies. The process technology is known; package systems are available; less pollution is generated than for most other alternatives, and the technology for economically harvesting the resource exists or is under development. Wood can be chipped, densified into pellets and briquets to improve its fuel qualities, distilled into alcohol, gasified, pyrolyzed to produce oil and charcoal and converted to chemicals and plastics to replace petroleum based products.

The U.S. Forest Service has outlined a national program for achieving a goal of 6.4 quads* of energy from woody biomass by 1990.

There are relatively large quantities of unutilized wood that could be used for energy. This unutilized wood includes logging residues, thinnings, wood manufacturing residues, urban wood waste, and trees and brush that cannot now be economically manufactured into wood products. The Forest Service has estimated that over 25 million tons of this material could be made available on an annual basis in California. The Honey Lake Project has shown that utilitization of biomass can be economic. With increasing petroleum prices and better application of research and development efforts, we expect greatly increased use of wood for energy in the years ahead.

World petroleum prices have leveled off during the last few months and this has given rise to a proliferation of optimistic forecasts. The most reliable look at the future is given in the Global 2000 Report (Entering the Twenty-First Century, A Report to the President of the United States, 1980.) Very briefly, the projection for energy is spiraling costs and decreased supply.

Achievement of the 6.4 quads goal for woody biomass will have a profound effect on the economy, primarily in rural areas. Nationally it will mean at least 300,000 new jobs, $9 billion annually in wood industry receipts, and an equal amount of business for supporting industry. The Forest Service expects an additional $60 million in stumpage receipts plus a savings of $75 million annually in timber management costs. The equivalent of 760 million barrels of oil will be displaced annually by wood energy. The proportionate effect in California would also be significant. (A National Energy Program for Forestry, USDA, Forest Service, MIS. Publication No. 1394.)

The specific focus of discussion today is the proposed unique electric power generation facility located near Susanville, Lassen Co., California. You may hear the project referred to variously as the "Wendel Project," the "Honey Lake Project," the "Susanville Project," or sometimes just "The Project."

The preferred name is "The Honey Lake Hybrid Geothermal Wood Residue Power Project." The proposed output is 50 MW of electricity.

Basically, low temperature geothermal fluid (estimated to be in the range of 275° to 340°F) will be used in two ways: (1) to provide process heat to reduce the moisture content of the biomass fuel; and (2) to provide preheated boiler feedwater and combustion air. A wood burning furnace will then raise the preheated feedwater to usable steam temperature for electric power generation.

Backing a series of feasibility studies is a diverse group including the project proponent, GeoProducts Corporation, an Oakland, California Company; Department of Water Resources, State of California; U.S. Department of Energy and the Forest Service, USDA. Each member of this consortium is involved for their own valid reasons, many of which are mutually shared. The fact that they are involved is a testimony to mutual cooperation for the common objective of energy production.

It is at the least unusual to find Federal and State government joining with a private company to determine the feasibility of a business venture. It should serve as a useful precedent for the future as a positive means of addressing energy development of unique and untried systems.

Utilizing low temperature geothermal and wood to produce steam sounds quite simple. The theory is simple, the technology is understood, the hardware is available, but no such hybrid facility actually exists. Since the project is extensive, complete feasibility studies are obviously required. Joint participation in funding these studies is logical considering the strong interest of the involved agencies. The participation of the Forest Service in this project stems from several strong interests:

1. We have a mandate to assist in improving wood utilization in general and energy production from forest residue has special emphasis. Since we already have an expanding program of supplying fuel wood both by sale and free use, we are looking beyond that for methods that will utilize much more volume.

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* 1 quad = 10^{15} Btu; this is roughly the equivalent energy content released by burning one-half million barrels of oil per day for one year.

2. We are concerned with the accumulation of timber harvesting residue, the expense of burning it and the added fire protection cost. Historically, such debris has been a net liability.

3. There are vast areas of young timber which are in need of thinning, but for which no market exists. Timber growth rates could be greatly accelerated if such thinning were accomplished. An additional long-term bonus for increased biomass utilization is expected to be a reduction in timber losses from forest fires and in actual fire fighting expenses. If extensive areas were cleaned up and dense stands were thinned, fire fighting would be made easier and at least some holocausts would be averted.

One of the primary needs in the feasibility study is an accurate assessment of the volumes of available biomass. The market has consisted primarily of saw timber and there was no justification to inventory other biomass. Our fire management people in recent years did develop an inventory to determine fuel loading and this provides some data.

One of the Honey Lake Project feasibility studies focused on the fuel assessment, harvesting equipment, fuel processing and transportation. The study area involved forest land within a nominal radius of 100 miles of the proposed plant site. We expect the inventory system developed by the consultant to have application elsewhere. Computer based, the system offers wide flexibility.

A 50 MW plant even with the geothermal assist will require an estimated 1000 tons per day of dry biomass. That means 2000 tons per day of green wood. This is no small quantity and the attendent logistics of supply must be carefully analyzed.

Here are the main questions some people have raised about the biomass supply impacts.

1. Environmental impacts including nutrient recycling, effect on wildlife and possible increased erosion potential.

Prior to entering any unit to remove utilized biomass, an environmental assessment would determine requirements. Ample residue will be left on the harvest site to provide for the above concerns.

2. Long term wood supply.

It is true that a volume of approximately 720,000 tons per year represents a substantial commitment. However, this is volume that is unutilized and listed on the debit side of the land manager's ledger. Removal represents a gain in all respects without interference with other uses.

There would be no adverse effect on regular saw timber production. Also, the national policy of the Forest Service to make fuel wood available free to individuals and by sale to commercial wood cutters would not be effected.

CONCLUSION

The final feasibility studies are not complete, but at each checkpoint the signals have been positive. When the studies are completed, it will still be a decision on the part of the project partners whether or not to proceed with the project.

Perhaps the main reason we are here to tell you about the Honey Lake Project is to suggest that conceivably, this type of hybrid power plant could fit a number of locations where the geothermal-biomass resources come together.

GOVERNMENTAL POLICIES OF THE COUNTY OF LASSEN TOWARD THE UTILIZATION OF GEOTHERMAL RESOURCES

MARK A. TOTTEN

LASSEN COUNTY PLANNING DEPARTMENT

By October 1979, the City of Susanville within the County of Lassen was well into its geothermal program. Greenhouses had gone into production, permits had been issued for some time in several locations within the County for shallow test wells, and the Board of Supervisors felt it was time for the adoption of an interim geothermal policy. That policy adopted October 2, 1979 is as follows:

Resolution Adopting An "Interim Geothermal Policy For The County Of Lassen

Whereas, Geothermal Energy has become a significant factor in the future growth and development of Lassen County.

Whereas, the 1968 Lassen County General Plan lacks any discussion of geothermal energy.

Whereas, a Geothermal Element to the General Plan would be necessary to manage and control the development of the geothermal resources within Lassen County.

Now, Therefore, Be It Resolved that it shall be the policy of this Board of Supervisors to seek funding from appropriate State and Federal agencies to prepare the Geothermal Element and necessary environmental documents.

Be It Further Resolved that until such a time a Geothermal Element is prepared and adopted the following shall serve as an "Interim Geothermal Policy for Lassen County":

1. Lassen County encourages the development of its geothermal resources by private and public concerns.

2. That the development of its geothermal resources should be for the purpose of furthering the goal of the County to be energy independent.

3. That the development of its geothermal resources should work for the diversification of our economy and provide employment opportunities for our citizens.

4. That the development of its geothermal resources should be in conjunction with other available alternative energy sources whenever possible.

5. That the development of its geothermal resources will comply with existing Federal, State and County laws, and the California Environmental Quality Act (CEQA), until such time a detailed development strategy can be prepared as a Geothermal Element to our General Plan.

6. That the development of its geothermal resources should compliment the efforts of the City of Susanville and the Susanville Geothermal Energy Project goals.

7. That the usage of the geothermal resources be optimized for the temperatures available without the destruction of the resource.

1978 saw the publication of a Final Environmental Assessment Record for Geothermal Leasing in the Honey Lake Valley, by the Bureau of Land Management. With the leasing of a parcel in that area and subsequent block leasing in the immediate vicinity, GeoProducts began investigating the possibility of power production. At first it was hoped that there would be enough direct heat for direct power production (there may possibly still be) but investigations to date have shown that some other form of fuel added to the geothermal will probably be necessary. Several possibilities of hybridization were and are considered. Currently the joint proposal by the U.S. Forest Service, Calif. State Department of Water Resources and GeoProducts contemplates the construction of a conventional steam power plant fired by wood with large quantities of geothermal heat being used to dry the wood products to the optimum moisture content for maximum energy release at combustion. What does this proposal mean in terms of the Board of Supervisors' adopted interim geothermal policy and the community concerns?

Since a county in California is primary in land use planning and land use regulation by legislative direction, we must look to our respective goals in our approach to this kind of facility. We must find the answers to a myriad of questions about this facility and in those and relate those answers as near as possible to the law and to the policy set forth by the Supervisors. Some of these questions might be as follows:

What is our relationship with our applicant? What have we done, the County, to start that relationship out on a friendly basis? We need to discuss with the applicant the interface with State, Federal, and local agencies. For instance, a recent field trip for two deep geothermal wells was recently attended by myself, another member of my staff, a member of the Board of Supervisors, two employees of the State Department of Oil and Gas, one employee from the State Department of Water Resources, two employees of the Bureau of Land Management, one employee of the State Department of Fish and Game, and the applicant, and this was followed up a week later by a field tour of the site by the entire County Planning Commission, who will be issuing the use permits on the project.

We understand that approximately 1,000 tons of fuel per day will be needed. This translates into approximately 40 truck and trailer loads of combustibles being consumed in every 24 hour period, what about our transportation facilities?

What effect will the combustion of this fuel have on the air quality in the local basin? What role will our local Air Pollution Control Board play in setting the standards for emission? What about the impacts of construction on the local communities? This project is in the 100 million dollar bracket; a large project to us, considering the total assessed valuation of the entire County is approximately 106 million dollars. How about schools and the school impact during construction? What about the labor force? One of our geothermal policy goals is to enhance the opportunities for our seasonal labor force. Will this tend to add more seasonal employees or will it , as we hope, tend to level off the winter-summer unemployment cycle we have known for so long? What about more plants such as this? Some of us feel that the resource has potential for as many as four or five more units of similar size, perhaps using fossil fuels. How long will this power plant be in operation? Can we expect its 30 - 35 years life to be extended? Will it be a good neighbor to the greenhousing and other anticipated uses of geothermal?

If man lived in an ideal state of harmony, there would be no need for government to settle disputes, and leading to the resolution of the questions just asked, there will probably be disputes between those people in the community and outside the community with those who will ultimately have to make the decisions regarding this facility. Since differences of opinion exist, the role of government is created. The processes we are obligated to administer and function within demand that all parties cooperate and share information. Failure to do so will only prolong the agony of review and assure certain defeat.

