MASTER

SPECIAL STUDY GUIDE No. 7

GEOTHERMAL ENERGY: A NATIONAL OPPORTUNITY
(THE FEDERAL IMPACT)

Prepared for

SPECIAL SHORT COURSE NO. 7

*GEOTHERMAL ENERGY: A NATIONAL OPPORTUNITY
(THE FEDERAL IMPACT)*

*May 17-18, 1978
Quality Inn - Capitol Hill
Washington, D.C.*

GEOTHERMAL RESOURCES COUNCIL
P.O. Box 98
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Geothermal Resources Council

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SCHEDULE AND PROGRAM

Wednesday, 17 May 1978

7:45 - 8:30 a.m.	REGISTRATION AND CHECK-IN FOR ALL PARTICIPANTS
8:30 - 9:05 a.m.	A WORLDWIDE OVERVIEW OF GEOTHERMAL DEVELOPMENT <i>A summary of geothermal development throughout the world, including present levels of technology</i> Dr. Patrick Muffler, U.S. Geological Survey
9:05 - 9:15 a.m.	Discussion
9:15 - 9:50 a.m.	THE UNITED STATES "GEOTHERMAL INDUSTRY" <i>A review of the companies, their expertise, resources, activities and needs</i> Dr. Robert Rex, President, Republic Geothermal, Inc.
9:50 - 10:00 a.m.	Discussion
10:00 - 10:15 a.m.	Coffee Break
10:15 - 10:50 a.m.	PROGRESS IN GEOTHERMAL DEVELOPMENT IN THE UNITED STATES VS. PROGRESS WORLDWIDE <i>A comparative history of the major technical accomplishments and capital investments in the U.S. and abroad, including a film on recent developments at Hatchobaru, Japan</i> William Dolan, Manager of Geothermal Operations, AMAX Exploration, Inc.
10:50 - 11:00 a.m.	Discussion
11:00 - 11:50 a.m.	GEOTHERMAL RESOURCES OF THE ATLANTIC COASTAL PLAIN OF THE EASTERN U.S. <i>Their nature, location, potential and possible uses; and the needs for continued research</i> John Costain, Professor of Geophysics
11:50 - 12:00 noon	Discussion
12:00 - 1:30 p.m.	Lunch Break
1:30 - 2:30 p.m.	THE U.S. DEPARTMENT OF ENERGY AND ITS GEOTHERMAL PROGRAM (1) Department of Energy Organization and the Geothermal Program Louis Werner, Assistant Director, Division of Geothermal Energy, Department of Energy
	Discussion

Wednesday, 17 May (continued)

1:30 - 2:30 p.m.
(continued)

(2) The Geothermal Technical Research Program
John Walker, Chief of Research & Development
for Utilization Technology, Division of Geo-
thermal Energy, Department of Energy

Discussion

(3) Geothermal Loan Guaranty Program
Lawrence Falick, Division of Commercial Applica-
tions, Department of Energy

Discussion

2:30 - 3:05 p.m.

MAJOR GEOTHERMAL LEGAL ISSUES

*Definition of the resource, ownership of the resource,
water rights, power plant siting jurisdiction, regula-
tion, etc.*

Owen Olpin, O'Melveny & Meyers

3:05 - 3:15 p.m.

Discussion

3:15 - 3:30 p.m.

Coffee Break

3:30 - 4:05 p.m.

FEDERAL GEOTHERMAL REGULATIONS

*A brief history and background, the agencies involved,
their areas of authority, problems and present status*

Dale Zimmerman, Chief- Division of Mineral Resources,
Bureau of Land Management

4:05 - 4:15 p.m.

Discussion

4:15 - 4:50 p.m.

THE POTENTIAL OF GEOTHERMAL ENERGY IN THE UNITED STATES

*A realistic look at both electric and non-electric
potentials and their positions in the future national
energy mix*

Bob Greider, Vice President, Intercontinental Energy
Corporation and President, Geothermal Resources
Council

4:50 - 5:00 p.m.

Discussion

5:30 - 7:30 p.m.

INFORMAL DISCUSSION - NO HOST COCKTAILS

Thursday, 18 May 1978

8:30 - 9:05 a.m.

FEDERAL LAND ISSUES

*The Federal "Land Policy and Management Act," wilder-
ness area reviews, lease longevity, investor rights,
bonding, planning, EIS preparation, etc.*

Donald Sherwood, Dawson, Nagel, Sherman & Howard

9:05 - 9:15 a.m.

Discussion

9:15 - 9:50 a.m. WESTERN STATES GEOTHERMAL POLICY, LAW AND REGULATIONS
An overview and discussion of the major state issues, e.g., definition of the resource, tax reforms, common guidelines, etc.
 Douglas Sacarto, Associate Director, Geothermal Policy Project, National Conference of State Legislatures

9:50 - 10:00 a.m. Discussion

10:00 - 10:15 a.m. Coffee Break

10:15 - 11:00 a.m. PERMITTING CONSTRAINTS TO THE DEVELOPMENT OF GEOTHERMAL RESOURCES

(1) Federal Permitting Constraints
 Robert Wright, Phillips Petroleum Company
 Discussion

(2) Permitting Problems, California and Other States
 David N. Anderson, Executive Director, Geothermal Resources Council
 Discussion

11:00 - 11:35 a.m. THE EFFECT OF FEDERAL TAX POLICY ON GEOTHERMAL DEVELOPMENT
A comparative look at discrepancies in tax treatment, leasing, and other requirements which have delayed geothermal development, and recommended remedial legislation
 Samuel Eisenstat, Eisenstat & Gottesman

11:35 - 11:45 a.m. Discussion

11:45 - 1:30 p.m. Lunch Break

Following Lunch Break, the Short Course will reconvene in Room 3110, Dirksen Senate Office Building

1:30 - 5:00 p.m. SUMMARY OF THE SHORT COURSE AND A REVIEW OF GEOTHERMAL ENERGY--A BRIEFING ON CAPITOL HILL
 Bob Greider, Chairman

PROGRAM

THE INFORMATION NEEDS OF LEGISLATORS CONCERNING GEOTHERMAL ENERGY
 Senator Frank Church, Idaho

STATUS OF THE GEOTHERMAL INDUSTRY
 Bob Greider, President, Geothermal Resources Council

GEOTHERMAL FINANCING
 Joseph W. Aidlin, General Counsel, Magma Power Company

LEGISLATIVE ASPECTS OF GEOTHERMAL ENERGY
 Dr. John Andelin, Director, House Subcommittee on Advanced Energy Technologies and Energy Conservation, Research, Development and Demonstration

GEOTHERMAL INSTITUTIONAL BARRIERS
 Domenic Falcone, Vice-President, Geothermal Resources International

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PERMITTING PROBLEMS IN CALIFORNIA AND OTHER STATES

David N. Anderson

Geothermal Resources Council

Although the title indicates "other states," I will concentrate primarily on the state of California in this paper as this state is clearly the leader in regard to regulatory experience for geothermal energy. Being in the lead, however, is not necessarily synonymous with having a sound and realistic regulatory program. Other major differences between states, and states and the federal government will be covered elsewhere in this course.

California is the leading geothermal state in the nation. It was the first state to have power on line from a geothermal power plant, the first state to pass a geothermal regulatory law, the first state to develop a comprehensive and very complex environmental protection procedure that affected geothermal development, the first state with heavy county involvement in geothermal development, the lead state for the development of federal geothermal regulations, the first state with a comprehensive geothermal power plant siting law, the state with the largest geothermal potential, and finally, the state with the greatest geothermal permitting muddle.

In order to understand California's regulatory structure, problems and complexities, one must approach the problem from a historical standpoint. Slide one, and later two, show the chronological order of events from the enactment of the first geothermal law in California and, for that matter, in the nation, to the present. I will develop each of these historical steps and its impact on geothermal development.

Geothermal Regulatory Law

The state of California was reluctantly pressed into the enactment of a geothermal regulatory law in 1964, a full four years following the dedication of its first geothermal power plant in 1960 and at least seven years following the first serious drilling for geothermal energy. This first geothermal law, being the prototype, could not be based upon experience as there was none available. Therefore, the law was based upon the most convenient form of energy available, oil and gas. Nevertheless, it has stood the test of time rather well. This was the first in a series of events in what has evolved into one of the most complex regulatory structures anywhere for an alternative energy source.

At this point I would like to say something about the nature of this resource and why it is generally misunderstood. Geothermal energy development does not follow the classic patterns of the development of other sources of energy, the prime difference being that geothermal energy does not lend itself readily to transportation. Therefore it must be developed and utilized in the same area. Essentially, this means that the entire industrial complex must be developed where the resource occurs, whether in the scenic Mayacamas Mountains of northern California, the flat farmland of the Imperial Valley, or the arid valleys of Central Nevada. This fact has been extremely difficult to understand for those who are in the position of developing guidelines and laws for its development, in particular those who do not have a strong technical background in earth sciences and thermodynamics.

Environmental Protection

In 1970, one year after the passage of the National Environmental Protection Act, California enacted the California Environmental Quality Act (CEQA). The act stipulated that an Environmental Impact Report (EIR) would be prepared for any project on state land or for any project in which the state had a substantial monetary investment. CEQA was subsequently challenged in court and the infamous Mammoth Decision was handed down which stipulated that any project requiring a permit must be preceded by an EIR. In essence, even the construction of a carport would necessitate an environmental report.

Recognizing that this situation was unrealistic, the state legislature enacted the Knox Bill which placed the development of environmental guidelines in the hands of the Resources Agency, which subsequently developed the first set of guidelines.

The significant fact here is that our present environmental laws, regulations and guidelines were born of a crisis brought on by a court decision and do not reflect the intent of CEQA in its original form. Recently, CEQA and the guidelines have been amended, making them more realistic. However, gross complexities still remain.

County Involvement

In general, the counties of the western states have little authority. However, California counties differ. They are unique in that their elected

boards of supervisors have the land use authority, i.e., the prerogative to say yes or no to whatever project that is to be undertaken in their county. Some of this authority, however, has been usurped by the enactment of the Warren-Alquist Bill which created the State Energy Commission, which I will cover later.

Because of this special authority, the gross burden of certifying EIR's was suddenly placed upon the shoulders of the counties via the Knox Bill and the related environmental guidelines. This immediately stressed the counties as they were suddenly faced with processing and passing on extremely complex documents that dealt with the development of a resource that they know very little about. Many of the counties, if not all, did not have the technical staff to handle such problems nor the ready means to provide funds to develop such a staff. Needless to say, this one aspect caused an approximate two-year delay in the development of geothermal energy as the counties got their regulatory agencies up to speed. This problem is in some respects still in existence as EIR's must be certified by-and-large by nontechnical persons with limited physical science backgrounds and those that do develop an expertise could be voted out of office during the next election.

County Accomplishments

In the last year and a half, significant advances have been made on the county level. The County of Imperial, with a large geothermal potential, which occurs on flat farmlands and slightly raised arid alluvial terraces, has developed a geothermal element for its master plan. This comprehensive element includes regulations, a set of terms and conditions, and a well-developed policy toward geothermal development. This task was made easier because the entire geothermal province lies within a single county and the environmental conditions are essentially similar throughout.

This significant accomplishment is in direct contrast to The Geysers Geothermal Area in northern California which is overlain by parts of four counties: Napa, Lake, Sonoma and Mendocino. In addition, the resource is in an area of rugged scenic terrain with numerous mountain ridges and valleys containing a semi-developed vacation/retirement community. The rugged terrain has made environmental documentation an extremely difficult task as numerous separate ecosystems exist.

Recently a Joint Powers Agreement has been signed by the four counties and incorporated as a Joint Powers Agency locally referred to as the GRIPS Joint Powers Commission. This commission, when fully staffed, will at last be able to administer the entire region as a single unit. This cooperative effort can now provide for a combined approach to environmental and development problems.

Federal Component

Over 50% of the geothermal potential in California is on federal lands. This aspect caused considerable early grief due to the fact that a federal geothermal law was not enacted until 1970,

ten years after the first geothermal power plant came on line, and the environmental and land leasing procedures took three additional years to develop. Although federal leasing and regulatory procedures have been promulgated, they are still in a state of evolution and are far too time consuming.

One of the most exciting new developments in federal geothermal regulations was the initiation of a cooperative regulatory program. This low-key but extremely valuable program deals with the development of environmental documents, power plant siting and related problems. In California, it has brought together, at least briefly, the federal, state, county and local governments to allow them to share their concerns and develop common procedures. This aspect is extremely important at this time as power plants are being designed for and constructed on federal lands where significant geothermal reservoirs have been recently discovered.

Power Plant Siting (State)

In January of 1975, a new state agency was created by the Warren-Alquist Act--the State Energy Resources Conservation and Development Commission. This commission was given exclusive jurisdiction over geothermal power plant siting. This authority was previously held by the State Public Utilities Commission. Although the commission has been in existence for almost three and a half years, it is only now seriously working toward the passage of guidelines and regulations for the siting of geothermal power plants. Its most significant accomplishment in respect to geothermal development was the declaration that the commission would not get involved in the regulation of geothermal wells. Prior to this pronouncement, there was a potential for duplication of effort with the California Division of Oil and Gas.

One of the more adverse aspects of the law that gave the commission the power plant siting authority was that it did not recognize geothermal energy for what it is. It treated geothermal energy like any other energy source in respect to siting procedures instead of clearly recognizing the fact that it must be utilized in close proximity to its occurrence. These procedures (NOI-AFC), coupled with the CEQA requirements and the land use authority of the counties, have resulted in a very complex permitting situation with no easy answers save relinquishment of some bureaucratic authority. At this time, it takes at least 60 days to process an EIR through the state, as long as one year to get an EIR certified by a county government, and, if all goes well, at least a year to obtain a permit from the state to construct a power plant.

Nuclear Energy

The most recent chapter in this brief history was the denial, first by the Energy Commission and then by the State Legislature, of a chance for San Diego Gas and Electric Company to obtain a permit on its proposed Sun Desert nuclear power plant. This action has placed great pressure on not only California's active geothermal operators, but on the state's regulatory agencies as well. Even though

geothermal energy is not an alternative to nuclear power, if developed, it could have a significant impact on California's energy production in the future.

State Geothermal Potential

California is naturally endowed with an abundance of geothermal energy. It has been conservatively estimated that from 10,000 to 20,000 MW could be developed by the year 2000, and these figures could conceivably be revised upward as more is learned about the resource. Herein lies the irony: in a land of great potential, very little can be accomplished as full-scale development is stifled by complex regulatory procedures, as many as three layers of governmental jurisdiction, inept regulatory agencies that are restricted by the bureaucracy and special interest groups that apply pressure to slow and/or stop projects for a variety of reasons.

Summary

California is passing through a very painful period of evolution in geothermal development; however there are steps that can be taken to hasten the process. The State Energy Commission, saddled by its power plant siting procedures, must strive to shorten the time needed for environmental reporting and certification of power plant sites that must be constructed on or adjacent to the resource. The newly initiated cooperation between federal, state and county regulatory agencies must be continued and intensified. A standard environmental reporting document, usable by the federal, state and county governments, must be developed. Federal, state and county regulators must get out of their offices and into the field to actively work with developers during the formation of drilling and utilization programs. All areas of the regulatory process that cause undue delays should be reviewed, and, if possible, shortened through cooperation or amendments of laws and/or regulatory procedures.

Even in recognition of the progress described above, I believe California is not ready to regulate the development of the resource at a pace that will allow significant development by the year 2000. A highly complex regulatory system exists, one that can cover any conceivable environmental problem. Unfortunately, however, it is based upon the premise that geothermal developers and utilities are guilty until proven innocent. Thus it places an undue time-consuming burden upon the development companies at every step of a project.

This existing regulatory policy is not going to provide the flexibility so critically needed to allow the development of the resource in time to have an early impact in the solution of this nation's balance of payments problems.

Finally, I would like to say that just about everything imaginable in the way of geothermal regulations has been tried or is being tried in California. Therefore, I would like to advise you to inspect very closely what has been done in California prior to setting up a regulatory system elsewhere. There is a lot to be learned from the California experience.

HISTORICAL ORDER OF EVENTS IN THE DEVELOPMENT OF GEOTHERMAL REGULATIONS IN CALIFORNIA

- 1) 1950'S SERIOUS GEOTHERMAL DRILLING GETS UNDER WAY AT THE GEYSERS GEOTHERMAL AREA
- 2) 1960 FIRST GEOTHERMAL POWER PLANT IN U.S. GOES ON LINE AT THE GEYSERS
- 3) 1964 FIRST STATE GEOTHERMAL LAW IS ENACTED
- 4) 1970 CALIFORNIA ENVIRONMENTAL QUALITY ACT PASSED
- 5) 1972 MAMMOTH DECISION HAIDED DOWN
- 6) 1972 KNOX BILL (ABB 889) PASSED
- 7) 1973 FIRST SET OF ENVIRONMENTAL GUIDELINES PROMULGATED BY STATE

HISTORICAL ORDER OF EVENTS IN THE DEVELOPMENT
OF GEOTHERMAL REGULATIONS IN CALIFORNIA (CONT.)

- 8) 1973 OIL EMBARGO
- 9) 1974 REGULATORY LOAD IMPACTS CALIFORNIA COUNTIES
- 10) 1975 STATE ENERGY COMMISSION CREATED BY THE WARREN-ALQUIST ACT
- 11) 1977 COUNTY OF IMPERIAL PASSES COMPREHENSIVE GEOTHERMAL REGULATORY PACKAGE
- 12) 1978 GRIPS COMMISSION BECOMES A LEGAL ENTITY
- 13) 1973 SUN DESERT NUCLEAR PLANT PERMIT DENIED

Geothermal Exploration and Development in the United States: A Tax Analysis Under the Internal Revenue Code

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ABSTRACT

Hundreds of millions of dollars are invested annually by the private sector to explore and develop oil and gas properties in the U.S. The risk of such investments is reduced by the tax benefits of such activities. A significant portion of the cost of drilling and completing the well is deductible from the ordinary income of the investor; and if production is established, it is subject to depletion (that is, part of the income is tax free).

Geothermal exploration and development should receive comparable treatment. The *Reich* and *Rowan* cases, the only two reported cases relating to geothermal exploration, found that the same favorable tax consequences which result from oil and gas exploration applied to geothermal exploration.

The U.S. Internal Revenue Service is still challenging the tax treatment of geothermal exploration. Congress has proposed certain changes in the Internal Revenue Code to benefit the geothermal industry, but additional legislation is necessary to clarify the tax treatment.

Once the tax treatment of geothermal exploration and development has been conclusively determined, substantial funds could be deployed to develop geothermal properties. The tax benefits would reduce the risk of the exploration and would also significantly improve the economics of such an investment.

INTRODUCTION

The tax laws of the U.S. as set forth in the Internal Revenue Code have traditionally provided certain incentives for oil and gas exploration and production. These incentives reduce the risk in exploring for the resource and increase the economic potential of the venture.

In the U.S., private capital has traditionally funded the cost of exploration and development, although there is presently an attempt to have the government actually engage in exploration activities. Proposed legislation was introduced by Senator Stevenson (Democrat-Illinois) in the Senate in March 1975 (S-701) which provides for the creation of the National Energy Supply Corporation which will engage in exploration and development of oil and gas properties. The bill calls for initial funding of \$50 000 000 and in addition would authorize this corporation to raise additional funds from the private sector.

During 1974, 85.2% of the exploratory wells were drilled

by independents, and 78% of the new wildcat discoveries were made by independent producers as opposed to the integrated oil companies (*Oil and Gas Jour.*, 1975). The source of a significant portion of the capital of the independent producers is public and private drilling funds which amass money from investors and engage in exploration.

During 1974, \$329 000 000 was raised by the public drilling funds as compared with \$348 000 000 in 1973. Approximately two-thirds of these funds raised in 1974 were by funds which were predominately exploratory in emphasis (*Resource Programs Institute*, 1975). It is impossible to ascertain the amount of money invested through private drilling funds, but it could very well be comparable to the amount raised by the public drilling funds.

The tax incentives available to the investor in such drilling funds are an integral and decisive factor in the making of the investment. In fact, most of the investments are limited to individuals whose taxable income puts them in an income tax bracket which would permit them to avail themselves of the tax benefits from investing in a drilling fund. A good example of this may be found in the McCulloch Geothermal Energy Program, which restricts the investment to individuals with either a net worth greater than \$200 000 or a net worth of \$50 000 with income, some part of which will be subject to federal income tax of at least 40%.

The geothermal industry, which is in its infancy in the U.S., must be able to tap private capital if it is to grow. In order to obtain such funding, the same tax incentives which are available to oil and gas exploration and production must be available to geothermal exploration and production.

TAX INCENTIVES

The two primary tax incentives involved in oil, gas, and geothermal exploration and production are (1) the intangible drilling deduction, which permits part of the cost of drilling a well to be expensed as opposed to being capitalized; and (2) the percentage depletion which excludes a portion of the production income from taxable income.

Intangible Drilling Deduction

Under Section 263 (c) of the Internal Revenue Code and accompanying regulations (*Treasury Regulation* 1.612-4), certain amounts expended in the drilling and completing of a well can, at the option of the payor, be expensed or deducted. The expenses are for items which do not have

a salvage value and include the following: wages, fuel, repairs, hauling, and supplies incident to and necessary for the drilling of wells and in the preparation of wells for the production of oil and gas (Treasury Regulation 1.612-4a). These items are deductible whether or not the well is productive or dry. An example of the deduction follows.

Example 1: A has income from salary of \$27 000. He invests \$7000 in the drilling and completing of a well which is a commercial well and which costs in the aggregate \$10 000. B invests \$3000 in the well and is the operator. Income is shared 70% to A and 30% to B. Of the \$7000 invested by A, 70% consists of intangibles and 30% tangibles. His taxable income, assuming he elects to expense the intangibles, is as follows:

Taxable income, salary	\$27 000
Intangible drilling deduction (limited to 70% of the intangibles)	4 900
Taxable income	\$22 100

The unique feature of the intangible deduction is that it permits the expensing of items which if found in other assets would have to be capitalized and depreciated.

Percentage Depletion

Under Section 613 of the Internal Revenue Code, 22% of the gross income (but in no event more than 50% of net income) from oil, gas, and geothermal production income may be excluded from taxable income. Under the Tax Reduction Act of 1975, depletion on oil and gas has been eliminated to a great extent with certain enumerated exceptions including domestic production up to 2000 barrels per day. See Section 613A of the Internal Revenue Code.

Because percentage depletion is based on gross income with a 22% factor, the effective exclusion of net income received by the taxpayer is significantly higher. An example of the exclusion follows.

Example 2. A has gross income from production of \$100 000. Royalties, operating expenses, and so on, total \$25 000. Net income from production is therefore \$75 000. Depletion at 22% would be \$22 000. A has taxable income as follows:

Net income from production	\$75 000
Percentage depletion	22 000
Taxable income	\$53 000

The unique feature of percentage depletion is that, unlike depreciation which is limited to the investment less salvage value, there is no limitation on the amount of percentage depletion. It is based on income and not on capital investment. Thus, 100%, 200%, or even 1000% of the investment can be "recouped" through percentage depletion. The Internal Revenue Code also provides for cost depletion in Section 612. This form of depletion resembles more traditional cost amortization. However, since most oil and gas investment have a low cost as a result of the intangible deduction, cost depletion is usually not used.

Clearly, these favored provisions of the tax laws have historically been enacted to encourage oil and gas exploration.

The aim of these provisions has been achieved and has fostered oil and gas exploration and development. These provisions should also apply to geothermal exploration and production, but that conclusion is not clear (Eisenstat, 1973).

GEOTHERMAL TAX CONSEQUENCES

Logically, the same tax consequences which flow from exploring and developing oil and gas properties should also result from exploring and developing geothermal properties. Whatever rationale lies behind the intangible drilling deduction for oil and gas must apply as well to geothermal exploration. Likewise, although possibly not as clearly, the geothermal wells are depletable and percentage depletion should apply.

Until the enactment of the Tax Reduction Act of 1975 (Public Law 94-12) on 29 March 1975, the term "geothermal" never appeared in the Internal Revenue Code. In order for the provisions of the Internal Revenue Code to apply to geothermal resources, the resource would have to be determined to fit within the existing terminology and be deemed a "gas."

There are only two reported cases involving the tax treatment of geothermal exploration and development, and both cases found comparable tax treatment for geothermal as exists for oil and gas. The leading case is *Arthur E. Reich* (Tax Court, 1969a) which was argued before the U.S. Tax Court and, after a favorable decision for the taxpayers, was appealed by the Internal Revenue Service to the Court of Appeals for the Ninth Circuit which agreed with the tax court and affirmed the decision.

In *Reich*, the taxpayers drilled numerous geothermal wells at The Geysers in California and also in other areas. The two issues before the court were (1) whether the intangible drilling and development costs incurred in the drilling of the wells could be expensed by the taxpayers, and (2) whether production income from The Geysers was subject to percentage depletion.

Both issues were decided by both courts in the affirmative. The analysis of the tax court decision turned out the following points:

1. The geothermal resource at The Geysers is not merely the inexhaustible heat of the earth, but rather it is heat and water combined in such a way so as to create steam under pressure. It is the steam which is the source of the power, not merely the heat.
2. Steam is gas for purposes of the percentage depletion provisions of the code. The court looked to the normal use of the word gas and concluded that it would include steam. Nor would the court accept the argument of the government that steam is really water, and therefore not depletable under the provision of the Internal Revenue Code. The term water was used in its ordinary sense said the court, and refers to water in its liquified state, not its gaseous state.
3. Having determined that the steam was a gas, the court next concluded that it was exhaustible and was depleting. The court looked to the fact that the steam was enclosed in a reservoir which was not being recharged. The drawing off of the steam to produce energy depleted the reservoir.

Therefore, since the steam was a "gas" which was

depleting, it was subject to the percentage depletion provisions of the code, and likewise the election to expense intangibles drilled and development costs was also applicable.

The only other reported case, *George D. Rowan* (Tax Court, 1969b), involved the intangible drilling and development deduction. This was a companion case to *Reich*, above, and the tax court concluded that the deduction was valid and in so doing, it relied on *Reich*.

Although the only two reported cases have been decided against the government, the Internal Revenue Service has not acquiesced in the decisions and is continuing to challenge the tax treatment of geothermal exploration and production. In *Charles Thornton* (Docket No. 181-66), a case docketed in the tax court, the Internal Revenue Service was challenging the intangible drilling deduction taken by the taxpayer on geothermal drilling. The case was settled, and therefore no decision was rendered. Another case, *Dunnigan Enterprises, Inc.* (Docket No. 657-74) is presently pending in which the Internal Revenue Service is challenging the intangible drilling deduction taken by the taxpayer on certain drilling activities in New Mexico.

What is needed is to have the Internal Revenue Code amended to specifically provide that the intangible drilling deduction applies to geothermal drilling and that percentage depletion applies to geothermal production.

In the Tax Reduction Act of 1975 the word "geothermal" became part of the Internal Revenue Code for the first time. A new section 613A of the Internal Revenue Code was enacted which provides in part that any geothermal deposit in the U.S. which is determined to be a gas (as defined in the percentage depletion sections) will be depletable at a rate of 22% and not at a lower rate.

The immediate effect of this provision is very limited, for it begs the issue. It does not say that geothermal production will receive a percentage depletion rate of 22%, but merely says that if geothermal is a gas, it will be depletable at a rate of 22%. The underlying problem is still present and will become more pronounced when the resource which is produced and depleted is not steam but rather hot water. It does, however, show a clear intention on the part of Congress and the Executive to encourage geothermal development; for at a time when percentage depletion on hydrocarbon gas is being reduced from 22% and in fact eliminated in many cases, if percentage depletion applies to geothermal production it remains at 22%. A sympathetic position has been manifested but it falls far short.

Nothing concrete has been proposed regarding the intangible drilling deduction. However, in a document published by the Democratic members of the Ways and Means Committee of the House of Representatives, a suggestion is made to expand the definition of the intangible drilling deduction to include intangible costs associated with geothermal wells (U.S. Congress, House Committee on Ways and Means, 1975).

It would appear that sound judgment will prevail and the necessary legislation will be enacted in the near future. The intangible drilling deduction will apply and may very well be expanded to include all geological and geophysical expenditures and not just those necessary for well site selection as is the present case. Furthermore, it is assumed that percentage depletion will also apply to all geothermal production although the rate of depletion may be less than the present 22%.

TAX PLANNING

On the assumption that the tax incentives in the Internal Revenue Code which exist for oil and gas apply to geothermal resources, the effect of tax planning on a geothermal investment should be examined.

As was heretofore noted, the intangible portion of the investment could be deducted from the taxpayer's other income; however, only part of the investment in a geothermal project relates to the intangible items, and thus less than 100% of the investment can be expensed. This is so even if another party pays part of the costs, if income were divided between both parties from the time production commenced [Treasury Regulation 1.612-4(a)(3)]. If, however, a partnership were formed by the operator and the investor, where the investor paid those costs related to the intangible items and the operator paid the tangible or capital items, then the partnership, if the agreement so provided, could elect to allocate the intangible items to the investor and the tangible items to the operator. The investor would then be able to expense his entire investment. This would be proper even though the investor and operator share the production income from inception (Internal Revenue Code). An example of this allocation follows.

Example 3. A has income from salary of \$27 000. He invests \$7000 in the drilling and completing of a well which is commercial. B, the operator, pays the tangible costs of the well amounting to \$3000 and A's \$7000 goes to pay the intangible costs. The agreement between A and B allocates the intangibles to A. Income is shared 70% to A and 30% to B. A's taxable income, if the partnership elects to expense the intangibles, is as follows:

Taxable income, salary	\$27 000
Intangible drilling deduction	7 000
Taxable income	\$20 000

Thus, as appeared in Example 1 when the taxpayer could only expense \$4900, here for the same investment and interest in the well, he can expense \$7000.

Under the law as it exists today, the results are even more interesting if the investor is able to borrow a portion of his investment on a nonrecourse basis. The investment and related deduction is thereby increased through the use of leveraged funds. The following example illustrates the results.

Example 4. The facts are the same as in Example 3 except that instead of putting up the entire \$7000 from his own assets, A invests \$3000 and borrows \$4000 from a third party, on a nonrecourse basis, which is used for the drilling of the well. The results are as follows:

Taxable income, salary	\$27 000
Intangible drilling deduction	7 000
Taxable income	\$20 000

Thus on an out-of-pocket investment of \$3000, the taxpayer has reduced his income by \$7000. Assuming that A is married and filing a joint return, the amount of taxes saved would make his actual and out-of-pocket cash investment in the well a little more than 1/4 of what he invested. (If the well were dry and the loan ultimately foreclosed,

the taxpayer would then have to recognize income.) Needless to say, the higher the tax bracket of the investor, the greater the saving.

The purpose of these examples is not to show how taxes can be saved as such, but how the tax incentives can be used to reduce the risk of the investor. If an investor can effectively reduce his investment, he will be more inclined to make the investment—for his risk has been reduced and the potential return, therefore, increased.

CONCLUSION

The significant geothermal potential of the U.S. is available for development. It can and will be developed with private capital so long as operators act in a responsible fashion and utilize all that is available to them—including the tax laws—to increase the return to investors.

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TAX TREATMENT OF EXPLORING AND DEVELOPING GEOTHERMAL RESOURCES

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"Exploration and development of geothermal resources should be subject to same tax treatment as exploration and development of oil and gas."

Introduction

The exploration and development of properties for geothermal resources is no longer merely a theoretical topic of inconsequential practical significance. The increasing cost of fossil fuel coupled with the growing concern of the environmentalists has provided the setting for what should be a very active period for the development of this source of energy.

According to the often cited Hickel report,¹ geothermal resources in the United States have the capacity of producing 132 million kilowatts by the year 1985. Present total domestic energy production is 350 million kilowatts but it is estimated that power needs double every eight years.² Obviously, to develop this potential capacity will require the expenditure of considerable effort and financial resources and will result in the drilling of thousands of geothermal wells.³

Tax Considerations

As in the case of exploring and developing oil and gas properties, the tax consideration will play an important role. The risks inherent to the develop-

ment of the geothermal resources will be reduced to the investor if he is able to receive the same tax treatment as he would were he drilling for oil and gas. There is absolutely no reason why comparable treatment should not be available to exploring for geothermal resources as exists for exploring for oil and gas. The purpose of this article is to examine the applicability of the provisions of Internal Revenue Code, Sections 263(c) and 611 relating respectively to the election to expense the intangible drilling and development costs and the depletion allowance to geothermal exploration and development.

There are two basic forms of geothermal energy:

- 1) Dry steam.
- 2) Superheated water.

A successful well will pierce a geothermal reservoir and the steam or hot water will be used on the site to create electrical energy. The energy is then transported to the place of consumption. In the case of steam, the resource discovered is used to drive a turbine. In the case of hot water, it is either flashed into steam which is used to drive a turbine or it is passed through a system where the heat from the water is transferred to a volatile substance which, when heated, expands into a gas and in turn drives the turbine.

Prior Cases

In *Arthur E. Reish*, 52 T.C. 700 (1969) *aff'd*, 454 F.2d 1157 (9th Cir.1972), the Tax Court was faced with taxpayers who had drilled numerous geothermal wells both in the area of the Geysers⁴ and also in other areas. There were two issues before the Court; i.e., whether the income from the successful steam wells at the Geysers was subject to percentage depletion and whether the intangible drilling and development costs of the wells drilled could be expensed.

⁴The Geysers is located approximately 75 miles north of San Francisco. It is the only dry steam field presently producing in the United States. Its present capacity exceeds 300,000 kilowatts and projected capacity for 1976 is 600,000 kilowatts. Estimates of the field's potential run from 1 million to 4 million kilowatts.

¹Geothermal Energy, A National Proposal for Geothermal Resources Research, University of Alaska, 1972.

²Gottschalk, "Steam Below Ground Seen Giving Big Boost to U.S. Energy Supply," *Wall Street Journal*, p.1, March 20, 1973. An excellent discussion of the geothermal resources can be found in the January 1972 issue of *Scientific American* in an article written by Joseph Barnea entitled "Geothermal Power" (page 70).

³According to Dr. Geoffrey Robson, Technical adviser in the Energy Section, Resource and Transport Division, United Nations, a minimum of 26,000 geothermal wells would have to be *successfully completed* between now and 1985 to reach the Hickel projected capacity. This assumes an average capacity per producing well of 5,000 kilowatts. From a paper delivered at a *Seminar on Geothermal Energy*, United Nations, Jan. 8, 1973.

The Court found in favor of the taxpayers on both issues. In a rather lengthy and detailed analysis, the Court found as follows:

- 1) The geothermal resource at the Geysers is not merely the inexhaustible heat of the earth, but rather it is heat and water combined in such a way so as to create steam under pressure. It is the steam which is the source of the power, not merely the heat.
- 2) Steam is gas for purposes of the percentage depletion provisions of the Code.⁵ The Court looked to the normal use of the word gas and concluded that it would include steam. Nor would the Court accept the argument of the Government that steam is really water, and therefore not depletable under I.R.C. 613 (b)(7)(A).⁶ The term water was used in its ordinary sense said the Court, and refers to water in its liquified state, not its gaseous state.
- 3) Having determined that the steam was a gas, the Court next concluded that it was exhaustible and was depleting. The Court looked to the fact that the steam was enclosed in a reservoir which was not being recharged. The drawing off of the steam to produce energy depleted the reservoir.

Therefore, since the steam was a "gas" which was depleting, it was subject to the percentage depletion provisions of the Code and likewise the election to expense intangibles drilled and development costs as applicable.

⁵ I.R.C. Sec. 611 provides in pertinent part as follows:

"(a) *General Rule*--In the case of mines, oil and gas wells, other natural deposits and timber, there shall be allowed as a deduction in computing taxable income a reasonable allowance for depletion. . . ."

Sec. 613 (b) relating to percentage depletion rates provides in part as follows:

"(b) *Percentage Depletion Rates*--The mines, wells, and other natural deposits, and the percentages . . . are as follows:

(1) 22 percent

(A) Oil and gas wells.

Thus having concluded steam was a gas, it would be subject to percentage depletion of gas--which today is 22% but for the years involved in *Reich*, *supra*, was 27 1/2%.

⁶ Under I.R.C. 613 (b)(7)(A) water is specifically excluded from the percentage depletion provisions.

⁷ Pursuant to the provisions of I.R.C. §263(c), a taxpayer has the option to deduct as expenses the intangible drilling and development costs of *oil and gas wells*. After it was decided that the wells in question were gas wells, the expensing of intangibles applied.

Despite the feeling of the dissenting judges that the result of the majority was "eccentric," the Ninth circuit affirmed without dissent.

The only other reported case, *George D. Rowan*, 28 T.C.M. 797 (1969), involved the intangible drilling and development deduction. This was a companion case to *Reich*, *supra*, and the Court concluded that the deduction was valid and in so doing, it relied on *Reich*, *supra*.⁸

Treatment Not Certain

An initial reading of the cases would leave the impression that insofar as geothermal exploration and development is concerned, the favorable tax benefits of depletion and expensing intangibles will apply. Unfortunately, this is an erroneous conclusion.

Initially, the case law is truly sparse and insignificant. It is unreasonable to assume that the Internal Revenue Service will capitulate in light of one Ninth Circuit decision and two Tax Court decisions. To the contrary, the fact that the Internal Revenue Service has not published an acquiescence to the reported decisions could very well lead one to conclude that there will be further resistance by the Government to the favorable tax treatment accorded geothermal drilling by the courts up until now.⁹

Furthermore, and more importantly, what will be the treatment of hot water geothermal prospects as distinct from steam prospects?

It is one thing to argue that steam is a gas--it is quite another, however, to argue that hot water in its liquid state is a gas. The taxpayer's position is complicated even further if a heat transfer process is used. The distinction, however, is not one of substance but merely the result of existing statutory language.

In connection with the intangible drilling and development costs, there is no reason why the tax treatment should be any different whether the geothermal power source is steam or hot water; the same techniques for exploration are involved and the expenditures are comparable.

The application of the depletion allowance is somewhat more complicated but, it is submitted, the source of power is being depleted and the allowance should be permitted.

⁸ In *Rowan*, *supra*, the depletion issue was not before the Court as there apparently was no income from the wells in question.

⁹ In *Reich*, *supra*, the Government conceded that gas as used in Sec. 613(b)(1) of the Internal Revenue Code was not limited to hydrocarbonaceous products. The concurring opinion in the case points up this concession and by its statement seems to indicate that this concession may have been without basis. In future tests, the Government may very well argue that gas for purposes of the percentage depletion provisions was intended by Congress to include only gas of a hydrocarbon nature--thereby excluding steam.

The source of power is not the inexhaustible heat of the earth as the Government argued in *Reich, supra*. This heat alone could not, at least under present technology, serve as a source of power. The presence of heat *together with* a readily available carrier, i.e., water, combine to form the geothermal resource. As the carrier is consumed and the source of power utilized, it is depleted.

To permit certain tax treatment where the geothermal resource is steam and to deny comparable treatment when the geothermal resource is superheated water is without basis.¹⁰

Conclusion

It is clear, therefore, that the status of the tax treatment of geothermal exploration and development is anything but settled. The present favorable decisions serve as little more than a hopeful precedent as to favorable tax treatment. What is necessary, however, if this question is truly to be resolved, is immediate and unambiguous legislation providing that the same tax consequences which flow from exploring and developing for oil and gas prospects will also apply to the exploring and developing for geothermal resources.

¹⁰ Another interesting problem relates to disposal wells which are an integral part of any geothermal field. Once the energy has been used to turn the turbine, the remaining water must be disposed of. In light of the environmental problem, the water cannot be spewed out in the vicinity of the well. More likely than not, the water will be reinjected back into the ground and probably into the same formation (thereby avoiding potential subsidence). Query, whether the intangible drilling and development costs of the disposal well will qualify for treatment under 263(c) or whether the costs must be capitalized? See Rev. Rul. 70-414, 1970-2 C.B. 132 in which it is held that salt water disposal wells drilled in connection with an oil well were not related to production but rather to operations and therefore had to be capitalized.

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THE EFFECT OF FEDERAL TAX POLICY
ON GEOTHERMAL DEVELOPMENT

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I. Tax policy has traditionally treated the exploration and development of natural resources in a favorable manner.

A. Rationale

1. Reduction of risk
2. Wasting asset

B. Forms of tax benefit:

1. Ability to expense part of investment
2. Depletion - portion of income received is tax-free.

II. Hard Minerals

- A. I.R.C. Sec. 617 - Taxpayer may elect to currently deduct all exploration expenditures paid or incurred prior to the development stage of the mine.

1. If mine outside of U.S., then there is a dollar limitation.
 2. Recapture of exploration expenditure when mine reaches production stage. Two options:
 - a. Include all exploration expenditures as gross income in year;
 - b. Foregoes depletion otherwise allowable until the amount of depletion otherwise allowed equals prior exploration expenses.
 3. Recapture if property transferred; ordinary income to extent of exploration expenditures.
- B. I.R.C. Sec. 616 - expenses incurred in developing the mine (driving of shafts, tunnels, etc.) making the mineral accessible after a commercial deposit has been established - are deductible in the year incurred.
1. Taxpayer may elect to defer expensing these amounts and deduct them ratably as the mine is produced.
- C. Depletion - Sec. 613 of Code - permits excluding portion of gross income from taxable income.
1. Two forms - cost depletion
percentage depletion - varies depending on mineral. Eg., molybdenum - 22%; gold, silver, copper and iron - 15%.

III. Oil and Gas

- A. Intangible drilling deduction
1. Legislative source

- a. Internal Revenue Code ("Code") §263(c);
Treas. Reg. 1.263(c)(1); 1.612-4;
 - b. Gives the holder of a working or operating interest the option to expense the costs instead of capitalizing costs and recovering through cost depletion. Must make proper election. Treas. Reg. 1.612-4(d).
2. Examples (Treas. Reg. 1.612-4(a) - expenditures incurred in the drilling and completing of a well and preparing the well for production which do not have salvage value, e.g., labor, fuel, repairs, hauling, etc. arising in connection with site preparation, drilling and completing well and preparing well for production.
3. When available -
- a. Pauley v. United States, 63-1 USTC 9280 (S.D. Cal. 1963) - Taxpayer enters into oral agreements in 1947 to drill well which is finalized on last day of year. Money paid in 1947 and some preparatory work done but well not spudded until January 1948. Held - deduction available in 1947.
 - b. Rev. Rul. 71-252, 1971-1 C.B. 146 - Service will follow Pauley decision so long as the payments are required under drilling contract to be made in year prior to drilling.
 - c. Rev. Rul. 71-579, 1971-2 C.B. 225 - disallowed deduction since it was made prior to time required.
4. Tax Preference - Intangibles, to extent deduction in year exceeds what would have been allowable under straight line depreciation is deemed a tax preference subject to minimum tax. I.R.C. Sec. 57(a).
- a. Under Rev. Act of 1977, no preference income (for 1977) from intangibles unless amount deducted exceeded net income from oil and gas.
 - (i) This provision is extended without limitation in pending energy legislation.

5. Depletion

a. Cost depletion

- b. Percentage depletion - permits exclusion from taxable income of % gross income from oil and gas, but depletion can't be more than 50% of taxable income from property nor more than 65% of taxable income (without regard to depletion or carryback). I.R.C. 613A

(i) limited to 2,000 bbls/day or equivalent - declining scale and rate.

6. Recapture - Sale of oil and gas property deemed a sale of a Sec. 1231 asset (capital gain) except to extent of the lower of:

- a. intangible deduction taken less deemed cost depletion; or
- b. realized gain which generates ordinary income tax treatment. I.R.C. Sec. 1254.

IV. Treatment of geothermal expenditures and income under Internal Revenue Code.

Intangible Drilling Deduction

- A. Arthur E. Reich, 52 T.C. 700 (1969) aff'd 454 F. 2d 1157 (9th Cir. 1972). Case involved tax treatment of geothermal drilling at the Geysers and other areas.

Issues

1. Whether income from the successful steam wells at the Geysers was subject to percentage depletion;
2. Whether the option to expense intangible drilling costs applied to the expenses incurred;

Held - Both the depletion allowance and the intangible deduction apply.

Rationale

1. The geothermal resource at the Geysers is not merely the inexhaustible heat of the earth, but rather it is heat and water com-

bined in such a way so as to create steam under pressure. It is the steam which is the source of the power, not merely the heat.

2. Steam is gas for purposes of the percentage depletion provisions of the Code. The Court looked to the normal use of the word "gas" and concluded that it would include steam. Nor would the Court accept the argument of the Government that steam is really water and therefore not depletable under Code §613 (b)(7)(A). The term "water" was used in its ordinary sense, said the Court, and refers to water in its liquified state, not its gaseous state.
 3. The steam was exhaustible and was depleting. The Court looked to the fact that the steam was enclosed in a reservoir which was not being recharged. The drawing off of the steam to produce energy depleted the reservoir.
- B. George D. Rowan, 28 TCM 797 (1969) - a companion case to Reich. Held - option to expense intangible drilling costs applies to geothermal drilling.
- C. The Internal Revenue Service refuses to follow the decisions in Reich and Rowan and is challenging both the applicability of the depletion allowance and the option to expense intangibles.
1. Charles Thornton - (Tax Court Docket No. 181-66): intangibles - (settled);
 2. Dunnigan Enterprises, Inc. - (Tax Court Docket No. 657-74): intangibles - (settled);

Depletion

- D. Tax Reduction Act of 1975 - Sec. 613A of the Code:
1. Eliminated percentage depletion of foreign oil and gas production and domestic production

(with certain exemptions.)

2. "(b) Exemption for Certain Domestic Gas Wells. -

(1) In General - The allowance for depletion under Section 611 shall be computed in accordance with Section 613 with respect to -

* * *

(C) Any geothermal deposit in the United States or in a possession of the United States which is determined to be a gas well within the meaning of Section 613(b)(1)(A),

and 22 percent shall be deemed to be specified in subsection (b) of Section 613 for purposes of subsection (a) of that section.

3. If geothermal deemed to be a gas then entitled to depletion at 22%.

E. Drilling Ventures (Shelters)

1. Used to finance exploration and development activities. Provides operator with control, permits passive investors to participate in a venture with a flowthrough of tax consequences.
2. Vehicles: joint venture (general partnership), limited partnership;
3. Limited Partnership - General Partner (operator), limited partners (investors).
 - a. Limited liability: assuming limited partnership is formed in accordance with local statutes (Uniform Limited Partnership Act) then investor limited partners' liability will be "limited" to the amount of their investment in the partnership.
 - b. Allocation of tangibles and intangibles;

- (i) §704(a) of the Code; Treas. Reg. 1.704-1(a); 1.704-1(b)(2) Example (5).
- (ii) Rev. Rul. 63-139, 1968-1 C.B. 311.
- (iii) It is possible to provide in the partnership agreement that the limited partners who put up capital for the venture receive all of the intangible deductions and the general partner pay for and receive all of the tangible deductions thereby maximizing the write-off to the limited partners.
- (iv) Were the partnership vehicle not used, then the limited partners deductible share would be limited to their interest in the well and based on the sharing of production proceeds from commencement of production. Treas. Reg. 1.612-4(a)(3) (e.g., if operator shares in profits and losses 50-50 with investors, then investors can only deduct 50% of intangibles.)

4. Presidential 1978 Tax Reform Proposal - limit partnership status to 15 or fewer limited partners.

F. Proposed Changes in Tax Treatment

1. Both the House of Representatives (H.R.84444) and the U.S. Senate (S.1961) passed energy bills presently before the House - Senate Conference Committee. The pertinent geothermal provisions are as follows:

	<u>House</u>	<u>Senate</u>
Intangibles	Both bills codify the applicability of the intangible drilling deductions to geothermal wells.	
Depletion	10% allowance based on adjusted cost basis.	Percentage depletion of 22%-same as oil and gas.
Energy tax credit	10% credit on equipment used in production of geothermal power-not turbine.	10% credit includes generating equipment (turbine).

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GEOTHERMAL RESOURCE DEVELOPMENT IN ISRAEL

GEOTHERMAL RESOURCE DEVELOPMENT IN ISRAEL

SAMUEL M. EISENSTAT*

The State of Israel is about to celebrate its 30th birthday. Its existence has been less than secure having been born into battle and having to exist through four wars and constant terrorist attacks to reach this day.

It is no wonder, therefore, that geothermal resource development has not received priority treatment. In fact, energy development in general has to date been neglected. Approximately 260 wells have been drilled for oil and gas, of which approximately one-third have been development wells.

This situation has begun to change and with the recent election of the Likud government, which will encourage investment from the private sector with less government involvement, a dramatic and exhausting program of resource development will be undertaken during the next three years.

One particular indication of this new orientation is the establishment for the first time of a Ministry of Energy and Infrastructure. Thus, like his counterpart in the United States, a member of the Israeli cabinet will concern himself with energy matters.

Israel's first Minister of Energy is Yitzhak Modai, an imaginative, forceful and articulate engineer with a degree in law who is determined to carry out an exhaustive program of exploration to evaluate the country's resources. Foreign capital investments are encouraged under very favorable terms providing opportunities which should be closely examined*; and, in fact, certain foreign companies have already commenced oil and gas exploration activities in Israel and others are about to begin operations. It is anti-

cipated that the next few years will witness some significant discoveries in this "untested" area.

Geothermal resource development has been neglected even more than oil and gas development. This too is expected to change in the future and the purpose of this article is to present a brief overview of what has taken place to date and what may occur in the future.

Numerous groups and agencies in Israel have been involved in geothermal development. The prime coordinating body has been the Task Force for Geothermal Energy under the Office of the Chief Scientist, Ministry of Commerce. This group has served as a clearing house and monitor of geothermal activities and has been functioning under the guidance of Dr. Michael Bayit, Coordinator for Earth Science Research, Office of the Chief Scientist. The following is an outline of the various organizations involved:

To what extent the new Ministry of Energy will be involved in geothermal development remains to be seen.

EXPLORATION

In April of 1976, a detailed five year plan for geothermal exploration was prepared. This plan called for various phases of exploration to examine the geothermal potential of Israel.

The first phase of this program called for geophysical activities in certain areas under the auspices of the Institute of Petroleum Research and Geophysics ("Geophysical Institute"). The focus of this work was in the areas of (1) Lake Kinneret and Emeq Israel in the northern part of Israel; (2) the Dead Sea area and the Negev in the south of Israel.

According to Amos Levanon of the Geophysical Institute, some interesting anomalies were uncovered south of Lake Kinneret, in the Emeq Israel and around the Dead Sea which warrant

**The author wishes to express his gratitude to Dr. Joseph Barnea for his advice and guidance in writing this article. After reading a draft of this paper, Dr. Barnea felt it advisable to express his own views on the geothermal potential of Israel (they appear at the conclusion of the article) which differ somewhat from the views cited in this article. The author welcomes Dr. Barnea's views and trusts that their articulation will have a positive effect on geothermal development in Israel.*

**Information regarding oil and gas investments can be obtained from Mr. Israel Lior, National Oil Co. of Israel, P.O. Box 20115, Tel Aviv, Israel.*

further investigation. Levanon hopes to be able to drill 100 shallow wells to 100 meters during 1978 and to conduct mercury studies to further define and evaluate these anomalies. If the results warrant it, a deep well or wells would then be drilled to test the potential.

Two recent studies are of particular interest.

In March of 1977, at the request of the Office of the Chief Scientist of the Israel Ministry of Commerce, L.J. Patrick Muffler of the U.S. Geological Survey spent time in Israel reviewing the geothermal potential. He concluded that there was no present evidence of either intermediate or high temperature geothermal reservoirs in Israel at depths of less than three kilometers. However, low temperature (less than 90°C) systems seem common at drillable and reasonable depths especially adjacent to the Dead Sea Rift. In addition to developing the low temperature potential, Dr. Muffler did suggest further examination of certain areas to understand better the

geothermal system and to ascertain for certain whether hotter reservoirs exist.

In April and May of 1977, George V. Keller of the Department of Geophysics, Colorado School of Mines, visited with the Geophysical Institute to review their activities.

He concluded that geophysical and geological evidence collected to date is inconclusive and incomplete. The areas of low resistivity along the Jordan Valley and possibly in Emeq Israel are encouraging but by no means conclusive. Additional exploration is warranted in the Dead Sea—Jordan Valley—Sea of Galilee and along Emeq Israel.

Thus it would appear that to date no specific defined reservoir exists which appears capable of commercial energy generation. However, there are a number of interesting areas which should and will be further investigated which could develop into promising geothermal prospects for energy generation.

NON-ELECTRICAL USES OF GEOHERMAL RESOURCES

Considerable research has been done with low temperature water in Israel and the results have been most exciting and promising.

Two projects, in particular, are worthy of note; i.e., use of low temperature geothermal water (1) for crop growth and development, and (2) for shrimp farming.

AGRICULTURE

The Research & Development Authority of Ben Gurion University at Beersheba in the Negev has been working with low temperature brackish water for crop development.

A team of five individuals (D. Pasternak, E. Rapoport, Y. De Malach, M. Twersky and I. Borovic) including agronomists, plant physiologists and a consulting engineer, have developed a technique for using the brackish water (2,300 ppm total dissolved solids) at a temperature of 40-42°C to grow crops including cotton, cucumbers, tomatoes and melons.

The Negev is a desert area which extends through the southern part of Israel. Rainfall averages less than four inches per year and the soil for the most part is sandy loess to loess. One can drive for mile after mile through nothing but sand and dunes.

The desert sits on shallow brackish water aquifers. It has been estimated that between 50-70 million cubic meters per year can be efficiently pumped from these aquifers.**

Were this source of water to be tapped and effectively used, it could turn a part of the Negev into productive land. It is toward this goal that the team at Ben Gurion University has turned its efforts with very exciting initial results.

The technology involves the use of the geothermal waters to heat the soil of the plants and also to heat the greenhouse in which the plants grow.

The first phase involved the heating of the soil of the plants and took place in the Negev at a Kibbutz near Mashabe Sadeh. It was tested in a controlled experiment where the same crop was grown under two sets of conditions: one without geothermal heating of the soil while the other group had a plastic tube run approximately 30 cm below the surface at the roots of the plants through which 40°C geothermal brackish water was pumped from a nearby well.

The result showed that the crop yield with geothermal brackish water both from the point of size of overall crop yield and size of individual fruit or vegetable was comparable or better than

***There are other estimates which place the potential significantly higher.*

Figure C—View of Soil Heating System
—Courtesy of the Research & Development
Authority of Ben Gurion University

Figure A—Rock Melon nonheated growing in white plastic approximately 1½ months after sowing.

Figure B—Rock Melon Heated with Geothermal Water growing in white plastic approximately 1½ months after sowing.

—Courtesy of the Research & Development
Authority of Ben Gurion University

that of fresh water and further that the crop treated with geothermal water matured faster than those grown without the heated water.

The second phase involved the use of the geothermal water to heat greenhouses.

A double-tiered roof was placed on the greenhouse and the geothermal water which had been circulated at the roots of the plants was pumped between the two layers of the roof after it was passed through the soil. At night when the temperature dropped, the geothermal waters were used to heat the greenhouse. During the day, the same system on the roof is flushed with cool water from a nearby pool to keep the temperature down.

Thus the use of the greenhouse and two-phased geothermal heating provides a setting for year-round crop development in a very efficient manner and at a fuel saving estimated at \$1,000 per dunam (1/4 acre) per year.†

The limited experiment will be expanded this year to cover 1/2 acre and if successful, will be expanded at a rapid rate in the years to come.

With the estimate that 100 cubic meters of

†A closed greenhouse (which is possible if temperature is controlled) permits artificial application of CO₂ leading to higher and better quality yields.

water can properly heat 10 acres, the potential is certainly exciting and very commercial. Israel's involvement in the European Common Market would enable it to export various crops grown in the barren desert during periods when they are otherwise unavailable in Europe.

FISH FARMING

At the other end of Israel, geothermal springs have been successfully used by a molecular physiologist, Dr. Dan Cohen, of the Genetics Department of Hebrew University, to breed shrimp.

The program was initiated in 1974. During the past year 100,000 shrimp were successfully bred and test marketed with outstanding success. Operations are presently being commenced to breed 1 million shrimp during the coming year with future plans calling for a materially expanded program using the existing capability of the country and ultimately expanding it.

"*Macrobracium rosenbergii*" (giant freshwater shrimp) was selected because it yields itself to cultivation, it recapitulates early and is an excellent source of protein with strong marked appeal. In addition, the shrimp grow on the bottom of ponds and thrive off waste and therefore was

Figure 1—Six month old shrimp grown in geothermal project

Figure 2—Stocking shrimp in 29°C geothermal pond (Dr. Dan Cohen in Hat)

most compatible with the multiple utilization of the ponds permitting the raising of other fish in the same pond. (It is ironic that the shrimp is a forbidden food under the dietary laws observed by members of the Jewish faith. The shrimp grown, therefore, will be exported from Israel and not consumed within the country.)

The program was commenced by bringing to Israel specimens from Hawaii and Thailand and having them adapt to Israeli conditions. Dr. Cohen and his associates had to have the shrimp complete their life cycle and to hatch them in large quantities.

The basic system involves two stages. The larvae are grown in a hatchery and at a suitable point are transferred to ponds for growth and production.

A constant temperature of 25°C-29°C is necessary for the cultivation of the shrimp which posed an initial problem in Israel for this temperature was not present during four to five months of the year.

Enter geothermal resources. Southeast of Lake Tiberias there is a complex of geothermal springs yielding 1,000 to 3,000 cubic meters of water per hour. One in particular, "Ein Sahina," yields fresh water with a constant year-round temperature of 29°C—ideal for shrimp breeding. In addition, another spring nearby yields water at 51° which water cannot be used to initially breed the shrimp because of its high dissolved salt content but the heat of the water can and is being used to insure the constant temperature of the breeding pond.

Present plans call for the construction of a central larviculture and nursery which will produce the prawn fingerlings during the winter and until the ponds located all over the country are of sufficient temperature to support growth. It is projected by Dr. Cohen that the prawns will be kept at the geothermal site for 1 to 3 months and will require another 5 to 6 months of growth in the polyculture ponds to achieve market size.

The fact that the prawn can also grow in brack-

Figure 3—Over view of fish ponds comprising 150 Dunam at geothermal site

Courtesy of Dr. Dan Cohen of Hebrew University.

ish water makes the potential even greater. In fact, one possibility presently contemplated by Dan Cohen is to use the water from Mashabe Sadeh to first heat the crops in the greenhouses and then to be pumped into ponds to grow shrimp since the temperature of the water after being used in the greenhouse is 29°C which is ideal for shrimp-breeding.

CONCLUSION

The geothermal potential of Israel is indeed most exciting and has significant potential. Non-electrical uses of the resource have taken priority to date. The next few years should determine the geothermal potential of the country from an overall point of view and it is conceivable that multiple use of the resource both as an energy source and as a medium for nonelectrical uses will develop.

One thing is certain—this dynamic little country will maximize its geothermal potential for its own good and for the good of all mankind.

Additional information can be obtained from the following:

Michael Bayit
Earth Science Department
Office of the Chief Scientist
Ministry of Commerce
Rechov Ben Yehudah 3
Jerusalem, Israel

Amos Levanon
The Institute for Petroleum Research
& Geophysics
P.O. Box 1717
Holon, Israel

Dan Cohen
Ass't. Professor, Genetics Department
Hebrew University
Jerusalem, Israel

Ilan Borovic
Research & Development Authority
Ben Gurion University
Beersheba, Israel

Figure 5—51°C Spring

Spring	Coordinates	Temperature (°C)*	Description
A	2126/2320	51—53	steaming and bubbling spring, strong sulfur smell
B	2124/2322	41—42	warm spring complex, issuing in a bath and overflowing into an open pool. Sulfur smell
C	2128/2321	37	warm spring complex, issuing in a bath house. Sulfur smell
D	2130/2327	29	fresh water spring. Strong and large flow into canals that cross the bathing installation area

*Temperatures were measured on 20.7.67, 31.1.68 and 20.10.70, and remained practically unchanged.

*Figure 6—Data on Israeli Geothermal Springs.
Courtesy of Dr. Dan Cohen of Hebrew University.*

COMMENTS BY DR. JOSEPH BARNEA

My friend Sandy Eisenstat has shown me his article and Dr. Muffler's report evaluating Israel's geothermal potential, and I would like to comment on Dr. Muffler's report.

Dr. Muffler is a competent, scientific geothermal geologist, but he spent only six days in Israel. He carefully points out that his judgments are based on the data he has seen. He, however, failed to realize that (a) Israel has no experts in geothermal energy nor has it geothermal enthusiasts, (geologists or entrepreneurs), who, in most countries pioneered geothermal energy, and (b) his stay in Israel was too short to make sure that he saw all data relevant to geothermal energy.

Among the data he missed is the 130°C geothermal gradient per kilometer at the Tamar Water well, in the Jordan Valley quoted by Keller, and the warm water area at Mashabe Sadeh,* quoted in Eisenstat's article and many other data.

The first obvious geothermal area is the Rift Valley. Muffler writes: "Low temperature geothermal systems appear to be common at drillable depth throughout much of Israel, particularly adjacent to the Dead Sea Rift. These warm fluids are apparently due to deep circulation of groundwater in a region of normal geothermal gradient."

I disagree with this evaluation because (a) it would imply that the Rift Valley shared by Israel and Jordan is not part of the rift system starting in East Africa and continuing through the *Awash Valley to the Red Sea* (Red Sea hot brines) to Israel, (b) his evaluation neglects data available on the Jordan side of the Rift Valley and their favorable evaluation by such experienced geothermal experts as Mr. McNitt, and (c) the Rift Valley is full of water flowing down from the mountain ranges of both sides and the North, thus a very considerable cooling and mixing of any hot water or steam coming from below must occur. Consequently, drilling through the water mixing zone might reach much hotter water.

In many respects, the Rift Valley is similar to the Imperial Valley. Until the end of 1957 when a petroleum wildcatter hit a hot geothermal brine at the Salton Sea, no one realized that the Imperial Valley is a geothermal province, because of the absence of any striking surface indications.

At the end of his short report and after his recommendations, Dr. Muffler indicates some uneasiness concerning his evaluation of the Rift Valley; he writes: "The rift shows structural analogies to the northern Gulf of California, and

both features may be 'leaky transform faults.' If so, the Dead Sea Rift seems to have undergone insufficient oblique spreading to produce igneous rocks and geothermal systems as in the Gulf of California. The whole question is an outstanding, long-term research problem that deserves continuing attention." I do not believe that it is a research problem but a challenging exploration task.

Dr. Muffler has also not discussed the potential of geopressure zones in Israel, presumably because no one told him of that possibility. Finally, Dr. Muffler has not commented on the reliability of the data he saw, nor described the methods applied in data collection and interpretation.

He has, however, recommended that "a concerted effort should be made to collate, evaluate and interpret the abundant thermal, chemical, and resistivity data already in Israel." He has also drawn attention to the many opportunities existing for the utilization of low-temperature geothermal resources in Israel. He has, therefore, written a useful report. 17 October 1977

**The temperature of the warm water of the brackish underground aquifers were first noted by me in connection with a United Nations Electrodialysis project in that area. I was told that a magnetic anomaly was found over this area which might indicate a magma chamber at-depth. But these and many other indications were never followed up.*

Samuel M. Eisenstat is a practicing lawyer in New York City with the firm of Eisenstat & Gottesman, P.C. He has written numerous articles on the tax treatment of geothermal exploration and has lectured at various seminars on the subject.

He is actively engaged in oil and gas exploration in the United States, Canada and Israel where he has just returned from an extended trip and obtained the material for this article. In addition, he is President of Geothermal Exploration Co., Inc., which holds geothermal leases in Utah and will be commencing exploration there shortly.

Sup

Summary of Section I

Present Status of Resources Development

L. J. PATRICK MUFFLER

U.S. Geological Survey, Menlo Park, California, USA

INTRODUCTION

The first two years after the 1970 United Nations geothermal symposium in Pisa, Italy, saw a slow but steady growth in geothermal development and exploration, mainly based on decisions made in the late 1960s. This period was highlighted by the increase of electrical capacity at The Geysers, California, USA, from 78 megawatts electrical (MWe) in 1970 to 237 MWe by the end of 1972 (Worthington, 1975). This period also saw the beginning of construction at Cerro Prieto, Mexico, and the continued development of space-heating and agricultural systems in Iceland, the USSR, and Hungary. Geothermal exploration increased steadily from 1970 to 1972, with substantial efforts in Italy, Japan, Iceland, USA, Indonesia, the Philippines, and Mexico. In addition, the continuing efforts of the United Nations supported exploration in Chile, El Salvador, Ethiopia, Kenya, Nicaragua, and Turkey. Also during these years, an increasing popular and governmental awareness developed of the nature and possible importance of geothermal energy.

The slow, steady increase in geothermal activity accelerated abruptly in 1973 when imported oil became difficult for many countries to obtain and petroleum prices rose sharply. This price rise, combined with a belated awakening to the fact that oil and gas resources are indeed limited, led private industry and governments to pay much more attention to alternate energy sources, particularly in those countries dependent on imported oil. This attention has been manifested in accelerated exploration, increased drilling, and marked expansion of geothermal research and development.

The status of geothermal electricity generation in 1975 is shown in Table 1. Geothermal exploration efforts are not listed in Table 1 but are outlined below. Also, Table 1 does not reflect the continuing growth in the use of geothermal energy for space-heating and agricultural purposes.

ITALY

The status of geothermal development in Italy is covered in admirable detail by Ceron, Di Mario, and Leardini (p. 59). As of March 1975, the total installed geothermal electrical capacity in Italy was 417.6 MWe, of which 380.6 was in the Larderello region, 15 at Travale, and 22 in the Monte Amiata region (Fig. 1). Net geothermal power production

in 1974 amounted to 2.29×10^9 kWh, which represents an average utilization of 64% of total installed capacity.

Although 20 productive new wells were drilled in the Larderello region between December 1969 and March 1975, the production of old wells decreased notably, resulting in a net decrease of 9.1% in steam production. In part this decrease was offset by replacing atmospheric turbines with more efficient condensing turbines.

In the Monte Amiata region, steam production from December 1969 to March 1975 decreased 28%, in part due to rapid inflow of recharge water into the Bagnore field.

Extensive exploration in the Travale region since 1969 has extended the old field (Cataldi et al., 1970) northeast where five wells have been drilled and a sixth was in progress in May 1975 (Burgassi et al., p. 1571). Although all of the wells encountered high temperatures (up to 270°C), only three are productive (T22, R4, and probably C1). Dry steam from well T22 has been used since July 1973 to supply a 15-MWe power plant (Burgassi et al., p. 1571).

Extensive exploration is being carried out throughout the pre-Apennine belt by the Ente Nazionale per l'Energia Elettrica (ENEL) in cooperation with the Consiglio Nazionale Ricerche (CNR). In the Monte Sabatini region (Baldi et al., p. 871), a well drilled at Cesano in January 1975 discovered a geothermal reservoir that produced a brine of 356 000 ppm total dissolved solids, primarily SO_4^- , Na^+ , and K^+ (Calamai et al., p. 305). Temperatures at depth are at least 210°C and may exceed 300°C. At Torre Alfina in the Monte Volsini region, a hot-water geothermal system at a production temperature of 120 to 140°C has been discovered (Ceron, Di Mario, and Leardini, p. 59; Cataldi and Rendina, 1973); and in the Monte Cimini region a hot-water system at 60 to 80°C reservoir temperature was discovered (Ceron, Di Mario, and Leardini, p. 59). Exploration is being carried out in the Naples region (Cameli et al., p. 315; Baldi, Ferrara, and Panichi, p. 687), near Siena (Fancelli, Nuti, and Noto, Abstract III-23)¹, and in the Roccastrada, Colli Albani, Roccamonfina, and Vulture areas (Ceron, Di Mario, and Leardini, p. 59). According to Barelli, Calamai, and Cataldi (Abstract I-3), the electrical energy potential of the pre-Apennine belt is 130 to 660 MW-centuries.

¹The Abstract number refers to the numbering in the abstract volume for this symposium.

Table 1. World geothermal generating capacity in megawatts (electrical), 1975.

Country	Field	Operating	Under construction
United States	The Geysers	502	216
Italy	Larderello	380.6	
	Travale	15	
	Monte Amiata	22	
New Zealand	Wairakei	192	
	Kawerau	10	
Japan	Matsukawa	22	
	Otake	13	
	Onuma	10	
	Onikobe	25	
	Hatchobaru		50
	Takinoue		50
Mexico	Pathé	3.5	
	Cerro Prieto	75	
El Salvador	Ahuachapán		90
Iceland	Námafjall	2.5	
	Krafla		55
Philippines	Tiwi		100
Soviet Union	Pauzhetsk	5	
	Paratunka	0.7	
Turkey	Kizildere	0.5	2.5
Total		1278.8	563.5

USA

The status of geothermal development in the USA is summarized by Koenig, Anderson, and Hutter (p. 139). Geothermal electrical capacity at The Geysers, California, has increased rapidly from 78 MWe in 1970 to 502 MWe in 1975. Additions of approximately 100 MWe per year are planned through 1980, although it appears that the installation timetable will be delayed by protracted regulatory and environmental hearings.

Although no other geothermal areas in the USA are currently producing electricity, the past five years have seen greatly accelerated exploration by private industry, in great part stimulated by the increased costs of fossil fuel. In addition, the Geothermal Steam Act of 1970 finally was implemented in 1973, and the vast areas of geothermal potential on federal government land are gradually being made available for exploration by private industry. Signifi-

cant geothermal discoveries have been made at the Valles Caldera, New Mexico; Roosevelt Hot Springs, Utah; Carson Desert of western Nevada; and the Heber, East Mesa, and Brawley areas of the Imperial Valley in southern California (Fig. 2). Step-out drilling has extended both The Geysers and the Salton Sea geothermal fields, and there has been continued exploratory drilling at Beowawe, Nevada, and Surprise Valley, California. Exploratory drilling, however, met with little success in California at Honey Lake, Sierra Valley, and Mono Lake; in Oregon at La Grande and Lakeview; in Nevada at Tipton; in Idaho at Mountain Home; in Utah at Brigham City; and in Arizona at Casa Grande and Chandler (Koenig, Anderson, and Hutter, p. 139). With the exception of the Casa Grande area (Dellechiaie, p. 339), virtually none of the data from these drilling ventures have been released by the private companies involved.

The past five years have also seen an upsurge in geothermal research and development financed by the federal government. The Energy Research and Development Administration (ERDA), created in January 1975 from the old Atomic Energy Commission, is funding research and development in all aspects of the geothermal cycle. Major efforts include the development of technology to extract heat from hot dry rock (Smith et al., p. 1781), investigation of new conversion technologies (particularly binary cycles and impulse turbines), development of new drilling technologies (for example, Altseimer, p. 1453), and investigation of representative geothermal areas, including the Raft River area in Idaho, the area just west of the Valles Caldera in New Mexico (Smith et al., p. 1781), several sites in western Nevada (Beyer, Morrison, and Dey, p. 889), and the Coso Mountains of California. The National Science Foundation (NSF) also carried out a substantial geothermal program in 1973 and 1974, including site investigations at Marysville, Montana (Blackwell and Morgan, p. 895), at Kilauea Volcano, Hawaii (Zablocki et al., 1974; Furumoto, p. 993), and at Roosevelt Hot Springs, Utah (Ward, Rijo, and Petrick, Abstract III-90; Whelan, Nash, and Petersen, Abstract II-55). Since 1971 the U.S. Geological Survey (USGS) has had an extensive program of investigations aimed at the nature and distribution of geothermal resources, including major investigations at Long Valley (February 1976, *Journal of Geophysical Research*). The Geysers (McLaughlin and Stanley, p. 475; Hearn, Donnelly, and Goff, p. 423; Donnelly and Hearn, Abstract III-18; Isherwood, p. 1065), the Coso Mountains, California (Duffield, Abstract II-12; Duffield, 1975; Lanphere, Dalrymple, and Smith, 1975), southeastern Oregon (MacLeod, Walker, and McKee p. 465), Raft River, Idaho (Williams et al., p. 1273), and Yellowstone (White et al., 1975; Eaton et al., 1975; Fournier, White, and Truesdell, p. 731). In addition, the USGS recently produced a substantial report evaluating the geothermal resources of the United States (White and Williams, 1975). The Bureau of Reclamation has also carried out geothermal research, primarily aimed at self-desalination of geothermal fluids from the East Mesa area, southern California (Mathias, p. 1741; Fernelius, p. 2201; Swanberg, p. 1217).

The geopressed resources of the Gulf Coast are attracting increasing attention (Jones, p. 429; Wilson, Shepherd, and Kaufman, p. 1865). These deposits have a huge energy potential (Papadopoulos et al., 1975) consisting both of thermal energy and dissolved methane.

Geothermal heat is being used directly for space heating on an increasing but still small scale in the United States.

Figure 1. Map showing geothermal regions of Italy (after Ceron, Di Mario, and Leardini, p. 59).

Figure 2. Map showing locations of geothermal drilling in the United States and northern Mexico.

primarily at Klamath Falls, Oregon (Lund, Culver, and Svanevik, p. 2147), and at Boise, Idaho (Kunze et al., p. 2141). Geothermal waters are also used for greenhouse heating at scattered localities in the western United States.

Development of the extensive geothermal resources of the USA continues to be plagued by institutional problems (Koenig, Anderson, Huttner, p. 139; Aidlin, p. 2353; Eisenstat, p. 2369; Finn, p. 2295; Schlaugh and Worcester, 1974; Olson and Dolan, 1975). These problems include ownership considerations (surface vs subsurface), leasing delays, uncertainties about tax status (with respect to depletion allowance and intangible drilling deductions), legal definition of geothermal resources (mineral, gas, water, or *sui generis*),

overlapping and multiple regulatory bodies, and environmental litigation.

JAPAN

Geothermal exploration and development in Japan experienced rapid acceleration since 1970, primarily in response to the 1973 energy crisis. The dry-steam system at Matsukawa (Fig. 3) and the hot-water system at Otake continue to produce electricity at 22 MWe and 13 MWe respectively, and there are plans to expand Matsukawa to 90 MWe (Mori, p. 183). A 10-MWe installation has been operating at the Onuma hot-water system since 1973 (UN, Centre for Natural

Figure 3. Map showing major geothermal areas of Japan.

Resources, Energy, & Transport, p. 3), and a 25-MWe installation has been put into service at the Onikobe caldera (Yamada, p. 665). Drilling is in progress at Takinoue (7 km southwest of Matsukawa) where a 50-MWe plant is to be completed by 1977 (Mori, p. 183). A geothermal power plant of 50-MWe capacity is also under construction at Hatchobaru (Yamasaki and Hayashi, p. 673; Aikawa and Soda, p. 1881). Intensive exploration is being carried out on northern Honshu and on Hokkaido (Mori, p. 183). If these exploration ventures are successful, the geothermal electrical capacity of Japan could well exceed 1000 MWe by 1982.

In addition to the exploration and development efforts described above, the government of Japan has instigated an aggressive program of geothermal investigations, aimed at establishing perhaps 50 000 MWe of geothermal generating capacity by the year 2000 (Mori, p. 183). This program is part of the "Sunshine Project" (Sakakura, p. 2431) and includes extensive regional evaluation by the Japanese Geological Survey (for example, Baba, p. 865; Sumi and Takashima, p. 625).

ICELAND

Geothermal development in Iceland during the past five years is highlighted by the development of the Krafla field (Fig. 4). Production wells have been drilled, and a 55-MWe power station is to be completed in 1976 (Pálmason, Ragnars, and Zoëga, p. 213). In addition, the Svartsengi area (235°C reservoir temperature) has been drilled to 1.7-km depth and will be used via a heat exchanger to provide 80 megawatts thermal (MWt; 1 MWt = 10^6 joule/sec) for house-heating in communities on the western part of the Reykjanes peninsula and at the Keflavík international airport (Arnórsson-

son et al., p. 2077). The Krísuvík area has also been explored (Arnórsson et al., p. 853) and could supply perhaps 500 MWt for 100 years.

Geothermal energy in Iceland continues to be used primarily for space heating, but with some electrical generation and process use. Warm water from the Reykjavík and Reykir thermal areas supplies 340 MWt and meets nearly all the heating requirements of Reykjavík and neighboring towns (Tómasson, Fridleifsson, and Stefánsson, p. 643; Arnórsson et al., p. 853; Thorsteinsson, p. 2173). New district heating systems using water from which steam has been flashed were installed at Námafjall (2 MWt in 1971) and Hveragerdi (8 MWt in 1973; Thórhallsson et al., p. 1445). These geothermal systems are at temperatures of 200 and 215°C respectively, and the district heating systems are consequently plagued with silica-scaling problems. At Námafjall, the geothermal steam is used to dry diatomite and to generate 2.5 MWe of electricity. A plant for drying seaweed is being constructed at Reykhólar (Björnsson and Grönvold, Abstract II-3; Ludvíksson, Abstract IX-7), and studies are being carried out with a view to producing NaCl and MgCl from the saline Reykjanes geothermal area (Lindal, p. 2223; Björnsson, Arnórsson, and Tómasson, 1972).

Owing to its ideal location on the mid-Atlantic Ridge, Iceland has a very large geothermal potential, both for electricity generation and for space heating. Bodvarsson (p. 33) estimates that the high-temperature areas of Iceland have a production potential of 3200 MWt for 50 years, and that the heat content of recoverable low-temperature resources may amount to the equivalent of 4×10^9 tons of petroleum.

MEXICO

Geothermal development in Mexico has been primarily at Cerro Prieto (Fig. 2) where electricity has been generated at 75-MWe capacity since November 1973 (Alonso, p. 17). The 15 wells that supply the power plant produce a water-steam mixture from depths of 900 to 1500 m (Isita S., Mooser H., and Soto P., Abstract I-17). Plans are being implemented to expand the generating capacity to 150 MWe (Guiza, p. 1973), and the potential of the field is estimated by Tolivia M. (p. 275) to be between 33 and 235 years at a production rate of 150 MWe. Alonso (p. 17) estimates a minimum

Figure 4. Map showing explored and developed geothermal areas of Iceland.

capacity of 450 to 500 MWe, and Mercado G. (p. 487) estimates a capacity on the order of 1000 MWe for several decades. Isita S., Mooser H., and Soto P. (Abstract I-17) note that a recent well (M-53) achieved a reservoir temperature of 344°C and produced separated steam at 117 tons per hour at 11 bars wellhead pressure, and suggest that there may be important extensions of the Cerro Prieto field east of the presently exploited area.

Geothermal exploration has taken place at many areas in Mexico (Alonso, p. 17), and extensive investigations including exploratory drilling have been carried out at Ixtlan de las Hervores and Los Negritos (Fig. 5). In addition, intensive geological surveys have been carried out at Los Azufres, La Primavera, and San Marcos. Alonso (p. 17) estimates the geothermal potential of Mexico to be roughly 4000 MWe.

CENTRAL AMERICA AND THE CARIBBEAN

The most noteworthy geothermal advance in Central America since 1970 has been the development of the Ahuachapán field in El Salvador (Fig. 5), where 16 production wells have been drilled (Romagnoli et al., p. 563). In 1975, 30 MWe were to be installed with 60 MWe additional by 1977 (Einarsson, p. 2363). A reservoir study carried out in 1971 estimated the geothermal reserve as at least 50 MWe-centuries (UN, Centre for Natural Resources, Energy, & Transport, p. 3). Ahuachapán is also notable for the apparently successful demonstration of reinjection into the reservoir as a means of effluent disposal (Einarsson, Vides R., and Cuéllar, p. 1349).

Geothermal development is also proceeding in Nicaragua, Costa Rica, and Guatemala, and geothermal energy could

allow Central America to become independent of petroleum imports for power generation by 1980 (Einarsson, p. 2363). Investigations in Nicaragua from 1969 to 1971 under the auspices of the United States Agency for International Development revealed two promising areas, San Jacinto-Tisate and Momotombo, but development efforts were set back several years by the disastrous Managua earthquake of 23 December 1972. Temperatures of 209°C were recorded at 210 m at Momotombo (F. Morlock, oral commun., 1975). In Costa Rica, reconnaissance geothermal exploration has been carried out for several years by the Costa Rica Institute of Electricity. Current attention is focused on Guanacaste Province where geological and geophysical surveys beginning in July 1976 may lead to the siting of exploration wells later in the year (J. Kuwada, oral commun., 1976). The Guatemalan government expects to begin geothermal drilling at Moyuta in 1976.

Although little geothermal exploration has been carried out in Panama, Mérida (Abstract I-26) reports the recent discovery of a field having "great possibilities."

On Guadeloupe in the French West Indies, a drilling program carried out at Bouillante resulted in one well with high production of water and steam from a zone at 338 m and a temperature of 242°C (Demians d'Archimbaud and Munier-Jolain, p. 101). Three other wells, to depths of 800 m, 850 m, and 1200 m, did not achieve significant production. It appears that an extensive reservoir might exist at greater depth, and further drilling is proposed (Demians d'Archimbaud and Munier-Jolain, p. 101).

SOUTH AMERICA

Beginning in 1968, the United Nations Development Program and the Government of Chile conducted an intensive

Figure 5. Map showing geothermal areas being explored or developed in Central America.

Figure 6. Map showing major geothermal areas of Chile, Peru, and Bolivia.

geothermal exploration program at El Tatio in northern Chile (Fig. 6). Geological, geochemical, and geophysical investigations, carried out in great part by New Zealand scientists, led to the drilling of six exploration wells (10-cm diameter) and in 1973-1974 to the drilling of seven production wells (20-cm diameter) to a maximum depth of 1.8 km (Lahsen and Trujillo, p. 157; UN, Centre for Natural Resources, Energy, & Transport, p. 3). The principal producing zone is at 800 to 900 m and has a temperature of 265°C (Lahsen and Trujillo, p. 157). The wells produce a mixture of steam and water, with the water containing appreciable lithium, arsenic, and cesium (Cusicanqui, Mahon, and Ellis, p. 703). Steam equivalent to 18 MWe is obtained from three wells at El Tatio, and a pilot desalination plant has been installed on one well.