The California Environmental Quality Act sets forth two basic tenents:

(1) The process serves not only to protect the environment but also to demonstrate to the public that it is being protected.

(2) The process is to demonstrate to an apprehensive citizenry that the agencies have in fact analyzed and considered ecological implications of its actions.

These two basic tenents guide the actions of local government, as well as state agencies and the private sector within California.

This burden is on all of us!

How do we chart the course of future action? We have 2 basic choices:

(1) No action, or

(2) Planned action.

We can continue to allow things to drift day to day, reacting to stimulants upon demand, without information; the ultimate chaos no one will benefit from; or we can plan our actions and analyze our responses, considering the ecological implications of our decisions. Our Board of Supervisors proposes through its interim Geothermal Resolution that our response be done through the preparation of the Geothermal Element to its General Plan as set forth within AB2644 of the 1979 Session and implemented through AB1905 of the 1980 Session of the California Legislature.

A partial listing of those with whom the County and the applicants (Department of Water Resources, U.S. Forest Service, and GeoProducts with its private partners) must be in contact with and respond to from their viewpoint include the following: Bureau of Land Management, U.S. Department of Energy, U.S.G.S., the California Energy Commission, California Department of Conservation, Division of Oil and Gas, California Department of Forestry, California Department of Transportation, California Air Resources Board, California Department of Fish and Game, California Regional Water Quality Control Board, California Office of Historic Preservation (archeology), California State Lands Commission, California Solid Waste Management Board, and the Governor's Office of Planning and Research through its State Clearing house. Also of course the local County agencies, roads, schools, fire protection, etc. who through the Board of Supervisors have a direct interest in the proposal. This of course will include others as interest expands in this proposal. I have listed these agencies to show that the Board of Supervisors will at one time or another during the course of this project receive from or send information to all of these named groups. The most important group which must be considered is the general public. Through contact with our Board of Supervisors, these people will ask "What is going on?" The Board will respond through hearings, notices, and personal contact. It will be the responsibility of the applicants as well to maintain open communication with the people and agencies enumerated in order to assure a smooth transition of this project from conception to reality.

In reviewing the Board of Supervisors' geothermal policy, we will find that the proposed development is partly a result of our invitation to develop geothermal resources and that there is a possibility that some of the power generated by the facility can be utilized locally. This helps our community to become partially energy independent; we know that the development of the geothermal resource could work for the diversification of our economy and offer employment opportunities for our citizens. We also know that the concerns previously expressed should be solved in the context of Federal, State and County laws and California Environmental Quality Act (CEQA) and that in applying these laws we will protect the resource itself. We know that we are involved in a pioneering effort in energy development. We know that we must proceed carefully, but we know that we must proceed. We know that our policy is an interim measure and must be reviewed in its direction as development occurs. We know that any change in this policy will be from the perspective that geothermal resource development is an essential event in our County's future.

In summation, the County's solution to the management of geothermal resources within the County is as stated before in the Board's Resolution:

"Now Therefore, Be It Resolved that it shall be the policy of this Board of Supervisors to seek funding from appropriate State and Federal agencies to prepare the Geothermal Element and necessary environmental documents."

NON-ELECTRIC UTILIZATION OF GEOTHERMAL RESOURCES

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ABSTRACT

Direct utilization of geothermal energy has been used by many countries in the past on a small scale for bathing, cooking, and heating. Today, there are still many small-scale individual uses; however, many large-scale projects have been developed for district heating, greenhouse complexes, and industrial processing. The number of large-scale projects will continue to grow due to the escalation of fossil fuel costs and the proven technology of using insulated transmission lines and efficient heat exchangers for geothermal fluids. Today, over 3,000 MW (thermal) of geothermal energy are used in direct applications, mainly in Iceland, New Zealand, USSR, Japan, and Hungary. In all cases, the cost of geothermal utilization is below that of comparable fossil fuel energy.

INTRODUCTION

Direct utilization of geothermal energy for space and process heating, for the most part, utilizes known technology. Basically, hot water is hot water whether from a boiler or from the earth. The utilization of geothermal energy requires only straightforward engineering progress rather than revolutionary advances and major scientific discoveries. The technology, reliability, economics, and environmental acceptability have been demonstrated throughout the world.

It must be remembered that each resource is different and the systems must be designed accordingly. Granted, there are problems with corrosion and scaling, generally confined to the higher temperature resources, but most of these problems can be surmounted by materials selection and proper engineering designs. For some resources, standard engineering materials can be used if particular attention is given to the exclusion and/or removal of atmospheric and geothermally generated gases. For others, economical designs are possible which limit geothermal water to a small portion of the overall system by utilizing highly efficient heat exchangers and corrosion-resistant materials in the primary side of the system.

Direct utilization of geothermal energy was probably practiced by early man for cooking and heating. Recorded history shows uses by Romans, Chinese, Japanese, Turks, Icelanders, Central Europeans, and the Maori of New Zealand for bathing, cooking, and space heating. These uses have continued to today where, for example, over 1,500 hot-spring resorts exist in Japan, visited by 100 million guests every year.

Early industrial applications include the use by the Etruscans of boric acid deposited by the steam and hot water at Lardarello, Italy. They used the deposits to make enamels to decorate their vases. Commercial extraction of the acid started in 1818, and by 1835, nine factories had been constructed in the region. Municipal district heating was first undertaken in Reykjavik, Iceland, in 1928.

Today, over 3,000 megawatts thermal (MWt) are utilized in the world for space heating and cooling (space conditioning), agriculture and aquaculture production, and for industrial processes. Of this figure, over 1,300 MWt are used for space heating and cooling; approximately 1,400 MWt for agriculture, aquaculture, and animal husbandry; and over 200 MWt for industrial processes. Bathing and balnelogical uses are not included in these figures.

Typically, the agriculture-related uses utilize the lowest temperatures, with values from 80°-180°F (27°-82°C) being typical. Use of wastewater has wide applications here. The amount and types of chemicals and dissolved gases, such as boron, arsenic, and hydrogen sulfide, are a major problem for this use. Heat exchangers and proper venting of gases may be necessary in some cases to solve this problem. A major portion of the agriculture-related energy utilization is in the Soviet Union where over 1,000 MWt are reported being used.

Space heating generally utilizes temperatures in the range of 150°-212°F (66°-100°C), with 100°F (38°C) being used in some marginal cases and heat pumps extending this range down to 55°F (13°C). The leading user of geothermal energy for space heating is Iceland, where over 50 percent of the country is provided with geothermal heat. The only known cooling is in Rotorua, New Zealand, at the International Hotel and on the Oregon Institute of Technology campus; however, many other applications are presently being considered.

Industrial processing typically requires the highest temperatures, using both steam and superheated water. Temperatures up to 300°F (150°C) are normally desired; however, lower temperatures can be used in some cases, especially for drying of various agricultural products. Though there are relatively few examples of industrial processing use of geothermal energy, they represent a wide range of applications, from drying of wool, fish, earth, and lumber to pulp and paper processing and chemical extraction. The two largest industrial uses are the diatomaceous earth drying plant in Iceland and the paper and wood processing plant in New Zealand.

EXAMPLES OF CURRENT UTILIZATION

Traditionally, direct use of geothermal energy has been on a small scale by individuals. Surface hot springs were utilized and shallow wells could be justified with on-the-spot use or short transmission distances in uninsulated pipes or channels. However, at today's prices for development and hardware, the cost savings of these individual uses are often marginal. Large-scale use requires more production and can thus justify deeper wells, longer transmission distances, more sophisticated utilization, and lower temperatures.

Most of present-day developments involve large-scale projects, such as district heating (Iceland), greenhouse complexes (Hungary), or major industrial use (New Zealand). Heat exchangers are also becoming more efficient and better adapted to geothermal use, allowing the use of lower-temperature waters and highly saline fluids. Heat pumps are extending geothermal development into traditionally nongeothermal countries, such as France, Austria, and Denmark, as well as the eastern U.S.

Space Conditioning. The most famous space-heating project in the world is the Reykjavik municipal heating project, serving about 97 percent of the 113,000 people in the capital city of Iceland. At present, a total of 1.0 x 10^{10} gallons (3.8 x 10^{10} liters) of geothermal fluid are used annually to supply 16,000 homes with space heating. One field supplies water through two 14-inch and one 28-inch (35- and 70-cm) diameter pipelines over a 12-mile (19-km) distance. Insulated storage tanks (6.9 x 10^6 gallons; 2.6 x 10^7 liters) are used to meet peak flows and provide an emergency supply in the event of breakdown in the system. A fossil-fuel-fired peaking station is used to boost the 176°F water to 230°F (80°-110°C) during 15 to 20 of the coldest days of the year. The city is served by nine pumping stations, distributing fluid through 200 miles (320 km) of pipelines. The entire system provides 1,840 GWh per year or 420 MWt (including the peaking station; Lienau/Zoega, 1974).

An example of individual home space heating is in Klamath Falls, Oregon, where over 400 wells are used for space heating, using waters from 100°-230°F (38°-110°C). The principal heat-extraction system is the closed-loop downhole heat exchanger utilizing city water in the loop (Lund, 1975). Larger examples of space heating in Klamath Falls include the Oregon Institute of Technology campus, where three wells up to 1,800 ft (550 m) deep produce up to 450 gpm (28 ℓ/s) of 192°F (89°C) water and heat approximately 500,000 ft^2 (46,000 m^2) of floor space. The geothermal water is pumped from the well using deep-well turbine pumps, and in most cases, is used directly in the heating system for each building. The annual operating cost of the campus system is approximately $30,000, a savings of almost $250,000 per year when compared with the cost of heating with conventional fuel. Other notable uses in the community include the 311-bed Merle West Medical Center hospital and nursing home, where the present worth of a 20-year savings due to a geothermal retrofitted heating system is over one million dollars, and Maywood Industries, where 118°F (48°C) water is used for heating a large manufacturing building (Geo-Heat Utilization Center Bulletin, Lienau, 1977; Higbee, 1978).

Several large-scale district heating projects are presently either under design or construction in Klamath Falls and Lakeview, Oregon; Susanville, California; and Boise, Idaho. These each involve the optimal use of several wells along with major supply and distribution pipeline. Both the Klamath Falls and Boise projects will initially supply government buildings in the downtown area.

Agriculture and Aquaculture. In Hungary, greenhouse heating is second only to the USSR, with over 13 million ft^2 (1.2 million m^2) being geothermally heated. Many of these greenhouses are built on rollers, so they can be pulled from their location by tractors, the ground cultivated with large equipment, and then the greenhouse returned to its location. In addition, to minimize cost, much of the building structure pipe supporting system also acts as the supply and radiation system for the geothermal fluid. About 60 wells are used for animal husbandry projects, mainly for heating and cleaning of animal shelters. Priority is given to agricultural use of geothermal energy in Hungary, as this increases the volume and variety of production. Some experimental work is being performed with grain, hay, tobacco, and paprika drying. In these cases, hot water supplies heat to forced-air heat exchangers and 120°-140°F (49°-60°C) air is blown over the product to be dried (Lienau/Boldizar, 1974).

In Japan, greenhouses cover about 157,000 ft^2 (14,600 m^2), where a variety of vegetables and flowers are grown. Many large greenhouses are operated as tropical gardens for sightseeing purposes. Raising poultry through the use of geothermal energy has been a very successful enterprise. Here, under-the-floor heating is utilized in sheds where 40,000 chickens are raised annually. Another successful business is breeding and raising carp and eels. Eels are the most profitable and are raised in 10-in. diameter by 20-ft long (25-cm by 6-m) earthenware pipes. Water in the pipes is held at 73°F (23°C) by mixing hot spring water with river water. The adult eels weigh from 3-1/2 to 5-1/4 oz (100-150 g), with a total annual production of 8,400 lbs (3,800 kg). Alligators and crocodiles are also raised in geothermal water. These reptiles are being bred purely for sightseeing purposes. In combination with greenhouses offering tropical flora, alligator farms are offering increasingly large inducements to the local growth of the tourist industry (Japan Geothermal Energy Assoc., 1974).

Excellent examples of greenhouse operation exist in the U.S., the largest being the Honey Lake Hydroponic Farms complex near Susanville, California. Cucumbers and tomatoes are grown in a hydroponic system. Heat is provided to the greenhouses by geothermal fluid. At present, 30 greenhouses have been constructed, with expansion planned to over 200 units. Channel catfish are raised by Fish Breeders of Idaho near Buhl, using geothermal water. Using 6,000 gpm (380 ℓ/s) of 90°F (32°C) water, approximately 500,000 lbs (230,000 kg) of fish are raised annually (GRC Special Report No. 5, Ray, 1979). Prawns (Machrobrachium rosenbergii), trout, and goldfish are being raised on the Oregon Institute of Technology campus.

Industrial Processes. An example of industrial processing is the use of geothermal steam for the Tasman Pulp and Paper Company in New Zealand. Here, 100-125 MW (180 tons/hr steam) of thermal energy are used for the lumber drying, black liquor evaporation, and pulp and paper drying. The total investment cost for geothermal is $6.8 million, the majority of which is for well development. This amounts to approximately $70 per kWt and will reduce the price of energy to 70 percent that of conventional fuels for an annual savings of $1.3 million. The annual maintenance costs are two percent of the capital cost (Lienau/Wilson, 1974).

In northern Iceland, a diatomaceous slurry is dredged from Lake Myratn. This slurry is transported through a pipeline and held in storage ponds. The 80 percent moisture is then removed in large rotary-drum driers using high-temperature geothermal steam. The plant produces 27,000 tons (24,494 t) of diatomite filteraids per year, most of which are used in beer processing in Germany (Lienau/Lindal, 1974).

Two industrial-processing uses of geothermal energy are of note in the U.S.: Medo-Bel Creamery in Klamath Falls, where low-temperature fluid is used for pasteurizing milk; and Geothermal Food Processors at Brady Hot Springs, Nevada, where high-temperature fluid is used for dehydration of onions and other vegetables (GRC Special Report No. 5, Belcastro, 1979; GRC Bulletin, Vol. 7, No. 5, Nov./Dec. 1978).

BENEFITS OF DIRECT APPLICATIONS

The main advantages of direct utilization of geothermal energy are:

1. No conversion to another form of energy.
2. The use of low-temperature resources, which are numerous and readily available.
3. The use of many off-the-shelf items for exploitation (pumps, controls, pipe, etc.).
4. Short development time as compared to electrical energy development.
5. Lower-temperature resources require less expensive well development (and shallower, in some cases), can be drilled with conventional drilling equipment in many cases, and the water can be transported 20-40 miles (32-64 km).

All of these advantages give a favorable economic situation when compared to conventional fuel. At present-day prices, the geothermal application will cost about the same or less than the corresponding annual fossil fuel cost. Due to the expected escalation of fossil fuel prices, the costs of the geothermal system will become more favorable with time. Most geothermal direct-use systems will pay for themselves in five to ten years from savings in conventional fuel.

The economics are greatly enhanced where cascading (multi-stage use) is considered. The Japanese optimize cascading where geothermal fluids are first used for electrical power production, then space heating, cooking, and bathing (Otake). Here, an attempt is made to "squeeze" the "last drop of energy" from the fluid. Lower-temperature cascading could consider space heating, agriculture, bathing (swimming pools), and snow melting. Low- and intermediate-temperature geothermal resources can also be used to meet the base load of an energy demand. Heat pumps and fossil fuel can then be used to meet the peak demands, thus conserving the resource and minimizing capital investments (Ryback, 1979).

POTENTIAL OF THE PACIFIC NORTHWEST

During 1979-1980 an assessment of the geothermal potential in the BPA marketing area was prepared (Lund, et al, 1980). This assessment included both electric and nonelectric potential and probable use in the three states of Oregon, Washington and Idaho, and portions of surrounding states. Since Oregon and Washington include the Cascade Range, a summary of the results for these two states are of interest.

According to USGS Circular 790 for resource potentials above 194°F (90°C) and from estimates by the author for resources below 194°F (90°C), the following was determined:

	Thermal Potential (Wellhead) (MWt)	
	Oregon	Washington
>302°F (>150°C)	21,952	332
302°-194°F (150°-90°C)	14,312	285
<194°F (<90°C)	68,107	12,194
Total	104,371	12,811
=	3.12x10^{15} Btu/yr	0.38x10^{15} Btu/yr

Considering only that portion of the resource potential that has a significant direct-use load within 25 miles, the conversion potential (beneficial heat) is then reduced to:

Oregon: 682 x 10^{12} Btu/yr
Washington: 84 x 10^{12} Btu/yr

The total population, and direct-use load that could be served by geothermal energy (residential, commercial and industrial) and the estimated development schedule to the year 2000 is as follows.

Thus by the year 2000, the Northwest could be using the equivalent of over 1.3 million barrels of oil annually in geothermal energy.

State	Number of Resource Sites*	1980 Population	1980 Direct-Use Load x 10^{12} Btu/yr	Geothermal Development Schedule x 10^{12} Btu/yr				
				1980**	1985	1990	1995	2000
Oregon	10	122,000	5.64	0.26	0.54	1.12	2.08	3.41
Washington	7	266,000	6.64	0.01	0.38	0.87	1.72	2.72
Total	17	388,000	12.28	0.27	0.92	1.99	3.80	6.13

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*Since many individual resources had the potential of serving overlapping areas, those serving the same general population were grouped together for evaluation purposes.

**Reference: Geothermal Progress Monitor, USDOE (DOG/RA-0051/4), 1980.

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GEOTHERMAL POLICY OF THE STATE OF CALIFORNIA

SUSAN BROWN

CALIFORNIA ENERGY COMMISSION

ABSTRACT

The California Energy Commission is the State agency responsible for formulating energy policy in California. Since its creation in 1975, the Commission has set forth in its Biennial Report to the Governor and the Legislature those policies, goals, and priorities which govern the State's future energy and electricity needs. This paper will address geothermal energy policy of the State of California in the context of these overall state energy policy goals. The paper will also describe the current status of a geothermal development in California and state programs and policies to encourage maximum development of this indigenous, alternative energy resource.

OVERVIEW OF THE STATE ENERGY POLICY

In its 1979 Biennial Report, the Commission demonstrated that California cannot meet its future energy and electrical needs if the State relies only on conventional sources in the short-term, but stresses energy conservation and renewable resources, such as solar and geothermal energy, biomass and wind, as sources favored for the future. In addition, the Commission set forth as a goal for the electrical utility sector displacement of 50 percent of oil and gas use by 1992.[1] To achieve this goal, energy conservation and the accelerated development of alternative energy sources like geothermal energy must be given high priority by the public and private sectors.

The California Energy Commission has been a strong supporter of energy conservation and renewable resources since the early 1970s. The Commission, therefore, endorses the following state energy policy objectives as a practical energy strategy for providing affordable and reliable energy supplies, while reducing the nation's dependence on imported foreign oil:

1. Promote energy conservation as the fastest and most economical way to meet our energy needs.
2. Decrease gasoline use and reduce oil and gas in existing power plants by up to 50 power plants by up to 50 percent by 1990.
3. Support a synthetic fuels program that focuses on California markets and meets California's environmental quality standards.
4. Maximize the use of geothermal energy, cogeneration, biomass, solar energy and wind turbines to generate electricity.
5. Meet the remaining electrical need with direct coal-fired power plants, limiting their total statewide capacity to 5,000 megawatts for air quality reasons.[2]

Achieving the objective of maximum use of alternative electrical generation sources like geothermal energy will depend on the utilities' willingness to invest in these sources. In California, utility commitments to developing renewable energy sources have doubled during the last two years. Yet, this commitment is still relatively small and utility resource plans for 1981-1992 remain dominated by nuclear projects under construction and planned additional coal-fired plants. Further state and federal action is needed to lessen the financial risk and to reduce the regulatory barriers to utility investments in alternative energy sources.[3]

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[1] California Energy Commission, 1979 Biennial Report, Sacramento, CA, March 1980, p. 1.

[2] Ibid., pp. 7-8.

[3] Energy Tomorrow: Challenges and Opportunities for California, 1981 Biennial Report, p. 210.

STATUS OF GEOTHERMAL ENERGY DEVELOPMENT IN CALIFORNIA

Geothermal energy continues to be one of the cheapest sources of electrical power. With 908 megawatts of capacity on-line, The Geysers dry steam field in northern California is the largest geothermal energy development in the world. In addition, over 455 megawatts in new power plants are under construction and about 240 additional megawatts are currently under regulatory review. The Geysers Known Geothermal Resource Area (KGRA) alone---a resource unique in the nation---has the potential to provide up to 2,700 megawatts of electrical generating capacity during the 1990s and beyond.

Large geothermal resource areas are also located elsewhere in the State. The U.S. Geological Survey has identified 15 hydrothermal (hot water) reservoirs with estimated temperatures of 150° centigrade. These KGRAs are shown in Figure 1. Those resources with temperatures above 150°C may be suitable for electrical power generation, while those under 150°C will be useful for direct use applications. If converted to electrical energy, the recoverable heat from the moderate-to-high temperature resources could provide the equivalent of 11,300 MWe of power for 30 years.[4]

In the Imperial Valley, where an extremely large geothermal reservoir exists, demonstration and pilot projects are underway to utilize the flash and binary cycle technologies to convert the moderate temperature and highly saline resources to electrical power. The success of these demonstration projects, once expanded to commercial-scale installations, could lead to the generation of additional 1,000's of megawatts by the end of the century.

Although California leads the nation in geothermal electrical capacity, the State is lagging behind other states in realizing the potential for geothermal direct use applications. Present direct use of geothermal heat amounts to about 0.5 megatherms per year and includes only small-scale greenhouse heating and space heating applications.