In addition to the intensive work at El Tatio, geothermal exploration has been carried out elsewhere along the Andes Mountains of South America, most notably at Puchuldiza and Polloquere in northern Chile (UN, Centre for Natural Resources, Energy, & Transport, p. 3). In addition, the Andes in southern Peru and western Bolivia are likely to have similar geothermal potential; Parodi I. (p. 219) emphasizes the potential around the Ubinao volcano in Peru, and Carrasco C. (p. 43) describes areas of geothermal potential in the Cordillera Occidental and Altiplano of Bolivia.

TURKEY

During the past five years, the Mineral Research and Exploration Institute of Turkey (MTA) has carried out extensive geothermal exploration (Kurtman and Şamilgil, p. 447), primarily in western Turkey (Fig. 7). Geothermal energy is likely to supply 10% of the Turkish electrical energy requirements in the year 2000, and geothermal exploration and development have a prominent place in the 1975 to 1979 five-year economic plan (Alpan, p. 25).

Development of the Kızıldere field (Tezcan, p. 1805) has proceeded slowly, owing in great part to serious CaCO_3 scaling problems. Six out of fourteen existing wells are

considered productive (Alpan, p. 25), with a maximum subsurface temperature of 207.4°C. The MTA has built an 0.5-MWe pilot generating plant, and has plans for an 11.4-MWe facility (Alpan, p. 25). In addition, a pilot greenhouse is in operation.

Exploration and drilling are being carried out in the surroundings of Ankara and Afyon, primarily to supply hot water for space heating. At Afyon a well to 905 m recorded a bottom-hole temperature of 106°C and produced at 20 l/sec (Tan, p. 1523). Near Ankara, three geothermal areas are under exploration: the Kızılcahamam graben, the Murtet graben, and the Çubuk graben (Kurtman and Şamilgil, p. 447); the Çubuk graben apparently is the same as the Meliksah area of Keskin et al., Abstract III-51). The Na:K ratio at Kızılcahamam suggests a reservoir temperature of greater than 195°C, and accordingly the area is being considered for the possible production of electricity as well as for space heating.

Exploration and shallow drilling in the Seferihisar and Tuzla regions of western Turkey have discovered areas promising for the production of electricity from hot-water geothermal systems. The Seferihisar area is characterized by many Quaternary rhyolite domes, and chemical geothermometers suggest a reservoir temperature greater than 200°C (Kurtman and Şamilgil, p. 447); a temperature of 137°C was measured at 70 m in well G-2 (Eşder and Şimşek, p. 349). At Tuzla, post-lower Pliocene dacite domes are associated with sinter-depositing springs, and Na-K-Ca geothermometry suggests temperatures of approximately 215°C (Kurtman and Şamilgil, p. 447). One shallow drillhole has produced a water-steam mixture, with a measured bottom-hole temperature of 145°C (Öngür, Abstract II-36).

NEW ZEALAND

Although approximately 8% of the electrical energy used in New Zealand comes from geothermal sources, Wairakei and Kawerau (Fig. 8) remain the only two producing areas. Installed capacity at Wairakei remains constant at 190 MWe, but modifications of the steam collection system to allow multiple flash resulted in a gain in electrical output equivalent to a 20-MWe increase in electrical capacity (Bolton, p. 39). At Kawerau, geothermal fluids continue to supply approximately 11% of the total energy required by the Tasman

Figure 7. Map showing geothermal areas being explored in Turkey and Greece.

Figure 8. Map showing major developed geothermal areas of New Zealand.

Pulp and Paper Company mill (Bolton, p. 37). Geothermal fluids also are used extensively in Rotorua for heating homes (Burrows, 1970) and for the air conditioning of a hotel (Reynolds, 1970).

Geothermal drilling was suspended in New Zealand from 1971 to 1973, largely because of the expectation that substantial quantities of electricity would be generated from a large offshore natural gas field. In 1973 a program of four wells per year was reactivated at Broadlands, and in 1974 the worldwide energy crisis stimulated a similar drilling program to establish the full potential of the Kauerua field.

Twenty-eight wells have now been drilled in the Broadlands field, and seventeen of these wells produce fluid sufficient to sustain a 165-MWe plant. The New Zealand Power Planning Committee has recommended a 150-MWe station to be commissioned in 1981 (Bolton, p. 37).

Bolton (p. 37) estimates that the New Zealand geothermal fields could produce approximately 1.45×10^{10} kWh/yr. from an installed capacity approaching 2000 MWe. Hochstein (Abstract I-16) gives a similar estimate for proved and "semiproved" reserves. Bolton (p. 37) notes that only 15% of the estimated geothermal potential is proven, and accordingly it has been difficult to incorporate geothermal energy into national energy planning.

EAST AFRICA

Since 1970, the French government has carried out geothermal exploration in the French Territory of Afars and Issas, primarily in the Asal Rift (Fig. 9). This exploration has led to the conclusion that optimum sites for geothermal wells are not in the central part of the rift but on the margins where any geothermal systems will be sealed (Stieltjes, p. 613). Two wells were drilled in 1975. One of these wells had a temperature of 253°C at 1050 m and produced a brine of salinity greater than 190 000 mg/l (A. C. Gringarten and L. Stieltjes, data presented at the Workshop on Geothermal Reservoir Engineering, Stanford University, Dec. 15-17, 1975).

Geothermal exploration in Ethiopia has been carried out since 1970 under the United Nations Technical Assistance program, and promising areas were identified in the Lakes District, the Awash Valley, and the northern Danakil Depression (Fig. 9; UN, Centre for Natural Resources, Energy, & Transport, p. 3). There are proposals for further work in the Lakes District, possibly leading to a 10-MWe power station.

Of the many hot-spring areas in the Rift Valley of Kenya, only Olkaria, Eburru, and Lake Hannington have been explored (Fig. 9). At Olkaria, two wells were drilled to 502 m and 942 m in 1957 to 1958 (Noble and Ojiambo, p. 189), but no further exploration took place until a joint program of the United Nations Development Program and the East African Power and Lighting Company began in 1970. In addition to bringing the deeper Olkaria hole into intermittent production, the program drilled four additional holes at Olkaria to depths of 1.3 km (Noble and Ojiambo, p. 189) and temperatures up to 287°C. Although the Olkaria field appears to be large, output of the wells drilled to date is restricted by the great depth to the water table and by low permeability. Deepening of the existing wells at Olkaria to 1.7 km is planned, along with further drilling in the Olkaria area and possibly the Lake Hannington and Eburru areas. In an area of high-power costs such as Kenya, even wells of only moderate output such as Olkaria 3 and 4 appear to be economically attractive (Noble and Ojiambo, p. 189).

Geothermal exploration in the western rift of Uganda was renewed in 1973 by the Uganda Geological Survey and Mines Department, with limited resistivity and microearthquake surveys conducted at Sempaya, Kitagata, and Lake Kitagata (Fig. 9). From chemical and resistivity data, Maasha (p. 1103) estimates a subsurface temperature of at least 160°C at Sempaya, the most promising of the three areas.

Figure 9. Map showing geothermal areas in East Africa.

Figure 10. Map showing major geothermal areas under exploration in Java and Bali, Indonesia.

INDONESIA

Extensive geothermal exploration has been carried out in Indonesia during the past five years, primarily on the islands of Java and Bali (Fig. 10). This exploration is highlighted by the confirmation of the Kawah Kamojang area as a vapor-dominated geothermal system of large potential (Hochstein, p. 1049). As of May 1975, four holes had been drilled to depths of 500 to 800 m, and at least two of these wells produce dry steam (Hochstein, p. 1049; Kartokusumo, Mahon, and Seal, p. 757).

The Dieng area of central Java was investigated from 1970 to 1972 by the Indonesian Power Research Institute with initial assistance from the United States Government (Truesdell, 1971; Muffler, 1971). Five holes were drilled in 1972 to depths ranging from 84 to 183 m. Maximum temperature encountered was 173°C at 139 m (Radja, p. 233, as quoted from Danilchik, 1972). Unlike the Kawah Kamojang area, the Dieng geochemistry suggests the presence of a hot-water geothermal system at depth (Truesdell, 1971).

Exploration has also been carried out at Kawah Derajat, Kawah Cibeureum, Cisolok-Cisukarame, and Tambanan (Bali) jointly by the Geological Survey of Indonesia and Geothermal Energy of New Zealand, Ltd. (Akil, p. 11; Radja, p. 233). In addition, the North Banten area has been investigated by Pertamina (the Indonesian oil and natural gas company) and Kyushu University of Japan (Radja, p. 233). Reconnaissance evaluation of the Indonesian islands (Radja, p. 233) indicates substantial geothermal potential throughout the nation.

CANADA

The regional geothermal potential of Canada has been evaluated in an excellent study by Souther (p. 259). Significant geothermal potential in Canada appears to be concentrated near young, silicic volcanic centers in British Columbia, most prominently Mt. Edziza and Meager Mountain (Fig. 11). The latter has been studied in detail by the British Columbia Hydro and Power Authority, and a 347-m hole has found 69°C water (Nevin and Stauder, p. 1161). The chemistry of thermal waters in the area suggests a subjacent reservoir of over 185°C (Souther, p. 259).

INDIA

Geothermal reconnaissance has been carried out throughout India during the past five years, with emphasis on tectonic setting and the interpretation of hot-spring chemistry in terms

of subsurface temperatures (Krishnaswamy, p. 143; Subramanian, p. 269; Gupta, Narain, and Gaur, p. 387). The region of most immediate potential appears to be the Himalayan arc in northwestern India (Fig. 12), but the Konkan area, and the Sanha, Cambay, Narbada-Tapti, and Godavari grabens may have significant potential.

Exploration efforts through 1975 have concentrated in the Puga, Chumathang, and Parbati Valley areas of northern India. In the Puga area, six wells at depths up to 80 m recorded temperatures up to 135°C and flowing steam and water; chemical geothermometers suggest a base temperature of 220 to 270°C (Shanker et al., p. 245). At Chumathang, 20 km north of Puga, a temperature of 109°C was recorded at 30 m, and geochemistry of fluids suggests a reservoir temperature of 145 to 184°C (Shanker et al., p. 245). In the Parbati Valley (which contains the Manikaran area), geochemistry of fluids suggests reservoir temperatures of over 200°C (Jangi et al., p. 1085; Gupta, Saxena, and Sukhija, p. 741; Chaturvedi and Raymahashay, p. 329). In all three areas, scaling by CaCO_3 appears to be a significant production problem (Subramanian, p. 269; Chaturvedi and Raymahashay, p. 329).

In the Cambay graben, high temperatures and pressures (up to 170°C and 100 kg/cm²) have been found at depths of up to 3.4 km (Krishnaswamy, p. 143), suggesting the

Figure 11. Map showing geothermal areas being explored in British Columbia, Canada.

Figure 12. Map showing geothermal areas and regions of geothermal potential in India.

presence of a geopressed resource similar to that in the Gulf Coast of the United States.

Geothermal exploration in India is likely to progress rapidly in the next few years as a new cooperative program between the Ministry of Energy and the United Nations Development Program gets under way in the Parbati Valley and the West Coast (Krishnaswamy, p. 143; Subramanian, p. 269). In addition, further exploration is planned by the Geological Survey of India in the Puga, Chumathang, and Sonha areas (Krishnaswamy, p. 143).

FRANCE

Geothermal development in France has been highlighted since 1969 by the utilization of 70°C water from Jurassic rocks at a depth of 1.8 km in the Paris Basin to heat apartments at Melun (Maugis, 1971; BRGM, 1975; Fig. 13). A similar installation is now being constructed at Creil, 50 km north of Paris (P. Coulbois, oral commun., 1975). Aquifers of temperature greater than 50°C have also been identified in other sedimentary basins of France, in particular the Aquitanian Basin and Alsace (BRGM, 1975). Geochemical exploration for geothermal resources has also been carried out in the Massif Central (Fouillac et al., p. 721).

GREECE

Since 1970, reconnaissance geochemical exploration has been carried out in six areas of Greece (Domingo and Papastamatoki, p. 109): the Sperchis graben, Sousaki, Methane, Lesbos, Nisiros, and Milos (Fig. 7). The most promising area of the six appears to be the island of Milos, where a 70-m hole drilled in 1972 discharged steam and water and had a bottom-hole temperature of 138°C (Domingo and Papastamatoki, p. 109). A program of deep test drilling on

Figure 13. Map showing areas of geothermal development and exploration in France.

Milos is planned. Greek thermal waters appear to be a mixture of sea water and meteoric water, with salinities as great as, and locally exceeding, that of sea water (Domingo and Papastamatoki, p. 109).

EASTERN EUROPE AND THE USSR

The temperature map given by Čermák, Lubimova, and Stegena (p. 47, Fig. 6) shows that temperatures greater than 40°C at 1 km exist over much of southeastern Europe. The Pannonian Basin of Hungary and the basins immediately

Figure 14. Map showing geothermal areas and regions of eastern Europe.

north and south of the Caucasus have temperatures greater than 50°C at 1 km, and geothermal resources have been developed for space-heating and agricultural purposes in all three areas.

In Hungary, thermal waters are produced from highly permeable upper Cenozoic sandstones at depths up to 2.5 km and temperatures up to 150°C (Boldizsár and Korim, p. 297). Most of the geothermal production is from southeastern Hungary, in a belt extending northeast from Szeged to Debrecen (Fig. 14), with some utilization in northwestern Hungary and at Budapest (Boldizsár and Korim, p. 297, Fig. 1; Balogh, p. 29). At the end of 1974, there were 433 wells in Hungary producing water at greater than 35°C wellhead temperature. These 433 wells produced 461 m³/min, giving 1010 MWt (Boldizsár and Korim, p. 297). Balogh (p. 29) estimates that 5 to 30 × 10¹⁰ m³ of thermal water can be recovered from depths of 1.5 to 2.5 km beneath Hungary. Boldizsár and Korim (p. 297) estimate the water recoverable from the main reservoir (the lower Pliocene sandstones) to be 28 × 10¹⁰ m³, with a usable heat content of 5 × 10¹⁹ J.

Geothermal resources similar to those of Hungary also occur in the surrounding countries, but there has been little utilization to date. Figure 1 of Boldizsár and Korim (p. 297) shows clearly that the area of high geothermal gradients in southeast Hungary extends into Romania (see also C. Opran quoted in *Geothermics*, 1974, v. 3, p. 82), and that the area of high gradients in northwestern Hungary extends northeast into Czechoslovakia. Figure 6 of Čermák, Lubimova, and Stegena (p. 47) suggests that temperatures of greater than 50°C at 1 km occur in Austria and Yugoslavia.

Geothermal investigations have been carried out in the Slovakian Socialist Republic (Franko and Račický, p. 131) and are beginning in Bohemia (the Czech Socialist Republic; T. Pačes, oral commun., 1975). In Slovakia, the most promising region is the central depression of the Danube Basin, southeast of Bratislava, where water at 138°C has been found at 2.5 to 3 km (Franko and Račický, p. 131).

Although heat-flow and geothermal gradients are not as high in Poland as in the countries to the south, there still may be opportunities for geothermal utilization in southwestern Poland (Dowgiałło, p. 123). Water up to 60°C has been produced from drillholes into granite at depths of 660 and 750 m at Cieplice, and water up to 46°C has been produced in a drillhole into granite at a depth of 700 m at Ladek. The silica content of the Cieplice water suggests that temperatures at depth exceed 100°C. Thermal waters also have been found in drillholes into Mesozoic sediments beneath Silesia; one well has produced 19.4 l/sec of 59.5°C water (Dowgiałło, p. 123).

From all indications, the use of geothermal energy in the USSR continues to expand rapidly, although very few specific data were presented to the United Nations Symposium. Kharahashiyan and Khelkvist (Abstract I-18) state that 28 geothermal fields in the USSR are in industrial operation, mainly supplying heat to houses, industries, and agricultural operations, and that 200 000 m of exploratory geothermal wells have been drilled since 1966. According to Fomin et al. (p. 129), geothermal resources in the USSR could supply greater than 10¹⁸ J/yr. Mavritsky and Khelkvist (p. 179) estimate the "reserves" (potential yield?) of thermal waters with temperatures of 40 to 250°C in the USSR to be 22 × 10⁶ m³ per day. These "reserves" consist of "steam-water deposits" (>100°C reservoir temperature?) in

Kamchatka and the Kuril Islands, and "thermal water deposits" in Kamchatka, the Caucasus, Middle Asia, Kazakhstan, and Siberia. Hydrothermal convection systems with temperatures up to 257°C in Kamchatka have a natural heat discharge of 3.8 × 10⁹ J/sec, enough to support an electrical generating capacity of 350 to 500 MWe (Fedotov et al., p. 363).

PHILIPPINES AND TAIWAN

Extensive drilling has taken place in the Tiwi area of southeastern Luzon, the Philippines (Fig. 15), and a 100-MWe geothermal plant is to be completed by 1977, with an additional 100 MWe to follow soon thereafter (UN, Centre for Natural Resources, Energy, & Transport, p. 3). In addition, drilling indicates that the Los Banos area, also

Figure 15. Map showing geothermal areas in Taiwan and the Philippines.

on Luzon, is of considerable promise. Exploration and some drilling have also been carried out at Tongonan on Leyte, and exploration has been proposed for several promising sites on Negros and Mindanao.

Although no information on Taiwan could be presented at the United Nations Symposium, two geothermal fields have been explored (Chen, 1975). The Tatun field (Fig. 15) has reservoir temperatures up to 293°C, but acidity of the water (pH 2) has precluded development to date. A well drilled to 240 m in the Tuchang field found temperatures of 173°C and a sodium bicarbonate fluid of pH 8.5.

AZORES (PORTUGAL)

Geothermal exploration has proceeded in the Azores, albeit somewhat inadvertently, since 1970. One hole was drilled to 981 m on the north flank of Agua de Pau volcano on the island of São Miguel by Dalhousie University (Halifax, Nova Scotia, Canada) as part of an investigation into the processes of formation of oceanic islands. Although the drill hole was not intended for geothermal exploration, temperatures of over 200°C were found at depths greater than 550 m (Meucke et al., 1974). Further exploration and development are planned for the area (V. Forjaz, 1975, oral presentation at the Workshop on Small Geothermal Power Plants, Furnas, the Azores, September 8-14, 1975).

CONCLUSION

The acceleration in geothermal development since 1973 has not yet had a major effect on the world's installed geothermal capacity (Table 1) owing to the lag of two to five years between discovery of a field and commercial utilization. Also, the electrical capacity figures do not reflect the continuing steady growth of direct utilization of geothermal heat. The upsurge in geothermal exploration and production drilling, the dramatic expansion of geothermal research and development, the continuing high petroleum prices, the dwindling supplies of petroleum and natural gas, and the increased awareness of the need for environmental protection are combining to bring geothermal energy from a minor curiosity to a significant source of electricity and heat throughout the world.

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Tectonic and Hydrologic Control of the Nature and Distribution of Geothermal Resources

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ABSTRACT

Under foreseeable economics and technology, extraction of geothermal resources is limited to the upper few kilometres of the earth's crust. At these depths, the global distribution of geothermal resources is primarily controlled by plate-tectonic features. Geothermal resources related to igneous intrusions in the upper crust occur along spreading ridges, subduction zones, inter-arc basins, and melting anomalies. Geothermal resources unrelated to igneous intrusions in the upper crust occur most commonly in porous sedimentary rocks near convergent or divergent plate boundaries where regional heat flow is high. Geothermal reservoirs at pressures well in excess of hydrostatic occur commonly in young tectonic basins characterized by high rates of sedimentation and subsidence; these reservoirs are commonly termed "geopressured." Except for the scattered melting anomalies, the central parts of crustal plates have low heat flow, little volcanism or tectonism, and accordingly no geothermal potential except at depths beyond present drilling limits.

The hydrologic properties of crustal rocks are very important in determining location, size, and type of geothermal resource. Hot dry rock can result from solidification of a young intrusive body or from conductive heating of impermeable rock around such a body. Convective hydrothermal systems result either from convection of meteoric water around young intrusive bodies or from deep circulation of meteoric water along fracture zones. Geopressured reservoirs are formed in deep sedimentary basins when escape of connate water and water produced by the thermal dehydration of clays is impeded by sediments of low permeability.

INTRODUCTION

This paper presents a broad overview of the geologic controls of the nature and distribution of geothermal resources. Consideration of the basic principals of crustal heat transfer, plate tectonics, and igneous processes allows us to split geothermal resources into two broad classes: (1) geothermal resources related to young igneous intrusions in the upper crust, and (2) geothermal resources not related to young igneous intrusions in the upper crust. The first class can be broken down into three types of resources: (a) magma, (b) hot dry rock, and (c) convective hydrothermal systems. The second class can be subdivided into four resource types: (a) resources in a low-porosity conductive

environment, (b) resources in a low-porosity conductive environment modified by circulation of meteoric water, (c) resources in a high-porosity environment at hydrostatic pressure, and (d) resources in a high-porosity environment at pressures greatly in excess of hydrostatic (that is, "geopressured").

PRINCIPLES OF HEAT TRANSFER IN CRUST

Geothermal energy consists of heat produced naturally within the earth by a combination of several mechanisms: (1) decay of long-lived radioactive elements, particularly uranium, thorium, and potassium; (2) segregation of the earth into the present core, mantle, and crust; (3) dissipation of rotational energy as the rate of rotation of the earth decreases with time; and (4) conversion of kinetic energy to heat as the earth was accreted from primordial matter some 4.5 billion years ago (Smith, 1973, p. 135-139). Of these four mechanisms, radioactive decay is likely to have been the most important.

The heat of the earth is transmitted to the earth's surface at a rate of about 10^{21} joules per year (Smith, 1973, p. 105) primarily by three mechanisms: (1) conduction, (2) movement of magma, and (3) movement of water. In order to understand the nature, distribution, and extent of geothermal resources, we must consider both the principles that govern these modes of heat transfer in the earth's crust and the ways in which these modes interact.

Extensive study of conductive heat transfer in the earth's crust has demonstrated that the regional heat flow at the earth's surface (q) has two components: (1) heat flow due to conduction from the lower crust and mantle (q^*), and (2) heat flow due to the decay of radioactive elements in the upper crust (Roy, Blackwell, and Birch, 1968). In some granitic terranes, these components are related by the equation $q = q^* + DA$, where A is the radioactive heat production of local intrusive rock and D is a constant with units of length. For a given geologic province, a plot of q vs. A is nearly linear; the intercept at $A = 0$ is q^* , and the slope D . Geologic provinces display characteristic values of q^* but variable values of q depending on the amount of U, Th, and K in the upper crust (Fig. 1). If A decreases exponentially with depth in the crust (Lachenbruch, 1968), q^* is a good approximation to heat flow from the mantle (Sass, 1970). The worldwide average heat flow is approximately $1.47 \mu\text{cal cm}^{-2} \text{sec}^{-1}$ [$= 1.47$ heat-flow units (hfu) $= 61.4 \text{ mW m}^{-2}$; Sass, 1971]. The value of q^* ranges from

Figure 1. Relation between heat flow and surface heat production for three provinces of the United States (from Roy, Blackwell, and Birch, 1968, Fig. 6).

about 0.4 hfu for geologic provinces like the Sierra Nevada to approximately 1.4 hfu for geologic provinces like the Basin and Range (Fig. 1).

Assuming a purely conductive regime, the temperature distribution with depth may be inferred from a knowledge of surface heat flow and surface heat production (Lachenbruch, 1970). Representative temperature distributions for several heat-flow provinces (Fig. 2) show clearly that high values of q^* imply magmatic temperatures at the base of the crust. Consequently, penetrative movement of magma in the crust is likely in these provinces, and high surface heat flows cannot be interpreted by a purely conductive model. According to Roy, Blackwell, and Birch (1968), partial melting at the base of the crust would occur in those oceanic areas (crust 5 to 10 km thick) where regional heat flow is 5 to 10 hfu, and in those continental areas (crust 30–40 km thick) where regional heat flow is about 2.5 hfu.

Igneous bodies emplaced in the upper crust in impermeable rocks could produce high near-surface conductive gradients and heat flows (Blackwell and Baag, 1973). Alternatively, intrusive bodies in permeable rocks could drive overlying convective hydrothermal systems (White, 1968; Taylor, 1971), also producing high near-surface gradients and heat flows (Blackwell and Morgan, 1975). Heat flow measured at the surface, therefore, gives us information about deeper crustal processes only when the influence of meteoric circulation of water can be ruled out. Even in regions where there are no young intrusions to drive overlying convection systems, meteoric water can penetrate to depths of 5 to 10 km, acquire heat by conduction from rocks, and rise to the surface in warm plumes of relatively restricted cross section. Near-surface gradients and heat flows near these plumes can be very high, but extrapolation of gradients to depth is not warranted (Fig. 3).

Even under purely conductive crustal conditions, near-

Figure 2. Temperature distributions in three heat-flow provinces of the United States at various heat flow (q) and surface heat productions (A) for an exponential decrease of heat production with depth in the crust (from Sass, 1971, Fig. 5.3 after Lachenbruch, 1970, Fig. 5).

surface heat flow can be misleading in that it does not reflect young transients at depth. For example, using any of the models of Lachenbruch et al., (1975) the thermal effect of a granitic pluton intruded 10 000 years ago at a depth of 4 km would not be detectable at the surface today if conduction were the only mode of heat transfer.

Heat flow information can also be misleading in a region of rapid sedimentation and diagenesis, such as the Gulf Coast. Here the conductive transfer of heat is grossly distorted by rapid sedimentation and subsidence, by expulsion of water upon compaction and diagenesis, and in some regions by the presence of salt domes (Jones, 1970).

These general concepts of heat transfer through the crust allow us to divide geothermal resources into two broad classes depending on whether or not the region is characterized by recent emplacement of magma into the upper crust. These two classes can then be further divided into geothermal resource types that depend on the nature of the local hydrologic regime.

PLATE TECTONICS

Consideration of the modern principles of plate tectonics allows us to delimit geographically the broad areas in which

Figure 3. Temperatures measured on July 24, 1972, in USBR-UCR No. 15 (solid line) and DWR Dunes No. 1 (dashed line) from Combs (1973, Fig. 5). Drilling of USBR-UCR No. 15 was completed on Feb. 2, 1971; drilling of DWR Dunes No. 1 was completed on June 29, 1972, Fig. 27.

the two primary categories of geothermal resources are found. The central precept of plate tectonics is that the outer 100 km or so of the earth consists of large, rigid plates that move relative to each other at rates of several centimetres per year (See reviews by Wylie, 1971; Bird and Isacks, 1972; Cox, 1973; Le Pichon, Francheteau, and Bonnin, 1973). Where plates move apart, molten material rises and forms new crust at spreading ridges. Where plates move together, one plate is thrust beneath the other along subduction zones. Parallel movement of plates is taken up along transform faults. Tectonic activity is concentrated primarily along all these plate boundaries, whereas magma generation takes place along spreading ridges, along subduction zones, and at intraplate melting anomalies (such as Hawaii). Consequently, one would expect to find geothermal resources related to magma intrusion primarily near spreading ridges, subduction zones, and hot spots. Geothermal resources related to a conductive crustal regime would be expected throughout.

Figure 4 shows the general framework of the earth's plates and the major, known, high-temperature, convective hydrothermal systems. It should be kept in mind that this map displays the present plate configuration. This pattern has not been static with time, however, and the present thermal structure of the crust reflects the history of plate movements throughout at least the past few million years. Interpretation of the thermal structure and the geothermal resources of western North America clearly requires consideration of position and nature of plate margins and related tectonic and igneous activity in the late Cenozoic (Atwater, 1970; Scholz, Barazangi, and Sbar, 1971; Christiansen and Lipman, 1972).

YOUNG IGNEOUS INTRUSIONS

Geothermal resources related to young igneous intrusions in the upper crust require transient storage of heat high in the crust (<10 km) either as magma, hot dry rock, or a convective hydrothermal reservoir. All three modes of heat storage are due to emplacement of a body of magma in the upper crust, with subsequent cooling by a variety of conductive and/or convective schemes. The resource is either the intrusion itself (magma, or solidified hot rock), the adjacent country rock heated by the intrusion, or a hydrothermal convection system driven by either of the above. In all three situations, the model requires that the upward movement of at least part of the magma be arrested within the earth's crust. If magma comes directly and quickly to the surface from the mantle or lower crust, the heat is dissipated rapidly to the atmosphere and no significant geothermal resource is produced.

It is commonly accepted that ocean crust is formed at mid-ocean spreading ridges and that ophiolite sequences represent fragments of ancient oceanic lithosphere (Coleman and Irwin, 1974). Field observations of these ophiolites show layered cumulates and some differentiated rocks, indicating that magma is stored as intrusions in the crust, at least along slow-spreading ridges (Coleman and Peterman, 1975). Although oceanic spreading ridges are therefore attractive targets for geothermal exploration (Lister, 1973, 1975; Williams, 1975), they have received little attention except at Iceland, where the mid-Atlantic ridge is above sea level.

Where a spreading ridge impinges a continent, the magmatic situation becomes far more complex because the crust is thicker and more silicic. At such situations, silicic magma can be formed by partial fusion of mantle peridotite, by differentiation of basalt, or by partial fusion of crustal material (Robinson, Elders, and Muffler, 1975). Accordingly, silicic extrusions and intrusions are more common where spreading ridges impinge on continents than at mid-oceanic sites.

Zones of subduction provide an ideal setting for generation of silicic magma (Gilluly, 1971). At these zones a variety of materials ranging from exceedingly siliceous sediments to mafic and ultramafic rocks are thrust down into the mantle where they are partly melted to produce a variety of intermediate and silicic rocks. The composition of the rocks thus produced varies according to whether the subduction zone is an oceanic-oceanic plate contact (for example, the Marianas), an oceanic-continental plate contact (the west coast of South America), or a continental-continental plate contact (the Himalayas).

Melting anomalies within plates also provide situations in which magma can be stored in the shallow crust. The origin of these melting anomalies is subject to controversy. According to Morgan (1972), they lie above narrow (<150 km diameter) plumes that originate deep in the earth's mantle; others relate melting anomalies to propagating fractures (McDougall, 1971) or to shear melting (Shaw and Jackson, 1973). One of the best known melting anomalies is beneath Hawaii (Dalrymple, Silver, and Jackson, 1973), where voluminous basaltic magma has been erupted from depths of at least 60 km (that is, well into the mantle). An example of an intracontinental melting anomaly may be Yellowstone (Christiansen and Blank, 1969) where not only basalt but also voluminous rhyolite was erupted throughout the Pleistocene, the rhyolite probably produced by partial fusion

Figure 4. Map showing major lithospheric plates (after Le Pichon, Francheteau, and Bonnin, 1973, Fig. 27) and geothermal areas developed or being explored. Spreading ridges are shown by double lines, subduction zones by barbed lines, and transform faults by single solid lines. Plate boundaries of uncertain nature shown by dashed lines.

in the lower crust (R. L. Christiansen and H. R. Blank, Jr., written commun.).

Petrologic and experimental studies have shown that basalts are generated by partial melting of material in the mantle (Wylie, 1971, p. 168-208). Field studies of intrusive rocks of all ages show that most large (10^2 - 10^5 km³) igneous intrusions in the upper 10 km of the continental crust are silicic (Smith and Shaw, 1973). Basaltic magma tends to rise directly to the surface in thin sheets or pipes without forming large shallow intrusive bodies. Accordingly, as a first approximation, geothermal resources on the continents are more likely to be associated with silicic volcanism than basaltic volcanism (Smith and Shaw, 1973). This generalization does not seem to hold for oceanic spreading ridges, where the crust is thin and extensive ophiolite complexes with large intrusive components can form.

Accepting that large volumes of molten rock can be intruded into the shallow crust, we can then look at the types of geothermal resources than can occur in this magmatic environment, continuing to restrict our discussion to the upper 10 km. The most obvious potential resource is the magma itself. A cubic kilometre of granite magma at 800°C contains 3×10^{18} joules (above surface temperatures), which is equivalent to the heat content of 480 million barrels of crude oil. Obviously molten rock is an attractive potential energy source, even in small volumes such as at Kilauea Iki lava lake (Kennedy and Griggs, 1960), but the technological problems of utilization are extreme (Colp and Brannvold, 1974).

A magma intruded into the crust will cool and solidify with time, losing heat by conduction and convection. If the permeability of the intrusion and the rock into which it is intruded are low, one might develop a hot dry-rock resource in both the intrusive rock itself and in the surrounding country rock. Even though solid, this could be still an immense potential energy resource. One km³ of granite at 600°C contains 1.6×10^{18} joules of heat (above 0°C); at 300°C, 0.8×10^{18} joules. However, the technological problems of extraction and utilization of the heat in this impermeable rock are formidable. Proposals for hydraulically fracturing hot dry rock and circulating pressurized water in a closed loop have been put forward (for example, Smith, et al., 1973), and an extensive program of experimentation is underway at the Los Alamos Scientific Laboratory (Smith, 1974; Tester, 1974; Smith, et al., 1975). Significant problems concern the creation of sufficient heat-transfer area between rock and water (Gringarten, Witherspoon, and Ohnishi, 1975), possible extension of cracks owing to thermal contraction (Smith, et al., 1973), and chemical reaction of hot rock and water.

If, however, an igneous intrusion is emplaced in rocks of significant intergranular or fracture permeability, the cooling history will be greatly affected by movement of water. In this model, the intrusive body will act like a stove burner under a tea kettle, setting up a strenuous convection system of meteoric water (White, 1968). This water can penetrate not only through the country rock but also through the cooling intrusion as demonstrated by studies of ¹⁸O in young intrusive and volcanic rocks (Taylor, 1971; Friedman, et al., 1974). The heat thus convected upward from the intrusion can either go to the surface directly or be stored at an intermediate depth in a hydrothermal reservoir, the only type of geothermal resource exploited to date. Depending on the local hydrologic situation this reservoir can be

either hot water- or vapor-dominated (White, Muffler, and Truesdell, 1971).

Any particular crustal thermal anomaly can give rise to all three types of geothermal resources (magma; hot dry rock; convective hydrothermal), either simultaneously or sequentially. The overall potential of these three types of geothermal resources in any given area can be evaluated crudely by considering the size-age relations of the crustal igneous anomaly (Smith and Shaw, 1973). Clearly, the geothermal potential of any igneous system increases with the size of the anomaly and decreases with age. These relations have been quantified by R. L. Smith and H. R. Shaw (written commun., 1972-1975; White and Williams, 1975) by plotting age and volume data against a family of curves showing solidification times of hypothetical magma chambers as functions of various geologically reasonable boundary conditions.

It is clear that the major potential resource in this regime of upper crustal magmatism lies in the magma itself and in the hot dry rock. Calculations by my associates in the U.S. Geological Survey (White and Williams, 1975) indicate that the potential geothermal resources of magmatic and associated hot dry rock systems in the United States are many times the potential geothermal resources of associated convective hydrothermal systems. However, it must be emphasized that this analysis considers only heat in the ground. Many convective hydrothermal systems are utilizable under present or foreseeable (by 1990) economic conditions and technology, whereas the technology for tapping the heat in hot dry rock and magma is only just beginning to be developed (Smith, 1974; Colp and Brannvold, 1974).

REGIMES NOT RELATED TO YOUNG INTRUSIONS

It has long been recognized that the large regions of normal thermal gradients in the crust contain an immense amount of heat. White (1965), for example, calculated that the total heat stored above surface temperatures in the earth to a depth of 10 km is about 1.3×10^{27} joules. At a geothermal gradient of 20°C per km (typical of crystalline rocks of the eastern United States) temperatures at 10 km would exceed 200°C. At 35°C per km (approximately that for crystalline rocks in the Great Basin) temperatures at 10 km would approach 400°C.

Most of this potential resource, however, is at depths too great to allow economic exploration and development with existing drilling technology. The deepest well drilled to date for geothermal energy is approximately 3 km, whereas the deepest well drilled in petroleum exploration is slightly less than 10 km. But at depths greater than 3 km drilling costs go up exponentially with depth (Anderson, 1973). A well to 3 km should cost less than \$500 000, whereas a well to 10 km probably would cost over \$6 000 000. Accordingly, the vast regions of normal geothermal gradients are unlikely to be explored and utilized at depths greater than 3 km unless there is a major technological breakthrough that drastically lowers deep drilling costs. The leverage of such a breakthrough would be immense, however, and research in advanced drilling technology presents an exciting opportunity.

Geothermal resources unrelated to upper crustal magmatism can be subdivided into four types:

1. Resources in a low-porosity, conductive environment.

2. Resources related to deep circulation of meteoric water along faults and fractures.
3. Resources in a high-porosity environment at hydrostatic pressure.
4. Resources in a high-porosity environment at pressures greatly in excess of hydrostatic (that is, "geopressed").

These types are actually end members, with most natural situations displaying intermediate characteristics.

Resources in a Low-Porosity Conductive Environment

A purely conductive thermal regime requires that there be no movement of water and thus implies either no vertical hydraulic gradient or no permeability. The latter condition may be approximated in crystalline basement rocks and in terranes characterized by metamorphic complexes or homogeneous intrusions. Extraction of significant quantities of heat from these conductive environments is impossible without artificial fracturing of extensive volumes of rock, either by hydrofracturing or by explosive devices. The mechanical problems are similar to those referred to previously with regard to extraction of heat from hot dry rock but are exacerbated by the much greater depths required to get high temperatures. Extraction of geothermal energy from a purely conductive non-magmatic environment would therefore seem to be a step beyond the successful demonstration of energy extraction from hot dry rock in an environment of crustal magmatism.

Deep Circulation of Meteoric Water

Many regions characterized by low to moderate regional geothermal gradients do contain sporadic warm springs, usually along faults. One example is in the eastern United States, where springs with temperatures up to 40°C occur in a belt along the Appalachian Mountains. This area shows no evidence of late Cenozoic volcanism, and geothermometry based on existing chemical analyses gives no indication the temperatures at depth are significantly higher than surface temperatures (A. H. Truesdell, oral commun., 1975). These warm springs appear to be related to deep circulation of meteoric water along faults and accordingly can be viewed as a convective aberration of the basically conductive crustal regime.

The eastern United States is a region of low to normal heat flow (Fig. 1). One would expect that in regions of higher heat flow, thermal springs would be in general more abundant. With even greater regional heat flow, such a regime would grade into a regime characterized by intrusion of basalt into the upper crust and eventually to emplacement of silicic material in the upper crust.

The transition from a regime characterized by deep circulation of meteoric water to one characterized by movement of magma into the upper crust is perhaps illustrated by the Basin and Range Province of the western United States. Regional heat flow is approximately twice normal (Fig. 1), and the area is characterized by many hot springs (Waring, 1965), a number of which have a chemistry suggesting high subsurface temperatures (Mariner, et al., 1974). The Basin and Range Province is an area of extensive normal faulting and tectonic extension (Thompson and Burke, 1973), and most hot springs are located along faults. The province displays sporadic late Cenozoic basaltic volcanism and is

underlain by relatively shallow mantle of anomalously low seismic velocity (Archambeau, Flinn, and Lambert, 1969). During the late Cenozoic, silicic volcanism spread east and west from the center of the Great Basin, and Quaternary silicic volcanic rocks occur only along the east and west margins of the Great Basin (Armstrong, et al., 1969). Scholz, Barazangi, and Sbar (1971) suggest that these geologic and geophysical characteristics can be explained by upward and outward flow of partially melted material originating from the Farallon plate subducted beneath the North American plate in the late Cenozoic.

The hot springs and geothermal systems of the Basin and Range Province are unlikely to be related to intrusions in the upper crust, except at the east and west margins where Quaternary silicic volcanic rocks occur. The sporadic basalts probably came directly to the surface from the mantle or lower crust, producing few if any shallow intrusions. Accordingly, the hot springs of the Great Basin can best be interpreted as due to deep circulation of water along faults in a region of elevated heat flow (Hose and Taylor, 1974). Major unknowns are the volume and permeability of any reservoirs that may exist at depth.

High-Porosity Environment, Hydrostatic Pressure

Many regions throughout the world are characterized by deep basins filled with sedimentary rocks of high porosity and permeability. Where these basins occur in regions of elevated geothermal gradient and heat flow, temperatures approaching 200°C can be achieved at depths where extraction is feasible. Even in regions of normal heat flow, permeable sedimentary rocks at great depth (3 to 10 km) have been found in the course of oil exploration and represent a significant potential source.

Geothermal resources at hydrostatic pressure in young sedimentary basins are typified by the Hungarian Basin (Boldizsár, 1970), where up to 3 km of porous, Cenozoic sediments occur in a region characterized by temperature gradients of 50 to 70°C/km. Boldizsár (1970) concludes that over 4000 km³ of water at 60 to 200°C is stored in porous rocks at depths greater than 1 km. Successful extraction and utilization of this geothermal resource for space and agricultural heating have been demonstrated in Hungary, as well as in similar geologic environments of the USSR (Tikhonov and Dvorov, 1970) and France.

Geothermal resources of this type require two coincident factors: (1) a sedimentary basin containing rocks of high porosity and permeability; and (2) elevated regional heat flow. The second condition is likely to be met only near plate margins, which are also tectonically active zones where the formation of deep, sedimentary basins is likely.

Geopressed Resources

Extensive drilling for oil in many sedimentary basins has delimited zones characterized by pressures greatly in excess of hydrostatic. These geopressed zones are also at elevated temperature, and the interstitial fluids contain significant quantities of dissolved methane. Accordingly, three kinds of energy could be extracted from geopressed reservoirs: kinetic, geothermal, and combustion.

Most data on geopressed resources come from oil wells drilled in the Gulf Coast of the United States. These data were summarized and interpreted by Jones (1970), and the

following discussion is based primarily on Jones's paper.

Since the early Cenozoic, the Gulf Coast has been the site of extensive deposition of clastic sediments eroded from the central United States, particularly the Rocky Mountains. These sediments consist of interfingering deltaic and marine sand and clay. Sedimentation rates ranged up to 1.2 m per 1000 years (Jones, 1970, Table 1), and the maximum thickness of the Cenozoic sedimentary pile approaches 15 km. In general subsidence has kept pace with deposition, with the locus of deposition shifting gulfward with time. The depositional pattern is modified by major faults parallel to the basin margin; these faults were active throughout the formation of the sedimentary pile and have broken up the sand layers into discrete reservoirs.

In the upper few kilometres of the Gulf Coast pressures are hydrostatic and temperature gradients are normal (20–40°C/km). But at depths of 1.5 km or greater, both pressures and temperatures rise strikingly, with pressures approaching lithostatic (Fig. 5) and temperatures exceeding 200°C.

These geopressed zones occur in sand beneath low-permeability shale, and are bounded laterally by faults to produce discrete reservoirs several tens or hundreds of square kilometres in area. The overlying impermeable clay beds act as thermal insulators because of their high content of static water, a substance that has low thermal conductivity (Lewis and Rose, 1970).

The water in these reservoirs is not meteoric but is both connate water and water released upon dehydration of montmorillonite during diagenesis at temperatures of 80 to 120°C. These waters are expelled into adjacent sand reservoirs.

Salt domes, derived from the Louann Salt (Jurassic) that underlies the basin, are abundant throughout the Gulf Coast sedimentary section (Halbouty, 1967). Some of these domes

have penetrated many kilometres bringing salt at relatively high temperature (200–300°C) to shallow depths in a manner analogous to the intrusion of an igneous body. Furthermore, salt has a thermal conductivity two to three times that of the sediments (Clark, 1966), and the salt diapirs thus provide a mechanism whereby heat is transported upward in an irregular manner.

It is not known whether the regional heat flow in the Gulf Coast is normal or high. Traditional measurements of gradient and thermal conductivity, even at great depths, cannot be used to calculate a regional heat flow, owing to the aberrations induced by movement of water, sediment compaction, diagenesis, and salt dome intrusion. The relatively shallow Moho and the basalt of unknown age recently identified beneath some offshore salt domes (P. H. Jones, oral commun., 1975) may suggest that the regional heat flow is indeed elevated.

Geopressed reservoirs in the Gulf Coast are likely to be very abundant and quite large in aggregate. The oil well data are more than adequate to define a belt of geopressed reservoirs extending over 1000 km along the coast of Texas and Louisiana, both onshore and offshore (Jones, 1970, Fig. 20). Unknown are the rate at which these reservoirs might be produced, the longevity of production, the economics of use, and the environmental impact, particularly subsidence. The determination of these factors will depend largely on hydrologic analysis; the major unknown is how the geopressed reservoirs will react to prolonged fluid extraction. It seems clear that the geopressed resources of the Gulf Coast are ripe for a demonstration study involving reservoir delineation, production testing, electricity generation, economic analysis, and environmental monitoring.

SUMMARY

There is a geologic rationale for dividing geothermal resources into two broad categories, depending on whether the resource is or is not related to young igneous intrusions emplaced in the upper crust. Resources related to such intrusions can be subdivided into magma, hot dry rock, and convective hydrothermal reservoirs; any given upper crustal thermal anomaly can produce all three subtypes. Geothermal resources unrelated to young intrusions in the upper crust can be subdivided into resources in a low porosity, conductive environment, resources related to deep circulation of meteoric water along faults and fractures, resources in a high-porosity environment at hydrostatic pressure, and geopressed resources.

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Figure 5. Graph showing pressure vs. depth in a geopressure area offshore from Louisiana (from Myers, 1968).

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The increased interest in the development of geothermal resources has given rise to the need for the formulation of a legal framework in which this development can be carried out. In this article, Mr. Olpin and Professor Tarlock analyze the proper relationship between western water law and geothermal resources development. They present an argument against the blanket application of western water law and propose a means of accommodating geothermal resources development with the protection of conventional water users.

WATER THAT IS NOT WATER

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I. INTRODUCTION

Anyone desiring to write about western water law soon encounters a problem analogous to one facing all new water users. Just as many western streams are over-appropriated, water law scholarship has been over-appropriated by Frank Trelease. Fortunately, senior scholars cannot make calls on junior scholars and preempt the supply of ideas. But a problem of scholarly preemption remains. There is scarcely an area of western water law on which Dean Trelease has not written comprehensively and with great insight into the problems of this harsh and wonderful region. In the same manner that appropriators seek constantly to develop water not within a system of prior vested rights, we offer the following analysis of a new and potentially complex problem—the proper relationship between western water law and geothermal resources development—to honor Dean Trelease and to circumvent the constraints of scholarly prior appropriation. This article is drawn from a forthcoming larger study and is designed only to outline the major issues that must be faced in establishing a functional relationship between water law and geothermal resources development.

II. THE NATURE OF THE RESOURCE AND ITS RELATION TO CONVENTIONAL WATER RESOURCES

Geothermal energy is energy derived from heat beneath the earth's surface. Sub-surface temperatures are primarily controlled by the conductive flow of heat through solid rocks, the convective flow in circulating fluids, and by mass transfer in magma. "Where conduction is dominant, temperatures increase continuously with depth, but not at a constant gradient. The important interrelations are those between thermal gradient, heat flow, and thermal conductivity. . . ." At the present time we are unable to exploit commercially the heat produced by the thermal gradient. Instead, commercial interest centers on the exploitation of hydrothermal convective systems,² geothermal anomalies. The Far West is an area of recent volcanism, high regional conductive heat flow and a relatively shallow mantle. As a result there are a number of "hot spots" where high silica varieties of volcanic rock at shallow levels below the crust can sustain high-temperature convection systems for a prolonged period of time.³ These geothermal reservoirs can be tapped and heat extracted from the transfer medium for the production of electricity and

other uses such as space heating. There are two types of hydrothermal systems with commercial potential: vapor and liquid dominated systems. A vapor-dominated system is thought to be caused by a very high-temperature hot-water system with a low recharge rate so that more water is boiled off than is being replaced by recharge. The result is high-temperature steam which transfers the heat to the surface. In a liquid-dominated system, the heat transfer medium is water trapped by a relatively impermeable formation with few fractures or inter-connected pores. This water may contain brines of a high salinity and can be "flushed" to produce steam or converted by other technologies such as the binary cycle.⁴

According to the United States Geological Survey, there are three known vapor-dominated fields with commercial potential in the United States, but there are many potential liquid-dominated fields.⁵ The Geysers in Northern California is already in commercial production and is thought to have a potential of 1000-2000 megawatts. The other two potential steam fields are located in Yellowstone and Mount Lassen Volcanic National Parks. Geothermal leasing is prohibited in national parks⁶ so liquid-dominated systems will be the source of commercial geothermal production in the foreseeable future.

Conflicts with conventional water users may result from the exploitation of a liquid-dominated system. Development of the field may interfere with the quantity and quality of water available to conventional water users, primarily high capacity pumpers. A geothermal field may tap liquids which are part of a developed ground aquifer causing a diminution in the pressure and quantity of "sweet water" available to a conventional user. Both for conservation reasons and to comply with the no-discharge policy of the 1972 Federal Water Pollution Control Act Amendments, liquid wastes must be re-injected into the reservoir after the conversion of the liquid to steam, and thus there is a risk of groundwater contamination.⁷

Whether or not these conflicts will actually occur depends upon the physical relationship between a geothermal reservoir and an aquifer dedicated to conventional uses. The law structuring the relationship between geothermal and conventional water uses should flow from physical relationships between the two resources. Unfortunately, there is a critical lack of scientific information concerning the physical nature of geothermal resources and their relation to conventional groundwater resources.

There is general agreement among scientists that the ultimate source of heat in a geothermal reservoir is the natural radioactivity of the earth.⁸ Beyond this it is difficult to gen-

1. White, *Characteristics of Geothermal Resources*, in *GEOTHERMAL ENERGY: RESOURCES, PRODUCTION, STIMULATION* 69, 72 (Kruger & Otte eds. 1973). The best comprehensive technical introduction to geothermal resources is *PROCEEDINGS, SECOND UNITED NATIONS SYMPOSIUM ON THE DEVELOPMENT AND USE OF GEOTHERMAL RESOURCES*, Vol. I-III (1976) [hereinafter cited as *UNITED NATIONS SYMPOSIUM*].
2. In 1975 the installed global geothermal electrical generating capacity was only 1,400 megawatts. *ENERGY: GLOBAL PROSPECTS 1985-2000* 39 (Wilson 1977). At the present time only one geothermal field in the United States, The Geysers, north of San Francisco, produces electricity commercially. The present total output of the Geysers is about 500 megawatts. Commercial production is also anticipated in California's Imperial Valley and the Roosevelt Hot Springs area in Utah. In the early 1960's and 1970's projections for geothermal production were very optimistic, but these projections have now been revised downward, in response to a more realistic understanding of the limits of current technology to exploit the resource at rates competitive with conventional power sources. The leading assessment of geothermal reserves in the United States, *ASSESSMENT OF GEOTHERMAL RESOURCES OF THE UNITED STATES-1975* argues that known high temperature convection systems alone could supply 30,000 megawatts for 100 years or 100,000 megawatts for 30 years at prices between one and two times current power costs. The history of reserve estimates is summarized in SCARTO, *STATE POLICIES FOR GEOTHERMAL DEVELOPMENT* (National Conference for State Legislatures 1976). In 1976, fifty-two geothermal wells were drilled in the states of California, Idaho, Nevada, Oregon and Utah. Of these "39 (75%) are now considered to have found at least potentially commercial quantities of steam or hot water. . . ." Smith, Isselhardt & Matlick, *Summary of 1976 Geothermal Drilling—Western United States*, 5 *GEOTHERMAL ENERGY* 8 (May 1977).
3. A geothermal reservoir with appreciable commercial potential has four characteristics identified by the United States Geological Survey. They are: (1) a temperature between 150-400° Fahrenheit; (2) a depth of less than 10,000 feet to permit drilling; (3) sufficient permeability of the rocks to allow the heat transfer agent—water

or steam—to flow continuously at a high rate, and (4) sufficient water recharge to maintain production for a number of years. Goodwin, et al., *Classification of Public Lands Valuable for Geothermal Steam and Associated Geothermal Resources*, *GEOLOGICAL SURVEY CIRCULAR* 847 (1971).

4. "Flashing" converts a hot liquid into steam by lowering the pressure of heat transfer medium as the liquid is injected into a flash separator which separates the vapor from the remaining liquid fraction. A binary cycle concept uses a heat exchange system to transfer a fraction of the brine enthalpy to vaporize a secondary working fluid. "Expansion through a turbine to a lower pressure, fixed by the heat rejection temperature, provides the means for power generation." Austin, *Prospects for Advances in Energy Conversion Technology for Geothermal Development*, in *UNITED NATIONS SYMPOSIUM*, at 1925, 1927 (1976).
5. *ASSESSMENT OF GEOTHERMAL RESOURCES OF THE UNITED STATES-1975*, *supra* note 2.
6. 30 U.S.C. § 1014(c) (1970).
7. See *STANFORD ENVIRONMENTAL LAW SOCIETY, GEOTHERMAL ENERGY: LEGAL PROBLEMS OF RESOURCE DEVELOPMENT* 25-27 (1976); Swanberg, *Physical Aspects of Pollution Related to Geothermal Energy Development*, in *UNITED NATIONS SYMPOSIUM*, at 1435 (1976).
8. Muir, *Summary of Section II, Geology, Hydrology, and Geothermal Systems*, in *UNITED NATIONS SYMPOSIUM*, at xiv (1976).

eralize about the origins of the heat and heat transfer medium in a particular reservoir. This scientific uncertainty poses a complex problem for lawyers concerned with developing an allocative regime for geothermal resources. There is a high level of consensus that geothermal energy is a relatively clean resource, and it should be developed as an alternative to fossil fuel and nuclear energy;⁹ however, when one tries to fit geothermal energy into an existing property rights scheme or to create a new one, one must confront the problem that there may be rival claimants to the heat transfer medium. The purpose of this article is to describe briefly what is known about the relationship between geothermal resources and conventional sources of water in order to analyze the proper relationship between the law of geothermal development and western water law.

In a liquid or vapor dominated system, heat is transferred in a medium containing water. However, the presence of water alone should not determine whether geothermal resources should be allocated as water. A conventional groundwater user draws from circulating systems which are relatively shallow compared to geothermal systems. Use of these recharging or non-recharging systems is the limit of the pumper's historic expectations. Geothermal resources should be allocated as water only when a geothermal developer is drawing from the same source of water as a conventional groundwater user. Science provides no blanket answer to this question for every reservoir is different. In some cases shallow groundwaters will be heated by a geothermal system. In other cases geothermal fluids will be formed by processes unrelated to the initial supply and recharge of conventional groundwater basins. But, considerable evidence has accumulated from different systems throughout the world to suggest that in order to have a viable geothermal system the heat source must be sealed from a conventional groundwater source and whatever mixing between the sources that does occur, occurs late in the fluid formation cycle.¹⁰ In short, there is a scientific basis to presume non-interference between geothermal developers and conventional groundwater users.

The scientific basis behind the presumption is a distinction between sources of water based on the length of time the water has been in the ground. Controversies over the nature of geothermal resources go back to the seventeenth century, but recently it became necessary to resolve the controversy at the Big Geysers in Northern California. Rival geothermal developers held conflicting leases from the surface and mineral owners. A very sophisticated trial court opinion held for the mineral lessee on the basis of expert testimony that the fluids were formed from connate as opposed to juvenile waters.¹¹ Connate waters are waters trapped within a host formation for millions of years. When the intrusive system expels volatiles, the connate waters are absorbed from

the host rock and, after a complex process, are boiled several times before they reach the surface as a heat transfer medium. One cannot generalize from the Geysers to every geothermal reservoir, but the experience in Northern California indicates the scientific potential exists for segregating geothermal fluids from conventional sources of water.

We argue that a geothermal reservoir is simply a natural resource to be exploited efficiently for commercial uses. Exploitation should be regulated for environmental and conservation reasons so the developer is forced to bear all the costs of exploitation. Subject to these constraints, geothermal energy should be allocated, as have other resources in the past, through the recognition of private rights subject to well-defined police power regulations.¹² However, the nature of the likely heat transfer medium—water—poses a problem for geothermal developers and regulators attempting to integrate the resource into existing property rights and regulatory regimes. Two analogies have been suggested to accomplish this result. Federal and much state legislation proceeds on the assumption that geothermal reservoirs are analogous to oil and gas reservoirs, and thus the resource should be regulated as a mineral. Other state legislation and scholarly commentary proceed on the assumption that because the heat transfer medium is water, the resource is water.

III. EXISTING CLASSIFICATIONS OF GEOTHERMAL RESOURCES

A. Federal and State Geothermal Legislation

The federal government and thirteen Western states have some form of regulation of geothermal resources to promote their development. Prior to the passage of federal and state legislation there was great uncertainty as to the proper legal classification of geothermal resources, and it was argued

For a more general statement of Dr. Austin's testimony written for the lawyer see Austin, *Technical Overview of Geothermal Resources*, 13 LAND & WATER L. REV. 9 (1977).

12. Sato & Crocker, *Property Rights to Geothermal Resources: Part I*, 6 ECOLOGY L.Q. 250 (1977) make a contrary argument. They assert that the state has the power to declare all geothermal resources underlying privately held lands to be public resources subject to lease by the state. Three analogies are put forward in support of the thesis. The first is the elimination of unused riparian rights when a state shifts from the common law to prior appropriation; the second is the limitation of landowner trespass claims for overflights; and the third is the long standing recognition of the navigation servitude. These analogies are said to support the theory that all property rights are based on reasonable expectations and because "[u]ntil the recent activity concerning geothermal resources, most land owners had no expectation of capturing the resources value. Therefore, if incidents of landownership should be held to include property rights in these resources, the landowner would receive a windfall." *Id.* at 318. Part II of the study recommends that geothermal rights be allocated by an administrative agency applying a prior appropriation system similar to that used to allocate western groundwater. Sato & Crocker, *Property Rights to Geothermal Resources: Part II*, 6 ECOLOGY L.Q. 481 (1977).

We disagree with both of the principal conclusions of the Sato-Crocker study. The argument for state ownership is unconvincing for two reasons. First, the analogies relied upon by Sato and Crocker do not support their conclusion. The first two analogies provide scant support for an assertion of the state's power to shift resources from private to public uses for they involve only the recognition of correlative rights among competing resource users. The third analogy provides mild support for such a shift, but the navigation servitude doctrine should not be extended to the recognition of state ownership of geothermal resources. Normally, expectations that private ownership rights will be recognized by the government are valid unless the state puts affected property owners on notice that the claims will not be recognized. Michelman, *Property, Utility, Fairness: Comments on the Ethical Foundations of "Just Compensation" Law*, 50 HARV. L. REV. 1165 (1967). The understanding is not, as Sato and Crocker suggest, that expectations need not be recognized if the property owner has only recently come to rely on exploiting a new and now valuable use of his property. The burden is on the state to put the property owner on notice of non-recognition, as it has allegedly historically done with respect to the navigation servitude; the state should not be able to invoke a non-expectation rule simply because the value of a resource has only been recently recognized. Our second ground of disagreement flows from this analysis. Adoption of the Sato-Crocker rule might lead to the inefficient allocation of resources because it creates a disincentive for property owners to respond to societal demands for new uses of their property.

An administrative prior appropriation system is recommended because the permit granting agency can manage the reservoir, by timing the issuance of and conditioning permits, to maintain optimum reservoir levels over time. Utilization, based on the oil and gas model, is rejected, in part, because the transaction costs are high. Sato & Crocker, *Property Rights to Geothermal Resources: Part II*, 6 ECOLOGY L.Q. 527-35 (1977). In light of the high cost to a public agency of acquiring adequate information to implement their proposed administrative management system, we conclude that utilization is the most efficient method of conserv-

9. The leading scientific critic of the blanket proposition that geothermal energy poses no significant environmental risks has nonetheless concluded with respect to the adverse environmental impacts which may occur from field development: "every field presents a unique mix of environmental problems, and most of the worst impacts are avoidable. In short, each geothermal installation presents abundant opportunities for creative environmental engineering." Axtmann & Peck, *Geothermal Chemical Engineering*, 22 AM. INST. CHEM. ENGRS. 317, 323 (1978). See generally Tarlock & Waller, *An Environmental Overview of Geothermal Resources Development*, 13 LAND & WATER L. REV. 289 (1977).

10. E.g., Stefánsson & Arnórsson, *A Comparative Study of Hot-Water Chemistry and Bedrock Resistivity in Southern Lowlands of Iceland*, in UNITED NATIONS SYMPOSIUM, at 1207; Tezcan, *Geophysical Studies in Saraykoy-Kizildere Geothermal Field Turkey*, in UNITED NATIONS SYMPOSIUM, at 1231.

11. We have drawn on the deposition of Dr. Carl Austin, Naval Weapons Center, China Lake, California in *Geothermal Kinetics v. Union Oil Co., Inc.*, No. 75314 (Superior Court for Sonoma County, California). The decision was filed June 1, 1976, and affirmed by the Court of Appeal of the State of California, First Appellate District, Division Three, Nov. 15, 1977, ___ Cal. App. 3d ___ 141 Cal. Rptr. 579 (1977).

that this uncertainty impeded their development.¹³ When the federal government and the states turned to the problem of encouraging and regulating geothermal development, most legislation followed either the mineral or water model, although some states classified geothermal resources as *sui generis* to no particular end. Most federal and state geothermal legislation was enacted between 1967 and 1975. Because the resource was considered a clean one environmentally at this time, the primary objective of most legislation was to provide a legal structure which would induce development of the resource. The federal government and most states authorized leasing on lands they owned. Most states undertook to provide a definition of a leaseable private resource and to regulate drilling on privately owned lands to prevent blowouts and pollution. Some states enacted compulsory unitization statutes to increase the efficiency of resource recovery.

The federal government and most of the states define geothermal resources but not in a manner designed to integrate them into the property rights regimes of other resources.¹⁴ Rather, geothermal resources have been defined almost exclusively for the purposes of assigning them to an existing regulatory regime to provide a definition of a leaseable resource. Integration problems, for the most part, have been postponed. For this reason, to solve the problems we are addressing, no great weight can be assigned to the existing definitions. This is unfortunate because it affects where geothermal resources are placed in the scheme of previously recognized property rights systems, although it is simplistic to assume that classification will resolve all conflict problems. Constitutional protection of vested property rights prevents legislatures from solving all conflicts by the simple expedient of classification, but a definition can avoid some conflicts and provide a framework for the solution of others.

Scientifically, geothermal resources are simply useable heat energy from beneath the earth's surface, and thus they are neither conventional mineral or water resources. However, the medium by which the heat is transferred is important to the lawyer because other resource users may assert competing claims to the medium. In the West, the medium will initially either be steam or heated waters consisting of low to high saline brines if the reservoir is a hydrothermal convection system. Also, proposals exist to exploit hot dry rocks by injecting water into the formation and taking it out as steam.¹⁵ If the exploitation of hot dry rocks proves commercially feasible, the medium will, of course, be conventional water. Thus, the heat transfer medium links geothermal resources to water, but the use to which they are put does not. Heat will be generally used to produce electricity so functionally geothermal resources are linked to hydrocarbon minerals, although the mechanics of an oil and gas reservoir and a geothermal reservoir are quite different. In short, neither analogy provides an adequate characterization of the resource.

Because the object of state legislation has been to promote geothermal resource development, it is not surprising that many states elected, directly or indirectly, to treat geothermal resources as minerals. Mineral resources are generally owned by the state, the discoverer, or the overlying landowner, and the classification of geothermal resources as minerals has the advantage of assigning them to a regime where exclusive property rights are recognized. Water, on the other hand, is said to be the property of the state in the sense that the state, in its sovereign capacity, is trustee for the public. Private rights can be obtained but usually by a valid appropriation. If geothermal resources are classified as water, the overlying landowner would have no right to lease them if he had not perfected an appropriation. State "ownership" could be used by the state to assert an exclusive right to lease all non-federally-owned geothermal resources and to collect royalties from state lessees. There have been vigorous constituencies within each state to treat geothermal as water, so states sometimes have dual classifications embedded within their statutes even when the resource is formally defined as a mineral or at least not water.

California and New Mexico were the first states to regulate geothermal development, and other states have either followed their lead or that of the Geothermal Steam Act of 1970. California defines geothermal resources as:

[T]he natural heat of the earth, the energy, in whatever form, below the surface of the earth present in, resulting from, or created by, or which may be extracted from, such natural heat, and all minerals in solution or other products obtained from naturally heated fluids, brines, associated gases, and steam, in whatever form, found below the surface of the earth, but excluding oil, hydrocarbon gas or other hydrocarbon substances.¹⁶

New Mexico¹⁷ and Hawaii¹⁸ follow the California model. Regulatory jurisdiction is assigned to the state oil and gas commission in California and New Mexico and the state lands department in Hawaii.

An immediate problem presented by the California definition is the characterization of the heat transfer medium. The definition does not clearly include water as a geothermal resource. The energy and extracted solution materials clearly are; oil, hydrocarbon gas and other hydrocarbon substances are not. It could be argued that water is part of the resource by virtue of the provision including energy "in whatever form" since the energy is usually in fluids that are the transporting media for geothermal energy. But, a contrary argument can be made from the definition's inclusion of minerals and other products derived from natural fluids, brines and associated gases, and steam suggesting that only the extracted substances are part of the resource and substances from which the extraction is made are not.

Oregon¹⁹ and Idaho²⁰ have adopted the California definition but go further and take a position on the heat transfer medium. Oregon excludes hot waters of less than 250° Fahrenheit bottom hole temperature at depths less than 2000 feet from its definition of geothermal resources, and thus the state has a dual mineral-water regime for geothermal resources. The 250° or under limitation was selected to exclude

ing geothermal resources. See Goldstein, *Unitization for Geothermal Resources: United We Save*, 13 LAND & WATER L. REV. 159 (1977).

13. Olpin, *The Law of Geothermal Resources*, 14 ROCKY MOUNT. MIN. L. INST. 123 (1968).

14. A useful discussion of the purpose of classification, emphasizing the need to separate geothermal from water resources, is SCARTO, *STATE POLICIES FOR GEOTHERMAL DEVELOPMENT: UNCOVERING A MAJOR RESOURCE* 43-46 (National Conference of State Legislatures 1975). See also Elmer & Rogers, *Legal Issues in the Development of Geothermal Resources of Texas and Louisiana Gulf Coast*, in V SECOND GEOPRESSURED-GEOTHERMAL ENERGY CONFERENCE (Center for Energy Studies, University of Texas 1976), which contains a useful discussion of existing statutes. The authors emphasize the need to define more precisely the different sources of geothermal energy.

15. Ewing, *Stimulation of Geothermal Systems*, in *GEOTHERMAL ENERGY: RESOURCES, PRODUCTION, STIMULATION* 217 (Kruger & Otte eds. 1975).

16. CAL. PUB. RES. CODE § 6903 (West 1977).

17. N.M. STAT. ANN. § 65-11-3 (Supp. 1975).

18. HAWAII REV. STAT. § 132-6 (1) (Supp. 1975).

19. ORE. REV. STAT. § 522.005 (1) (1975).

20. IDAHO CODE § 42-4002 (1) (1977).

the hot-water wells around Klamath Falls and other areas of the state which have long been used for space heating. These wells are treated as water wells and to date the state has not restricted hot-water pumping.²¹ Idaho adds the following to the California definition: "Geothermal resources are found and hereby declared to be *sui generis*, being neither mineral resource nor a water resource, but they are also found to be closely related to and possibly affecting and affected by water and mineral resources in many instances." Geothermal resources in Idaho might be more aptly characterized as quasi *sui generis* resources, and the Idaho solution teaches that just as assignment to a traditional natural resource category does not solve hard conflicts among resource users, the creation of a meaningless new classification is equally ineffective for it creates no new protection for either the water user or geothermal developer. Geothermal development is regulated by the Idaho Department of Water Administration so, in effect, the resource is water. Idaho has a leasing statute, and an appropriation is required for a geothermal well that involves the use of water. Montana has adopted the Idaho definition in its statute authorizing geothermal leasing on state lands, but recognizing the difficulties of the *sui generis* classification, adds "unless the context requires otherwise."²²

The other competing definition of the resource is the federal definition. Section One of the Geothermal Steam Act of 1970 provides:

Geothermal steam and associated geothermal resources means (i) all products of geothermal processes, embracing indigenous steam, hot water and hot brines; (ii) steam and other gases, hot water and hot brines resulting from water, gas, or other fluids artificially introduced into geothermal formations; (iii) heat or other associated energy found in geothermal formations; and (iv) any byproduct derived from them:

"Byproduct" means any minerals (exclusive of oil, hydrocarbon gas, and helium) which are found in solution or in association with geothermal steam and which have a value of less than 75 per centum of the value of the geothermal steam or are not, because of quantity, quality, or technical difficulties in extraction and production, of sufficient value to warrant extraction and production by themselves.²³

The major difference between the federal and California definitions is that the federal definition explicitly includes the heat transfer medium within the definition of the resources. Otherwise both the California and mineral definition treat geothermal heat as essentially a mineral resource. Arizona²⁴ and Colorado²⁵ have adopted the federal definition, but Arizona goes further by including "any artificial stimulation or induction thereof" of the geothermal reservoirs within the definition and it has a slightly different byproduct definition than the federal definition. Arizona has apparently anticipated the possibility that steam may be produced by injecting water into hot rocks. Washington's statute is similar to the federal model in that the heat transfer medium is included in the definition of the resource, but geothermal resources are limited to those "from which it is technologically possible to produce electric energy commercially. . . ."²⁶

A final group of states have not adopted either of these definitions but treat the resource as water. Wyoming amended the definition of underground water in 1973 to include "geothermal steam and hot water,"²⁷ and an appropriation permit is required. Utah apparently reached the same result. The resource is not yet defined in Utah law, but in 1973 the division of water rights was given jurisdiction over "all wells for the discovery and production of water to be used for geothermal energy production in the State of Utah. . . ."²⁸ Similarly, Montana includes geothermal resources on privately owned lands within the definition of groundwater in the water code.²⁹ Nevada, which has many potential geothermal sites, classified the resource as water by a 1965 opinion of the Deputy Attorney General and required all drillers to obtain a permit to appropriate. In 1975 the situation became somewhat more confused when the legislature defined the resource simply as "heat or other associated geothermal energy found beneath the surface of the earth."³⁰ Regulation is still in the State Engineer's Office, but the 1975 legislation allows him to adopt special regulations for geothermal development.

These statutory definitions are not the only place where the relationship between geothermal and water resource development is addressed. States have references to water used in geothermal development, water recovered from steam and liquid brines, and waste disposal. However, these additional references add little to the resolution of the conflicts with which we are concerned.

B. Relation Between Geothermal and Water Rights

Some states recognize the possibility that a geothermal well may interfere with a conventional water use. The statutes solve the problem by treating the geothermal developer as an appropriator in those cases where the state water agency or an existing water user contests a geothermal well permit. For example, the statutes in Colorado and Washington seem to cast the burden of proving non-interference on the geothermal developer.³¹ In discharging the burden, however, the statutes give the geothermal operator the same rights as a conventional groundwater pumper. Washington's statute provides that a permit shall not be granted if the Department of Natural Resources "finds that the operation of any well will unreasonably decrease ground water available for prior rights in any aquifer . . . unless such rights are acquired by condemnation, purchase, or other means."³² Under Washington law, a pumper has a right only to the maintenance of the water table at the safe annual yield so an assertion of a right to lift above that level could not be used to defeat a geothermal claim.³³ Only California has tried to avoid water geothermal conflicts by a statutory procedure which allows the geothermal developer to make a preliminary showing of non-interference. This statute is discussed in detail in Section VI.

Another water problem addressed by some geothermal statutes is the well that produces water for conventional uses rather than energy. These wells are treated as water wells, and an appropriation permit must be obtained. For example,

27. WYO. STAT. § 41-121 (Supp. 1973). However, the State Board of Land Commissioners uses the California definitions in lease forms for state lands. SCARTO, STATE POLICIES FOR GEOTHERMAL DEVELOPMENT, *supra* note 14, at 44.

28. UTAH CODE ANN. § 13-1-20 (Supp. 1977).

29. MONT. REV. CODES ANN. § 89-367(1) (Supp. 1975).

30. NEV. REV. STAT. § 322.005 (1975). See SCARTO, STATE POLICIES FOR DEVELOPMENT OF GEOTHERMAL ENERGY, *supra* note 14, at 44.

31. COLO. REV. STAT. § 34-70-107(4) (Supp. 1976); WASH. REV. CODE ANN. § 79.76.030 (Supp. 1976). In Colorado the State Engineer must determine whether or not inappropriated water is available except where the "permit clearly does not contemplate the appropriation or use of groundwater." See Vranesh & Musick, *Geothermal Resources: Water and Other Conflicts Encountered by the Developer*, 13 LAND & WATER L. REV. 109 (1977).

32. WASH. REV. CODE ANN. § 79.76.030 (Supp. 1976).

33. WASH. REV. CODE ANN. § 90.44.070 (Supp. 1976); see A SUMMARY DIGEST OF STATE WATER LAWS 779 (Dewsnup & Jensen eds. 1973).

21. Interview with Mr. Chris Wheeler, Deputy Director, Oregon State Department of Water Resources, Salem, Oregon (Aug. 15, 1977).

22. MONT. REV. CODES ANN. § 31-2602 (Supp. 1975).

23. 30 U.S.C. § 1001 (1970).

24. ARIZ. REV. STAT. ANN. § 27-651(5) (1976).

25. COLO. REV. STAT. § 34-70-103 (Supp. 1976).

26. WASH. REV. CODE ANN. § 79.76.030 (Supp. 1976).

in Washington a geothermal well that produces only water suitable for beneficial uses is converted to a water well.

C. Judicial Classifications of the Resource

Courts have addressed the classification of geothermal resources in two contexts: title disputes where the surface and mineral estates were severed prior to the recognition of the commercial worth of geothermal resources and tax deduction allowance claims. In both contexts the courts have unanimously held that geothermal resources are minerals.³⁴ Unfortunately, the resolution of the mineral versus surface conflict does not answer the important question which principally concerns us here. It is useful to have the question of proprietorship answered, whoever the ultimate victor might be, since the elimination of doubt will remove a potential deterrent to development. Once proprietorship is settled, prospective geothermal developers know whom to approach to secure development rights. But, proprietorship does not determine whether or how state water laws might apply to geothermal development. Surprisingly, on this there seems to be some unwarranted confusion. One state water agency has expressed concern that a victory for the mineral owner would strip that agency of power to regulate water extraction through geothermal wells, but this need not follow. It is logical to assign proprietorship to the mineral owner and at the same time regulate geothermal wells pursuant to water laws. This would multiply the number of steps for the would-be developer. The developer would have to secure both a geothermal lease or other property right from the mineral owner (or the surface owner if the cases should go the other way) and an appropriate right from the state for any water to be produced. This two-step process has been routinely followed in both California and Nevada.

The mineral-surface owners title dispute cases, however, have important implication for regulatory choices. For the most part, the courts in these cases have exhibited a willingness to look behind labels and to inquire into what kind of water is involved in geothermal phenomena. The Court of Appeals for the Ninth Circuit was satisfied the congressional action with respect to water for livestock raising did not establish the legal order that should be applied to "underground sources of energy for use in generating electricity."³⁵ A California trial court has rejected the argument that surface owners should have geothermal rights because they have rights to freshwater when, for the surface owners' purposes, "there is no realistic basis to find that the water condensed from the steam is or could be beneficial."³⁶ This same willingness to discriminate should allow regulatory choices to be made on more substantial grounds than labels such as water and mineral. It may make sense to apply some of the laws and regulations dealing with water resources or with mineral resources. On the other hand, it may make sense to create new laws and regulations tailored specifically for geothermal resources.

IV. DEVELOPMENT ON FEDERAL LANDS

The Geothermal Steam Act of 1970³⁷ removed consider-

34. *United States v. Union Oil Co.*, 369 F. Supp. 1239 (N.D. Cal. 1973), *rev'd*, 549 F.2d 1271 (9th Cir. 1977), *cert. denied*, 48 U.S.L.W. 3257 (No. 76-1796). *State of California v. Pariani*, No. 637-291 (Superior Court for County of San Francisco, California 1977); and *Geothermal Kinetics, Inc. v. Union Oil Co.*, No. 75314 (Superior Court for Sonoma County, California 1976), *aff'd*, — Cal. App. 3d — 141 Cal. Rptr. 379 (1977). See generally Bjerre, *The Development of Geothermal Resources and the 1970 Geothermal Steam Act—A Law in Search of a Definition*, 6 COLO. L. REV. 1 (1974). The leading case upholding a depletion allowance for geothermal resources is *Reich v. Commissioner*, 54 F.2d 1157 (9th Cir. 1972). *United States v. Union Oil Co.*, *supra* note 34, at 1279. *Geothermal Kinetics, Inc. v. Union Oil Co.*, No. 75134 at 17 (Superior Court for Sonoma County, California 1976), *aff'd*, — Cal. App. 3d 141 Cal. Rptr. 379 (1977).

able doubt as to whether geothermal development rights could be obtained in federal lands. Prior to the passage of the Act, would-be developers had sought to secure development rights under the Mining Law of 1872³⁸ and the Mineral Leasing Act of 1920,³⁹ but the Department of the Interior took the position that neither statute was apt and, indeed, that no legal authority existed under which development rights could be obtained.

In opening federal lands for development, the 1970 Act followed the pattern of the Mineral Leasing Act in providing a system of competitive and noncompetitive leasing.⁴⁰ The question of the availability of development rights under prior law was addressed by granting limited privileges to convert mining claims and mineral lease rights to geothermal leases under the new Act.⁴¹ The issue of state water rights, though discussed during congressional deliberations, was essentially left unresolved. After some thrashing about on water rights, Congress ducked the issue:

Nothing in this chapter shall constitute an express or implied claim or denial on the part of the Federal Government as to its exemption from State water laws.⁴²

Some state water agencies contend the result of this language is that state water laws apply, and in states requiring permits or other authorizations to drill water wells, those same permits and authorizations are required to drill geothermal wells on federal lands.⁴³ Neither the Department of the Interior nor any federal lessee has challenged this assertion of state regulatory power. In this section, we will consider whether a successful challenge might be made.

A. Provisions in the Geothermal Steam Act Dealing With Water

The words Congress used in defining geothermal resources are broad enough to include water.

(c) "geothermal steam and associated geothermal resources" means (i) all products of geothermal processes, embracing indigenous steam, hot water and hot brines; (ii) steam and other gases, hot water and hot brines resulting from water, gas, or other fluids artificially introduced into geothermal formations; (iii) heat or other associated energy found in geothermal formations; and (iv) any byproduct derived from them;⁴⁴

This definition differs from definitions adopted in some states (including California), where there is considerable doubt as to whether the water content is part of the defined resource.

Byproducts of geothermal resources are also defined in the Act.

(d) "byproduct" means any mineral or minerals (exclusive of oil, hydrocarbon gas, and helium) which are found in solution or in association with geothermal steam and which have a value of less than 75 per centum of the value of the geothermal steam or are not, because of quantity, quality, or technical difficulties in extraction and production, of sufficient value to

37. 30 U.S.C. § 1001-25 (1970).

38. 30 U.S.C. § 22 *et seq.* (1970).

39. 30 U.S.C. § 181 *et seq.* (1970).

40. 30 U.S.C. § 1003 (1970).

41. 30 U.S.C. § 1003(a)-(f) (1970).

42. 30 U.S.C. § 1021 (1970).

43. See, e.g., U.S. DEPT. OF THE INTERIOR, FINAL ENVIRONMENTAL STATEMENT FOR THE GEOTHERMAL LEASING PROGRAM, Vol. III, at C-D 23 (the Colorado position) and C-D 25 (the Nevada position). The Department of the Interior responded that the proposed federal regulations were adequate "to put the public on notice that states' rights are not in any way enlarged, diminished, or modified" by the regulations. *Id.* Vol. III, at C-74.

44. 30 U.S.C. § 1001(c) (1970).

warrant extraction and production by themselves;⁴⁵

The byproducts definition appears to be aimed at minerals in solution that might profitably be extracted; it does not seem to include the geothermal fluids that contain those solution minerals. A subsequent provision of the Act, however, injects some uncertainty.

If the production, use, or conversion of geothermal steam is susceptible of producing a valuable byproduct or byproducts, including commercially demineralized water for beneficial uses in accordance with applicable State water laws, the Secretary shall require substantial beneficial production or use thereof unless, in individual circumstances he modifies or waives this requirement in the interest of conservation of natural resources or for other reasons satisfactory to him.⁴⁶

The structure of this last sentence suggests that commercially demineralized water is a byproduct and requires that beneficial use of such water be in accordance with state water laws. The Act is entirely silent on whether there is also state authority to regulate the production of noncommercial water. The question is posed whether state law applies to water which evaporates or which is reinjected or which must be treated as waste because it is unfit for beneficial uses. The most that can be said is that the provision by inference seems to negate state regulatory power. If it was necessary to provide explicitly that state laws apply to the use of commercially demineralized water, it must be that state laws would not otherwise apply. Although this analysis has a plausible ring, it is certainly not dispositive.

In the final analysis, Congress enacted but a single section directly addressing the federal-state water issue and that is the sentence stating that the 1970 Act is neither a "claim or denial" as to federal exemption from state water laws. State agencies grounding their claimed regulatory powers on that sentence rely on a precarious statutory structure. The best argument they can make is that Congress intended to leave the question to resolution under existing legal principles and those principles (the Desert Land Act of 1877,⁴⁷ in particular) repose regulatory power in the states. This argument will be explored in greater depth in the following section.