Figure 2 illustrates the expected rate of geothermal electrical power development and direct use applications based on "current trends" under a business-as-usual case, versus the "maximum reasonable" potential which could be expected with the resolution of the key constraints to geothermal development.[5]

FIGURE 2

CALIFORNIA ENERGY COMMISSION STAFF
STATEWIDE GEOTHERMAL ENERGY PROJECTIONS

	Current Trends*		
	1985	1992	2000
Geothermal Electric (Megawatts)	1,758	2,300	3,000
Direct Use (Megawatts)	9	13	33

	Maximum Reasonable**		
	1985	1992	2000
Geothermal Electric (Megawatts)	2,108	3,650	5,100
Direct Use (Megawatts)	20	110	220

STATE POLICIES AND PROGRAMS TO ENCOURAGE GEOTHERMAL ENERGY DEVELOPMENT

Many of the constraints to full utilization of California's geothermal energy potential are the same constraints faced by alternative energy resources and technologies in general. Still others, such as the need for advanced hydrogen sulfide abatement technologies, are those particular to geothermal energy development.

In California, recently enacted state programs provide financial assistance for research and development for alternative electrical generation technologies. These programs are intended to subsidize the risk associated with emerging new technologies, such as geothermal flash and binary cycle technologies, solar photovoltaic and wind electric technologies--a major constraint to their development. These legislatively-created state programs include:

- <u>The California Alternative Energy Financing Authority</u> issues up to $200 million in bonds to assist solar, biomass, wind, geothermal, small hydroelectric, and other projects "which reduce the use of fossil and nuclear fuels." (AB 2324, Hayes)
- <u>The California Pollution Control Financing Authority</u> issues tax exempt bonds to finance the installation of "renewable energy resource devices." (AB 2646, Bates)

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*Based on utility plans, technology status, and policies and programs in place as of October 1980.

**If CEC staff policy and program recommendations are implemented. December 1980.

[4] CEC staff report, <u>Nontraditional Energy Technologies: Issues and Actions</u>, December 1980, p. 15.

[5] <u>Ibid.</u>, pp. 23-24.

- Tax Incentives for Alternative Energy Technologies

  Accelerated depreciation for cogeneration and alternative energy equipment. (AB 1404, Hayes; AB 2893, Cline)

- The Energy and Resources Fund

  $120 million in direct financing of special alternative energy and resource projects and programs, financed by increased revenues from oil production on state lands resulting from federal oil price decontrol. (AB 2973 Vasconcellos)

Additional state funds are being requested to support alternative energy projects and programs, such as the Heber binary cycle geothermal hot water demonstration project, and to provide forgiveable loans and direct financing for feasibility studies, reservoir confirmation, engineering design studies, and demonstration projects.

The Energy Commission, in its 1981 Biennial Report, has also recommended a number of other legislative and policy actions to encourage utility investment in alternative electric generation technologies. These actions include:

- Providing preferential rate treatment for alternative energy development by the California Public Utlities Commission.

- Offering favorable regulatory treatment for preferred, alternative electric generation facilities, such as geothermal power plants and cogeneration facilities under 300 megawatts.[6]

As early as March 1978, the Commission adopted a geothermal regulatory policy which established an optional, expedited power plant permitting process for geothermal power plants sized over 50 megawatts. Since 1978, the Commission has approved 576 megawatts in new geothermal power plant development under the expedited review process. These recommended policies are just some of the actions needed to remove technical and regulatory barriers to alternative energy sources.

Furthermore, current state and federal programs are helping to develop geothermal direct use projects as an attractive alternative to natural gas and electricity. Both the state and federal government are undertaking several feasibility studies and market surveys for geothermal direct uses in California. The U.S. Department of Energy is funding 14 technical and economic feasibility projects for such uses as food processing, chemical processing, fertilizer production, and district heating. The Energy Commission has also funded several geothermal direct use projects.[7] Specific examples include the engineering feasibility of using geothermal energy at Mammoth Lakes Village for district space and water heating and the feasibility of using geothermal for industrial process and space heating at Rohr Industries in San Diego, California.

The Commission, working jointly with other state agencies, is also investigating the potential for using geothermal energy for heating and cooling state facilities. One such facility, which the Commission is funding during the current fiscal year, is the retrofit of the California State Correctional Center at Susanville with a geothermal heating system.

Finally, during the coming fiscal year, the Commission will continue to support a variety of geothermal energy projects with state contract and grant funds. With the passage of Assembly Bill 1905 (Bosco), the Energy Commission will provide financial assistance to local governments in planning for and developing their geothermal resources. This legislation, which became law in May 1980, allows the Commission to disburse revenues from federal geothermal leases to counties, cities, and special districts with known or potential geothermal resources. It is expected that this new grant program at the state level will further accelerate environmentally acceptable geothermal energy development.

CONCLUSION

In summary, California's energy policy places top priority on increased use of conservation and renewable resources, like geothermal energy, in meeting the state's future energy needs. The goal of California state energy policy is to direct public and investments into those energy resources that minimize long-term costs and adverse social and environmental impacts.

Geothermal energy development will continue to play an important role in meeting California's electrical energy needs. It is also anticipated that rapidly-rising energy costs and newly-enacted state financial incentives and assistance programs will further expand and encourage direct (non-electric) uses of geothermal energy as well.

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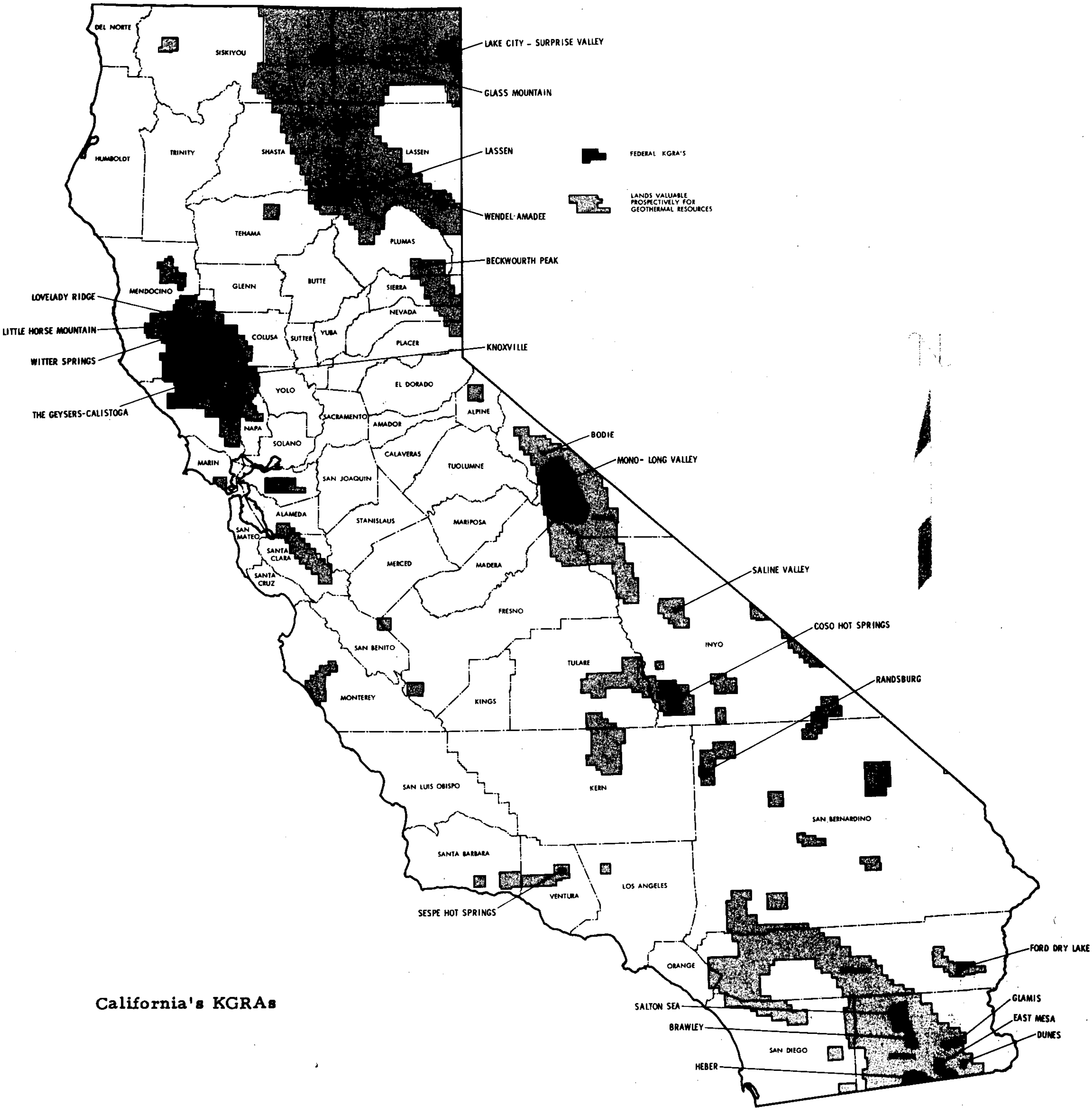
[6] Energy Tomorrow, pp. 211-214.

[7] Energy Tomorrow, pp. 327-328.



California's KGRAs

GEOTHERMAL POLICY IN OREGON

Patricia Amedeo

Office of the Governor

In Oregon, we are just beginning to realize our energy portentials -- natural gas, coal and geothermal included. Oregon is basically unexplored and we are now working on developing our energy frontiers.

Many of these energy potentials are just coming to light. There have been recent discoveries of commercial natural gas and coal which give us cause to be enthusiastic in these areas. The potential for geothermal development is also exciting. I want to take this opportunity to welcome you and invite your participation in the development of this important resource.

Oregon has a message for those who search for and extract energy from the earth. Coal, oil and natural gas are not the only energy treasures beneath our feet. There is geothermal energy.

It is Oregon's policy to encourage the development of geothermal energy resources. The Legislative Assembly has declared by statute that, "the people of the state of Oregon have a direct and primary interest in the development of geothermal resources situated in this State."

This policy is manifested in several pices of legislation which have frequently served as models for other states, such as:

- the separation of high and low temperature geothermal resources for regulatory purposes;

- authorization for municipalities to form geothermal district heating systems;

- policy direction and regulations regarding disposal of geothermal fluids; and

- tax credits for end-use applications.

This policy is also duly reflected in the active geothermal programs of the State's Department of Geology and Mineral Industries, Department of Energy, and Department of Water Resources. The cooperative spirit between state programs, federal geothermal activities and private development interest is indicated by the case of the Borax Lake chub in the Alvord Valley. By working together, the various groups were able to reach an agreement that will allow both geothermal exploration and protection of an endangered species.

There is enough geothermal energy in Oregon to displace seven million barrels of home heating fuel annually or - put another way - Oregon's geothermal potential is equivalent to the output of three large coal-fired generating plants. Development of geothermal and other renewable energy resources will likely cost as much as conventional energy but, in addition to being "home-grown" and sustainable, energy from geothermal, given resource confirmation, could be brought on-line far sooner than a new coal plant, for example.