B. State Authority Over Water in Federal Lands and the Federal Reserved Water Rights Doctrine

A logical beginning assumption might have been that the United States would be regarded as the owner of water in federal lands. If that were so, it would appear to follow that the United States would own and control geothermal fluids whether they be classified as water or something else. If the slate were clean, such a simple analysis would be almost indisputable; however, the slate is not clean. What Congress and the federal courts have written on the slate presents some difficulty in delineating federal-state relationships with respect to waters on and under public lands.

In the course of the early westward migration during the nineteenth century, settlers helped themselves to both min-

erals and waters on public lands.⁴⁸ Both were there for the taking, and no government objection was interposed. The first rules were made by the settlers themselves in an attempt to define "property" rights and avoid bloodshed. The United States gave no signal that this situation was unacceptable and in due course approved the settlers' practices by explicit legislation, both as to minerals⁴⁹ and waters.

By a statute passed in 1866 and amended in 1870,⁵⁰ Congress recognized and sanctioned possessory water rights on federal lands asserted under local laws and customs. By the Desert Land Act of 1877,⁵¹ Congress went further and severed, for purposes of future acquisition, the soil and water rights. The key provision reads:

Provided, however. That the right to the use of water by the person so conducting the same, on or to any tract of desert land of three hundred and twenty acres shall depend upon bona fide prior appropriation; and such right shall not exceed the amount of water actually appropriated, and necessarily used for the purpose of irrigation and reclamation; and all surplus water over and above such actual appropriation and use, together with the water of all lakes, rivers, and other sources of water supply upon the public lands and not navigable, shall remain and be held free for the appropriation and use of the public for irrigation, mining, and manufacturing purposes subject to existing rights.⁵²

In a 1935 opinion the Supreme Court wrote as though the statutory severance were complete and the resulting state power were plenary. Specifically,

The purpose of the Acts of 1866 and 1870 was governmental recognition and sanction of possessory rights on public lands asserted under local laws and customs. . . . The Desert Land Act severed, for purposes of private acquisition, soil and water rights on public lands, and provided that such water rights were to be acquired in the manner provided by the law of the State of location.⁵³

But, even before 1935 a landmark case had already articulated the doctrine that would substantially impinge on state powers. In *Winters v. United States*,⁵⁴ the Supreme Court held that the establishment of the Fort Belknap Indian Reservation in 1888 resulted in the retention of such water rights as might be needed to irrigate reservation lands and sustain the Indian settlement.

For a time it was widely believed the *Winters* doctrine applied only to Indian reservations, but subsequent Supreme Court decisions have made clear that it applies in numerous other settings. The *Pelton Dam* case, decided in 1955,⁵⁵ held that the withdrawal or reservation of land for power purposes resulted in the reservation of water rights necessary to fulfill the purposes of the withdrawal or reservation. The State of Oregon's contention that the Desert Land Act required the United States to perfect water rights in accordance with state law was rejected on the ground that the Desert Land Act did

48. The problems of settlement in the arid lands west of the 100th meridian were many. Major John Wesley Powell explored much of this country and wrote a report recommending national programs and policies to improve the chances of the settlers. Unfortunately, his recommendations were largely ignored, and more settlers failed than succeeded. See POWELL, REPORT ON THE LANDS OF THE ARID REGION OF THE UNITED STATES (1879).

49. The history of mineral resources laws affecting public lands is told in a highly readable treatment in Swenson, *Legal Aspects of Mineral Resources Exploitation*, in GATES, HISTORY OF PUBLIC LAND LAW DEVELOPMENT (1968).

50. 43 U.S.C. § 661 (1970).

51. 43 U.S.C. § 321 *et seq.* (1970).

52. 43 U.S.C. § 321 (1970).

53. Federal Power Comm'n v. Oregon, 349 U.S. 435, 447-48 (1955).

54. 207 U.S. 564 (1908).

45. 30 U.S.C. § 1001(d) (1970).

46. 30 U.S.C. § 1008 (1970). If state water laws were fully applicable to commercially demineralized water, no by-product royalty would appear to be payable to the United States since the appropriation of water rights under state laws does not result in any royalty obligations when water is taken from federal lands. The Secretary of the Interior's regulations take the position, however, that royalty payments must be made on such water. 43 C.F.R. § 3205.3-6 (1976). A persuasive argument might be made that the royalty payment on water called for in the regulations is contrary to the 1970 Act.

47. 43 U.S.C. § 321 *et seq.* (1970).

not apply to "reservations":

[T]hese Acts are not applicable to the reserved lands and waters here involved. The Desert Land Act covers "sources of water supply upon the public lands," but "reservations." Even without that express restriction of the Desert Land Act to sources of water supply on public lands, these Acts would not apply to reserved lands. "It is a familiar principle of public land law that statutes providing generally for disposal of the public domain are inapplicable to lands which are not unqualifiedly subject to sale and disposition because they have been appropriated to some other purpose." . . . The instant lands certainly "are not unqualifiedly subject to sale and disposition. . . ." Accordingly, it is enough, for the instant case, to recognize that these Acts do not apply to this license, which relates only to the use of waters on reservations of the United States.⁵⁵

The broad scope of the possible reserved federal rights was briefly sketched with yet more completeness in the second *Arizona v. California* case decided by the Supreme Court in 1962:

The Master ruled that the principle underlying the reservation of water rights for Indian Reservations was equally applicable to other federal establishments such as National Recreation Areas and National Forests. We agree with the conclusions of the Master that the United States intended to reserve water sufficient for the future requirements of the Lake Mead National Recreation Area, the Havasu Lake National Wildlife Refuge, the Imperial National Wildlife Refuge and the Gila National Forest.⁵⁷

After *Arizona v. California*, the nature of federal reserved water rights became much clearer; however, many problems remained. When the federal government withdraws or reserves public lands for specific purposes, by necessary implication it reserves from appropriation under state laws such water as may be required to serve those purposes. The power to make withdrawals and reservations may be grounded upon several possible constitutional provisions, with the commerce and property clauses being the most frequently invoked. Reserved water rights are not dependent on actual appropriation and application to beneficial use. Such rights are senior to the water rights of subsequent appropriators under state laws, and subsequent state appropriators take the risk that their water investments may be impaired if there is increased use under reserved federal rights. Appropriators under state laws whose rights antedate the federal withdrawal or reservation, however, remain senior to the federal reserved rights.

The most recent Supreme Court opinion concerning the reserved water rights doctrine dealt with groundwater pumping, and for that reason it provides a closer analogy to geothermal development. In *Cappaert v. United States*⁵⁸ the United States brought an action to enjoin levels of groundwater pumping that threatened the habitat of the Devil's Hole Pupfish. Devil's Hole is a deep limestone cavern in Nevada that is a remnant of a prehistoric Death Valley system of lakes. The pupfish that live in the cavern are found nowhere else in the world. In 1957 President Truman issued a procla-

mation withdrawing the forty-acre parcel of public-domain land surrounding Devil's Hole and adding it to Death Valley National Monument. The expressed purpose of the withdrawal was to preserve the pool's "unusual features of scenic, scientific and educational interest" and specifically the "peculiar race of desert fish." In 1968 the Cappaerts began pumping groundwater on their nearby ranch within two and one-half miles of Devil's Hole and in time their pumping began to lower the water level in Devil's Hole. The United States brought the action to limit pumping from locations near Devil's Hole except for domestic purposes, grounding its claim on the federal reserved water rights doctrine. The District Court and the Court of Appeals ruled in favor of the United States and ordered limits on the Cappaerts' pumping.

The Supreme Court held that President Truman's action had the effect of reserving unappropriated and available water necessary to accomplish the purposes of the reservation of Devil's Hole. The purpose was to protect the pupfish habitat, and water necessary to maintain the pool at a level required for that purpose was accordingly reserved. The water required for the federal purpose is the measure of the right, and no balancing of the equities with subsequent appropriators is necessary. The Court did specify, however, that the amount of the reservation is "only the amount of water necessary to fulfill the reservation, no more."⁵⁹

Without accepting Nevada's argument that the doctrine should only apply to surface water, the Court noted the physical interrelationship of the surface water in the pool and the groundwater being pumped by the Cappaerts and noted Nevada itself acknowledged this physical fact by its appropriation laws which apply to both surface water and groundwater. The Court's strict holding could be narrowly stated to apply only to situations where federal surface waters require protection from subsequent diversions through groundwater pumping. The thrust and reasoning of the opinion suggest, however, that federal reserved rights can attach to groundwater as well as surface water. It should follow that if geothermal fluids are classified as groundwater, it is possible in appropriate circumstances that such fluids could be reserved.⁶⁰

For geothermal fluids in federal lands to be the subject of a federal reserved water rights, some event competent to serve as a withdrawal or reservation of water must be found. The only events that singularly or in combination are arguably competent to that end are:

(1) an Executive Order issued by President Hoover in 1930⁶¹ withdrawing vacant, unappropriated public lands containing hot springs or springs possessing curative properties;

(2) a withdrawal by the Secretary of the Interior in 1967 of public lands valuable or prospectively valuable for geothermal steam from all appropriation under public land laws, "including, without limitation, the mining laws and mineral leasing laws;" and

(3) the Geothermal Steam Act of 1970 and leases issued by the United States pursuant to that Act.

On its face, President Hoover's executive order hardly

55. Federal Power Comm'n v. Oregon, *supra* note 55.

56. *Id.* at 448.

57. *Arizona v. California*, 373 U.S. 546, 601 (1962).

58. 426 U.S. 128 (1975). See generally Meyers, *Federal Groundwater Rights: A Note on Cappaert v. United States*, 13 LAND & WATER L. REV. 377 (1975).

59. *Id.* at 141.

60. Indeed, federal groundwater pumping was sustained as a proper exercise of a federally-reserved water right in Nevada *ex rel. Sharnberger v. United States*, 165 F. Supp. 600 (D. Nev. 1958), *aff'd on other grounds*, 279 F.2d 699 (9th Cir. 1960) (sovereign immunity).

61. Exec. Order No. 5389 (July 7, 1930).

seems competent to reserve geothermal fluids. It was expressly concerned with hot springs and springs with "curative properties" so that such resources could be made available under a 1925 Act of Congress authorizing permits "for the erection of bathhouses, hotels or other improvements." Despite the difficulty of fitting geothermal fluids into this language, the Acting Solicitor of the Interior Department issued an opinion in 1961 suggesting that the executive order is broad enough to do so. The opinion concluded there was nothing in the executive order restricting its application to hot springs valuable primarily for curative properties or to hot springs "created solely by the forces of nature." Thus, in the view of the Acting Solicitor, the executive order could apply to wells drilled to create hot springs for public use and benefit and geothermal wells drilled to produce electricity.⁶²

Despite the Acting Solicitor's opinion, the executive order does not seem competent. The bathhouse purpose of 1930 hardly seems apt to encompass geothermal steam used to produce electric energy, especially when there is no intimation that the fluids possess or will ever be used for curative properties. Further, the term "hot springs" does not seem broad enough to include drilled geothermal wells.

In another setting, a federal court has rejected Interior opinions oversimplistically treating geothermal fluids as water. The Court of Appeals for the Ninth Circuit found totally unpersuasive the Solicitor's opinions ruling that geothermal resources passed to patentees under the 1916 Stock Raising Homestead Act because they were essentially water and, therefore, not within United States mineral reservations.⁶³ The opinion on the executive order might suffer a similar fate for its simplistic assumption that geothermal wells are merely hot springs within the meaning of the order.

The second event that affords a possible basis for a federal reserved water right in geothermal fluids is the 1967 withdrawal by the Secretary of the Interior,⁶⁴ which created a minor congressional furor over the claimed "implied authority" upon which the Secretary relied. The existence of that authority was implied, in view of the Secretary, from long-continued congressional practice of acquiescing in or ratifying former withdrawals by the Executive Branch. The contrary view held Congress had in the Pickett Act⁶⁵ specifically spelled out the statutory basis for making withdrawals and the 1967 withdrawal could not be squared with the statute. The validity of the 1967 withdrawal has never been determined, and the rules for future executive withdrawals have been entirely rewritten by the Federal Land Policy and Management Act of 1976.⁶⁶ The new rules in the 1976 Act do not, however, invalidate previous withdrawals.

If the 1967 withdrawal was valid when it was made, there can be no question that the Secretary thereby withdrew geothermal resources in the lands described in the withdrawal. It presents none of the constructional difficulties associated with President Hoover's 1930 executive order. A question remains, however, as to whether a consequence of the withdrawal was the creation of federal reserved water rights and,

if so, the nature and extent of those rights. It was intended that the withdrawal at least have the effect of barring the acquisition of geothermal resources under then existing laws until federal administration could be "attained through the enactment of geothermal legislation."⁶⁷ But, was it intended that the withdrawal reserve federal "water" rights? If the answer is yes, do such rights attach to geothermal fluids produced from geothermal wells, to conventional surface and subsurface waters needed in geothermal operations (such as cooling water for geothermal power plants), or to both such categories of "water"?

If geothermal fluids are water for these purposes, then the classic federal reserved water rights analysis can be utilized and a federal priority established for geothermal fluids as of 1967. This would mean federal geothermal lessees of lands having such rights may have no need to concern themselves with state water rights perfected after the 1967 withdrawal.

The Congressional enactment of the Geothermal Steam Act of 1970 is the third event that could be the basis for federal reserved water rights. The 1967 withdrawal anticipated this Act and was calculated to preserve federal geothermal resources until Congress could legislate an appropriate federal regulatory scheme. Ultimately, it is necessary to consider the possible cumulative effects of the 1967 withdrawal, the 1970 Act, and the issuance of federal geothermal leases under the Act. First, however, it will be useful to focus on the ways in which the factual setting of geothermal development will differ from the factual settings in which federal reserved water rights have previously been recognized.

In all of the Supreme Court's cases, the recognized reserved water rights were associated with specified parcels of land—an Indian reservation, a power site, a national forest. Moreover, the reserved water related to the needs of the specified parcel in order to serve the purposes of the withdrawal for reservation. The focus as to Indian lands has been on irrigable acreage, but reserved rights have also been recognized for other purposes, such as preservation of fisheries, and consideration is being given to industrial and other uses on Indian lands. The *Cappaert* decision provides an example where the use of the specified land required preservation of the water level in a surface pool to protect a rare fish. A lower federal court has recognized federal reserved rights in groundwater for the needs of a military reservation.⁶⁸ In each instance specified land was identified, and the water use contemplated had to do with the utilization of that land to accomplish the purposes for which it was withdrawn or reserved. The limitation this analysis places on federal reserved rights is illustrated by a recent New Mexico Supreme Court opinion. *Mimbres Valley Irrigation Co. v. Salopek*⁶⁹ refused to recognize Forest Service claims to reserved rights to support minimum stream flows for environmental and aesthetic reasons on the grounds the purposes for which the Gila National Forest was withdrawn were limited to watershed protection for downstream users and the maintenance of timber as a renewal resource.

Federal geothermal development will differ markedly from the usual reserved rights fact patterns. Apart from the specifications of geothermal prospect areas in the amended 1967 withdrawal, it is not immediately possible to ascertain the lands to which federal reserved rights might attach. Is

62. Solicitor's Opinion M-36625 (August 28, 1961).

63. *Union Oil Co. v. United States*, *supra* note 34.

64. 32 Fed. Reg. 2558 (Feb. 3, 1967), as amended, 32 Fed. Reg. 4506-4508 (March 21, 1967). The March amendment confined the withdrawal to certain designated land which partially quieted the furor when the Secretary initially withdrew simply "all public lands which are valuable for geothermal steam."

65. 43 U.S.C. § 141 (1970).

66. Pub. L. No. 94-579, § 204, 90 Stat. 2743 (1976) (to be codified as 43 U.S.C. § 1714).

67. Letter of Interior Secretary Udall to Congressman Wayne Aspinall (May 19, 1967), reprinted in *Hearings Before the Subcomm. on Mines and Mining of the Comm. on Interior and Insular Affairs*, 90th Cong., 1st Sess., 52 (1967).

68. *Nevada ex rel. Shamberger v. United States*, *supra* note 60.

69. 564 P.2d 613 (N.M. 1977), cert. granted, 46 U.S.L.W. 3426 (No. 77-510).

there, for example, an inchoate federal reserved right in all federal public lands awaiting future geothermal development in order to flower into maturity? If so, will that reserved right have a priority dating from the enactment of the 1970 Act or from the date of the issuance of a geothermal lease? (Or, perhaps, from the date of the 1967 withdrawal if the leased lands were described in the amended withdrawal notice?) The greatest complaint water users and state officials have leveled at federal reserved rights is the difficulty in planning and building water projects in the face of unquantified federal rights that do not depend on actual use. The difficulties would be compounded if it were not possible even to ascertain which federal lands might enjoy federal reserved rights.

The manner of use of geothermal fluids is also different from usual patterns. Conventional water resources have been held subject to federal reserved rights when the water was needed on the land to serve the purposes of the withdrawal or reservation, to make the land serve values that were explicitly or implicitly sought to be served. In the case of geothermal development, the purpose would presumably be to extract geothermal resources primarily to serve values away from the lands on which the extraction occurs. The geothermal fluids would simply not be used with relation to the lands in the same manner that conventional waters have been used with relation to withdrawn or reserved federal lands. A more apt analogy might exist if federal reserved rights had been recognized as entitling the United States to develop water on federal lands and market it for offsite uses. This, however, has not been the case.

For reasons that may be implicit in the foregoing, federal reserved rights have not been recognized as attending permits or licenses to extract resources from federal lands. Neither the holder of a timber contract with the United States nor the lessee of a mineral permit or lease under the Mineral Leasing Act of 1920 is thought to obtain the right to take water for his operations pursuant to federal reserved rights. By parity of reasoning, the geothermal lessee would not be thought to enjoy federal reserved rights to conventional waters. In these situations, the conventional water needs will probably be regarded as problems of the federal contractors, permittees and licensees; the solutions would seem to lie in perfecting state water rights or acquiring water from the holders of existing rights.⁷⁰

This brings us to the attribute of geothermal resources that argues most convincingly for the recognition of federal reserved rights even though such rights have not been recognized for the benefit of the holders of timber contracts or federal mineral lessees.

A meaningful line can be drawn between conventional waters required in the course of extracting various resources from federal land and geothermal fluids produced from geothermal wells. The former represent but one of numerous needs

attending various resource extraction operations and are indistinguishable from many of man's activities that require water consumption. Geothermal fluids, on the other hand, must of necessity be produced in the very course of utilizing the resource. All geothermal resources that man has thus far tapped have utilized the geothermal fluids to transport the heat energy and other values to places where it can be utilized. If the fluids are not produced, the resource is of no use. This physical fact supports an argument for recognition of reserved federal rights. Since fluid production is essential to realizing the purpose of the 1967 withdrawal, the 1970 Act, and the leases under the 1970 Act, federal reserved rights to produce can reasonably be implied. It could then follow that federal geothermal lessees could be regarded as having production rights senior to the holders of subsequent water rights acquired pursuant to state laws. Under the standard reserved water rights analysis, the federal lessees would not be required to follow state water procedures.

The recognition of federal reserved water rights in federal geothermal lessees would, however, leave some bothersome issues. First, the priority date of the federal right would have to be chosen from among the uncertain options of 1967, 1970, the date of the geothermal lease issuance, or some other date. State rights antedating whatever date is ultimately selected would remain senior under federal reserve rights theory, and it would be necessary to determine when such rights are impaired by geothermal operations. Remedies would have to be fashioned to protect these senior state rights. In states applying prior appropriation principles, remedies could well result in cessation of geothermal operations.

In sum, a case can be made for recognizing a federal reserved right to produce geothermal fluids under the rubric of the Supreme Court's opinions on the reserved water rights doctrine. The mere recognition of such rights, however, would create considerable problems in integrating geothermal operations into the fabric of federal-state water jurisprudence. This jurisprudence is cumbersome in dealing with conventional water resources and is totally unsuited to the vastly different situation of geothermal development.

In the next section, consideration will be given to an analysis that is better adapted to dealing with the development of federal geothermal resources.

C. Federal Supremacy and Federal Geothermal Development

It is basic to American federalism that federal laws control over contrary state and local laws. The supremacy clause of the Constitution provides that in such conflicts state and local laws must give way.⁷¹ A straightforward supremacy analysis of the Geothermal Steam Act of 1970 can yield a convincing case for overriding any state laws, including state water laws, that would prevent or hinder orderly development of federal geothermal sources.

A graphic example of federal supremacy in a water setting was presented in the Supreme Court's opinion in *First Iowa Hydro-Electric Cooperative v. Federal Power Commission*.⁷² An Iowa cooperative had applied to the Federal Power Commission for a license to construct and operate a dam, reservoir, and hydro-electric power plant on an Iowa river.

70. In dictum, however, the Supreme Court has alluded to the possibility of reserved rights for the development of oil shale on Naval Petroleum and Oil Reserves "which, if ever developed, would require water to accomplish the purpose for which the reservation was made." *United States v. District Court in and for Water Division No. 5*, 401 U.S. 527 (1971). Even taking this dictum at full face value, it speaks to specifically identified petroleum and oil shale reserves, which is quite a different thing than reserved water rights to develop federal resources whenever they might in the future be found on federal lands. See also Comment, *The Federal Reserved Water Doctrine—Application to the Problem of Water for Oil Shale Development*, 3 LAND & WATER L. REV. 75 (1968); Holland, *Mixing Oil and Water: The Effect of Prevailing Water Law Doctrines on Oil Shale Development*, 52 DEN. L.J. 657, 682-688 (1975). See generally Ranquist, *The Winters Doctrine and How It Grew: Federal Reservation of Rights to the Use of Water*, 1975 B.Y.U.L. REV. 639.

71. U.S. CONST. art. 6, § 2. Dean Trelease has made a prior appropriation here also as he has preceded us in suggesting that constitutional supremacy analysis better explains the Supreme Court's decisions in the federal-state water rights area. TRELEASE, *FEDERAL-STATE RELATIONS IN WATER LAW* (1971).

72. 328 U.S. 152 (1946).

Among other things, the project was designed to divert water from one river basin to another within Iowa. Iowa law provided that no dam could be constructed in the state unless a prescribed state license was first obtained. Further, state law prohibited diversion of streams outside their watersheds. Iowa petitioned to intervene in the FPC proceedings and actively opposed the granting of the license relying largely on the requirement of the Federal Power Act that an applicant must submit satisfactory evidence "that the applicant has complied with the requirements of the laws of the State," and the Commission dismissed the application for failure to present the required evidence of compliance.

The Supreme Court reversed, holding the Iowa requirements had no application to those activities affecting navigable rivers which Congress had given to the Commission.

To require the petitioner to secure the actual grant to it of a State permit . . . as a condition precedent to securing a federal license for the same project under the Federal Power Act would vest in the Executive Council of Iowa a veto power over the federal project. Such a veto power easily could destroy the effectiveness of the federal act. It would subordinate to the control of the State the 'comprehensive' planning which the Act provides shall depend upon the judgment of the Federal Power Commission or other representatives of the Federal Government.⁷³

In a surprisingly cavalier manner, the Supreme Court brushed aside the Federal Power Act language requiring the applicant to submit satisfactory evidence of compliance with state laws. This language, in the Court's view, "did not itself require compliance with any state laws," but was only "by way of suggestion" to the Commission on subjects as to which it "may wish some proof submitted to it of the applicant's progress."⁷⁴ While some state laws would remain applicable and effective, the Court said that could not be so as to state laws amounting to a dual system of control of power project permits.

Other Supreme Court opinions are consistent with *First Iowa* in striking down state laws that would impede federal water projects. In *Oklahoma v. Guy F. Atkinson Co.*,⁷⁵ the Court turned aside Oklahoma's strenuous objections to what the state regarded as a seriously detrimental water project.

[S]ince the construction of this dam and reservoir is a valid exercise by Congress of its commerce power, there is no interference with the sovereignty of the State. . . . And the suggestion that this project interferes with the State's own program for water development and conservation is likewise of no avail. That program must bow before the 'superior power' of Congress.⁷⁶

In the *Pelton Dam* case,⁷⁷ which has been previously discussed, Oregon's objections to another federal project were unavailing as the Court followed its *First Iowa* ruling.

Like the Federal Power Act, the Geothermal Steam Act of 1970 provides a federal plan of regulation that does not leave room for conflicting state controls. It is true that application of state water laws is expressly countenanced for utilization of commercially demineralized water, but this cuts against rather than argues for a state role amounting to dual

licensing or permitting of geothermal operations. The more logical inference is that deference to state law in this instance also marks the outer boundaries of the role to be played by state water laws.

For the same reasons, the disclaimer in the 1970 Act covering federal exemption from state water laws should not be read to sustain dual licensing. Congress provided that the Act is neither a "claim or denial" of federal exemption from state water laws; it would be a giant leap from there to reason that a state may adopt expansive measures undercutting the federal plan for geothermal development on federal lands. Under no other banner could a state erect a state veto, and the disclaimer should not be construed to authorize a veto simply because the state law erecting the barrier happens to be labeled a water law.

V. THE CASE AGAINST APPLICATION OF WESTERN WATER LAW DOCTRINES TO GEOTHERMAL DEVELOPMENT

If geothermal resources are characterized as water, they will be further classified as groundwater resources, but the experience of the western states in applying prior appropriation to groundwater is not a promising model for the development of geothermal resources. The consequence of this classification is that, in all western states except Arizona and California, rights to geothermal resources will have to be acquired by perfecting a valid appropriation. Prior appropriation was originally applied only to surface waters and it is only within the past two or three decades that most western states have required that groundwater rights be appropriated. States which attempt to conserve groundwater resources do so in ways that are detrimental to geothermal development. The states with extensive experience in applying appropriation to groundwater in declining basins, such as New Mexico, Colorado and Idaho, have found it easier to cut-off access to a basin at some point and let all the previous pumpers draw equally than to try and adjudicate priorities among pumpers. Other states with geothermal potential such as Montana, Oregon and Washington have elaborate prior appropriation laws giving state agencies the power to adjust rights among pumpers, but they have had little experience applying them, so it is impossible to predict the restrictions to which a groundwater appropriator might be subject. The Arizona doctrine of reasonable use and the California doctrine of correlative rights also constrain geothermal development for they provide no clear standards for apportionment of the resource. Further production may be limited to uneconomic levels in California, and in both states there are substantial restraints on the use of the resource on nonoverlying lands, which is the use to which most geothermal energy will be put. The net result is that in all states the law of groundwater either provides unnecessary constraints or, at a minimum, uncertainties to the geothermal developer. This section surveys the general disadvantages of applying groundwater doctrines to geothermal development. Specific state statutes and cases are used for purposes of illustration, as this article is not intended to be an exhaustive discussion of the law of each state.

A geothermal developer may face two basic types of water-related conflicts. He may be in competition with conventional agricultural, industrial and municipal water users for a share of a common supply, or these users and others may argue that the disposal of geothermal wastes, especially saline brines, will contaminate a common source of supply. Supply

73. *Id.* at 164.

74. *Id.* at 177-78.

75. 313 U.S. 508 (1941).

76. *Id.* at 534-35.

77. Federal Power Comm'n v. Oregon, *supra* note 53.

conflicts may arise when existing pumpers sue to enjoin the drilling of a geothermal well on the grounds the resulting production will interfere with prior vested rights, when a producing well has been drilled and existing pumpers bring an action for damages based on interference with vested rights, or when the state attempts to block a well on the grounds that the development will involve a use of water that is not in the public interest. Pollution conflicts will generally arise when the geothermal developer proposes to reinject wastes for conservation and environmental reasons, and either existing ground and surface water users or the state claim that the reinjection program will cause pollution.

To restate our basic thesis, in the case of supply conflicts, geothermal development should be presumed *not* to interfere with conventional water users. This presumption must be a rebuttable one, for its purpose is not to allow a geothermal developer to injure prior vested water right holders, unless the state makes an explicit choice that some injury is in the public interest. Rather, the purpose is to provide a means to minimize the needlessly constraining role of water law and regulation on geothermal development by eliminating conflicts based on hypothetical interferences with conventional water sources. No such presumption is warranted when the alleged injury is water pollution, for geothermal development is simply another form of waste-generating activity and should, therefore, be subjected to applicable federal and state pollution laws.

An appreciation of the proper resolution of geothermal-water supply conflicts must start with an understanding of the differences between the law of mineral exploitation and western water use. Although our mineral and western water laws share certain basic principles, there are subtle but fundamental differences between them which could hinder the development of geothermal resources if water laws and state regulatory systems are applied across the board to the geothermal development.

Our argument that there should be no blanket application of state and federal water laws to exploitation proposals is developed as follows: (1) an examination of the different assumptions underlying mineral and water exploitation, (2) an examination of the groundwater law of the fourteen western states with potential for geothermal development in the immediate future, (3) an examination of means of implementing the presumption of noninterference, and (4) an examination of the situations in which the presumption might be overcome and our suggestions for resolving the conflicts. The last two topics are discussed in Section VI of this article.

A. Assumptions Underlying Mineral and Water Exploitation

This section compares and contrasts the assumptions underlying the exploitation of oil and gas, the mineral most closely analogous to geothermal resources, and water.

The law governing the exploitation of oil and gas proceeds on the assumption that these resources are finite, exhaustible, and should be exploited according to market demand. The law implements this by giving overlying landowners, public and private, the right to capture oil and gas beneath their lands.⁷⁸ The right to capture is subject to the equal right of

adjacent landowners to do likewise so long as each surface owner confines his drilling to vertical planes extending downward from the surface.⁷⁹ There are three major exceptions to the law of capture, each based on the premise that these resources are finite and should be exploited according to market demand. First, federal and state governments as landowners can either withdraw land from leasing to meet future needs, for example, to assure adequate supplies in time of war, or reserve resources from exploitation to serve higher public purposes.⁸⁰ For example, some potentially valuable geothermal lands are unavailable for development because they are reserved as national parks. Also, state governments can in effect withdraw resources from production by establishing, as done before the Arab oil embargo, production quotas to maintain price.⁸¹ A second exception is judicial and statutory recognition of correlative rights. In *Ohio Oil Co. v. Indiana*,⁸² the Supreme Court defined correlative rights for the purpose of sustaining a state law requiring that gas wells be capped as follows:

Hence it is that the legislative power from the peculiar nature of the right and objects upon which it is exerted, can be manifested for the purpose of protecting all the collective owners, by securing a just distribution to arise from the enjoyment, by them of their privilege to reduce to possession, and reach a like end by preventing waste.⁸³

As enunciated by subsequent courts, correlative rights in oil and gas are not recognized to allocate a common supply on some principle of fairness, but only to assure each pumper the right of fair access to the common supply.⁸⁴ The doctrine prevents the deliberate waste of a resource to deplete a common source of supply,⁸⁵ negligent drilling operations which waste the common supply,⁸⁶ and actions such as the negligent failure to plug an abandoned well which result in the spoilage of a common supply.⁸⁷ Third, to encourage the maximum physical recovery of the resource, conservation measures may be imposed. These measures are generally designed to conserve reservoir pressure, thus extending the useful life of the reservoir by limiting the number of wells which can be drilled in the field. Pooling and unitization are state regulatory schemes of recognizing and protecting correlative rights.⁸⁸ Sub-

Meyers conclude: "The theory held by the state is of little importance apart from its influence on the classification of mineral, royalty, and leasehold interests as corporeal or incorporeal." 1 WILLIAMS & MEYERS, OIL AND GAS LAW § 204.9 (1959). For this reason we speak of the rule of capture without any further effort to distinguish between those states which follow the non-ownership theory and those which follow the ownership in place theory. The states are classified at *id.* at § 203.1.3.

79. *Id.* at § 227.

80. 1 AMERICAN LAW OF MINING § 2.1 (Martiz ed. 1960). Increasingly, the terms withdrawal and reservation are used interchangeably to describe legislative or executive action which segregates a designated area of federally owned land from access under the federal laws relating to entry, location or lease. Courts, however, occasionally refer to reservations as permanent withdrawals and withdrawals as temporary withdrawals. *United States v. Consol. Mines & Smelting Co., Ltd.*, 455 F.2d 432 (9th Cir. 1971). We maintain the distinction between reservation and withdrawal to differentiate between actions which require Congressional action to reverse and where such action is unlikely to occur and interim executive or legislative classifications which may change in response to new conditions. 1 AMERICAN LAW OF MINING § 2.46-2.63 (Martiz ed. 1960) for a discussion of the various reservations and withdrawals of federally owned land and of the status of the mineral claimant on them.

81. Proration was instituted to insure the maximum possible reservoir recovery and to restrict statewide production to the estimated demand for the next ensuing period. See LOVEJOY & HOMAN, ECONOMIC ASPECTS OF OIL CONSERVATION REGULATION 127-184 (1967) for a discussion of pre-1973 market-demand proration.

82. 177 U.S. 190 (1900).

83. *Id.* at 210.

84. The leading discussion of correlative rights is Kuntz, *Correlative Rights of Parties Owning Interests in a Common Source of Supply of Oil and Gas*, SEVENTEENTH ANNUAL INSTITUTE ON OIL AND GAS LAW TAXATION 217 (1963).

85. *Louisville Gas Co. v. Kentucky Heating Co.*, 117 Ky. 71, 77 S.W. 368 (1903).

86. *Eliff v. Texon Drilling Co.*, 146 Tex. 375, 210 S.W.2d 558 (1948).

87. *Cf. Higgins Oil Fuel Co. v. Guaranty Oil Co.*, 145 La. 202, 32 So. 206 (1919).

88. Pooling refers to the bringing together of small tracts to create a drilling unit to qualify for a well permit under applicable well spacing laws. Unitization means the joint operation of all or part of a reservoir. The reason for pooling and unitization is the same: the prevention of physical waste, the prevention of economic waste, and the protection of correlative rights. The amount of oil and gas recoverable from a reservoir is a function of the degree of natural or artificial pressure main-

78. Due to the early scientific uncertainty about oil and gas reservoir mechanics, different theories to describe the surface owner's interest were advanced. Some states adopted the non-ownership theory of oil and gas which holds that no person owns the oil and gas until it is produced. Most major producing states now follow the ownership in place theory which equates ownership of oil and gas with ownership of solid subsurface minerals. However, after a survey of the impact of these theories on the landowner's right to produce and the state's power to regulate, Williams and

ject to these limitations on the right to capture, the pumper obtains title to all oil and gas brought to the surface.

Western water law is also based on the principle of capture, but the similarity between oil and gas and water breaks down quickly. As is the case with oil and gas, the first person to divert water to a beneficial use obtains a prior right against all subsequent appropriators, but capture and appropriation are not the same thing. Under the law of oil and gas, absent a state-imposed allowable, or pooling or unitization scheme, a subsequent pumper can capture oil and gas being pumped by a prior pumper so long as there is no trespass or violation of correlative rights. A subsequent appropriator cannot displace a prior one when the supply is not adequate, for a prior right to call available water is vested.⁸⁹ Thus, unlike a prior oil or gas pumper, a prior appropriator may be able to block any subsequent use if he can prove that available supplies are necessary to protect vested rights. This result stems from two crucial differences between water and oil and gas. First, there is no substitute for water as there are substitutes for oil and gas; second, water is generally treated as a flow rather than a stock resource, as a replenishable rather than a wasting resource. For example, groundwater withdrawals can be limited to some level of safe yield⁹⁰ and surface streams are increasingly subject to minimum flow requirements.⁹¹ Geothermal resources are generally stock rather than flow resources and any effort to limit the amount which can be produced, other than to prevent waste, may be inefficient, yet the purpose of much recent groundwater legislation is to limit production.

An important exception to the principle that water resources should be managed to balance withdrawals against safe yields relevant to geothermal development occurs with respect to groundwater basins which are not located in alluvial fields. Such basins replenish very slowly. In some instances they have been adjudicated as wasting assets for purposes of the federal Internal Revenue Code's allowance of depletion deductions.⁹² Some of these basins are managed on the assumption that they should be mined, but ironically this may present greater problems for the geothermal developer than if the basin were not mined since access may be severely restricted.⁹³

Further, there is a "public interest" qualification to water withdrawals which is less defined than the "public interest" restrictions on the right to capture oil and gas. Compared to mineral usage,⁹⁴ the state has always asserted a substantial interest in the uses to which water is put.⁹⁵ This is because water is a scarce resource in the Far West and there are a variety

of competing uses of widely disparate economic value. Grossly inefficient uses are curtailed by the doctrine that an appropriation is valid only if the water is applied to a beneficial use, and the state's interest in the use to which water is put is asserted through statutory preferences. Further, it has long been the rule in the Far West that the state owns the water within its boundaries in trust for the public. Declarations of state ownership, as Dean Trelease demonstrated in his famous article "Government Ownership and Trusteeship of Water" written in 1957, are simply assertions of the state's police power over natural resources.⁹⁶ The ownership concept, however, serves to underscore the extent of the state's power to deny access to water in order to allocate it to a perceived higher use. Historically, prior appropriations were occasionally subordinated to subsequent ones under this standard. Today, however, there is increasing pressure to supplant the doctrine of prior appropriation by using the public interest standard as a means of allocating scarce supplies. The contours of the public interest standard are not clearly defined. However, for our purposes it is sufficient to state that the public interest limitations which can be asserted on water uses are potentially greater than those imposed on oil and gas where the doctrine of correlative rights has taken on a relatively precise meaning,⁹⁷ and serve to limit the amount of water which may be available for geothermal use in ways which may impede development of this resource. The differences between the law on oil and gas and water are nicely summed up in the legal doctrine that a water right is a usufructory one entitling the holder only to the right to use a certain quantity of water under certain conditions rather than giving him title to the source of supply itself.

B. Western Water Law Doctrines Inapplicable to Geothermal Development.

These differences between oil and gas exploitation and water use manifest themselves more concretely in various water law doctrines and state regulatory systems. We have identified the following nine features of western water law and administration which may operate to constrain geothermal development.

1. *Inappropriate Forms and Procedures.* The forms and procedures of water administration are not suited to geothermal development.⁹⁸ Required data on the rate of diversion, point of diversion and expected return flow may not be applicable to geothermal development. This is ultimately a minor problem as forms can be adapted to the geothermal developer if the state chooses to regulate the resource primarily through the state engineer. However, this problem underscores the differences between the two resources and the inappro-

ained. Pooling and unitization allow production to be maintained for a longer period of time than would be the case if the rule of capture were allowed to run its natural course because fewer wells are drilled in a field. The correlative rights of each overlying landowner are changed from the right to pump as rapidly as possible to avoid drainage to the right to a share of the production of the "conserved" reservoir. See generally 6 WILLIAMS & MEYERS, OIL AND GAS LAW (1973).

89. See Holland, *supra* note 70, at 670-72.

90. *E.g.*, Baker v. Ore-Ida Foods, Inc., 95 Idaho 575, 513 P.2d 627 (1973).

91. See generally Tarlock, *Recent Developments in the Recognition of Instream Uses in Western Water Law*, 1975 UTAH L. REV. 371, 388-93.

92. United States v. Shubert, 347 F.2d 103 (5th Cir. 1965). See Sato, *Tax Problems Relating to Water Rights and Water Works*, in WATERS AND WATER RIGHTS, § 37.4 (Clark ed. 1967).

93. See Trelease, *The Use of Fresh Water For Secondary Recovery of Oil and Gas in the Rocky Mountain States*, 16 ROCKY MTN. MIN. L. INST. 605 (1971).

94. This may be changing in the Far West as the mineral-rich states begin to appraise the consequences of rapid coal and oil shale development. States have considered legislation, for example, which would discourage energy conversion in the state of origin by inducing or requiring minerals to be exported before they could be converted to energy. See Van Baalen, *Mineral Export Legislation—Can It Withstand Federal Preemption and Commerce Clause Challenges?*, 12 LAND & WATER L. REV. 131 (1977).

95. See Trelease, *New Water Legislation: Drafting For Development: Efficient Allocation, and Environmental Protection*, 12 LAND & WATER L. REV. 385, 404-16 (1977).

96. Trelease, *Government Ownership and Trusteeship of Water*, 45 CALIF. L. REV. 838, 848 (1957).

97. *E.g.*, Environmental Defense Fund, Inc. v. East Bay Mun. Util. Dist., 125 Cal. Rptr. 601 (1975), hearing granted by California Supreme Court No. 23, 422, Feb. 26, 1976. *East Bay* held that an allegation that a utility must reclaim waste water before seeking supplemental fresh water supplies states a cause of action under Art. XIV, Section 3 of the State Constitution which provides, *inter alia*, "The waste or unreasonable use or unreasonable method of waste be prevented." See generally LEE, *LEGAL ASPECTS OF WATER CONSERVATION IN CALIFORNIA*, (Governor's Commission to Review California Water Rights 1977). North Dakota also recently expanded the public interest discretion available to the state engineer. United Plainsmen Ass'n v. North Dakota Water Conservation Comm'n, 247 N.W.2d 457 (N.D. 1976). United Plainsmen holds that the state's waters are subject to a public trust and citing, Sax, *The Public Trust Doctrine in Natural Resource Law: Effective Judicial Intervention*, 68 MICH. L. REV. 471 (1980), reasoned that, at a minimum, the state engineer must determine the potential impact of an allocation sought in an appropriation permit on the present water supply and future needs of the state. The suit challenged the issuance of all water permits for coal-related energy production, and plaintiffs obtained a trial on the merits of whether or not existing state water allocation planning was sufficient to meet the public trust requirements.

98. See Aidin, *Representing the Geothermal Resources Client*, 19 ROCKY MTN. MIN. L. INST. 27, 33 (1974): "It is not possible to know in advance how many gallons of geothermal water or how many pounds of steam will be required to produce one kilowatt hour of electricity."

priateness of a blanket analogy to water.

2. Necessity to Prove an Adequate Available Supply.

An appropriator must establish that an adequate supply is available for his use by proving that unappropriated water is available. Because the connection between a geothermal reservoir and an aquifer devoted to conventional water uses will probably not be well understood prior to geothermal development, placement of such a burden of proof on the geothermal developer is a possible means by which existing pumpers can block a geothermal development where no actual conflict would result.

3. Denial of Entry to Groundwater Basin in Overdraft.

The problem of proof of available supply is especially important in states where access to groundwater basins in overdraft is blocked by legislation which closes certain basins to new pumpers by designating them as critical groundwater areas. Once a pumper is in the basin it may be a free-for-all, but getting in may be a substantial problem since designation closes the basin to new pumpers. All western states, except California and Utah, have a procedure by which an administrative agency can designate a groundwater basin as critical.⁹⁹ This action generally closes the basin to new pumpers, but existing pumpers are generally allowed to keep pumping at pre-existing rates. Thus, should a geothermal reservoir overlap a critical groundwater area a geothermal developer might be denied entry. For example, in Idaho groundwater management is taking a more aggressive stance unfavorable to geothermal development. State law specifies "reasonably anticipated average rate of future natural recharge" as the standard for basin management, and this has resulted in junior pumpers being shut down on the ground that there is not enough recharge to satisfy senior rights.¹⁰⁰

4. Protection of Prior Surface Users' Rights.

A geothermal developer is not only in competition with other groundwater pumpers but with surface users as well. States are moving to close the artificial distinction between ground and surface waters by administering all water rights together. In practice, this means prior surface users now have senior rights against junior groundwater pumpers. Thus, the geothermal developer has another set of potential claimants arguing that his development interferes with prior rights.

Colorado adopted legislation in 1965 and 1969 to extend the doctrine of prior appropriation to "designated" non-tributary groundwater, which had been held not subject to appropriation,¹⁰¹ and to coordinate surface and prior rights. The legislation declared that it was policy of the state that "while the doctrine of prior appropriation is recognized, such doctrine should be modified to permit the full economic development of groundwater resources."¹⁰² Because coordination of ground and surface rights will often mean greater protection of surface rights because they are generally prior in time to pumpers, the legislature attempted to implement the "full development" policy by codifying the futile call doctrine.

Viewed from the perspective of geothermal development, however, the Colorado experience suggests that groundwater

legislation modeled after that state might constrain geothermal development because protection of prior rights emerges as the primary objective of the statute. Courts and administrators will opt for protection of prior rights rather than balancing the costs and benefits of new entrants as against existing pumpers in a basin. All things considered, this is a simpler and perhaps fairer solution. In the leading case of *Hall v. Kuiper*,¹⁰³ for example, the court approved the state engineer's decision to prohibit two new wells in a designated groundwater basin to protect surface rights in a stream fed in part by groundwater which moved at the rate of three-tenths of a mile per year. The state engineer conceded it would be difficult to show a casual connection between the new wells and any particular surface right, but the futile call doctrine could not be invoked simply by showing that there was no casual connection between particular wells and surface rights.¹⁰⁴ However, the futile call policy has been recognized in cases holding that groundwater which will take 173 and 356 years, respectively, to reach a surface stream is nontributary,¹⁰⁵ and junior pumpers have been able to continue pumping through participation in plans of augmentation.¹⁰⁶

5. Groundwater Mining.

One aspect of recent groundwater legislation is potentially more favorable to geothermal development. Colorado and New Mexico have consciously made the decision to mine groundwater in some basins.¹⁰⁷ Formulas have been developed which space the amount of extraction over a definite period. Limits over the amount which can be withdrawn and the number of new pumpers are established in order to keep the basin productive for the mining period. If a geothermal developer could secure a right, the groundwater mining precedents could be adapted to geothermal development. The experience from Colorado suggests the contrary, however, because mining works to the disadvantage of junior appropriators. For example, Colorado developed a scheme to tie depletion of a designated basin to the time necessary to amortize the investment in irrigation equipment. To protect existing pumpers a zone of influence concept was developed, and a new pumper was denied a permit on the grounds that it would cause a forty per cent depletion of existing wells within a three mile radius.¹⁰⁸ Colorado allows a form of mining in nondesignated groundwater areas¹⁰⁹ but the amount which may be mined may not be sufficient for a geothermal developer. To construct a well outside the boundaries of a designated groundwater basin, a permit from the state engineer is required. If the state engineer finds that there is unappropriated water available and the well will not interfere with the vested rights of others, the permit may be issued. In considering whether the permit should be issued, only the

103. 181 Colo. 130, 510 P.2d 329 (1973).

104. *Id.* at 331, following *Fellhauer v. People*, 167 Colo. 328, 447 P.2d 986 (1968).

105. *Kuiper v. Lundvall*, 157 Colo. 40, 529 P.2d 1328 (1974), cert. denied, 421 U.S. 996 (1975).

106. In cases where junior wells interfere with prior surface rights, Colorado law provides a procedure which allows junior wells to keep pumping. A junior well owner may participate in a plan of augmentation; COLO. REV. STAT. § 37-92-103(9) (1975 Cum. Supp.), which allows the burden of replacement water to be shared among pumpers. The standards the courts have established in reviewing plans are favorable to geothermal development. A plan of augmentation need not introduce any new water into the system to be valid. *Kelly Ranch v. Southeastern Colo. Water Conservancy Dist.*, ___ Colo. ___, 550 P.2d 297 (1976). The participants in the plan must prove that existing right holders are not injured. However, existing right holders are not entitled to require the participants in the plan to replace total diversions when they cannot otherwise prove injury. *Cache LaPoudre Water Users Ass'n v. Glacier Meadows*, ___ Colo. ___, 550 P.2d 338 (1976).

107. *Fundingsland v. Colorado Groundwater Comm'n*, 171 Colo. 487, 488 P.2d 835 (1970); *Mathers v. Texaco, Inc.*, 77 N.M. 239, 421 P.2d 771 (1966). See *Telesse, Developments in Groundwater Law* (September, 1976) (unpublished paper delivered at American Water Resources Association Symposium on Advances in Groundwater Hydrology).

108. *Fundingsland v. Colorado Ground Water Comm'n*, *supra* note 106.

109. COLO. REV. STAT. § 37-90-137 (1975 Supp.).

99. See *Harnsberger, Oeltje & Fisher, Groundwater: From Windmills To Comprehensive Public Management*, 52 NEB. L. REV. 179, 270-79 (1973); *Clark, Western Groundwater, in WATER AND WATER RIGHTS*, § 442 (Clark ed. 1972).

100. *Baker v. Ore-Ida Foods, Inc.*, *supra* note 90.

101. COLO. REV. STAT. § 37-90-102 *et seq.* (1973). Designated groundwater is defined as "groundwater which in its natural course would not be available to and required for the fulfillment of decreed surface rights, or groundwater in areas not adjacent to continuously flowing natural stream wherein groundwater withdrawals have constituted the principal water usage for at least fifteen years preceding the date of the first hearing on the proposed designation of the basin." COLO. REV. STAT. § 37-90-103(6) (1973).

102. COLO. REV. STAT. § 37-90-102 (1973).

quantity of water underlying the land owned by the applicant is considered to be unappropriated and the minimum useful life of the aquifer is one hundred years, assuming there is no substantial artificial recharge within such period. "The net effect is to limit pumping from these deep aquifers in any given year to nineteen per cent of the water stored in the applicable area. Any water derived from geothermal sources would probably fall into this category and production of geothermal resources which were classified as groundwater by the State Engineer would be limited by the Colorado Groundwater Management Act."¹¹⁰

6. *Assertion of a Right to Lift.* A geothermal developer's status will be further complicated if the state recognizes a senior appropriator's right to a fixed hydrostatic pressure. Originally, it appeared states would recognize a right to lift as incident to a senior groundwater right. However, due to the practical problem of proving cause and effect relationships in a basin where there are multiple pumpers and the argument that some decline in the water level is necessary to promote efficient use of the basin, courts and legislatures have backed away from giving senior pumpers an absolute right to lift.¹¹¹ The issue is very much open, however, in each state because courts and legislatures have broad discretion to define the appropriator's method of diversion. Thus, it is difficult to predict what duties a geothermal developer might owe to senior pumpers, assuming there was in fact interference between a geothermal and a water well.

7. *Restrictions on Use of Groundwater in California and Arizona.* Groundwater is not allocated exclusively by appropriation in all western states. In California and Arizona groundwater is allocated under common law regimes which define rights by virtue of ownership of the soil. Waters defused in "vagrant, wandering drops moving by gravity in any and every direction along a line of least resistance" are governed by the *ad coelum* doctrine, and the right to use them does not depend on a diversion and application to a beneficial use. The doctrine that percolating groundwater may not be subject to appropriation might seem to benefit the geothermal developer, but he may have the burden of segregating it from the appropriate regime. This problem is important in Arizona and California, which alone among the western states do not apply prior appropriation to all groundwaters. In Arizona, groundwater is presumed nontributary and is the property of the overlying owner. The right to capture is restricted by the rule of reason, which, as developed by the courts, prohibits the use of the water on nonoverlying land by nonmunicipal appropriators.¹¹² California, which has a mixed system of riparian rights and prior appropriation, applies a rule of correlative rights in groundwater controversies which carries forward the surface law of riparian and appropriative rights to groundwater controversies. Basically, the California court distinguishes between overlying and nonoverlying pumpers. All overlying owners are entitled to a fair allocation of the safe annual yield in times of shortage, but the water must be used on the overlying land. Only if there is a surplus of unused water not in excess of safe annual yield, can the water be appropriated for use on nonoverlying land.¹¹³ The correlative rights rule is not therefore suitable for a stock resource

such as a geothermal reservoir. The safe annual yield standard does not permit mining, and it is economically efficient to encourage geothermal reservoirs to be mined.

8. *Application of Public Interest Restrictions on Right to appropriate.* In most western states an appropriator must meet the three requirements of intent, diversion and application to a beneficial use and, in addition, in all states but Colorado, he must convince the permit-granting agency that the appropriation is in the public interest. Historically, state engineers have found appropriations to be in the public interest when there was no interference with prior vested rights. Occasionally, smaller projects have been subordinated to larger diversion projects on the grounds that there was a public interest in providing a right for a project that would yield greater economic benefits.¹¹⁴ Today, state agencies may use the public interest standard to subject appropriation applications to a crude benefit-cost analysis, and they may be able to use the standard to take diffuse environmental considerations into account. Washington and California have held their state environmental quality acts to apply to appropriation applications, so at a minimum many applications require an environmental impact statement.¹¹⁵ At the present time the purpose of an EIS has been defined as procedural and confined to data assembly and display. However, if environmental impact statements are found to have a substantive content, the public interest limitation may take on major but unknown new dimensions. Geothermal developers are, of course, already subject to an impact statement requirement in these states, so application of the public interest standard in water law would only introduce more uncertainty into what is already a confusing process.

9. *Application of the Relation Back Doctrine.* The first major public interest limitation asserted in water use was the idea that speculation in water rights should be discouraged. One anti-speculative doctrine which is firmly entrenched in water law is the doctrine that a water right must be perfected with due diligence after an intent to appropriate has been manifested. Intent to appropriate is manifested generally by filing an application with the state engineer. If the diversion is completed with due diligence, the right relates back to the time of the original intent, but if the diversion is unduly delayed the right is lost in favor of more enterprising junior appropriators. Due to the uncertainties concerning the potential of geothermal reservoirs for actual production, there is no assurance that the first well drilled will result in production. Thus, a geothermal developer forced to abandon a well and drill another may find himself faced with a lack of due diligence challenge from other claimants.

Colorado has long allowed an extended relation-back period for large publically financed, multi-purpose projects, so long as a timely first step is taken, by means of a statutory conditional decree procedure. However, this statutory precedent may not be applied to geothermal development because, unlike the case of a public entity such as a water supply district trying to finance a project, the ability to finance a geothermal development often lies in the hands of the geothermal lessee, rather than with Congress, state legislators or voters. Such lessees are more vulnerable, therefore, to the charge that resources are being held for speculative purposes when

110. Schlauch & Worcester, *Geothermal Resources: A Primer for the Practitioner*, 9 LAND & WATER L. REV. 327, 353 (1977).

111. E.g., *Wayman v. Murray City Corp.*, 23 Utah 2d 97, 458 P.2d 861 (1969).

112. *Farmers Inv. Co. v. Bettwy*, 113 Ariz. 520, 558 P.2d 14 (1976).

113. See *City of Los Angeles v. City of San Fernando*, 14 Cal.3d 199, 537 P.2d 1250 (1975). See generally Hanks & Hanks, *The Law of Water in New Jersey: Ground-*

water, 24 RUTGERS L. REV. 630-50 (1970).

114. See Trelease, *Policies for Water Law: Property Rights, Economic Forces, and Public Regulation*, 5 NAT. RESOURCES J. 1 (1965).

115. *Stempel v. Dept. of Water Resources*, 32 Wash.2d 109, 508 P.2d 166 (1973).

there is a long delay between the claim of right and institution of a project. Montana recently considered a challenge to an appropriation for an energy development which the state considered speculative.¹¹⁶ The State Supreme Court rejected the state's challenge to an appropriation for one per cent of the flow of Yellowstone River which had numerous legal and financial hurdles:

The direct answer to this issue is that there is nothing illegal, inequitable, or contrary to public policy so as to preclude Intake from claiming a right to appropriate 80,650 acre feet of water per year of the waters of the Yellowstone River. Intake has an existing right for the reasons and under the authorities previously cited. While this existing right does not constitute a valid and completed appropriation, it entitles Intake to pursue its project with reasonable diligence to that end for the reasons and under the statutes and case law heretofore discussed. The fact that final determination of the validity of Intake's appropriation may be years away does not place the rights of the people of Montana or subsequent appropriators in limbo for an indefinite and open ended term to any greater extent here than in any other case involving a multimillion dollar project of great magnitude and complexity which is clearly not prohibited. Intake, as well as any other person or business organization, has the right to litigate the constitutionality of any law including Art. X of the Yellowstone River Compact, section 39-346, R.C.M.1947, and the applicability of the Major Facility Siting Act. Considerations of equity and public policy in no way preclude this. The Montana Declaratory Judgment Act authorizes the instant action.¹¹⁷

Montana law now allows the state to condition appropriation applications by fixing a timetable for development of the project.¹¹⁸ However, *Intake* is a strong precedent for the proposition that energy development requires long lead times, and thus the relation-back doctrine should be liberally interpreted to facilitate such development.

This brief discussion of nine areas of contemporary water law development which impact on geothermal development indicates the unsuitability of a blanket application of western water law as a model for geothermal development. The doctrines emerging in the law of groundwater are symptomatic of the fact that most important contemporary water disputes no longer involve a single A against a single B. Rather, classes of A's sue classes of B's, often with C's and D's joining the suit, and water rights litigation looks to future as much as past damage. The impact of one class's use pattern on another class's is difficult to prove, but it is even more difficult to translate general casual relations into justifiable prohibitions on one use in favor of another. Courts and administrators, therefore, seek formulas which allocate scarce water resources in the aggregate between classes of users and conserve the resource. This is all to the good as scarce resources such as groundwater must be conserved. However, mineral development needs a more certain property rights regime which emphasizes reduction of the resource to individual ownership rather than sharing among classes of users. The techniques of pooling and unitization developed in oil and gas seem the best way to prevent the waste of geothermal resources. At some point, the geothermal developer may have to confront surrounding water users, but the time to put him in the system is when the presumption of noninterference is overcome. There is no reason to put the geothermal developer into the

system in the abstract.

VI. A POSSIBLE PHYSICAL SOLUTION

Efficiency may be served and resource values enhanced by an institutional mechanism which identifies geothermal resource deposits that are sufficiently separated from freshwater sources to merit a legal order that treats them as separate and unconnected. Where physical interconnection exists to a significant degree, the same ends might nonetheless be served by allowing separate treatment if geothermal development is undertaken subject to conditions and requirements that give reasonable assurance of noninterference with freshwater sources. An example of this latter situation might be where reinjection of geothermal fluids, limitations to binary production systems, or other expedients can be employed to protect fresh groundwater. These institutional mechanisms address only the possible conflicts over rights to produce geothermal fluids, and it is not expected that they would perform the functions of or supplant water pollution laws and regulations.

California has taken a step in this direction through certificates of primary purpose, but our proposals are considerably broader than this concept. Any geothermal driller in California may apply to the Geothermal Resources Board for a certificate of primary purpose. The Board must issue a certificate if it determines that "such well or wells are primarily for the purpose of producing geothermal resources and not for the purpose of producing water useable for domestic and irrigation purposes." A certificate creates a rebuttable presumption that the driller "has absolute title to the geothermal resources reduced to his possession by such well or wells."¹¹⁹ A person may rebut the presumption only if he establishes that the water content of the geothermal resource is useable for domestic or irrigation purposes without further treatment.

We propose a system which would assign an appropriate state agency the responsibility to make findings concerning the relevant physical facts early in the development of a geothermal area. This agency's charge would be to gather information on subsurface geology and hydrology, and it would be given authority to compel disclosure of drilling and production information on existing water and geothermal wells. In some instances, petroleum drilling and mining activities in the area might provide supplemental information. In extreme cases, it may even be appropriate to drill additional wells for information gathering or for monitoring freshwater pumping and geothermal production impacts and interrelationships. The proposed inquiry would extend beyond the narrow scope of the certificate of primary purpose device available by statute in California which deals only with geothermal wells and inquires only whether the water content of those wells is fit for domestic and irrigation uses without further treatment. Rather, the proposed inquiry by the state agency would deal with all matters that bear on the possible relationship between freshwater pumping and geothermal development.

In geothermal areas where the physical separation is almost total, such as appears to be the case at the Geysers, the agency may well be able to issue findings supporting totally separate treatment. In that event, entirely separate property rights systems could be recognized in the freshwater and geothermal formations, and the only problems other than pollution concerns would be the common pool problems that the

116. Montana Dep't. of Natural Resources and Conservation v. Intake Water Co., ___ Mont. ___, 538 P.2d 1110 (1976).

117. *Id.* at 1122.

118. MONT. REV. CODES ANN. § 39-386 (Supp. 1973).

119. CAL. PUB. RES. CODE § 3742.2 (West 1972).

multiple owners would have inter se within each formation.

In geothermal areas that are not adequately separated from freshwater sources, the agency's task would be more difficult. The agency would be charged not only to make findings concerning the degree of interconnection but would also have the responsibility to impose conditions and limitations on geothermal development designed to prevent substantial harm to freshwater sources. In effect, the agency would be formulating field production rules. If it is determined that harm to the freshwater sources can be prevented by reasonable physical solutions, the agency would order that production go forward implementing those solutions. Thus, production in particular areas might require one or more measures such as fluid reinjection, utilization of binary production methods, shutting in or cutting back particular wells that pose undue risks of harm to freshwater sources, and others. Any geothermal operator who complies with the prescribed conditions would have the benefit of a presumption that his operations cause no injury to or interference with freshwater sources in the absence of convincing evidence to the contrary. Until such convincing evidence is forthcoming, the two regimes would be treated as though they were totally separate and distinct from one another.

An additional problem is posed by the possibility of production of usable water as a by-product of geothermal development. This water should be treated as part of the separate geothermal regime and should go to the geothermal developers who produce it. Some existing state laws suggest a convenient answer as to that part of the water reinjected into the geothermal formation or used for cooling or electric energy generation or otherwise in connection with geothermal operations. Such fluids should not be regarded as any kind of "water" with which the separate freshwater regime is concerned regardless of the quality of the water so used. Normally, no royalty should be owing on such water to geothermal lessors, and no steps should be required under water laws to protect the title to this water. Excess water transported away for use or sale apart from geothermal operations should be treated under the developed water doctrine or should otherwise be deemed non-tributary to the freshwater formations. Where state laws require, that water could be appropriated by the geothermal developers whose efforts bring it into being.

Finally, there is a threshold problem that has thus far been ignored. What is a geothermal resource area? A starting point for thinking is that suggested by the California and Oregon statutes providing for certificates of primary purpose. An area could be classified as geothermal if it is valuable primarily for the production of geothermal resources rather than for the production of water for domestic and irrigation uses. This raises the interesting problem of what to do if an area is primarily valuable for water production but has secondary values for geothermal resources.¹²⁰

The proposed solution could be tied to a voluntary or

compulsory unitization of geothermal areas. At the time the unitization is accomplished, appropriate field rules could be promulgated under which unit operations could take place, and operations in accordance with those rules would give the benefit of the presumption of noninterference with freshwater sources absent clear and convincing contrary evidence. The incentive to unitization in the presumed noninterference with freshwater sources has parallels in other incentives offered for unitization such as exemption from acreage holding limitations and from anti-monopoly laws.

VII. CONCLUSION

Geothermal energy has a valuable role to play as a supplemental source of energy in the Far West. To date many institutional and technological constraints have impeded its development. One institutional constraint is the possibility that geothermal resources will be subjected to the blanket application of western water laws. Western water law has done an admirable job of promoting western development, but it has a more limited role to play in the development of the geothermal resources industry. This article has briefly presented the case against the blanket application of western water law and sketched a means of accommodating geothermal resource development with protection of conventional water users in situations where a potential interrelationship between the two resources is alleged.

120. Another problem which must be addressed in developing a physical solution to geothermal-groundwater conflicts is the coordination of federal and state procedures. If, as we have suggested, federal lessees are not subject to state water laws, the federal government may still wish to consider a procedure by which state water rights information could be taken into account in federal decisionmaking. The National Water Commission's recommendations on the coordination of federal reserved right claims with state water adjudication procedures provides a useful starting point of analysis. NATIONAL WATER COMM'N. WATER POLICIES FOR THE FUTURE 459-467 (1973). Dean Trelease wrote the background study from which the final recommendations were taken. TRELEASE, FEDERAL-STATE RELATIONS IN WATER LAW (1971). Our proposed state procedure could be the basis of the state's ability to influence federal decisions.

X

MINING-CLAIM RECORDATION AND PROSPECTING UNDER THE FEDERAL LAND POLICY AND MANAGEMENT ACT OF 1976

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INTRODUCTION

The Public Land Law Review Commission concluded in its 1970 Report¹ that "Congress should continue to exclude some classes of public lands from future mineral development,"² and that existing Federal systems providing for exploration, development, and production of mineral resources on the public lands, including the location-patent system derived from the General Mining Law of 1872, "should be modified."³ The Commission contemplated that Federal mineral legislation "should be equally applicable to all federally owned land where the type of mineral activity is permitted by law."⁴ Consistent with this philosophy, the Commission concluded that the locators of mining claims "should not be required to comply with state laws relating to the location and maintenance of valid mining claims other than those provisions requiring recordation."⁵ Convinced that "claims long since dormant remain as cloudson-title" and that Federal land managers need to "know where claims are located,"⁶ the Commission called for the elimination of long-dormant claims,⁷ and for notice to the Government of active claims.⁸

Over the years since publication of the Commission's Report, legislative attention has been concentrated not upon "mineral legislation" but rather upon "housekeeping" matters and the desire of the Bureau of Land Management for general authority similar to that enjoyed by the Forest Service under its Organic Act.⁹ The legislative process culminated, on October 21, 1976, in the adoption of the Federal Land Policy and Management Act of 1976,¹⁰ which is commonly referred to as the "BLM Organic Act." Our purpose here is to consider the effect of this Act upon prospectors and miners working on the public lands.¹¹

PROSPECTING AND MINING ON PUBLIC LANDS AFTER THE ORGANIC ACT

The key sentence in the Organic Act is found in Section 302(b),¹² which provides that with four exceptions:

No provision of this section or any other section of this Act shall in any way amend the Mining Law of 1872 or impair the rights of any locators or claims under that Act, including, but not limited to, rights of ingress and egress.

The four exceptions should be examined.

The California Desert Conservation Area

Under Section 601 of the Organic Act,¹³ a large portion of Southern California is designated for special management under a comprehensive long-range plan to be completed and implemented by September 30, 1980. The plan is to provide "for resource use and development, including, but not limited to, . . . mineral development,"¹⁴ under multiple-use, sustained-yield principles, while maintaining environmental quality. Assuming that that is possible in an "extremely fragile, easily scarred, and slowly healed" ecosystem,¹⁵ Congress amended the General Mining Law of 1872 as follows with respect to the California Desert Conservation Area:¹⁶

Subject to valid existing rights, nothing in this Act shall affect the applicability of the United States mining laws on the public lands within the California Desert Conservation Area, except that all mining claims located on public lands within the California Desert Conservation Area shall be subject to such reasonable regulations as the Secretary may prescribe to effectuate the purposes of this section. Any patent issued on any such mining claim shall recite this limitation and continue to be subject to such regulations. Such regulations shall provide for such measures as may be reasonable to protect the scenic, scientific, and environmental values of the public lands of the California Desert Conservation Area against undue impairment, and to assure against pollution of the streams and waters within the California Desert Conservation Area.

Here, then, is express authority for regulation by the Secretary of the Interior¹⁷ of some mining claims and mining activities on one portion of the public lands.

New Public-Land Wilderness Areas

Under Section 603 of the Organic Act,¹⁸ areas formally identified by the Secretary of the Interior "as natural or primitive areas" prior to November 1, 1975, and other roadless areas identified during the fifteen-year period ending in 1991 are to be considered for wilderness designation by the Secretary and upon recommendation of the President, by the Congress. Natural or primitive areas so identified prior to November 1, 1975, are to be covered by a report from the Secretary to the President by July 1, 1980. The President is to report his recommendations to Congress within two

years after any report is received by the President from the Secretary. But since Congress alone can create a wilderness area,¹⁹ what shall happen in the meantime? Congress provided, in Section 603(c) of the Organic Act,²⁰ for a second exception which amends the General Mining Law of 1872:

During the period of review of such areas and until Congress has determined otherwise, the Secretary shall continue to manage such lands according to his authority under this Act and other applicable law in a manner so as not to impair the suitability of such areas for preservation as wilderness, subject, however, to the continuation of existing mining and grazing uses and mineral leasing in the manner and degree in which the same was being conducted on October 21, 1976: Provided, That, in managing the public lands the Secretary shall by regulation or otherwise take any action required to prevent unnecessary or undue degradation of the lands and their resources or to afford environmental protection. Unless previously withdrawn from appropriation under the mining laws, such lands shall continue to be subject to such appropriation during the period of review unless withdrawn by the Secretary under the procedures of section 1714 of this title for reasons other than preservation of their wilderness character. Once an area has been designated for preservation as wilderness, the provisions of the Wilderness Act which apply to national forest wilderness areas shall apply with respect to the administration and use of such designated area, including mineral surveys required by section 4(d)(2) of the Wilderness Act, and mineral development, access, exchange of lands, and ingress and egress for mining claimants and occupancy.

Again, express regulatory authority is provided for with respect to some mining claims and mining activities on some portion of the public lands under limited circumstances. Whether the continuation of "existing mining uses" language will allow the location of new mining claims in an area not previously located under the mining laws but which is under review is not clear. Whether it would make any difference is, perhaps, a more pertinent question.²¹ Certainly, the "for reasons other than preservation of their wilderness character" language is a new departure in public-land legislation, and will most likely spawn some sort of litigation.

Regulation to Prevent Land Degradation

The last sentence of Section 302(b) of the Organic Act²² reads:

In managing the public lands the Secretary shall, by regulation or otherwise, take any action necessary to prevent unnecessary or undue degradation of the lands.

This third exception provides the Secretary of the Interior²³ with express regulatory authority, but only for certain purposes. Does it, or any other provision of the Organic Act, give the Secretary general regulatory authority with respect to the location, maintenance, and use of mining claims on the public lands?

REGULATION OF MINING CLAIM LOCATION, MAINTENANCE AND USE BY THE SECRETARY OF THE INTERIOR

The three just-described exceptions to the Organic Act proviso²⁴ preserving the General Mining Law of 1872 all relate to certain new and carefully circumscribed regulatory authority conferred upon the Secretary of the Interior. Is there any general regulatory authority in the Organic Act giving the Secretary of the Interior the power to interfere with mining-claim location, maintenance and use other than as may be necessary to prevent unnecessary or undue degradation of the public lands?²⁵

Section 303(a) of the Organic Act²⁶ requires the Secretary of the Interior to "issue regulations necessary to implement the provisions of this Act with respect to the management, use, and protection of the public lands, including the property located thereon," and, under Section 303(g), "the use, occupancy, or development of any portion of the public lands contrary to any regulation of the Secretary or other responsible authority, or contrary to any order issued pursuant to any such regulation, is unlawful and prohibited."²⁷ Further, Section 310²⁸ provides:

The Secretary, with respect to the public lands, shall promulgate rules and regulations to carry out the purposes of this Act and of other laws applicable to the public lands, and the Secretary of Agriculture, with respect to lands within the National Forest System, shall promulgate rules and regulations to carry out the purposes of this Act. The promulgation of such rules and regulations shall be governed by the provisions of chapter 5 of Title 5 (the Administrative Procedure Act, as amended), without regard to section 553(a)(2). Prior to the promulgation of such rules and regulations, such lands shall be administered under existing rules and regulations concerning such lands to the extent practical.

But Section 302(b)²⁹ makes it clear, as we have seen, that none of these provisions of the Organic Act "in any way amend the Mining Law of 1872 or impair the rights of any locators or claims under that Act, including, but not limited to, rights of ingress and egress." At the very most, the Secretary has the power to promulgate rules and regulations to carry out the purposes of laws applicable to the public lands; if Congress had wanted to give the Secretary general authority to impair the rights of mining claims and mining-locators under the 1872 Act, it knew how to do so--with the exceptions to the proviso already discussed. It did not do so, and the Secretary has therefore scratched around hopefully, looking for other congressional authority which might give the Department the power to impair the rights of locators and mining claims.

Incredibly, the Secretary has newly asserted³⁰ authority to do whatever he pleases with respect to the 1872 Law under the provisions of Title 30, Section 22, of the United States Code, which he describes as the source of "the general regulatory authority of the Department under the mining law of 1872."³¹ That section of the 1872 Law provides that valuable mineral deposits on the public lands may be appropriated "under regulations prescribed

by law, and according to the local customs or rules of miners in the several mining districts, so far as the same are applicable and not inconsistent with the laws of the United States."

The 1872 Law just quoted is not a grant of authority to the Secretary of the Interior to make law or to prescribe regulations.³² Even in that period Congress knew how to grant the authority to make regulations to officers of the Executive Branch; for example, see the Act of March 3, 1873,³³ which provided:

The Commissioner of the General Land-Office is authorized to issue all needful rules and regulations for carrying into effect the provisions of this and the four preceding sections.

No such grant of authority appears in Title 30, Section 22, and the only grant of authority to promulgate regulations in the 1872 Act is found in Title 30, Section 28, which grants that authority to "the miners of each mining district".³⁴ Title 43, Section 1201 of the United States Code, also relied upon by the Department, authorizes enforcement and carrying into execution, by appropriate regulations, of "every part of the provisions of this title not otherwise specifically provided for." But the power to enforce and carry the law into execution is not the power to amend the law or impair the rights accorded to a mining claim, except as specifically granted in the Organic Act.

RECORDATION OF MINING CLAIMS, MILL SITES, AND TUNNEL SITES UNDER SECTION 314 OF THE ORGANIC ACT

The fourth and final exception to the Organic Act proviso³⁵ preserving the General Mining Law of 1872 is the most important: Section 314 of the Act,³⁶ which Congress entitled "Recordation of Mining Claims and Abandonment." Significantly, this section of the Act contains no provision for the issuance of regulations thereunder; that authority is set forth in Section 310 of the Organic Act.³⁷ Read strictly, the Secretary of the Interior is authorized to promulgate regulations governing the recordation of mining claims located only on the public lands³⁸ and the Secretary of Agriculture is authorized to do so with respect to lands within the National Forests. But the use of the word "Bureau" in Section 314, which is defined in the Act³⁹ to mean the Bureau of Land Management, coupled with Title 16, Section 472 of the United States Code,⁴⁰ is sufficient to justify the issuance of regulations implementing Section 314 by the Secretary of the Interior under Section 310 of the Act.

So important an addition to the General Mining Law of 1872 should be set out in full:⁴¹

(a) The owner of an unpatented lode or placer mining claim located prior to October 21, 1976, shall, within the three-year period following October 21, 1976, and prior to December 31 of each year thereafter, file the instruments required by paragraphs (1) and (2) of this subsection. The owner of an unpatented lode or placer mining claim located after October 21, 1976, shall, prior to December 31 of each year following the calendar year in which the said claim was located, file the

instruments required by paragraphs (1) and (2) of this subsection:

(1) File for record in the office where the location notice or certificate is recorded either a notice of intention to hold the mining claim (including but not limited to such notices as are provided by law to be filed when there has been a suspension or deferment of annual assessment work), an affidavit of assessment work performed thereon, or [or?] a detailed report provided by section 28-1 of Title 30, relating thereto.

(2) File in the office of the Bureau designated by the Secretary a copy of the official record of the instrument filed or recorded pursuant to paragraph (1) of this subsection, including a description of the location of the mining claim sufficient to locate the claimed lands on the ground.

(b) The owner of unpatented lode or placer mining claim or mill or tunnel site located prior to October 21, 1976, shall, within the three-year period following October 21, 1976, file in the office of the Bureau designated by the Secretary a copy of the official record of the notice of location or certificate of location, including a description of the location of the mining claim or mill or tunnel site sufficient to locate the claimed lands on the ground. The owner of an unpatented lode or placer mining claim or mill or tunnel site located after October 21, 1976, shall, within ninety days after the date of location of such claim, file in the office of the Bureau designated by the Secretary a copy of the official record of the notice of location or certificate of location of the mining claim or mill or tunnel site sufficient to locate the claimed lands on the ground.

(c) The failure to file such instruments as required by subsections (a) and (b) of this section shall be deemed conclusively to constitute an abandonment of the mining claim or mill or tunnel site by the owner; but it shall not be considered a failure to file if the instrument is defective or not timely filed for record under other Federal laws permitting filing or recording thereof, or if the instrument is filed for record by or on behalf of some but not all of the owners of the mining claim or mill or tunnel site.

(d) Such recordation or application by itself shall not render valid any claim which would not be otherwise valid under applicable law. Nothing in this section shall be construed as a waiver of the assessment and other requirements of such law.

Notice of Mining-Claim Location

Federal law, unchanged since 1872, permits the miners of each mining district to make regulations not in conflict with the laws of the United States governing both the location and the manner of recording mining claims, subject to two requirements: First, "the location must be distinctly marked on the ground so that its boundaries can be readily traced," and, second, "all records of mining claims

... shall contain" the following information: (1) "the name or names of the locators," (2) "the date of the location," and (3) "such a description of the claim or claims located by reference to some natural object or permanent monument as will identify the claim."⁴² The first purpose and function of the posted location notice is to cause the mining-claim location to be distinctly marked upon the ground as contemplated by that Federal statute.

The locator of a mining claim posts notice of his appropriation upon the ground under one or the other of two different types of local notice requirements. In some states, notice is posted in the form of a sign giving little more than the name of the claimant, the date of the location, and the name of the claim. In other states, the posted notice is a duplicate of the record authorized by Federal and local law.⁴³ In either case, posting of the notice is intended to give actual notice of the location of the claim to subsequent prospectors coming upon the same land. A plain sign or notice prominently displayed is all that is necessary or required for that purpose.⁴⁴ However true it may be that the record of a claim should serve to tie down on the ground the actual location held by a mining claim, it must be remembered that the notice posted on the claim may and often does give actual notice to subsequent prospectors of the existence of the claim. And one who has actual notice of the location of a mining claim cannot relocate the ground upon the assertion of some technical defect in the record of the prior claim.⁴⁵ So the posting of notice initiates the "first-in-time, first-in-right" rule of priority of appropriation.⁴⁶

Because much more than the posting of a notice is required to complete the location of a mining claim, and because the true position of the claim upon the ground is so important, both to the Federal Government which owns the land so appropriated and to subsequent prospectors who need to know what ground remains open to location and which ground is already claimed, mining claims must be, at a minimum, (1) distinctly marked upon the ground so that their boundaries can be readily traced, (2) described, and (3) recorded. The record becomes most important when a claim is not being worked: in that case, actual notice may fail because, with the passage of time, the posted notice, the corner posts, and even the development workings may become obliterated, or otherwise disappear.

The purpose and function of recording mining claims is to accomplish by constructive notice to all the world what actual notice will always do, that is, protect the rights of the first-in-time.⁴⁷ The recording of an appropriation initiates the record chain-of-title, identifies the appropriators, and gives constructive notice by preserving evidence of the location and its priority. State claim-recording requirements thus typically require some information additional to that required by the Federal statute, albeit very little more. The local records do serve other useful functions, however, since they give the owners of mining claims the opportunity to preserve evidence of the maintenance of their claims through assessment-work recordation. And, by virtue of state recording acts, constructive notice of the record chain-of-title is provided.

An unpatented mining claim is property, but it is property which need not be defined with the precision of a formal land survey unless and until the owner decides to seek a patent.⁴⁸ Until then, in the contemplation of Congress, the recorded claim need only be identifiable as to its situs, so that it can be found and then traced upon the ground and be traceable to its owners through the local property records. But a mining claim, unlike ordinary real property, can also be abandoned, or be left open to forfeiture by relocation by others when necessary maintenance work is not performed.⁴⁹ Abandonment, however, is a matter of intent, and forfeiture is not to be lightly presumed. The local records rarely shed light on the factual questions involved in forfeiture, and seldom establish abandonment. Thus, the campaign for notice to and recordation of claims with the Federal land management agencies has been grounded in three suppositions: (1) No one can rely on the local records to find mining claims on the ground; (2) No one can tell which claims have been abandoned and which are being maintained, and (3) The Federal land managers need to know when and where claims have been located and are being maintained. These suppositions may or may not completely explain why land managers want to be notified of the location and continued assertion of interest in mining claims. But it is true that local-record descriptions could be more precise; that stale claims should be eliminated without expensive and time-consuming contest proceedings, and that the sooner the land managers know about the location of a mining claim, the easier it is to contest the claim and to harass its owner. True, few locators, unfortunately, take the time, spend the money, or are so courteous as to record a certificate of abandonment or to quit claim their locations to the United States when they no longer intend to maintain their claims. But suspicion persists that the Government has good reason to want mining claims recorded directly with its land managers. The typical land manager can use the filing of claim locations as an indication of areas which should be withdrawn from mineral entry. Since the Government demands in a government-contest that the evidence of the discovery of a valuable mineral deposit be equivalent to a feasibility study sufficient to justify development, no one can meet that test in time to win an early Government contest. If the location of a mining claim must be disclosed to the land manager within a few months, prompt withdrawal and contest will frustrate almost any prospector. One can only hope that such harassment will not be the fruit of Section 314 of the Organic Act.⁵⁰

Recordation of Mining Claims and Abandonment

Section 314 of the Organic Act⁵¹ is, basically, a statutory claim-registration requirement which calls for recording of certain information at the local level, to be followed by registration of that information with the Federal Government. Failure to file such instruments as are required by Section 314 "shall be deemed conclusively to constitute an abandonment...by the owner."⁵² Passing by for now the constitutionality of that harsh penalty, let us consider the various requirements of Section 314.

Filing Initial Notice of Location

Putting the cart before the horse, the legislative draftsmen dealt first with claim maintenance in Subsection 314(a) and only then dealt in Subsection 314(b) with claim initiation. To understand the new legislation, one must start with Subsection 314(b). The intent of this subsection is to require that "a copy of the official record of the notice of location or certificate of location, including a description of the location of the mining claim or mill or tunnel site sufficient to locate the claimed lands on the ground"⁶³ shall be in every case filed in the appropriate office of the Bureau of Land Management.⁶⁴ As to claims located prior to October 21, 1976, that filing must be completed within the three-year period following October 21, 1976, and, as to claims located after October 21, 1976,⁶⁵ that filing must be completed "within ninety days after the date of location of such claim." It is clear enough that a copy "of the official record"⁶⁶ will suffice if it contains a description sufficient to locate the claimed lands on the ground. It is less clear whether the copy must be a certified copy,⁶⁷ and it is not at all clear when the ninety-day period should begin to run in the case of new claims. Congress selected the "date of location" as the critical date, probably without knowing when location occurs.