In January of this year, Oregon's Governor Atiyeh submitted a $144 million energy program to the Oregon Legislature. That program will tap not only the State's geothermal potential, but also energy that can be acquired from conservation, solar, wind, hydro, biomass and alcohol fuels. It is an action plan by which Oregon can achieve a higher level of energy self-reliance. As a net importer of energy with little or no control over the cost and supply reliability of our imports -- and as one of the nation's fastest-growing states -- Oregon's key to a secure energy future is in reducing our energy dependence and vulnerability.

Although geothermal energy's "discovery" in the 1970s has stirred new interest and excitement throughout the State, the resource has been a mainstay in some parts of Oregon since the turn of the century.

Klamath Falls, for example, has both the largest concentration of direct geothermal applications in the United States. More than 500 relatively shallow wells supply hot water to heat 600 structures including homes, businesses and almost all public schools. The Oregon Institute of Technology, a State college, which is the home of the nationally recognized GeoHeat Center, uses geothermal to space heat more than 556,000 square feet and also to cool the new student union building. The use of this local resource at the college saves taxpayers approximately $486,000 per year. Natural hot water is also used in Klamath Falls to pasteurize milk, to melt snow and ice from pavements, to cure concete, heat swimming pools and greenhouses and even to nurture gian prawns in an aquaculture project. Peak use of natural hot water in the community displaces 60 megawatts of electricity.

A considerable number of Oregon cities and counties have significant geothermal potential that can be developed now. Exploration is underway in several areas, including the Cascades, Lakeview, Harney Basin, Vale and in other areas from the western Cascades eastward to the Idaho border.

We know geothermal is there -- and we are going after it.

In 1979, at the Governor's request, the Oregon Legislature created the State's first Alternate Energy Development Commission. The Commission's mandate was to design a comprehensive plan for the development of Oregon's renewable energy resources. Specifically, the Commission was directed to develop creditable estimates of the energy that can be acquired from conservation and renewables -- how much that energy will cost -- how development will be financed -- when the energy will be available -- and what Oregon must do "to get from here to there." The Commission's work was supported by resource-specific task forces.

The Commission completed its work in September, 1980 and its 87 action recommendations are the foundation for Governor Atiyeh's 1981-83 Special Energy Program.

Aside from quantifying Oregon's geothermal resource potential and estimating what it will cost to bring that energy on-line, the Alternate Energy Development Commission targeted three major constraints to geothermal development in Oregon.

Not surprisingly, a cumbersome and lethargic leasing process for exploration and development on federally owned land was singled out as a prime inhibitor to harnessing geothermal.

More than half of Oregon's land area is owned and managed by the federal government. Most of the State's geothermal resources, particularly in the case of the Cascade resources, are within those federal land holdings. Systematic exploration and development has been curbed because, in some instances, federal management agencies have chosen to lease only selected portions of a geologically promising area, if a lease was given at all.

Private companies are reluctant to risk making investments unless they control contiguous parcels. A discoverer who does not control a coherent lease block faces the unattractive prospect of competitive and more costly leasing for adjacent federal land. For this reason, the majority of resource assessment work that has been done in the Cascades has been publicly funded and conducted by federal and state agencies and universities.

Governor Atiyeh and the Oregon Department of Energy's geothermal program, with support from the Oregon Congressional Delegation, have been seeking ways to resolve the leasing barrier for several years. For example, in late 1980 Governor Atiyeh requested assistance from the Interagency Geothermal Coordinating Council in reviewing the adequacy of federal geothermal actions in Oregon to emphasize his support for an expedited leasing process of federal lands.

I hope that it is not premature to say that apparently the federal leasing situation is improving. An important example was the reversal of a U. S. Forest Service leasing decision on the Gifford Pinchot National Forest in Washington state, which Dr. Bloomquist will discuss in the next presentation. During 1980, Oregon realized a 73% increase in leased federal acreage, most of which was non-competitive land.

This sounds like a dramatic increase. But, it must be noted that many of these lease applications have been pending for five or six years and that most of these leases were for BLM land.

Leasing of Forest Service land is still a critical issue -- one which the State will continue to work to influence.

We expect to see a major increase in private exploration when lands are made available for leasing. This has been the case for the Breitenbush area, where Sunedco secured leases by competitive bids and is planning to drill a deep test well this summer.

A second constraint to geothermal development is the lack of detailed knowledge about the resource itself. We do know a good deal -- but not enough -- about the potential for direct use applications for low-to-moderate temperature resources.

Further, Oregon's potential for geothermal electrical production is neither documented nor well understood. The U. S. Geological Survey estimates the total electrical potential in known resource areas is about 1640 megawatts for 30 years. And, while it is probable that electric power generation will eventually be realized from geothermal, comprehensive resource assessment must be done to confirm that hope.

The third major constraint to development of geothermal is the initial cost. While energy companies are willing to commit risk capital to exploration and development, all potential users - industrial, commercial and residential - face high initial cost.

Oregon has attractive incentive programs in place to ease the cost of resource development. Industries which use renewable resources, including geothermal, can claim a 35% corporate tax credit for the cost of necessary equipment. In 1980, Oregon voters approved 300 million dollars in bonds to finance low-interest, long-term loans for local energy projects which use renewable energy. We expect to make loans totalling 20 to 40 million dollars for these projects in 1981.

Homeowners can claim a personal state income tax credit (in addition to a federal tax credit) of up to $1,000 for a geothermal system, including the hook-up costs to a geothermal heating district. Homeowners can also finance reneable resource systems with 6½ percent, State-subsidized loans and veterans can borrow up to $3,000 at less than 7 percent (in addition to a State Veterans Home Loan) to cover the cost of a renewable resource system.

The energy package that the Governor has submitted to the Legislature focuses sharply on the need for renewable assessments that would provide risk-reducing information about the location, quantity and quality of geothermal resources.

The Governor's recommended budget supports the need for resource assessment with a 1.6 million dollar fund for resource definition studies. The majority of the funds - 1.4 million - is earmarked for geothermal assessment which would be conducted by the Department of Geology and Mineral Industries.

If approved by the Legislature, funds for geothermal assessment will be used for exploration and drilling in areas that can produce the greatest benefit to the State. Recognizing the high cost of resource exploration, the 1.4 million is a modest gesture when viewed in terms of the enormous amount of work needed to characterize Oregon's resources. However, the 1.4 million comprises practically the entire budget for renewable resource assessment and should be viewed as a commitment by the state of Oregon to assume some of the risk of exploration and support for development

Another recommendation supported by the Governor includes $250,000 to local governments for district heating systems.

Recognizing the need for resource management, the Special Energy Program recommends two levels of reservoir management. Proposed legislation gives to the Department of Geology and Mineral Industries the authority for management and procedures for utilizing reservoirs with temperatures greater than 250 degrees Fahrenheit. A budget recommendation has been proposed to allow the Department of Water Resources to develop management plans for low-to-moderate termperature reservoirs.

The program also calls for new incentives for utility involvement in all types of renewable resource development. One legislative recommendation would allow the cost of construction for renewable resource projects to flow immediately into the utility rate base. We believe approval of this measure would be important if utilities are to undertake the high risks involved in early geothermal development. Another recommendation would delay the assessment of ad valorem property taxes on utility energy projects until the project begins to produce power.

Overall, the efforts of the Geothermal Task Force, the Commission, and the Governor's Special Program will provide an improved institutional climate to nurture development of Oregon's geothermal resources. The recommendations have attempted to rectify misplaced incentives that focus on post-development by putting the State and local governments in a more supportive role for resource development. Financing for high front-end project costs should also be more readily available, and the State's regulatory role is more clearly defined.

Enactment of the Special Energy Program will provide an increased level of stimulation for geothermal development. The entire planning process has underscored the significant level of commitment that the State has to geothermal energy. With the Special Energy Program, the Governor has demonstrated his support and the critical importance of policy and budgetary decisions which will affect Oregon's renewable resource development.

At a time when the Northwest states will be undertaking a retional energy planning approach and the level of energy planning in Oregon has been greatly increased, the future outlook for geothermal development in Oregon is very encouraging.

GEOTHERMAL ENERGY POLICY IN WASHINGTON
-- AN OVERVIEW --

By R. Gordon Bloomquist

Washington State Energy Office

ABSTRACT

The state of Washington is actively engaged in establishing the institutional framework within which the geothermal industry can successfully develop.

The Interagency Geothermal Development Council is working diligently to ensure access to both Federal and state lands for geothermal exploration and development. The State Department of Natural Resources is presently considering what could well become the most innovative royalty schedule yet adopted in the United States.

The Legislature also continues to play an active role. Legislation has been passed which provides utilities with a greater rate of return for geothermal projects. Property tax exemptions for renewable resources have been enacted; and, legislation favoring district heating and a state loan program are being considered.

The state, however, can only encourage development--the ultimate responsibility for development lies with industry.

Introduction

The state of Washington took an early lead in developing interest in geothermal energy and a conference held in Olympia in the early 1970's served to catalyze the formation of the Geothermal Resource Council. However, interest waned early, the GRC established itself in California and we in Washington State often felt neglected by the geothermal industry. The question of how to attract attention to the geothermal potential of our state was often debated in public as well as in private. Our resource potential seemed to pale in the light of that of our neighbors. Resource assessment and development by the private sector was all but non-existent due to the lack of information concerning the resource potential, the lack of financial incentives, and what often appeared to be insurmountable institutional barriers.

The situation has improved. The explosive eruption of Mount Saint Helens focused renewed attention upon the state. Federal, state, and local government has become more aware of the geothermal potential in the state, and more importantly, government has begun to respond to the needs of the geothermal industry.

The Washington State Legislature has made it a state policy to encourage development of the state's geothermal resources and, in order to ensure that this policy is carried out, the state has established a State Interagency Geothermal Development Council (IGDC) and a Technical Advisory Committee (TAC). The Council was established with the concurrence of the Governor in 1979. Membership consists of representatives of both the executive and legislative branches. The TAC brings to the Council the expertise of both public and private developers. The role of the Council is to ensure that geothermal resources in Washington State are developable by the private sector. In order to do so, we must first provide the institutional framework within which the geothermal industry can successfully develop.

Federal Leasing

At the Federal level this means guaranteeing access to high potential areas. The majority of the state's high temperature resources are expected to be discovered in the Cascades, and since 1974, the lack of access to this area has been quoted innumerable times as the greatest single obstacle to geothermal development in the state.

In January, 1978, the first draft Environmental Impact Statement (EIS) to address leasing of National Forest lands was released. The statement was overly restrictive in terms of the acreage to be made available for such leasing and was opposed by the Washington State Energy Office and the Department of Natural Resources--unfortunately without results. When the EIS was finally accepted in 1980 and lease offerings first made, our greatest concerns were realized--out of the 300,000+ acres in the study area, only 5,000+ acres were actually leased. The remainder of the lease applications were rejected, withdrawn or appeals were filed. The granting of leases that had been awaited for 6-1/2 years was not to occur. Through the combined efforts of the IGDC, the Washington State Energy Office, and our congressional delegation, especially Representative Foley and Senators Jackson and Magnuson, the Bureau of Land Management agreed to reinstate all of the withdrawn and rejected lease applications and the United States

It is presently being considered by the Department of Natural Resources that rules and regulations be promulgated in such a way that:

1. The state receives a fair return;
2. The lessee can purchase geothermal energy at rates lower than competing conventional energy sources;
3. Cascading, or multiple use, and reinjection are encouraged; and,
4. Efficient use of the resource is encouraged.

Some of the more interesting aspects of the proposed state leasing rules and regulations involve the establishment of royalties for both electric and direct use projects.

In the case of electrical generation, the royalty would be 10 percent of the net sale value of the electricity. However, if the lessee reinjects the spent geothermal fluids into the reservoir or cascades the use of the geothermal energy the royalty would drop to 9 percent. If the lessee both cascades and reinjects, the royalty rate would drop to 8 percent.

The proposed method for calculating the royalty for direct use projects is probably of greater significance in that Washington is the first state, to my knowledge, to acknowledge the inequality that existing Federal and state royalties impose upon direct use geothermal projects.

The amount of the royalty to be paid through a direct use of geothermal energy with the proposed rules and regulations would be calculated using ΔT (change in temperature), flow rate, and a factor that reflects the capital investment. Table 1 illustrates the relationship between ΔT, production rate, and percent royalty. The table also clearly indicates that by encouraging more efficient use of the resource, the state also benefits through a substantial increase in revenue, although the percentage royalty charged is decreased, benefiting the developer.

TABLE 1

Royalty Rates and Hourly Royalties
for Direct Uses of Geothermal Energy

	Production Rate (gpm)			(r)
	50gpm	100	500	
1	$0.0139/hr	$0.0279/hr	$0.1394/hr	18.593%
5	$0.0524/hr	$0.0105/hr	$0.5241/hr	13.976%
10	$0.0899/hr	$0.1798/hr	$0.8991/hr	11.988%
20	$0.1500/hr	$0.3000/hr	$1.5000/hr	10.000%
ΔT, 30	$0.1988/hr	$0.3976/hr	$1.9881/hr	8.836%
°F 40	$0.2403/hr	$0.4807/hr	$2.4033/hr	8.011%
50	$0.2764/hr	$0.5528/hr	$2.7641/hr	7.371%
60	$0.3082/hr	$0.6163/hr	$3.0816/hr	6.848%
70	$0.3363/hr	$0.6726/hr	$3.3632/hr	6.406%
80	$0.3614/hr	$0.7228/hr	$3.6138/hr	6.023%
90	$0.3837/hr	$0.7675/hr	$3.8374/hr	5.685%
100	$0.4037/hr	$0.8074/hr	$4.0373/hr	5.383%

Forest Service agreed to reevaluate its leasing policy. The latest news that I have is that 90 percent of the study area that the EIS covered will be offered for lease. At present, the Forest Service is reviewing what we believe to be redundant stipulations to the original lease offering and I am confident that, when the leases are again offered, the stipulations will reflect a much more realistic attitude on the part of the Forest Service. I feel that the above case clearly illustrates that the state of Washington is totally committed to ensuring that leasing policy adequately reflect the needs of the geothermal industry while giving ample protection to the environment. This is also an indication that the Bureau of Land Management and the United States Forest Service are gaining a better understanding of geothermal energy and the potential environmental impacts of exploration and development.

Our efforts in resolving questions regarding Federal leasing are continuing. The IGDC, state government, and several members of our congressional delegation have wholeheartedly supported measures to streamline the leasing provisions of the Geothermal Steam Act of 1970.

Most recently, Senator Jackson introduced Senate Bill 669 entitled the "Geothermal Steam Act Amendments of 1981" to fulfill the following purpose:

1. Effect a major overhaul of Federal geothermal leasing procedures to support a significant acceleration in the development of geothermal resources on Federal lands;

2. Modify the Geothermal Steam Act of 1970 to facilitate and require diligent exploration and development of geothermal resource leaseholds;

3. Assure competition in the geothermal industry; and,

4. Protect nationally significant thermal features in national parks or monuments.

We will give careful consideration to this proposed legislation as well as others that are expected to be introduced to streamline leasing, and we will support those provisions that we feel will best serve the interests of geothermal exploration and development.

State Leasing

The state is striving to make the leasing of state lands as attractive as possible to the geothermal industry while at the same time fulfilling its commitment to provide revenue to the General School Construction Fund.

In 1979 the state legislature paved the way for adopting rules and regulations for the leasing of state lands by establishing ownership rights.

The royalty rate is calculated using the following formula:

$$\text{Royalty Rate} = \frac{\ln\left(\frac{\Delta T}{653}\right)}{-34.86}$$

$$\text{Royalty (\$/hour)} = \frac{(\Delta T)(500)(\text{gpm})(\$3.00)(\text{royalty rate})}{1 \times 10^{6}}$$

The value of direct use geothermal energy has arbitrarily been set at $3.00 per million BTU for the above example.

A more detailed account of that which is being proposed in Washington is described by Charles V. Higbee of the Oregon Institute of Technology in the GRC Transactions V.4, Sept. 1980, p. 719-722.

It is also being proposed in Washington that royalties in dollars per million BTU should be adjusted annually to reflect inflation or deflation on the basis of annual changes in the overall Consumer Price Index (U.S. Department of Commerce) and not on the escalating cost of conventional fuel.

Hopefully, the adoption of such a royalty schedule in Washington will serve to encourage other states and the Federal government to reevaluate the royalty being charged on direct use projects in light of what we have learned about the economics of direct use projects over the past several years.

Financial Incentives

The state of Washington has taken the lead in encouraging utilities to use geothermal energy for electric generation and direct utilization. The 1980 legislature enacted legislation that allows regulated utilities a greater return on investment on projects that produce or generate energy from geothermal and other renewable resources. This return is established by adding an increment of two percent to the rate of return on common equity permitted on the company's other investments. The legislation also provides a financial incentive for non-regulated utilities. The non-regulated utilities presently pay a tax of 3.6 percent of gross sales. In computing tax under the adopted amendments to Chapter 82.16 RCW, there shall be deducted from the gross income an amount equal to the cost of production at the plant for consumption within the state of energy generated or produced from geothermal energy or other renewables. Deductions under this legislation shall be allowed for a period not to exceed thirty years after the project is placed in operation.

The Interagency Geothermal Development Council is considering recommending legislation to permit the UTC to allow utilities substantial research and development expense components for geothermal resource projects. This should allow utilities to establish an equity positon in geothermal reservoirs and thus better control their fuel costs.

The state, unfortunately, has been unable to provide a great many additional financial incentives. The state does not have a state income tax and, therefore, cannot provide tax credits for geothermal development such as does the Federal government or the state of Oregon. There is also a constitutional prohibition to lending the state's credit, so it has been impossible to initiate a program of low interest loans or guaranteed loans. The question of amending the state constitution to allow for such loans is, however, presently before the state legislature (April 20, 1981).

Legislation that would provide tax relief through a reduction in the Business and Operating Tax is expected to be introduced into the next session of the legislature.

Presently, the only form of tax relief available is a property tax exemption, passed by the 1980 legislature, for unconventional heating, cooling, domestic water heating, or electrical systems that utilize renewable energy resources, including heat pumps.

The state has come a long way in the past two to three years in establishing a climate condusive to geothermal exploration and development. The job, however, is far from completed, and we must continue to strive to meet the needs of the geothermal industry.

The Interagency Geothermal Development Council and the Washington State Energy Office will continue to coordinate these activities, but we need the help of the industry we are striving to assist. We need to be kept informed of the factors that remain as obstacles to development. And we need you, the representatives of utilities, energy companies, and private developers, to express your opinion in regard to proposed legislation and administrative changes, not only to our office or to the Council, but to the legislature and through public hearings.

We strongly believe that the resource potential is significant, and that development can contribute to solving the nation's energy problems; however, we recognize that it is ultimately the responsibility of industry, not government, to develop geothermal energy.

THE PACIFIC NORTHWEST ENERGY CONSERVATION AND POWER PLANNING ACT

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ABSTRACT

The Pacific Northwest Electric Power Planning and Conservation Act gives Bonneville Power Administration new authority which may, under certain circumstances, facilitate the development of geothermal energy. This authority includes the purchase of output or capability of new energy projects affecting the Pacific Northwest's electrical supply, the funding of investigations of proposed projects, and the study of renewable resources outside the Pacific Northwest which might be used for the region's benefit.

Introduction

On December 5, 1980, President Carter signed into law the Pacific Northwest Electric Power Planning and Conservation Act. This Act has major significance for power planning and development in the region. Among other things, it gives Bonneville Power Administration a role we've never had before in the acquisition of power from new renewable resource projects. This presentation will cover what Bonneville will be able to do as a result of the Act with regard to renewable resources, particularly geothermal energy.

As Section 2 of the Act states, the Act is designed to accomplish the following, among other things: (1) encouragement of conservation and efficient uses of electricity and the development of renewable resources in the Pacific Northwest; (2) assurance of an adequate, efficient, economic, and reliable power supply in the region; (3) provision for full public participation in regional energy planning and related environmental protection; and (4) protection, mitigation, and enhancement of fish and wildlife of the Columbia River and its tributaries.

This presentation will address Bonneville's authority to meet the first objective, particularly as it affects geothermal development. Ultimately the Planning Council appointed by the Governors of the States in the region will prepare a regional conservation and electric power plan which will guide Bonneville's activities regarding renewable resources. Meanwhile, Bonneville has the authority to carry out those activities independently in accordance with the criteria which the Act requires the Council to follow in developing its plan.

Provisions of the Act

The development of renewable resources has been addressed primarily in Section 6 of the Act. Section 6(a) and (b) enable the Administrator of Bonneville to acquire conservation and renewable resource projects without seeking Congressional approval, provided they are "nonmajor." As the Act defines that term, the projects must have a planned generation or displacement capability of no more than 50 average megawatts. For projects larger than that, hearings and Congressional approval are required.

The term "acquire" is also defined in the Act. It means only that Bonneville may purchase a project's output or capability. It does not permit Bonneville to construct or own electrical generating projects.

Under Section 6, Bonneville may acquire commercial renewable projects on either a short- or long-term basis. There are several conditions which must be met, however. First, the electricity displaced or generated by a given project must be necessary for Bonneville to meet its contract obligations to its customers. In the case of direct-use geothermal projects, Bonneville can acquire projects only to the extent to which they displace existing electrical consumption.

Second, the order in which resources may be acquired as set out in Section 4(e)(1) must be followed. The priority required by the Act is as follows: first, conservation; second, renewables; third, waste heat and efficient uses of fossil fuels; and last, other resources. An end-use or electrical geothermal project would have second priority and could be acquired, therefore, only if on a planning basis conservation were insufficient to meet the region's needs.

Third, new resources must be consistent with the considerations in Section 4(e)(2) which requires that environmental quality; compatibility with the existing power system; and fish and wildlife protection, mitigation, and enhancement be considered.