Under the General Mining Law, the date of location is not the date on which a claim notice is posted upon the ground; it is the date when all acts of location which must be performed upon the ground are completed.⁶⁸ Priority of location dates from the posting of notice, by relation back as may be necessary, but location does not occur unless and until all the acts of location are timely completed. The Department of the Interior wrongly chose to define the date of location to be the date of posting,⁶⁹ even though state laws have always allowed some months thereafter within which to complete the acts of location.⁷⁰ Premature recordation is no solution, because one must not record until the acts of location are complete;⁷¹ yet one must file with the Bureau of Land Management according to its regulations within ninety days after the date of posting.⁷² Unless posting, marking of boundaries, and location work are all completed early and almost simultaneously, the delays which often occur between recording and the return of the recorded location notice or certificate will seriously reduce the time available for filing a copy of the official record.

Filing Relocations and Amendments

Congress did not deal in Section 314 with the amendment and relocation of mining claims.⁷³ One can speculate that amended location notices and certificates, and relocations completed for any of a number of reasons should be filed with the Bureau within ninety days of the date of the amendment or relocation.⁷⁴ But what if a claim was located on or before October 21, 1976, and is now amended or relocated? In the absence of the amendment or relocation, no filing would be required until October, 1979; but if the location of the claim or site on the ground is altered so as to take in new ground or so as to forfeit some earlier claim and take up the ground theretofore held by it, the ninety-day provision will or should come into play.

To be consistent, however, any amendment or relocation of a claim which does not change or alter the location of the claim on the ground, and which does not take up new ground, should not operate as the location of a new claim. But the regulation provides little assistance and one might conclude that the relocation of any claim is the creation of a new claim. Whenever a relocation starts a new and independent chain of title, it should be considered a new location.⁷⁵

The Obligation to File with the Bureau

The Organic Act plainly provides that "it shall not be considered a failure to file...if the instrument is filed for record by or on behalf of some but not all of the owners of the mining claim or mill or tunnel site."⁷⁶ Obviously, Congress did not intend ownership of a claim to be affected under the new recordation system, so long as the claim is in fact recorded by someone. As contemplated by the Public Land Law Review Commission,⁷⁷ title was to remain a matter to be determined under state law. The Bureau, however, flying in the face of the evident Congressional intent, demands the names of all the owners of each claim, together with their current mailing addresses, if known, and "owner" is defined by the Bureau as any person who holds a recorded possessory interest in a claim, however acquired.⁷⁸ Clearly, the Bureau's attempt to cause title consequences not intended by Congress is contrary to Section 314(c) of the Act.⁷⁹

Filing Fees

The Bureau has elected to charge \$5 as a filing and service fee covering each claim recorded with the Bureau under the Organic Act.⁸⁰ If this charge is reasonable, it is authorized by Section 304(a) of the Organic Act.⁸¹ For the moment, at least, the Bureau is treating this fee as a one-time charge covering the initial filing and all subsequent filings pertaining to the same claim.⁸² As this is reasonable, considering like charges by county recorders over the average life of a mining claim, it will be interesting to see how long such reasonableness will continue.

Claim-Maintenance Filing Requirements

Once a lode or placer mining claim has been recorded under either provision of Section 314(b) with the Bureau of Land Management, an obligation arises to file annually thereafter either evidence of the performance for the benefit of the claim of assessment work or a notice of intention to hold the claim. The statute creates two filing requirements.

First, Subsection 314(a)(1) requires that some document evidencing maintenance of a lode or placer mining claim be filed annually for record in the local recording office.⁸³ This is a radical change in the law, which has been that claims could be maintained--if the necessary work was done--whether an affidavit attesting to the performance of the work was recorded or not, on the ground that failure to file merely shifts the burden of proof to the locator claiming that the work was done from the locator asserting that it was not done.⁸⁴ The statute requires that an affidavit of assessment work performed upon a mining claim shall be

recorded; in lieu thereof, a detailed report of geological, geochemical, or geophysical assessment work performed on the claim may be recorded,⁷⁵ and if neither an affidavit nor a detailed report is recorded, "a notice of intention to hold the mining claim (including but not limited to such notices as are provided by law to be filed when there has been a suspension or deferment of annual assessment work)" may be filed.⁷⁶ Adequate provision is therefore made in the Act for situations where the labor requirement has been suspended, as in the recent act concerning mining claims located in national parks,⁷⁷ or deferred under Title 30, Sections 28-b through 28-e of the United States Code.⁷⁸ More importantly, Congress plainly anticipated that under some circumstances a notice of intention to hold a claim might be filed even though the assessment work requirement be not suspended or deferred.⁷⁹ The Bureau, however, in promulgating its regulations, completely missed this point, blinded no doubt by its misinterpretation of the holding of the United States Supreme Court in the TOSCO case.⁸⁰ The Bureau considers that a claim can be canceled for failure to perform assessment work, even in the absence of a withdrawal or change in the mining law, such as was involved in the TOSCO case.⁸¹ But that, of course, is not the law. Section 28 of Title 30, United States Code, plainly contemplates that a locator may resume work upon his claim after failure to perform the required annual labor, provided he does so before some other locator attempts to relocate the same ground.⁸² Since the Organic Act contemplates that a "wholly owned Government corporation" may acquire and hold rights as a citizen under the Mining Law of 1872,⁸³ the Government can easily assume the position of a relocater whenever a claim is open to forfeiture by relocation. Accordingly, absent a withdrawal or circumstances such as that involved in the TOSCO case, one need not perform assessment work if he wants to chance the relocation and forfeiture of his claim. Taking that chance, the statute allows him to file a notice of intention to hold, whereupon the requirements of Section 314(a) have been met and the locator has preserved his right to resume the performance of annual labor. The Bureau's attempt to undo the Congressional intent violates both the Organic Act and the General Mining Law of 1872.

While Subsection 314(a)(1) requires the filing of one of three different kinds of documents with the local recorder, the second filing requirement is that a copy of the official record of that document shall be filed in accordance with Subsection 314(a)(2) with the appropriate office of the Bureau of Land Management.⁸⁴ Though the statute plainly intended that both filings can be accomplished simultaneously, the official record of an instrument filed for record in the local office must be obtained before a document of any kind can be filed with the Bureau.⁸⁵ More importantly, the document to be filed with the Bureau must include "a description of the location of the mining claim sufficient to locate the claimed lands on the ground."⁸⁶ Again, this is a radical change in the law with which all prospectors and mining lawyers must become familiar, even though there is no point in including such a description, because the same description must appear in the documents filed pursuant to Subsection 314(b).⁸⁷ Such thoughtless draftsmanship creates a multiplicity of possibili-

ties for ambiguous discrepancies which will henceforth clutter the Bureau's records.

Again, the filing requirements under Subsection 314(a) are keyed to October 21, 1976. Claims located on or before that date need not be recorded with the Bureau until October 21, 1979, and the owner of such claims therefore has until October 21, 1979, to comply with the local recording requirement of Subsection 314(a)(1) and the Bureau filing requirement of Subsection 314(a)(2).⁸⁸ Prior to December 31 of each year thereafter, like filings shall be made. Whether this last requirement begins on December 30, 1979, or on December 30, 1980, is not at all clear, although the regulations indicate that the Bureau assumes that 1980 is intended.⁸⁹ As to claims located after October 21, 1976, the instruments required by Subsections 314(a)(1) and 314(a)(2) shall be filed on or before December 30th of each year following the calendar year in which the claim was located.⁹⁰ It is plain that Congress intended the filing requirement to expire with the last day of the year, but inartful draftsmanship requires all filings under Subsection 314(a) of the Act to be made on or before December 30th. Such is the result of the unfortunate use of the words "prior to December 31." And since December 31st bears no relationship to the assessment year, which ends at noon on September 1st of each year,⁹¹ the statutory requirement that the locator shall file the necessary documents on or before December 30th of each year following the calendar year in which a claim was located, means that where a claim is located after noon on September 1st in any calendar year, the locator must file in the next full calendar year a notice of intention to hold, because no assessment work requirement has yet arisen.⁹²

Maintenance of Mill Sites and Tunnel Sites

The Bureau, with absolutely no justification in any statute, including the Organic Act,⁹³ requires annual filings with the Bureau of notices of intention to hold mill sites and tunnel sites.⁹⁴ The Organic Act, in Subsection 314(a), expressly refers to unpatented lode and placer mining claims and does not mention mill sites or tunnel sites. Clearly Congress did not intend that notices of intention to hold such sites should be required. The absurdity of the regulation is apparent in the section which requires a statement that a mill site is held and claimed for the valuable mineral contained therein.⁹⁵ A mill site owner who complies with that regulation will necessarily expose his mill site to invalidation under Title 30, Section 42, of the United States Code.⁹⁶ On the other hand, and with equal absurdity, the regulations which set forth the required form of notices of intent to hold lode and placer mining claims (and mill sites as well) require the inclusion of a statement that the owner intends "to continue diligent exploration or development of the the claim."⁹⁷ If the owner chooses the exploration rather than the development alternative, he will be admitting against interest that his claim is invalid under the Departmental rulings which hold that a claim held for exploration only is null and void.⁹⁸

The Bureau misconceives, as pointed out earlier, the function of the notice of intention to hold, and therefore requires that such a notice include a statement of the reasons, beyond the control of the

owners, which have prevented their filing either an affidavit of labor or a detailed survey report.⁹⁹ The notice of intent to hold is to be utilized when the annual labor requirement has not been met, for whatever reason. One may intend to hold his claim even though he has done no work, for whatever reason, whether beyond his control, or not.¹⁰⁰

Miscellaneous Provisions of Section 314

The regulations provide that when a final certificate has issued for a claim upon an application for patent, no further annual filings are required,¹⁰¹ and, similarly, the filing of an application for patent is deemed to be the equivalent of an initial recording of a claim with the Bureau under Subsection 314(b).¹⁰² As this is not authorized by the statute, one might consider filing anyway--in either situation--out of an abundance of caution.

Duplicate filings under the Mining Claims Rights Restoration Act of 1955 for lands within power site withdrawals¹⁰³ and for "O & C lands" in Oregon¹⁰⁴ are not required, if the filings submitted under the recordation regulations are marked so as to identify the claims as having been located on such lands.¹⁰⁵ Special rules apply to claims within units of the National Park System.¹⁰⁶

The statutory penalty for failure to record a claim or to file evidence of the performance of assessment work or a notice of intention to hold in lieu thereof will work a conclusive abandonment of the claim.¹⁰⁷ As to claims located after October 21, 1976, that is clearly within the constitutional power of the Congress to provide.¹⁰⁸ As there is at least some question, however, that that penalty meets constitutional concepts of due process,¹⁰⁹ it is at least arguable that the penalty should not apply to claims located before October 22, 1976.

Transfer of Claim Ownership After Recordation

The Bureau regulations, wholly without statutory authorization,¹¹⁰ require notice to the Bureau of any transfer of interest in a mining claim which has been recorded with the Bureau.¹¹¹ The obligation to record the transfer is placed upon the transferee, and he is allowed but sixty days within which to file his notice of transfer.¹¹² While failure to file a notice of transfer will void neither the claim nor the transfer, failure to file a notice of transfer does have the effect, according to the Bureau, of subjecting the claim to contest without notice to the transferee who so failed to file.¹¹³ Likewise, the regulations indicate that the Bureau will henceforth consider itself free to contest mining claims without personal notice to the owners or transferees thereof if the claim is not recorded with the Bureau or if notice of the transfer has not been filed with the Bureau.¹¹⁴ It threatens henceforth to contest claims in such cases by publication of notice only. It will not search local records; it will only search its own records. Heretofore, the Department has treated mining claims as property and accorded due process to the owners thereof in contest proceedings.¹¹⁵ By what authority the Bureau now feels that due process no longer need be accorded to a mining claimant is a total mystery. Congress neither required that notices of transfer be filed with the

Bureau nor authorized invalidation of claims upon mere publication of notice. As no change in title consequences was contemplated by reason of the Organic Act, if a claim is recorded under the Act by anyone in behalf of at least one of the owners thereof, the Bureau, like any other party, should be obligated to determine ownership from the local records.¹¹⁶

MISCELLANEOUS PROVISIONS OF THE ORGANIC ACT

The Organic Act contains the usual guarantees that nothing in the Act is to be construed as terminating any valid land use right or authorization existing on the date of the Act;¹¹⁷ that all actions by the Government under the Act shall be subject to valid existing rights,¹¹⁸ and that nothing in the Act shall be deemed to repeal any existing law by implication.¹¹⁹ Nonetheless, it has been the unhappy history of public land law that aggressive land managers regularly undo what Congress does and do what Congressional lethargy cannot prevent. In time, the Organic Act will be seen to have infringed upon the rights of prospectors and miners more than anyone expected.¹²⁰ Some of the more obvious provisions in the Act which will no doubt become increasingly important in years to come are the right-of-way provisions¹²¹ and the land-use planning provisions.¹²²

The Congress has finally declared the policy of the United States to be that the public lands shall henceforth remain in Federal ownership unless disposal of particular parcels will serve the national interest, as that interest is discovered through land-use planning procedures provided for in the Act.¹²³ The land-use planning provisions of the Act clearly bring to the public lands the nebulous concepts of "scenic values", "areas of critical environmental concern", and "systematic interdisciplinary" approaches to land-use evaluation.¹²⁴ Even as defined in the Act, no one knows what these and similar terms mean, so the land managers may be expected to make them mean whatever they want them to mean.

The Congress has at least endeavored to "overrule" United States v. Midwest Oil Co.,¹²⁵ the 1914 decision in which the United States Supreme Court gave unfettered withdrawal power to the Executive Branch.¹²⁶ The Congress has now reasserted its constitutional prerogatives in the withdrawal area, and the mining industry anticipates some relief from the haphazard and ill-conceived withdrawal programs which have infested much of the public lands.¹²⁷ Unfortunately however, it will be some years before the effect of these provisions can be felt, and there are many stratagems by which the Executive Branch can and no doubt will frustrate the Congressional intent in this area.¹²⁸

There are several provisions of the Act which require coordination between the Federal and state and local governments.¹²⁹ Generally, conflicts in this area have been resolved against the Federal Government. For example, the Secretary of Interior shall not make conveyances of public lands according to terms and conditions which at the time of the conveyance constitute a violation of any law or regulation pursuant to state and local land use plans or programs.¹³⁰ Likewise, he is to notify local authorities of proposed dispositions and give

local authorities the opportunity to zone or otherwise regulate or change or amend existing zoning or other regulations concerning the use of the lands before they are conveyed by the United States into private ownership.¹³¹ It is at least arguable that these provisions do not apply to patents issued under the provisions of the General Mining Law, which are neither repealed nor amended by the Act, but miners more, perhaps, than anyone else, must expect the worst from local zoning.¹³²

Conveyances of public lands issued under the act shall reserve all minerals in the lands to the United States, together with the right to prospect for, mine and remove the minerals under applicable law, and such regulations as the Secretary of Interior may provide.¹³³ Similar provisions have been frustrated by the Secretary of the Interior in the past through the simple device of not issuing regulations.¹³⁴ No real relief from the severed title problem is provided in the Organic Act, although provision is made for the conveyance of severed mineral interests or mineral interests which would otherwise be severed, if, and only if,

there are no known mineral values in the lands or if it is determined that the reservation of the mineral rights is interfering with or precluding appropriate nonmineral development of the land and such development is a more beneficial use of the land than would be mineral development.¹³⁵ Few, if any, such conveyances of mineral interests will occur under that provision of the Act unless fearless administrators wholly ignorant of Teapot Dome are found to make the necessary determinations.

CONCLUSION

Section 314 of the Federal Land Policy and Management Act of 1976, and the Interior Department regulations issued in response thereto, forecast an uncertain and difficult future for the mining industry. If so many mistakes can be made in one section of one bill, and in one small set of regulations, any wholesale revision of the General Mining Law is certain to be a catastrophe, and the regulations required thereunder should be sufficient, if and when issued, to support a whole generation of lawyers.

¹ ONE THIRD OF THE NATION'S LAND (June 1970). For an analysis of the recommendations of the Commission, see, e.g., Sherwood, "Mining Law at the Crossroads," 6 *Land & Water L. Rev.* 161 (1970).

² PUBLIC LAND LAW REVIEW COMM'N, ONE THIRD OF THE NATION'S LAND 123, Recommendation 46 (1970).

³ *Id.* at 124, Recommendation 47.

⁴ *Id.* at 124, unnumbered recommendation.

⁵ *Id.* at 129-130, unnumbered recommendation concerning uniform federal requirements, explained as follows: The General Mining Law currently requires compliance with location and discovery requirements of state law. State laws on this subject vary widely and many are obsolete or archaic in light of modern technology. The discovery work required by state law often serves no useful purpose and frequently conflicts with sound land use practices and causes needless harm to the environment. The Constitution gives Congress the basic responsibility for determining the disposition of public lands, and we believe that the development of mineral resources is so important that Federal statutes should fully prescribe uniform methods by which rights in these resources may be acquired.

⁶ *Id.* at 124.

⁷ *Id.* at 130, unnumbered recommendation. In this connection, the Commission there said:

Congress should establish a fair notice procedure (a) to clear the public lands of long-dormant mining claims, and (b) to provide the holders of existing mining claims an option to perfect their claims under the revised location provisions we recommend. Under such a procedure, failure to file proper notice of preexisting claims with county and Federal agencies within a reasonable time would constitute conclusive evidence of abandonment. This would be somewhat analogous to state quiet-title actions and to the surface right proceedings authorized by the Surface Use Act of 1955. Clearing the record of an estimated 5.5 million long-dormant claims would assist in achieving more efficient land planning and management by Federal agencies. We also believe that bona fide mineral explorers would often benefit from the predisclosure protection afforded under the procedures we recommend, which is lacking under existing law. [Emphasis in original].

The italicized portion is the unnumbered Commission recommendation.

⁸ *Id.* at 126:

In many cases, mining claim descriptions under existing law are totally inadequate to permit Federal agencies or other interested persons to find them on the ground.

The locator of a mining claim on public land records his claim under state law, usually with a county recorder. Federal land agencies often have no knowledge of his activities unless he applies for a patent. In our view, this is not consistent with sound land management. We do not favor any change in the title consequences which flow from recordation under state law. *However, we do recommend that locators be required to give written notice of their claims to the appropriate Federal land agency within a reasonable time after location.* This ordinarily could be accomplished simply by mailing a copy of the documents filed with a county recorder. [Emphasis in original].

The italicized portion is an unnumbered Commission recommendation.

⁹ Forest Management Act of 1897, 30 Stat. 34, 16 U.S.C. § 473 (1970).

10 Pub. L. No. 94-579, 90 Stat. 2743, 43 U.S.C.A. §§ 1701-1782 (Supp. 1977).

11 The Bureau's cherished notion that it administers "national resource lands" rather than the public's lands has gained acceptance, but the traditional term "public land" is still viable. See House Conference Report No. 94-1724, 94th Cong., 2d Sess., § 3(a) (1976), 5 U.S. Code, Cong. & Admin. L. News, at 6229 (1976). The traditional term should be preferred in all cases, because it will remind the administrator that he manages public property rather than the property of the national government; absent such a reminder, it is all too easy to begin thinking of the public lands as "BLM lands."

12 43 U.S.C.A. § 1732(b) (Supp. 1977).

13 43 U.S.C.A. § 1781 (Supp. 1977).

14 43 U.S.C.A. § 1781 (d) (Supp. 1977).

15 43 U.S.C.A. § 1781 (a)(2) (Supp. 1977).

16 43 U.S.C.A. § 1781 (f) (Supp. 1977) (emphasis added).

17 See 43 U.S.C.A. § 1702(g) (Supp. 1977) for definition of "Secretary."

18 43 U.S.C.A. § 1782 (Supp. 1977).

19 "A recommendation of the President for designation as wilderness shall become effective only if so provided by an Act of Congress." 43 U.S.C.A. § 1782(b) (Supp.); cf. 16 U.S.C. § 1132(c) (1970). Congress expects too much to assume that its authority is exclusive. See *Parker v. United States*, 309 F. Supp. 593 (D. Colo. 1970), *aff'd* 448 F.2d 793 (10th Cir. 1971), *cert. den.* 405 U.S. 989 (1972); *Izaak Walton League of America v. St. Clair*, 353 F. Supp. 698 (D. Minn. 1973), *rev'd* 497 F.2d 849 (8th Cir. 1974). It is difficult to say whether the Eighth Circuit Court of Appeals really did undo the mischief which the District Court worked upon the will of Congress.

20 43 U.S.C.A. § 1782(c) (Supp. 1977).

21 See e.g., the cases cited in note 19 *supra*. Mere mention of an area as suitable for wilderness designation tends to discourage mineral exploration. See e.g., U. S. Dep't of the Interior, "Final Report of the Task Force on the Availability of Federally Owned Mineral Lands," Vol. 1 at 54 (1977).

22 43 U.S.C.A. § 1732(b) (Supp. 1977).

23 See note 17 *supra*.

24 Section 302(b), 43 U.S.C.A. § 1732(b) (Supp. 1977), quoted at note 12 *supra*.

25 It is surely no accident that Section 302(b) of the Organic Act gives the Secretary of the Interior no more authority than that which has been cautiously exercised by the Secretary of Agriculture in behalf of the United States Forest Service. See Dempsey, "Forest Service Regulations Concerning the Effect of Mining Operations on Surface Resources," 8 *Natural Resources Lawyer* 481 (1975).

26 43 U.S.C.A. § 1733(a) (Supp. 1977).

27 43 U.S.C.A. § 1733(g) (Supp. 1977).

28 43 U.S.C.A. § 1740 (Supp. 1977).

29 43 U.S.C.A. § 1732(b) (Supp. 1977).

30 42 Fed. Reg. 5298-5300 (Jan. 27, 1977); cf. 41 Fed. Reg. 53428 (Dec. 6, 1976). See also BLM Organic Act Directive 76-11, Change 2, p. 5, § 27 (March 25, 1977).

31 42 Fed. Reg. 5298 (Jan. 27, 1977).

32 Powers which are reserved to Congress under the United States Constitution, art. IV, § 3, cl. 2.

33 Ch. 279, § 5, 17 Stat. 608, now 30 U.S.C. § 75 (1970).

34 In the absence of local regulations, a mining claimant was required to comply only with the provisions of the statute. Acting Comm'r Curtis to Hoyt, *Sears & McKee*, May 16, 1873, H. Copp, U. S. *Mining Decisions*, 200 (1874); *Golden Fleece Gold & Silver Mining Co. v. Cable Consol. Gold & Silver Mining Co.*, 12 Nev. 312 (1877).

35 See note 24 *supra*.

³⁶ 43 U.S.C.A. § 1744 (Supp. 1977).

³⁷ 43 U.S.C.A. § 1740 (Supp. 1977).

³⁸ See the definition of "public lands" in Section 103(e) of the Organic Act, 43 U.S.C.A. § 1702 (e) (Supp. 1977).

³⁹ Section 103(n), 43 U.S.C.A. § 1702(n) (Supp. 1977).

⁴⁰ Which provides (emphasis added):

The Secretary of the Department of Agriculture shall execute or cause to be executed all laws affecting public lands reserved under the provisions of section 471 of this title, or sections supplemental to and amendatory thereof, subject to the provisions for national forests established under subdivision (b) of section 471 of this title, after such lands have been so reserved, *excepting such laws as affect the surveying, prospecting, locating, appropriating, entering, relinquishing, reconveying, certifying, or patenting of any of such lands.*

⁴¹ 43 U.S.C. § 1744, as reported in 43 U.S.C.A. at § 1744 (Supp. 1977). The Act itself is even more difficult to read.

⁴² 30 U.S.C. § 28 (1970).

⁴³ See 1 AMERICAN LAW OF MINING § 5.51 (1976).

⁴⁴ Those who bury their notices somewhere on their claims in pipe-tobacco cans do so either out of fear that a prominent notice will be removed or destroyed, or in the hope that they can themselves later move them to better locations on someone else's newer but better-situated claims. Such shenanigans have led to an effort in some states, notably Colorado and Nevada, to require locators to fix the position of their claims with mappable accuracy. See Colo. Rev. Stat. Ann. § 34-43-106(2) (1973), and Nev. Rev. Stat. §§ 517.030(2), 517.040, 517.050(1) (e), 517.100, 517.140, 517.170, and 517.230(3) (1973).

⁴⁵ See, e.g., Claybaugh v. Gancarz, 81 Nev. 64, 398 P.2d 695 (1965); Atherly v. Bullion Monarch Uranium Co., 8 Utah 2d 362, 335 P.2d 71 (1959). Cf. McCarthy v. Morris, 497 P.2d 97 (Mont., 1972).

⁴⁶ The date of posting notice on the ground is usually construed to be the date from which priority of appropriation can be asserted by location rather than by *pedis possessio*, because the discovery of a lode or placer, which may occur earlier than on the date of posting, need not be followed up by any of the acts of location.

⁴⁷ See Sherwood & Greer, "Mining Law in A Nuclear Age: The Wyoming Example, Part II," 3 Land & Water L. Rev. 319, 338-342 (1968).

⁴⁸ See 30 U.S.C. § 29 (1970), which makes this abundantly clear.

⁴⁹ See 2 AMERICAN LAW OF MINING, Title VIII (1976). See also Sherwood & Greer, "Possessory Interests in Wyoming Mining Claims," 4 Land & Water L. Rev. 337, 349-370 (1969).

⁵⁰ Compare Sherwood, "Mining Law at the Crossroads," 6 Land & Water L. Rev. 161, 169-171 (1970).

⁵¹ 43 U.S.C.A. § 1744 (Supp. 1977). For procedural guidance, see Miller, "Recordation and Surface Management Regulations Affecting Mining in the National Forests, the National Park System, and on the Public Domain," 23 Rocky Mt. Min. L. Inst. 41 (1977).

⁵² 43 U.S.C.A. § 1744(c) (Supp. 1977). Compare 30 U.S.C. § 613 (1970).

⁵³ 43 U.S.C.A. § 1744(b) (Supp. 1977). Compare 30 U.S.C. § 28 (1970): "All records of mining claims...shall contain...such a description of the claim or claims located by reference to some natural object or permanent monument as will identify the claim." Why Congress should choose different language for Section 314 of the Organic Act is not clear, but one must now comply with both requirements, if they are in fact different.

⁵⁴ Defined as the state office of the Bureau having jurisdiction over the land. Compare 43 C.F.R. § 3833.0-5(g) (Jan. 27, 1977), with 43 C.F.R. § 1821.2-1 (Oct. 1, 1976).

⁵⁵ The statute says nothing about claims located on October 21, 1976. The regulations treat such claims as having been located before October 21, 1976. See 43 C.F.R. §§ 3833.1-2(a) and (b) and 3833.2-1(a)(1) and (2) (Jan. 27, 1977).

⁵⁶ Defined in the regulations as "the official document of recordation and all accompanying maps, papers or other documents filed for record with the recorder or other officer now authorized to record such instruments under state law in the local jurisdiction where the unpatented mining claim, mill site, or tunnel site is located." 43 C.F.R. § 3833.0-5(i) (Jan. 27, 1977). A copy of the documents made *after recording* is the minimum requirement.

⁵⁷ Neither the statute nor the regulation quoted in note 56 *supra* seem to demand certified copies.

⁵⁸ Morrison, MINING RIGHTS 24-25 (DeSoto & Morrison 16th ed. 1936).

⁵⁹ Technically, no doubt, location dates from the date of discovery, whenever that occurs, 2 C. Lindley, MINES § 330 (3d ed. 1914), but whether location dates from discovery or from the performance of the last act of location (or even the date of recording, if that be deemed an act of location), it does not date from the posting of notice as thought by the Department in 43 C.F.R. § 3833.0-5(h) (Jan. 27, 1977).

⁶⁰ See 1 AMERICAN LAW OF MINING §§ 5.59, 5.65, and 5.77 (1963).

⁶¹ At least in those states where to do so is a crime. See, e.g., Wyo. Stat. § 6-154.2 (1973 Supp.).

⁶² 43 C.F.R. § 3833.0-5(h) (Jan. 27, 1977) can be construed to allow some other date to qualify as the "date of location" if so indicated to be such on the posted notice. But that could only mean some even earlier date, such as the date of discovery.

⁶³ To understand the distinction between these terms and the various meanings of the word "relocation," see Reeves, "Amendment v. Location," 14 Rocky Mt. Min. L. Inst. 207 (1968).

⁶⁴ And the regulations so provide, at least where "the location" is "changed or altered," whatever that means. See 43 C.F.R. §§ 3833.0-5(i) and 3833.1-2(c)(2) (Jan. 27, 1977).

⁶⁵ While one can argue that the relocation of a claim open to forfeiture for failure to perform assessment work is not the location of public land, only the very brave will assume that the three-year provision still applies in that situation.

⁶⁶ 43 U.S.C.A. § 1744(c) (Supp. 1977).

⁶⁷ See note 8 *supra*.

⁶⁸ 43 C.F.R. § 3833.0-5(a) (Jan. 27, 1977).

⁶⁹ 43 U.S.C.A. § 1744(c) (Supp. 1977).

⁷⁰ 43 C.F.R. § 3833.1-2(d) (Jan. 27, 1977).

⁷¹ 43 U.S.C.A. § 1734(a) (Supp. 1977).

⁷² See BLM Organic Act Directive 76-11, Change 2, p.1, ¶ 3 (March 25, 1977): "[T]he fee covers all documents that may be filed under these regulations after the initial filing for recording."

⁷³ 43 U.S.C.A. § 1744(a)(1) (Supp. 1977). There is a typographical error in the Act, carried forward into the Code, which suggests that an assessment-work affidavit is to be "on" a detailed report as provided by 30 U.S.C. § 28-1 (1970). But either an assessment-work affidavit or such a detailed report is contemplated.

⁷⁴ See 2 AMERICAN LAW OF MINING § 7.25 (1960).

⁷⁵ Under 30 U.S.C.A. §§ 28-1 and 28-2 (1970).

⁷⁶ See 30 U.S.C.A. § 28a(note) (Supp. 1977); cf. 2 AMERICAN LAW OF MINING §§ 7.34-7.36 (1960).

⁷⁷ Pub. L. No. 94-429, § 5, 90 Stat. 1342, 16 U.S.C.A. § 1904 (Supp. 1977).

⁷⁸ The regulation, 43 C.F.R. § 3833.2-3(f) (Jan. 27, 1977), assumes that one can include "the order or decision disposing" of a petition submitted under 30 U.S.C. §§ 28-1 and 28-2 (1970), when he files a notice of intention to hold in lieu of an annual labor affidavit. How one can do so when no order or decision has been issued is one of the puzzles in the regulations.

⁷⁹ See 43 U.S.C.A. § 1744(a)(1) (Supp. 1977), particularly the "including but not limited to" language.

⁸⁰ Hickel v. Oil Shale Corp., 400 U.S. 48 (1970). See 37 Fed. Reg. 17836 (Sept. 1, 1972); cf. Sherwood, "Improvement of Mining Claims," 18 Rocky Mt. Min. L. Inst. 149 at 169-171 (1972).

- ⁹¹ *Hicke* v. Oil Shale Corp., 400 U.S. 48 (1970).
- ⁹² *Cf.* 2 AMERICAN LAW OF MINING §§7.29-7.33 (1960).
- ⁹³ 43 U.S.C.A. § 1712(e)(3) (Supp. 1977).
- ⁹⁴ See note 54 *supra*.
- ⁹⁵ See note 56 *supra*.
- ⁹⁶ 43 U.S.C.A. § 1744(a)(2) (Supp. 1977).
- ⁹⁷ 43 U.S.C.A. § 1744(b) (Supp. 1977).
- ⁹⁸ It will be interesting to see if those hardy souls who wait until Monday, October 22, 1979, to file are held to the strict terms of the Act or are given a day of grace under the Bureau's regulations. See 43 C.F.R. § 1821.2-2(e) (Oct. 1, 1976).
- ⁹⁹ See 43 C.F.R. §§3833.2-1(a)(1) and (2) (Jan. 27, 1977).
- ¹⁰⁰ Compare 43 C.F.R. §§3833.2-1(b)(1) and (2) (Jan. 27, 1977).
- ¹⁰¹ 30 U.S.C. § 28 (1970).
- ¹⁰² *Id.* See also 2 AMERICAN LAW OF MINING §§7.7 and 7.26 at n. 2 (1960).
- ¹⁰³ But see BLM Organic Act Directive 76-11, Change 2, p. 5, § 27 (March 25, 1977) and compare text *supra* at nn. 30-34.
- ¹⁰⁴ 43 C.F.R. §§3833.2-1(a)(2) and (b)(2) and 3833.2-3 (Jan. 27, 1977).
- ¹⁰⁵ 43 C.F.R. § 3833.2-3 (c) (Jan. 27, 1977).
- ¹⁰⁶ Because millsites must be located on nonmineral land. See Greer, "Millsites: Nonmineral Mining Claims," 13 Rocky Mt. Min. L. Inst. 143, 165-166 (1967).
- ¹⁰⁷ 43 C.F.R. § 3833.2-3(d) (Jan. 27, 1977).
- ¹⁰⁸ *E.g.*, United States v. Altman, 68 I.D. 235 (1961).
- ¹⁰⁹ 43 C.F.R. § 3833.2-3(e) (Jan. 27, 1977).
- ¹¹⁰ 30 U.S.C. § 28 (1970).
- ¹¹¹ 43 C.F.R. § 3833.2-4 (Jan. 27, 1977). The regulation requires issuance of the final certificate before the assessment-work requirement will be deemed to have terminated. *Cf.* 43 C.F.R. § 3851.5 (Oct. 1, 1976).
- ¹¹² 43 C.F.R. § 3833.1-3 (Jan. 27, 1977).
- ¹¹³ Compare 30 U.S.C. § 623 (1970) with 43 C.F.R. §§ 3833.1-2(c) (10) and 3833.5(c) (Jan. 27, 1977).
- ¹¹⁴ Compare 43 C.F.R. Subpart 3821 (Oct. 1, 1976) and 62 Stat. 162 with 43 C.F.R. §§ 3833.1-2(c)(10) and 3833.5(c) (Jan. 27, 1977).
- ¹¹⁵ Compare 43 U.S.C.A. § 1744(c) (Supp. 1977), particularly the "filed for record under other Federal laws permitting filing or recording" language.
- ¹¹⁶ See 36 C.F.R. §§9.5-9.7 (Jan. 26, 1977); *cf.* 43 C.F.R. §§3833.1-1 and 3833.2-1(a)(3) (Jan. 27, 1977).
- ¹¹⁷ 43 U.S.C.A. § 1744(c) (Supp. 1977).
- ¹¹⁸ United States Const. art. IV, § 3, cl. 2.
- ¹¹⁹ See *Mullane v. Central Hanover Bank & Trust Co.*, 339 U.S. 306 (1950).
- ¹²⁰ But see 42 Fed. Reg. 5297 at 5299-5300 (Jan. 27, 1977).
- ¹²¹ 43 C.F.R. § 3833.3 (Jan. 27, 1977).
- ¹²² *Id.* § 3833.3(a).

- 113 43 C.F.R. §§ 3833.5(d) (Jan. 27, 1977). *Compare id.* 3833.4(a).
- 114 43 C.F.R. §§ 3833.5(d) and (e) (Jan. 27, 1977).
- 115 43 C.F.R. §§ 4.450-3, 4.450-5, and 4.451 (Oct. 1, 1976). *Cf.* *United States v. O'Leary*, 63 I.D. 341 (1956).
- 116 It is astonishing to see the Government threatening to dispossess its citizens from their property without personal service of process.
- 117 Pub. L. No. 94-579, § 701(a), 90 Stat. 2786.
- 118 *Id.* 701(h).
- 119 *Id.* 701(f).
- 120 The process is described in Sherwood, "Prospecting for Locatable Minerals on Public Lands Classified for Retention for Multiple-Use Management," 14 *Rocky Mt. Min. L. Inst.* 167 (1968).
- 121 43 U.S.C.A. §§ 1761-1771 (Supp. 1977).
- 122 43 U.S.C.A. §§ 1711-1712 (Supp. 1977).
- 123 43 U.S.C.A. § 1701 (a)(1) (Supp. 1977).
- 124 *See* 43 U.S.C.A. §§ 1702(a), 1711 and 1712 (Supp. 1977).
- 125 236 U.S. 459 (1914).
- 126 Pub. L. No. 94-579, § 704(a), 90 Stat. 2792.
- 127 *See* Bennethum & Lee, "Is Our Account Overdrawn?" *Mining Congress Journal* (Sept. 1975). *Cf.* note 21 *supra*.
- 128 The withdrawal of lands in blocks of less than 5,000 acres should get around most of the Congressional safeguards. *See* 43 U.S.C.A. § 1714 (Supp. 1977).
- 129 *E.g.*, 43 U.S.C.A. § 1720 (Supp. 1977).
- 130 43 U.S.C.A. § 1718 (Supp. 1977).
- 131 43 U.S.C.A. § 1720 (Supp. 1977).
- 132 *See* Sherwood, "Zoning Against Mining," 2 *Colo. Lawyer* No. 9, at 27 (July, 1973).
- 133 43 U.S.C.A. § 1719(a) (Supp. 1977).
- 134 As happened under the Small Tract Act, 43 U.S.C. § 682(b) (1970), repealed 1976.
- 135 43 U.S.C.A. § 1719(b)(1) (Supp. 1977).

FEDERAL PERMITTING CONSTRAINTS

Robert L. Wright

Hamilton Hess, president of the Sierra Club in California, once made the statement that it was "unfortunate that geothermal development in this country came of age at the height of the environmental crusade because all the extensive and burdensome regulation was placed on it in its infancy."

This has proven to be a very true statement. The Geothermal Steam Act of 1970 was passed one year after NEPA (1969) and the various steps necessary in the Federal permitting process appear to be essential to carry out the spirit of NEPA. Geothermal exploration and development has never had the grace period to establish itself that the rest of the energy industry has been accorded. The permitting necessary for nuclear power plants today would totally discourage any newcomers to that industry yet most of those in that business today had several decades to get established and know some positive factors about that industry before becoming trapped in the present regulatory environment. This is also true of oil and gas development and the coal industry.

The harassment, restrictions and blizzards of paperwork involved in obtaining permits to drill and develop Federal acreage is definitely keeping a large segment of industry out of the geothermal business today.

Environmental reviews are conducted at every step of the process on Federal land. Prior to actual production from a geothermal project at least five separate environmental reviews and perhaps one or more environmental impact statements have occurred. First you have a general impact statement for the leasing program; second, a pre-lease environmental assessment; third, the environmental assessment for the plan of exploration; fourth, the environmental assessment for the plan of development, and fifth, an environmental assessment for the plan of production.

(At this point, it is the intention of the speaker to show the attached permit flow sheet using an overhead projector)

A permit to drill a well or any other surface disturbing activity on Federal leases is initiated by filing a plan of operation (POO) with the USGS Area Geothermal Supervisor (AGS), who, to implement the geothermal regulations has issued a series of geothermal resource operations orders (GRO's) which detail the requirements for drilling wells, abandoning wells, environmental protection, reporting, pipeline construction, royalty measurement, etc.

The POO is site-specific and is submitted for the joint approval of the AGS and the surface management agency. In response to each POO, the USGS writes an EA.

When a POO is received from a lessee or operator, the USGS and surface management agency arrange to jointly inspect the site and the USGS notifies all interested parties of the time and location of the inspection and distributes the POO.

All interested parties may submit their comments during a period of two weeks after the inspection.

The geothermal office considers all comments and prepares a final EA and the determination is made as to whether an EIS should be written. If an EIS is called for the time involved in obtaining a permit to drill could be two years. If a negative determination is made, copies of the final EA is distributed to interested parties and the POO is approved by the AGS and the surface management agency. This process takes at least six months.

The AGS also obtains advice from the Geothermal Environmental Advisory Panel (GEAP) before approving any plans in new geological or geographical areas. GEAP is comprised of about 13 members consisting of representatives from various bureaus in the Dept. of Interior and appointees from other Federal departments. The Sierra Club, State and County agencies also participate. The AGS furnishes GEAP with the various plans and the EA and the GEAP chairman calls a public meeting at a location near the project site. The AGS considers all comments received from GEAP before completing the EA.

Major causes for delay in issuing permits to drill or to perform work appear to be 1) time required to review the draft EA's, 2) time required to comment on the P00, 3) lack of personnel, budget, etc. and the time required to coordinate with all the interested parties. In this regard, it should be pointed out that the AGS's office is being called upon to act as a consultant for D.O.E. whose work load is steadily increasing, resulting in more work for the AGS and a further slowdown in permitting time.

The various surface management agencies also act very conservatively in their comments on the P00. Their expertise and interest is really not in minerals or the development of same. It appears this delay factor could be resolved by their relying more on the USGS decisions.

It appears that only a revision of NEPA and a streamlining of procedures can shorten the time required to obtain a permit.