And finally, new resources must be cost-effective. As defined in the Act, a cost-effective resource must be reliable and available when it is needed and it must cost no more than the least-cost alternative.

Section 6 further extends the Administrator's authority to acquire resources to nonmajor research, development, and demonstration projects. Under Section 6(a)(1), demonstration projects installed by a residential or small commercial consumers using renewable resources and consistent with Section 4(e)(1) and 4(e)(2) may be acquired. Again, the extent to which Bonneville can acquire direct-use projects depends on the extent to which those projects displace existing electrical loads.

Under Section 6(d), research and development projects may also be acquired, provided such acquisitions are included in the annual budget Bonneville submits to Congress. Eligible projects must use a technology having the potential for being cost-effective in the region. As with commercial projects, Bonneville's authority to acquire these projects does not allow us to construct or own the projects.

There is a way in which Bonneville can acquire new renewable resources indirectly, that is, through the provisions for billing credits in Section 6(h). Projects undertaken by Bonneville's customers, by entities acting on behalf of those customers, or by political subdivisions served by those customers would be eligible for billing credits. The amount of the credit must be included in the annual budget submitted to Congress and would be based on the extent to which a customer's net requirement for electric power or reserves from Bonneville were reduced. The Act requires that the granting of billing credits must not be inconsistent with the criteria of Section 4(e)(1) and the environmental considerations in Section 4(e)(2).

In the case of both billing credits and acquisition of resources, the Administrator must exercise effective oversight over all aspects of construction and operation, according to Section 6(i).

In addition to allowing Bonneville to acquire new resources either directly or through billing credits, the Act also permits Bonneville to provide funding for the investigation and initial development of commercial nonmajor renewable resource projects. The pertinent section of the Act is Section 6(f).

Bonneville is now working out the details of a program to solicit proposals from utilities which are considering such projects. We plan to fund or reimburse preliminary site analyses, feasibility investigations, and preconstruction studies.

There are two conditions which must be met in order for Bonneville to fund studies of proposed commercial projects. First, the Administrator must determine that his failure to provide financial assistance would result in an inequitable hardship to the consumers of a project's sponsor. And second, the sponsor must give Bonneville the first option to acquire the resource.

Finally, in Section 6(l) the Act directs the Administrator to investigate opportunities to add resources or reduce power costs for the region through accelerated or cooperative development of renewable resource projects outside the region. Such projects would be owned, sponsored, or otherwise developed by nonregional agencies or authorities.

USDA-FOREST SERVICE LANDS: GEOTHERMAL SITUATION

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There are 19 National Forests in the Pacific Northwest Region containing 24.5 million acres. The majority of these Forests lie along the Cascade Range where the potential for geothermal activity seems highests. Since 1974 action on applications for geothermal leases has evolved from site-specific, worst case assessments to broad assessments of resource protection and economic tradeoffs. Forest Service recommendations on many of the 563 lease applications received have been made. The Congress and the Courts have been active in the energy fields. The Forest Service is working to assure that its direction provides protection of surface resources, while promptly responding for lease applications and operations on those leases.

The Pacific Northwest Region of the Forest Service is largely within the States of Oregon and Washington. There are 19 National Forests (see attached map) in the Region containing nearly 24.5 million acres.

Increasing attention is being focused on the geothermal potential of the National Forests. The majority of the Region's National Forests are located along the Cascade Range where the potential for geothermal activity seems highest. All of the lease applications received in the Region (515) are located on seven Forests along or near the Cascades.

The Cascades are rich in other natural resources including spectacular scenery and undeveloped areas. The majority of the legislated Wilderness areas in Oregon and Washington lie on or near the Cascade Range.

EVOLUTION OF PROCEDURES TO RESPOND TO LEASE APPLICATIONS

The newness of geothermal leasing activity to the Forest Service, the sensitivity of the areas involved, and the stage of the Forest planning process have combined to delay Forest Service recommendations on the leases. From 1974 to 1981 Forest Service action on lease applications evolved generally as follows:

1. National Forest Plans

The Forest Service at one time considered waiting and addressing energy leasing in the Forest plans under preparation, as directed in the Forest and Rangeland Renewable Resource Planning Act of 1974 (as amended). However, this approach postponed leasing decisions until the plans were completed and approved some years ahead. This delay was not acceptable to the Chief of the Forest Service and in October 1979 he directed that energy leasing be considered separately.

2. Environmental Impact Statements

Geothermal lease applications were first addressed in late 1974 on the Willamette National Forest through the National Environmental Policy Act (NEPA) process, which resulted in an environmental impact statement due to the controversy that ensued. The final environmental impact statement was approved in June 1978. An environmental impact statement was also prepared on an area between Mount St. Helens and Mount Adams. Work on this statement began in 1974 and the amended decision was issued March 30, 1981. The statements were generally tied to smaller specific areas of land and addressed significant development (and the impacts) of geothermal energy that might be found.

3. Environmental Analysis

At this point it was recognized that issuance of a lease does not, of itself, cause environmental impact. Thus two types of analyses have evolved over the past few years:

A. Mt. Hood and Deschutes Environmental Assessments - These assessments were started in 1975 and completed in early 1981. In these cases it was decided that sensitive areas should be leased with a two stage (or conditional development) lease. The two stage lease allows exploratory wells to be drilled in the first stage. Production or full scale development would depend on the discovery of an exploitable resource and the completion of a (second stage) site-specific analysis. We recognize, of course, that the lease carries a basic right to reasonable development, and that our discretion at the second stage is limited to consideration of specific means and sites of operation to minimize conflicts.

B. Fremont Environmental Assessment - In this case the assessment covers the whole National Forest and the conditional development notice has been substituted for the conditional development stipulation. With this notice the Forest Service explains the type and degree of control available to the Government on future operations. The lessee has the right to develop or produce an economic resource subject to reasonable mitigative measures just as with the stipulations. The Fremont Assessment began as a two stage leasing situation in 1975, evolved into an assessment of the entire Forest in 1978, and is essentially completed at this time.

During this same period of time the Administration and Congress took an increasingly active role to streamline geothermal leasing procedures. President Carter's message to Congress in April 1977, the Energy Security Act of 1980, and President Reagan's Economic Recovery message to Congress are examples of the National direction.

PRESENT SITUATION

Over the years the Forest Service has moved from focusing on site-specific, worst case assessments to broad programatic assessments of resource protection and economic tradeoffs. Also, general lease stipulations which guide post lease site-specific activities are utilized. Flexibility is built in. As of April 20, recommendations on 149 leases have been made. This leaves 366 leases in varying stages of completion. Our recommendations on the great majority of these applications will be made by the end of 1981.

The Forest Service policy on mineral leasing recongizes that most National Forest System lands are subject to one or more of the various mineral leasing laws which authorize and regulate the exploration and development of Federally-owned leasable minerals (including geothermal). Unless specifically precluded by Congress or formal withdrawals, these Federally-owned minerals are generally available for development.

The Secretary of the Interior is responsible for issuance of prospecting permits, coal exploration licenses, and mineral leases on Federally-owned lands, including National Forest System lands. However, as a surface management agency, the Forest Service has the responsibility and obligation to ensure that mineral activities on National Forest System lands are conducted so as to minimize conflicts with other uses and damage to surface resources, and that damaged areas are rehabilitated after mineral operations. In accordance with this policy the Forest Service Washington Office is preparing Forest Service Manual changes and leasing standards, criteria, and guidelines for publication in the near future.

The Chief of the Forest Service is in the process of delegating to the Regional Forester the authority to respond to lease applciations on Wilderness and other special areas. Specific direction on how to respond to lease applications in these areas is being written. This direction, together with delegated responsibility for such areas will enable the Forest Service to respond to applications in a timely and uniform manner.

From time to time, court decisions are made that have an effect on geothermal leasing. The October 1980 decision in the case of Mountain States Legal Foundation vs. Andrus, et al. (Wyoming - oil and gas) indicates the following (which are considered applicable to geothermal situations):

1. Failure to diligently process lease applications for National Forest System lands may be interpreted as a de facto withdrawal, contrary to withdrawal procedures described in Section 204 of the Federal Land Policy and Management Act.

2. National Forest System lands have been declared by Congress to be available for mineral activities unless specifically withdrawn. The burden of proof is on the agencies to justify withdrawals, denial of leases, and disapproval of normal operations on leases.

3. Withdrawal requests must include information on the potential and value of mineral resources in the area for comparison with the values of other resources to be protected by withdrawal.

4. Wilderness preservation is not grounds for withholding action or approval of leases under the Geothermal Steam Act unless Congress has specifically withdrawn the area, or directed Wilderness preservation.

Our future policies and procedures will reflect the above concepts.

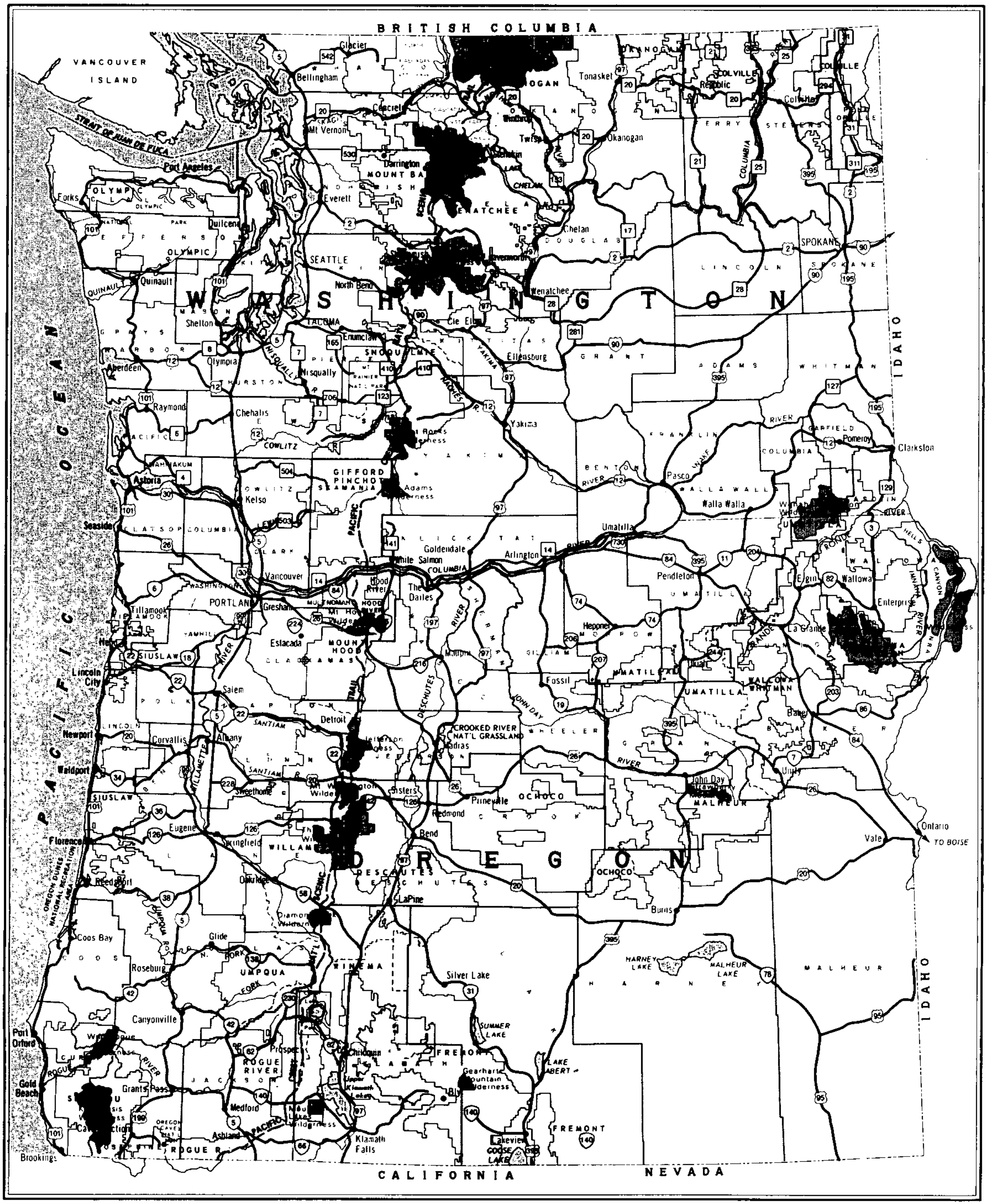
FUTURE

Forest land management plans will consider geothermal as an important resource (in areas where geothermal potential is high) and will be the key instrument for future leasing decisions.

We will strengthen our efforts to respond to lease applications in a timely manner and to keep current.

Based on the recent delegation, the Region will address the question of leasing in Wildernesses, and other special areas, which were previously the responsibility of the Chief.

You may rest assured that the Forest Service intends to continue an active and positive role in the geothermal area. This will be reflected in our National, Regional, and Forest programs.



U S DEPARTMENT OF AGRICULTURE
FOREST SERVICE

NATIONAL FORESTS
of
R-6 PACIFIC NORTHWEST REGION

LEGEND

26	US HIGHWAY	5	INTERSTATE HIGHWAY
66	OREGON STATE HIGHWAY	31	WASHINGTON STATE HIGHWAY
☐	NATIONAL FOREST LAND	—	COUNTY LINE
■	WILDERNESS	— —	PACIFIC CREST NAT'L TRAIL

USFS R 6 1980

CURRENT AND PENDING FEDERAL LEGISLATION AFFECTING GEOTHERMAL ENERGY DEVELOPMENT

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Department of Energy

ABSTRACT

A number of laws were passed in the last ten years to govern leasing, permitting, taxation, utility regulation, and other aspects of geothermal energy. These laws have removed uncertainties and established a predictable and favorable financial climate for geothermal resource development. A number of significant improvements to this body of legislation are likely to be enacted this year. The new legislation will be directed towards removing unnecessary regulatory delays and restrictions. Amendments to the Geothermal Steam Act, the Energy Tax Act of 1978, and the Clean Air Act are already being developed, and have excellent prospects for early enactment.

INTRODUCTION

The period from 1970 to 1980 saw the enactment by the U.S. Congress of nine (Ref. 1-9) laws with significant impacts on the development of geothermal energy, beginning with the Geothermal Steam Act in 1970 and ending with Title VI of the Energy Security Act in 1980. These laws, along with about a dozen laws concerning environmental regulation and Federal land management,[10] establish the current federal framework of regulation, taxation, ownership, leasing, and government programs relating to geothermal energy development in the U.S. A number of significant changes to these laws are expected in the present Congress in an attempt to reduce regulatory burdens and improve the financial aspects of geothermal projects. The Reagan Administration is proposing a major reduction in direct government involvement through Department of Energy programs, and a simultaneous and dramatic reduction in regulatory delays and barriers to allow commercial projects to proceed at a reasonable pace.

FEDERAL LAND MANAGEMENT

The Geothermal Steam Act of 1970 provides the basic authority for geothermal leasing and permitting on Federal lands. The implementation of this authority has up to now been a source of substantial delay and irritation to geothermal developers. Requirements under NEPA, the Federal Land Policy and Management Act, the Forest Management Act, and the Wilderness Act have been responsible for much of the delay.

In 1979 and 1980 the Congress considered legislation to overhaul the Geothermal Steam Act. The House and Senate passed separate bills that were very similar[11] but they were unable to resolve the final differences at the end of the session. The Interior Department is developing a bill that is based on those bills, to be submitted to Congress this year; and we expect early passage. Senator Jackson has already introduced a geothermal leasing bill (S669). The legislation will probably include an increase in the federal acreage limits, a narrower definition of KGRA's (limited to electric power prospects), "grandfather" rights for applicants for noncompetitive leases to protect them against KGRA designations after applications are filed, authority for free use permits for small scale nonelectric uses, reduced royalties for nonelectric applications, and other improvements to the Act.

Additional legislative proposals are being considered which will allow some exploration and possible later development in Wilderness Study and even Wilderness Areas. Senator Hayakawa has introduced S5842, relating to Forest Service lands, and the Interior Department is reviewing proposals for BLM lands. Provisions which would limit the establishment of new Wilderness Areas are being considered as well. These proposals are particularly important for geothermal energy because so little is known about the locations of promising resources at present.

The Interior Department and the Forest Service are, fortunately, not waiting for legislation to begin streamlining leasing and permitting. A major effort is underway by both agencies to eliminate backlogs, slash processing times, and eliminate unnecessary paperwork. Numerous regulatory and administrative changes will soon be proposed. Field offices will be instructed to eliminate all backlogs and offer all KGRA acreage for leasing by October of this year, and to routinely process lease applications in 90 days from now on. This is a dramatic change from the two-to-five year--or--longer--processing times we have seen in the past. A procedure for licensing nonelectric facilities will be established and reduced rentals and bonds will be set for small projects. Standards are being promulgated for lease terms which will reduce the use of restrictive conditions. These improvements are being developed and implemented on a crash basis.

DOI and USFS will take whatever steps are necessary to assure full compliance by field offices with these streamlined procedures. I think we can rest assured that Federal leasing and permitting processes are within a few months going to cease being a barrier to geothermal energy development.

TAX POLICY

The Energy Tax Act of 1978 and the Windfall Profits Tax Act of 1980 established an attractive set of tax incentives for geothermal energy exploration and development. These incentives include intangible drilling cost deductions, depletion allowance, a 40% tax credit for residential applications, and a 15% tax credit for business applications. The scope of the tax credits has been narrowed substantially by a provision in the Energy Tax Act[12] precluding the application of the business credit to public utility property, by a provision in the IRS implementing regulations[13] which defines geothermal deposits as only those resources with temperatures in excess of 50°C, and by another provision[14] which disallows the credit for systems which employ peaking or topping systems or which use geothermal as a preheat. IRS does allow the credit for geothermal systems which have backup boilers, but the costs of the backup systems are not eligible.

These limitations may be softened or eliminated by regulatory and legislative action. The rate exemptions available under the Public Utility Regulatory Policies Act (PURPA) of 1978, which will be discussed later, would apparently permit the tax credit for qualifying small power production facilities for electricity. At least one Congressman intends to introduce legislation to overrule the IRS temperature limitation and the limitation on hydrid systems.

PUBLIC UTILITY REGULATION

PURPA, as amended last year by the Energy Security Act,[15] provides that FERC may exempt geothermal small power production facilities up to 80 MWe in size from rate regulation and from the Public Utility Holding Company Act. It also allows FERC to order wheeling and interconnection by public utilities for such plants. The Energy Security Act amendments allowed FERC to extend the regulatory exemptions to geothermal plants owned by utilities as well as other parties.

The rate exemptions allow sales of geothermal power at the "avoided cost" rate, which substantially improves project economics over rate-regulated sales for some projects. Qualification of a project for the rate exemption will also qualify the project for the business tax credit. The Holding Company Act exemptions allow flexible project financing for geothermal plants.

FERC has issued regulations[16] implementing these provisions, but has backed off from proposed provisions which would authorize rate exemptions for utility-owned plants because of objections from public utility commissions in California, Hawaii and New Mexico. They are reconsidering that proposal.

In the meantime, the entire rate-standards approach of the Public Utility Regulatory Policies Act has been ruled unconstitutional by a Federal District Court in Mississippi.[17] FERC has appealed the decision to the U.S. Supreme Court, and a decision is expected about next spring. If the decision holds, the rate exemptions will be left up to state PUC's to implement or not as they prefer.

THE CLEAN AIR ACT

The Reagan Administration is reviewing proposed modifications to the Clean Air Act to reduce the projected costs to society of cleaning up our air. The Act must be reviewed by Congress this year. Among the proposals under consideration is eliminating or reducing the scope of the Prevention of Significant Deterioration requirements for areas which have emissions below the attainment levels, at least for all but Class I areas. This would eliminate requirements for Best Available Control Technology (BACT) for H_2S emissions for geothermal power plants. State agencies would still be free to set emission standards, but the delays, costs, and uncertainties associated with BACT designation would not be required by Federal law.

THE ENERGY SECURITY ACT

Title VI of last year's Energy Security Act included authorizations for several loan programs for geothermal projects, required consideration of the use of geothermal energy in new federal buildings or facilities in areas designated by DOE,[18] and required DOE to report to Congress on the need for and feasibility of a government geothermal reservoir insurance program.[19] The Reagan Administration is not proposing to implement the loan programs for reservoir confirmation and for nonelectric feasibility studies and project construction. However, the other two provisions will be complied with.

DOE will be working with other federal agencies over the next few months to identify new or existing federal facilities which could use geothermal energy and to establish procedures for those agencies to continue to seek and evaluate opportunities for geothermal use. Thus any federal facility should be considered a ready market for geothermal resource use by potential developers.

The Department has underway a study of the geothermal reservoir insurance issue and will report to Congress this summer. If the conclusions warrant it, a recommendation for legislative authorization of such a program may be made. Efforts by private insurance companies to establish commercial reservoir insurance programs have so far failed to result in any actual policies being issued. The proposed termination of DOE's geothermal loan guaranty program may help create a market for such insurance as a means for providing assurance to financial institutions against reservoir risks.

CONCLUSION

The next two years will see a flurry of legislative and regulatory activity to tune up, improve and implement the legislative enactments of the 1970's. The emphasis will be on streamlining and reducing regulatory and financial burdens to allow the private sector to proceed on its own with those projects that make economic sense. The Cascades area has been a major resource area where Federal government inaction has prevented exploration and development. With the impediments removed, the promising resource potential here should see rapid development.

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    Endangered Species Act of 1973
    National Historic Preservation Act of 1966
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    Resource Conservation and Recovery Act
    Noise Control Act of 1972
    Coastal Zone Management Act of 1972
    Wild and Scenic Rivers Management Act
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    Safe Drinking Water Act
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