In this regard, it should be pointed out that the AGS and others recognize the problems and are doing what they can to speed up the permitting process. Only last month, the USGS published in the Federal Register their final rules regarding simplification of procedural requirements for approval to conduct subsequent well operations, exploration operations, casual use activities and the construction or alteration of certain production facilities on lands leased for geothermal resources. Prior to this, these activities were covered by the P00 procedure and had to go through the process above mentioned.

However this important change has taken four years to obtain and time is growing short for development of geothermal resources on Federal lands. A Federal lease is good for a term of ten years, extendable for an additional five years and then it must be producing into a power plant or the lease terminates. When you consider that most leases were issued in 1974 and it takes five years minimum to permit and construct a power plant, the time appears to be already too late.

We are constantly being told that Federal regulation and environmental snags are a fact of life for American business. Yet, like accepting inflation, the acceptance of these facts seems to increase the regulations and the environmental requirements themselves. Industry, in their quest of trying to obtain permits, accepts more and more regulations and stipulations recognizing that to fight same results in delays that can kill a project. Environmentalists have learned that delays in courts, injunctions and harassment all work in their favor.

It appears that we are called upon to fight inflation, yet accept the biggest contribution towards that condition which is increased regulation and environmental harassment.

Departments of Defense, Labor, Agriculture
Bureau of Land Management, Geological Survey,
Sport Fisheries & Wildlife, Mines, Reclamation, Outdoor Recreation,
Office of the Solicitor, National Park Service,
Environmental Protection Agency, ERDA

EXOFFICIAL MEMBERS

Area Club, State, County Agencies,
Industries and other interested groups

WORKING PROCEDURE FOR POST-LEASE EA

ENVIRONMENTAL & SAFETY SECTION

GEOHERMAL RESOURCE POTENTIAL OF THE EASTERN UNITED STATES

J. K. Costain, L. Glover III, A. K. Sinha

ABSTRACT

Optimum sites for low-temperature ($<150^{\circ}\text{C}$) geothermal resource development in the tectonically stable eastern United States will probably be associated with crustal igneous rocks containing relatively high concentrations of radiogenic heat-producing elements concealed beneath insulating blankets of sediments. Choice of a site in the Atlantic Coastal Plain with a high geothermal resource potential depends on favorable: 1) concentration of radiogenic elements in granitic rocks beneath a sedimentary insulator; 2) thermal conductivity of the sedimentary insulator; 3) thickness of the sedimentary insulator; and 4) reservoir conditions in the sedimentary rocks overlying the radiogenic heat source.

Geothermal gradients determined to date in the Atlantic Coastal Plain are in the range $15\text{--}40^{\circ}\text{C/Km}$. Preliminary results suggest that the higher gradients are associated with negative Bouguer gravity anomalies, and therefore probably with concealed granitic plutons.

INTRODUCTION

The relatively stable tectonic setting of the eastern United States seems to preclude the possible occurrence of conventional, high-temperature hydrothermal resources; however, the region does contain geothermal resources which may be exploited in the future (White and Williams, 1975). The

geothermal resources anticipated will be low- to moderate-temperature fluids that are best suited for direct heat applications (Howard, 1975).

The normal geothermal gradient in the eastern United States is known to vary from approximately 10°C/Km to 40°C/Km . Temperatures can be reached at relatively shallow depths that are adequate for many geothermal applications. The most significant applications at the present time are for district-heating and industrial applications.

As low-temperature geothermal energy becomes competitive with conventional energy sources, a knowledge of the regional and local variations in the geological framework becomes essential for efficient site selection. The distribution of uranium and thorium has important implications for the development of geothermal resources where the heat flow is normal.

Geothermal resources in the Appalachian Mountain system and the Atlantic Coastal Plain may be grouped into four types:

- 1) Radiogenic granitic rocks concealed beneath sediments of the Atlantic Coastal Plain;
- 2) Normal geothermal gradient resources;
- 3) Warm water emanating from fault zones as a result of adiabatic leakage from greater depths;
- 4) Hot-dry-rock in regions of abnormal gradient resulting from radiogenic heat.

The resources are listed in the order in which they are most likely to be exploited in the eastern United States on a large scale in the near future. Resource (1) is referred to herein as the radiogenic model. Resource (2) is associated with generally lower temperatures and geothermal gradients in the absence of a concealed radiogenic source. Optimum sites for the

exploitation of the normal geothermal gradient resource will be in those regions underlain by thick sequences of sediments of relatively low thermal conductivity. Evaluation of the geothermal potential and study of the origin of the warm springs in the eastern United States is in progress (Costain, 1975; Geiser, 1976; Geiser and Costain, 1977). The hot-dry-rock resource is intended primarily for electric power generation, and techniques are under development at Los Alamos, New Mexico (Laughlin and West, 1976). Similar applications for the eastern United States beneath the Atlantic Coastal Plain are under consideration. Knowledge of these individual resource types varies considerably, and the resource assessment in the eastern United States is often a question of whether or not a known hot or warm water occurrence can be developed economically. The urban centers of the East Coast provide the most obvious possibilities for supplement and local replacement of conventional energy sources with geothermal resources by direct heat applications and heat pump technology.

GEOLOGIC FRAMEWORK OF CENTRAL AND SOUTHERN APPALACHIAN MOUNTAIN SYSTEM AND THE ATLANTIC COASTAL PLAIN

The Appalachian orogen is divisible into several complex divisions, or belts, which have been discussed elsewhere (Fullagar, 1971; Hatcher, 1972; Rankin et al., 1973; Glover and Sinha, 1973; Hatcher, 1978).

Intrusive igneous rocks of the compositional range including granodiorite and granite crop out over a large area of the Central and Southern Appalachian Piedmont and Blue Ridge. Rocks of the Piedmont Province extend eastward beneath shallow (0-3 Km) essentially horizontal sedimentary cover to beyond the coast. Limited petrographic data from drill holes penetrating basement

beneath the Atlantic Coastal Plain indicate a complex distribution of igneous and metamorphic rocks, similar to the exposed portions of the Piedmont.

In the central and southern Appalachians, most plutons have been overprinted by varying grades of metamorphism. Metamorphic redistribution may not allow premetamorphic plutons to become potential radiogenic resources. Our efforts have therefore been concentrated on post- to syn-metamorphic plutons.

Recent whole rock Rb-Sr and zircon ages of 330 m.y. to 270 m.y. outline a conspicuous belt of post-metamorphic granitic plutons thus far mostly restricted to the eastern margin of the Piedmont (Wright et al., 1975). Because higher concentrations of uranium and thorium are known to occur in younger, unmetamorphosed rocks, we have focused our attention on the 300 m.y. belt of plutons, and have drilled holes, in these younger plutons for the most part, to obtain representative heat generation values, and to provide new heat flow determinations.

REGIONAL HEAT FLOW AND HEAT GENERATION

IN THE CENTRAL AND SOUTHERN APPALACHIANS

Figure 1 shows our new sites in the southeastern United States where heat flow determinations are in progress. Additional values in the eastern United States can be found in Sass et al. (1976). Known values in the southeast range from less than 1 HFU to about 1.5 HFU (1 heat flow unit = $1 \text{ HFU} = 10^{-6} \text{ cal/cm}^2\text{-sec}$). As more data become available it is apparent that lateral variations in heat flow are as prevalent in the southeastern United States as they are known to be in the northeast (Birch et al., 1968).

The average heat generation determined from core samples from a hole drilled into the 300 m.y. unmetamorphosed Rion pluton (WN1) in North Carolina is 11.2 HGU (Costain et al., 1977d). Surface samples of the Petersburg granite (330 m.y.) in Virginia locally have a heat generation as high as 17 HGU (Costain et al., 1973, p. C-14).

Figure 2 shows the correlation between heat generation and heat flow for the first seven holes drilled by us into granitic plutons in the southeastern United States. For five of the values, the correlation between heat flow and heat generation is remarkable. The equation relating heat flow q to heat generation A , using all values except RL1 and RL2, is

$$q = 0.69 + 6.9 \times 10^5 A.$$

The correlation between heat flow and heat generation was first described by Birch et al., 1968; Roy et al., 1968; and Lachenbruch, 1968. Several authors have proposed explanations for the physical significance of the linear relationship (Birch et al., 1968; Lachenbruch, 1968, 1970; Albarede, 1975; Costain, 1978).

It is surprising to observe the linear relationship in such widely separated (450 Km) plutons with such a large age span (250 m.y.) in both pre- and post-metamorphic rocks. RX1, RX2, and RX3 are sites in the Roxboro Metagranite, emplaced at 575 ± 20 m.y. ago; the remainder of the sites are in syn- or post-metamorphic plutons, about 300 m.y. in age. Furthermore, in spite of the relatively small sizes of the plutons, the edge effects discussed by Roy et al. (1968) and Birch et al. (1968) do not appear to be important, apparently because of a low contrast in heat generation between any one pluton and the country rock into which it has been intruded. The value of heat flow and heat generation for RL2 probably falls on the linear

relationship within experimental error. Values for RL1 do not, and we are considering petrologic and structural reasons for this.

The addition of a thermally-insulating blanket of sediments overlying the granitic basement rocks will result in a substantial increase in subsurface temperatures. Figure 3 shows subsurface temperature distributions to be expected with and without 2 Km of overlying sediments of low thermal conductivity.

METHODOLOGY FOR EVALUATION OF THE GEOTHERMAL RESOURCE

Since granitic intrusive rocks are generally less dense than the rocks into which they have been intruded, negative Bouguer anomalies are commonly associated with granitic plutons. In addition, contact aureoles associated with intrusive granitic plutons often have a readily recognizable aeromagnetic signature.

At the present time, the region for widespread and economical use of geothermal energy in the eastern United States appears to be the Atlantic Coastal Plain because of known higher gradients there, even with normal heat flow. We are, therefore, examining geothermal gradients and potential field data for the Atlantic Coastal Plain in an attempt to identify concealed radiogenic sources and to define the normal geothermal gradient resource.

GEOTHERMAL RESOURCE POTENTIAL OF THE ATLANTIC COASTAL PLAIN

The optimum sites in the Atlantic Coastal Plain will probably be associated with granitic rocks relatively high in heat-producing elements concealed beneath thermally-insulating sediments of the Atlantic Coastal Plain.

Choice of a drill site in the Atlantic Coastal Plain with a high geothermal resource potential depends on favorable:

- 1) Concentration of radiogenic elements in granitic rocks beneath a sedimentary insulator;
- 2) Thermal conductivity of the sedimentary insulator;
- 3) Thickness of the sedimentary insulator; and
- 4) Reservoir conditions in the permeable sedimentary rocks overlying the radiogenic heat source.

The highest conduction gradient we have determined to date in an existing well is at Stumpy Point, North Carolina, where the estimated depth to basement is about 2.3 Km. The bottom-hole temperature at a depth of 1.35 Km was 66°C (151°F). The gradient is about 37°C/Km; the temperature at the base of the sediments should thus be close to 100°C. Similar gradients have been reported elsewhere in the Atlantic Coastal Plain (AAPG Geothermal Gradient Map, 1977).

Figure 4 shows the distribution of geothermal gradients in the Atlantic Coastal Plain based on our data and the AAPG (1977) regional geothermal gradient map in North and South Carolina, and based on the AAPG regional geothermal gradient map elsewhere. Apparent thermal anomalies are coincident with centers of high population density (Toth, 1977).

CONCLUSIONS

An extensive drilling program in the Atlantic Coastal Plain is about to begin in order to evaluate the geothermal resource. Partial confirmation of the radiogenic model is already available. The hole at Stumpy Point, North Carolina, is located on the flank of a broad gravity minimum. Assuming

a mean conductivity of Coastal Plain sediments of $4.2 \text{ mcal/cm-sec-}^{\circ}\text{C}$ and a conductivity for granitic rocks beneath the Coastal Plain sediments of $7 \text{ mcal/cm-sec-}^{\circ}\text{C}$, these parameters predict a reasonable value of heat generation of about 12.5 HGU for concealed granitic plutonic rocks.

ACKNOWLEDGMENTS

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CAPTIONS FOR FIGURES 1 - 4

Figure 1. New VPI&SU heat flow drill sites in the Piedmont Province of the eastern United States.

Figure 2. Relationship between heat flow and heat generation for seven sites in the Piedmont Province.

Figure 3. Effect on subsurface temperature of heat-producing elements in granitic rocks and overlying sediments of low thermal conductivity.

Figure 4. Preliminary map of relatively high geothermal gradients in the Atlantic Coastal Plain. Contour levels are in $^{\circ}\text{C}/\text{Km}$.

PLUTON

• V.P.I. & S.U. DRILL SITE

Hole	Map Location
KR3	1
WN1	2
RX1	3
RX2	4
RX3	5
SBI	6
RL1	7
RL2	8
RL3	9
RL4	10
RL5	11
PT1	12
PG1	13
LK1	14
PE1	15
ED1	16
SM1	17
SM2	18
PM1	19

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GEOTHERMAL: WORLD VS. USA

by
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Precis of Talk Presented at
GRC Short Course #7, Washington D.C., May 17-18, 1978

Those geothermal resources known as "hydrothermal" are the ones being exploited in the world today.

Italy commenced conversion of geothermal energy to electricity at Lardarello in 1904. Their progress and that of other countries is illustrated in Figure I.

The comparative progress of wet steam (hot water) and dry steam geothermal resources is summarized in Figure II.

Figure III emphasizes the estimated future of geothermal.

Figure IV is designed to summarize, in trend-line fashion (log-linear representation), geothermal's progress and likely future. Several observations should aid an appreciation of that figure. Those are:

- (1) The basic world trend is held to be excessively conservative in that it predominantly reflects a long period of complacency regarding hydrocarbon abundance.
- (2) The world trend since 1970, i.e. doubling capacity every three years, is seen as likely to continue. If so, that will result in one million barrels per day of oil equivalency by 1996.
- (3) The U.S. trend is somewhat less optimistic because of a number of factors, most of which are artificial. Some of those are:
 - (a) The 1970 Federal Geothermal Steam Act, which provides private developers access to public lands, is awkward to the point of being an institutional barrier. That is a natural consequence of its having been drafted in an era where attention to exploitation of the U.S.'s energy needs was not a priority concern. Unfortunately, though conditions have changed enormously, it is still the governing statute.
 - (b) Geothermal operates at an extreme disadvantage vis a vis other energy investment opportunities owing to both an adverse and an uncertain tax climate.
 - (c) The legal ownership of the geothermal resource has been, at best, uncertain since geothermal exploitation commenced in the U.S.

Direct geothermal heat applications, and those resources described as molten magma, hot dry rocks, and geopressured are topics that are neglected.

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WORLDWIDE GEOTHERMAL POWER PLANTS,
CUMULATIVE INSTALLED CAPACITY IN MEGAWATTS

YEAR	ITALY	NEW ZEALAND	USA	MEXICO	JAPAN	ICELAND	USSR	OTHER	TOTAL
1913	1/4								1/4
1914	8								8
1936	56								56
1939	140								140
1940	250								250
1944	10								10
1956	260	69							329
1960	300		12						381
1961	320	181							501
1963	320		26						527
1965	340		54						575
1966					20				595
1967				3.5	33		5.7		617
1968			82						645
1969						3.4			648
1971	391		192						810
1972			302						919
1973			412	78.5					1104
1974									1104
1975		231	522		58				1289
1976			632			63.4		110	1569
1977			742	153.5	158			170	1915
1978			852						2025
1979			962						2135
1980		281	1072	183.5					2325

SOURCE: GEOTHERMAL ENERGY UTILIZATION BY E.F. WAHL, 1977.

WORLD GENERATING CAPACITY, MW (1975)

COUNTRY	FIELD	OPERATING	UNDER CONSTRUCTION	VAPOR DOMINATED	HOT WATER
U.S.	THE GEYSERS	502	216	718	
ITALY	LARDERELLO	380.6		380.6	
	MONTE AMIATA	22		22	
	TRAVALE	15		15	
NEW ZEALAND	WAIRAKEI	192			192
	KAWERAU	10			10
JAPAN	MATSUKAWA	22		22	
	OTAKE	13			13
	ONUMA	10			10
	ONIKOBE	25		25	
	HATCHOBARU		50		50
	TAKINOUE		50		50
MEXICO	PATHE	3.5			3.5
	CERRO PRIETO	75			75
EL SALVADOR	AHUACHAPAN		60		60
PHILIPPINES	TIWI		100		100
SOVIET UNION	PAUZHETSK	5			5
	PARATUNKA	0.7			0.7
ICELAND	NAMAFJALL	2.5			2.5
	KRAFLA		55		55
TURKEY	KIZILDERE	0.5	2.5		3
	TOTAL	1278.8	533.5	1182.6	629.7

FIGURE II

ELECTRICITY GENERATING CAPACITY
FROM GEOTHERMAL RESOURCES

	1976 INSTALLED CAPACITY (MW)	1985 ESTIMATED CAPACITY (MW)	2000 ESTIMATED CAPACITY (MW)
UNITED STATES	522	6,000	20,000
ITALY	421	800	---
NEW ZEALAND	202	400	1,400
JAPAN	70	2,000	50,000
MEXICO	78.5	400-1,400	1,500-20,000
SOVIET UNION	5.7	---	---
ICELAND	2.5	150	500
TURKEY	0.5	400	1,000
CANADA	---	10	---
COSTA RICA	---	100	---
EL SALVADOR	60	180	---
GUATEMALA	---	100	---
HONDURAS	---	100	---
NICARAGUA	---	150- 200	300- 400
PANAMA	---	60	---
ARGENTINA	---	20	---
PORTUGAL	---	30	100
SPAIN	---	25	200
KENYA	---	30	60- 90
INDONESIA	---	30- 100	500- 6,000
PHILIPPINES	---	300	---
TAIWAN	---	50	200
TOTALS	1,362.2	11,335-12,475	14,775-100,000

SOURCE: MEIDAV ET AL IN GEOTHERMAL ENERGY MAGAZINE, 1977.

GEOHERMAL POWER CAPACITY - MEGAWATTS

Geothermal Fuels Comparison With Other Fuels

B. Greider
President, Geothermal Resources Council

ABSTRACT

Geothermal energy can compete with the other types of energy now being used in the U.S. To do so, the energy must be available from its reservoir at a temperature above 400°F. Below this temperature, operating cost rise significantly as the number of wells to produce and reinject the fluid increases. The cost of the plants rise rapidly as the temperature decreases as the volume of fluid moving thru the system increases rapidly. There are economic limits established by temperature that must be recognized. If the BTU content of a ton of coal drops, there is a point where it is not useable for power production. The same is true for oil and gas fluids as their associated water or inert gas ratio increases. Geothermal fluids quality and usefulness is also dependent upon its BTU content per unit volume. This is true of all other fuels.

The field costs to develop and operate the energy producing facility and the resulting costs to generate electricity are affected by interrelated variables. These include:

GEO THERMAL FIELD COSTS

Variables

Temperature of Fluids
Composition of Fluids
Geology of Reservoir
Cost Drilling
Flow Rate per Well
Well Spacing
Turbine System
Operating Costs

Because of this relationship, it is difficult to present a specific cost of electricity produced by the broad types of resource. The following table presents the probable range of prices for electricity generated from steam and hot water reservoirs today. Prices in 1980 will be higher.

GEO THERMAL GENERATION ELECTRICITY PRICE

	<u>Mills/KWH</u>
Steam 450°F and above	22.5 - 24
Hot Water Flash - Below 400°F	36 - 50
Above 400°F	25 - 30
Binary	40 - 48

Research must continue on making temperature below 400°F useful. The technology is now mature. There are vast quantities of heat in this resource awaiting the solution to the economic problems of using this low grade heat.

COMPARISON ELECTRICITY GENERATION FUELS
WITH GEOTHERMAL FUELS

December 1977

This discussion will compare the cost of new electricity generating plants and the resultant price of electricity at the busbar. A review of costs associated with present geothermal developments will be given. The cost comparisons between the various sources of energy that will be available and useable for electricity generation during the next decade may indicate the degree of geothermal energy's growth. The economic desirability of the production or use of a fuel is sensitive to its price. It is extremely difficult to maintain currency in the price of fuel and the cost of electricity generation from the various fuels. The factors that make this difficult include the cost of acquiring prospects, producing facilities and operation, transportation, and cost of conversion to useful form for each fuel. Regulatory requirements have direct effect upon production and construction costs. The tax treatment for each fuel system is a dynamic one. This makes it very difficult to assess the resulting economics.

Oil is the most widely used fuel in the United States for the generation of electricity. Coal is used to fuel the majority of the electricity generating plants. Electricity produced from oil fired plants is directly related to the cost of low sulfur fuel oil as the different plant configurations cost within \$100 per KW of each other to build. For instance, an oil fired turbine generator plant costs between \$385.00 and \$400.00 per KW. A combined cycle plant is about \$300.00 per KW so the difference in heat factor, operating cost, and available capital for these plants establish which will be used for meeting the increased demand and plant replacement schedule within a utilities service area.

The price of any fuel is the amount of money a willing buyer and a willing seller can agree upon in a free economy. Posted prices for commodities are the reflection of a seller's desired price and a customer's ability to pay for the quantity of heat that will meet his need. Government reports on fuel prices paid by utilities are reasonable evidence of the final fuel costs at the plant. To determine the actual sales price received by the producer for the fuel, the price reported as paid by the producing facility requires a careful analysis of fuel transportation, preparation, and handling charges. The concept of pricing are the same for electricity generation fuels and non-electric direct fuels. The principles of competition are the same. The fuel producer, in establishing his price, has several strong constraints such as his costs, the price of competing fuels, and the desire of potential customers to use his fuel. The supplier and user of geothermal energy must carefully consider if the price provides a reasonable return on investment to find and produce the energy. The customers must select the fuel to buy that will reliably provide a product at an attractive sales price. The amount of money needed to construct and operate plants to use the fuels is a strong component of how much the customer will pay per unit of fuel. The heat rate of the energy conversion system determines the amount of fuel needed to supply the plant. In electricity generating plants, the heat rate is the number of BTU's required to produce a net kilowatt hour. The average coal and oil burning plant uses 9,000 to 10,500 BTU/kwh. A nuclear plant uses about 14,000 BTU/kwh. Geothermal plants use between 21,000 to 33,000 BTU per net kwh.

OIL

The estimated cost of fuel oil in mills per kwh vary with the entity making the study. Data developed by Stanford Research Institute, a consensus of the fuel industry, and published utility estimates, are compared. SRI estimates

fuel oil within the next four year period will cost \$2.30 to \$2.50 per million BTU or approximately 23 mills per kwh. Fuel suppliers' published estimates of the cost of oil have anticipated ranges of 20.5 to 22.5 mills per kwh. This is a very narrow range and reflects the strong competition in oil markets. This strong competition between suppliers results in a stabilizing effect upon the overall price of oil. Utility planners have estimated the range of price of oil to be 20.5 to 21 mills per kwh. These cost ranges combined with new plant costs will produce electricity between 43 and 44 mills per kwh. Oil prices are relatively easy to predict in the near future as there is an active worldwide market, and the high transportability of oil allows a new source of supply to quickly move to areas of short supply. Thus posted prices around the world are not strongly area related.

COAL

Coal has a different pricing mechanism. Coal prices are more related to specific sources of supply and dedication of specific sources of coal to certain plants. Coal does not presently have the wide range of usefulness that oil enjoys today. This limits the substitution of one coal for another. Before a mine is opened, a major share of its production may be dedicated to certain plants designed for that specific coal. The demand for coal will continue to increase the price of this fuel as government orders coal to displace oil in new and old plants. The demand for this fuel will grow faster than new mines and transport facilities can be built unless capital formation is encouraged and the current environmental restraints are solved. Increasing the rate of leasing good federal lands would help increase the coal supply.

The cost of steam coal fuel and plant construction costs with the resulting estimated cost of electricity will probably produce electricity at \$35 mills. Coal sales prices are determined through negotiations between the buyer and seller, and unlike oil, does not have a national or regional posted price. SRI estimates coal to be delivered for approximately 11 mills per kwh or \$1.10 per million BTU. This price is dependent upon the distance from the mine mouth to the plant. SRI estimates new coal plants to cost about \$600 per KW of capacity. Fuel suppliers currently estimate coal can be delivered within a one-thousand mile radius for 9 to 10 mills per kwh if surface mining methods are used. Plant costs vary with the precipitation and sulfur removal equipment used in the plant. New coal (including lignite) plants, announced this past year, have prices ranging from \$580 to \$950 per KW. Utility sources estimate coal will cost between 10 to 11 mills per KWH and the plants should have an average cost of about \$630 per KW. An estimated cost of electricity using these parameters is between 35 to 36 mills per KWH.

NUCLEAR

Nuclear fuel plants appear to offer the least expensive electricity for a nonindigenous source. Slide3 shows SRI estimates of fuel costs as 3 to 5 mills per kwh, and nuclear plant costs of \$830 per KW. This is lower than the estimates of the fuel industry which place a cost of 6 to 7 mills per kwh as most likely.

The fuel industry estimates nuclear plants can be constructed to meet safety and health requirements for \$700 to \$1000 per KW. The utility industry estimates they will be paying 6 to 6.5 mills per kwh for nuclear fuels and plant costs in 1977 dollars will be \$800 to \$1000 per KW. The estimated cost of electricity from such plants will be between 32 to 34 mills per KWH.

The wide variation of estimates of fuel costs and plant costs derives from treatment of fuel processing and storage expense, income taxes, ad valorem taxes, insurance, interest during construction, return on investment required, and specific requirements for plants in the area of operation for the estimating companies. The project rate of return for these plant projects is dependent upon the debt to equity rate of the capital required. The utility usually expects to earn a minimum of 20% ROI on its equity portion. The interest charge for the debt capital brings the objective project ROI down to the 12 to 15% range.

To obtain a comparison of geothermal fuels with these more widely used fuels is quite difficult. The difficulty arises because each geothermal area is restricted to a plant design specifically useful for that local area. It is quite easy to find reference in current literature that geothermal energy should be obtainable for 5 to 50 mills per kwh. As a point of reference, consider that the California Geyser's steam price of 14.5 mills per kwh is about as inexpensive as geothermal energy can be produced today. This is a dry steam fuel, and the operators have had more than a decade of experience of drilling, completions, and production operations. Optimum techniques have been developed to drill and complete the wells in such fashion that maximum steam production per dollar invested can be maintained. The high energy content of this fluid provides a competitive heat rate, allows smaller diameter lines for the collection system, and the most simple of plant and reinjection facilities. The actual cost of the wells are frequently as high as \$750,000 - \$1,000,000 but the operation and the high utility of the steam allows a minimal price for the energy.

Much like coal and uranium, geothermal fuel prices will be a negotiated price between the supplier and the user. Each field will have significant differences so a uniform price cannot be expected either for construction of the producing facilities of the design in construction of the utilities conversion plant.

The pricing system first used in the Geysers was directly related to the number of kilowatt hours of electricity produced. A second pricing system based on the energy delivered is now in use. The disadvantage of pricing energy by the kilowatt produced is that there is less incentive for the utility to invest money in making their plants more efficient. An increase in efficiency resulting in more kwy per pound of steam results in the steam producer being paid more because of the utility's investment. The dry steam electricity producing system of the Geysers is relatively low cost so an increase in efficiency is not needed for the steam to be competitive with other available fuels. Dry steam reservoirs are at a nearly constant temperature so there is little incentive for the producer to conduct research and explore new depths for higher temperature reservoirs.

The nature of the reservoir geometry and the ability of the reservoir to respond to changes in production, rates, and temperatures, will determine the final costs for producing electricity from each Geothermal Project.

The costs in hot water systems that will be developed with proper environmental controls are of such magnitude that incentives must be provided to encourage increased efficiency in generation and increased search for greater temperature water reservoirs at depth. This is necessary if these systems are to compete successfully (commercially) with other fuels.

It is good business to consider the revenue stream for the producer as being composed of two parts. The first is money for providing useful heat to the utility, and the second for disposing of the fluid after the useful heat has been extracted by their machines. By buying fuel on a BTU basis, incentive is provided for continued improvement in the electricity generating system. The more kilowatts produced per million BTU, the more competitive the geothermal busbar price becomes.

The sale of geothermal energy can be based on a price per million BTU of "Useable Heat" delivered to plant inlet or the plant's pipeline. "Useable heat" would be the total energy difference between the delivered fluid mixture and the fluid returned to the producer at a specified temperature for disposal. Energy sales agreements should include clauses that provide for energy sales at a fair market value with escalation determined by negotiations between buyer and seller. If you have a wizard employed, you can develop a formula that will always recognize the truevalue of energy. If you don't have such capability, negotiations at reasonable intervals of time should provide the most equitable escalation factors.

The basic structure of price must provide an attractive rate of return to the prospector. To achieve this, the prospector's risk capital investment and time at risk before income must be minimized.

The BTU's provided should be priced on BTU's delivered above a reference temperature. These will be known as "useful BTU's". A useful BTU per pound of brine is the remainder of the difference between the enthalpy of the fluid at delivery temperature and the enthalpy of the fluid at a reference temperature such as 200°F. (Reference temperature depends upon agreement with purchaser and is limited by composition of the geothermal fluid and injection plans.)

The simple calculation to determine the useful BTU's at differing delivery temperatures is as follows:

USEFUL BTU

(1) Delivery temperature from field engineering	365°F	340°F	330°F
(2) Enthalpy (Inlet) BTU/Lb from heat tables	337.5	311.1	300.7
(3) Enthalpy @ Ref Temp 200°F from heat tables	168	168	168
(4) ΔH = Useful BTU/Lb of Brine (2)-(3)	169.5	143.1	132.7

The calculation of price is dependent on the amount of fluid that must be produced. This depends upon design parameters of the utilities' plants. The number of pounds of geothermal brine per KWH multiplied by the useful BTU's per pound has a product that is the number of useful BTU's per kilowatt hour of electricity. Heat rates (BTU per KWH) of geothermal plants vary from 21,000 to 32,000 BTU per KWH. The quality of the steam or heat increases as the temperature rises.

BRINE LBS

(5) Delivery temp from field engineering	365°F	340°F	330°F
(6) Flow for 50 MW (M Lbs/Hr) from plant design	7.58	9.25	10.2
(7) Net MW produced from plant design	45.5	45.2	45.0
(8) Brine required LB/Net kwh (6) - (7)	167	205	227

CALCULATION USEFUL BTU's/KWH

Brine required X useful BTU/lb			
(8) multiplied by (4)	28,300	29,300	30,000

The useful BTU's per kwh is divided into the fuel price in dollars per million BTU's to obtain the cost of fuel in mills per kwh.

PROSPECT DEVELOPMENT COSTS

A review of the costs associated with developing geothermal areas was presented by C. Heinzelman in Hilo, Hawaii, October 15, 1977. These costs illustrate that changes in costs are still being experienced in dry steam, high temperature flash, and moderate temperature flash or binary systems. The costs to find geothermal systems continue to increase as geologists learn there are cold

holes very near hot areas; there are hot areas within an overall cold area; there can be a steam zone within a hydrothermal area; and there can be two different type of geothermal systems, vapor and liquid dominated, vertically separated within the same geographic area.

Table 1 is from C. Heinzelman's presentation and illustrates exploration techniques and associated costs. The overall amount of money (per successful prospect) required is 2.5 million dollars to 4.75 million dollars. This provides for limited failure and follow up costs, but does not include the other exploration failures and land costs.

Table I

EXPLORATION TECHNIQUES & APPROXIMATE COSTS

(Small Prospects)

<u>Objective</u>	<u>Technique</u>	<u>Approximate Cost (\$)</u>
<u>Heat Source & Plumbing</u>	Geology	15,000
	Microseismicity	15,000
<u>Temperature Regime</u>	Gravity	20,000
	Resistivity	25,000
	Tellurics & magnetotellurics	40,000
	Magnetics	15,000
	Geochemistry (Hydrology)	12,000
	Temperature Gradient 20 holes	100,000
	Stratigraphic Holes (4)	160,000-240,000
<u>Reservoir Characteristics</u>	Exploratory Wells (3)	1,800,000-4,000,000
	Reservoir Test	250,000
Total to Establish a Discovery		<u>\$ 2,472,000-4,752,000</u>

To arrive at this stage, about 12 to 13 million dollars will be spent on related projects in search for a field large enough to produce 200 MW or more.

Upon deciding a significant geothermal anomaly exists, the rate of engineering expenditures increases rapidly to determine how the development can

proceed. Essentially, there are no set figures for what it costs to develop a geothermal field. The basic reason for this is that each depends upon engineering the development to the geology of the accumulation and the requirements of the electricity generating system. The electricity generating system must be designed within the constraints of available temperature, rate of production, and ambient conditions of the field site. The key variables are:

Temperature of the fluids produced.

Composition of the reservoir fluids.

Composition of surface or near surface fluids.

Geology of the reservoir framework.

Flow rates that can be sustained by the reservoir.

Cost of drilling in the prospect area.

Well spacing and geometry of the producing and injection sites.

Turbine system to be used.

General operating costs in the area.

Development wells are being drilled and completed for \$500,000 - \$1,500,000. Injection wells are in the same cost range. The ratio of producers to injectors depends upon reservoir characteristics. Water steam lines from the producers to the plant can be estimated to cost \$35 to \$100/KW capacity. This cost is dependent upon the development pattern and plant location in relation to the producing wells. Condensate return pipelines' design and cost depend upon the use of the condensate. If the condensate is mixed with the brine that is not flashed, a mixture similar to the produced fluid can be returned to the injection sites and return lines will be similar in size to the production lines. If the condensate is used in the cooling system and allowed to evaporate, a small diameter pipeline can be used to return cooled water to injection line. If this is so, the condensate pipeline can be as cheap as \$4-\$15 per KW.

Power plant costs published pre 1975 cannot be used in estimating the expected cost to develop generating facilities. Each geothermal area now under development has unique costs that were provided for when their application to build was approved. Changes in effluent treatment, atmospheric discharge regulation, and visual impact mitigation, affect historical concepts of costs. The following costs for power plants should be considered as a range of costs being achieved today. The delay of a field development and power plant project introduces significant costs because the sums of money committed to these phases have grown to ten times the 2.5 to 4.75 million dollars spent on the exploration techniques.

Plants built to use steam produced directly from a dry steam reservoir are the lowest in cost to build. PG&E's plant #15 is expected to cost \$320/KW with provisions for H₂S treatment. This is an increase of 250% over the average of the 1961-1974 period. In the same period, the cost of electricity generated averaged about 5.6 mills per net kilowatt hour. 1979 costs will have increased to 25 to 30 mills per kilowatt hour.

Hot water flash plants have an extremely wide cost range. This is because the temperature and chemical characteristics of the produced fluids and unit size have a wide range. It is this range of characteristics that create a range in costs of from \$400 per kilowatt to as much as \$700 per kilowatt. Double flash 45 net MW operating on low solids fluids at temperatures around 450°F most likely can be constructed for \$450 to \$475 per net kilowatt. Fluids 100°F cooler will require plants costing \$100 more per kilowatt capacity.

Binary units designed for using the low boiling point fluid to drive the turbine are experimental designs. No plant greater than 5 MW has been operated so cost criteria are tenuous. Research on this system may provide sufficient data to more accurately forecast their costs. Present estimates for approximately 50 MW plants range from Ben Holt Engineering's estimate of \$500 per kilowatt to Ford

Bacon & Davis shell and tube system at \$655/kwh. A small 10 MW binary system is being constructed by Imperial Magna. This has a reported cost of \$1,000 per KW.

A summary of estimated development costs after exploration expenses for the field supply, power plant, and ancillary equipment for a 50 megawatt hot water flash unit is as follows:

Table II

Development Wells (12)	\$ 10,800,000
Injection Wells (6)	5,400,000
Pipelines	2,800,000
Miscellaneous Field Expense (includes interest & working capital)	9,000,000
Power Plant	<u>25,000,000</u>
Total	\$ 53,000,000

ECONOMICS OF GEOPRESSURE - GEOTHERMAL RESERVOIRS

Tertiary basins around the world have been discovered to have reservoirs at greater than normal pressure gradients. These geopressured zones frequently have higher than normal geothermal gradients. Exploration and field developments for oil and gas production in Texas and Louisiana has outlined an area of interest extending several hundred miles from the Rio Grande River to the Delta of the Mississippi parallel to the Gulf Coast.

The economics of developing this combination of kinetic energy, low grade heat energy, and methane, is unfavorable at this time. Uncertainty as to the producibility is caused by the knowledge that to have geopressure, the sand formations must be discontinuous and the reservoirs must be confined in a limited areal configuration. Without such limits, normal temperatures and pressures would exist. A very detailed economic analysis by C.F. Riemann, L. Rios-Castellon, and G.K. Underhill for the Second Geopressure and Geothermal Energy Conference in 1976 covers all aspects of the economics of this resource. This analysis was for a

25 MW system costing \$101 million to convert 325°F geothermal fluid containing 40 SCF of methane per barrel. Even though a moderate depth of 14,000' was used and 40,000 barrels per day per well spaced only 1/2 mile apart, the project is not economic. This analysis included a very low ad valorem tax and sales revenue from the contained methane was estimated at a price of \$2.00 (20% greater than now allowed by the federal regulated price).

This economic analysis was for a 25 MW module that could be applied to a larger size field. Serious workers should read this carefully and adjust the author's assumption to actual field cases. Care must be exercised to 1) establish minimum well spacing to reduce surface facilities, 2) provide sufficient separation at point of production of producing wells to avoid interference, 3) establish the injection well pattern to effectively couple the producing wells allowing the mining of the heat from the rock frame work as the water moves thru the reservoir, and 4) realistically establish costs, operating expenses, and product prices.

In the deeper reservoirs of the geopressed areas, higher temperatures have been reported by Louisiana State University. These deeper reservoirs (18,000' to 19,000') are at temperatures above 400°F. The low permeabilities reported with the moderate reservoir thickness (400') will require a maximum producing rate of 20,000 bbls per day (instead of the 40,000 bbls usually used) per well if excessive drawdown is to be avoided. The wells would probably require 640 acre spacing to eliminate well interference effects. The producer-injector ratio should be planned for 1:1. However, an initial testing period for the first modules can confirm this assumption.

The Department of Energy plans a deep \$6,000,000 well test of this type of geopressed prospect. The results will be valuable in trying to design a workable method to recover and use this very expensive submarginal energy accumulation. The following summary statements synthesize my opinions on this resource.

Table III

GEOPRESSURE ECONOMICS

BASIS

Reservoir Thickness	400'
Permeability/Ft.	Less than 10 md
Surface Pressure	3,000 PSI - 4,000 PSI
Flow Before Injection req'd	1.0-1.1 billion bbls
Time Before Injection	Less than 2 years
Minimum spacing producers (interference)	640 acres
Draw Down Limit	3500 PSI
Injection Pressure	5000 PSI
Net Methane in Solution	75 SCF/bbl

Table IV

GEOHERMAL ECONOMICS

SCOPE FACILITIES

Field Size	200 MW
Barrels/year	600 Million
Barrels/Day/Well	20,500
10 Wells each	25 MW Unit
80 Producers	80 Injectors
Plant Net	200 x .85
Plant Load Factor	70%

Operating costs and taxes can only be estimated. It is certain they will not be less than those experienced in keeping a gas or oil field in operation for thirty years.

Table V

INVESTMENT & REVENUE

160 Wells @ \$6 M Ea. - \$960 M (includes surface facilities)	
Heat @ .020/kwh	Gas @ \$ 1.75 MCF
Energy Revenue	21.25 M/Yr
Gas Revenue	85.75 M/Yr
Revenue Total	\$ 107.00 M/Yr

Table VI

GEOPRESSURE ECONOMICS

EXPENSE

Operating Costs	\$200/Well/Day	= \$12 $\bar{M}$ /Yr
Property & State Tax	15% x Gross/Yr	= <u>16 $\bar{M}$</u>
Total Expense		= <u><u>28 $\bar{M}$</u></u>
Income - (\$107 $\bar{M}$ - \$28 $\bar{M}$)		= \$79 $\bar{M}$
Net \$79M x 50% (Income Taxes)		= 39.5 $\bar{M}$
Payout	\$960/\$39.5	= 24 Years +

There are adequate problems to solve in utilization of geopressured-geothermal reservoirs. These are primarily related to geologic problems. Discontinuous sands form the reservoir rocks in geopressured systems. The lack of continuity prevents fluid moving to lower pressured zones in a natural adjustment to normal pressure results in the abnormal geopressures. This very discontinuity results in limited reservoirs of restricted areal extent.

As pressures reach normal due to production, the sand grains will be more closely packed and the space between them will be reduced. As this is the space the gas and gas-carrying fluids must move within, the ease of movement is restricted. This loss in permeability will seriously affect the rate of production.

In many geologic situation, faulting and fracturing provide the plumbing that allows geothermal fluids to move into the producing reservoirs. The vertical movement of fluids along these faults is thought to be an important factor necessary for high production rates over the long life required for energy production.

Geopressured reservoirs have no such plumbing, otherwise, their pressures would be normal. The sealed faults in the geopressured areas will cause rapid pressure decline unless produced volumes are compensated by having equal volumes reinjected into the same sand bodies.

A summary of economic problems geopressed and geothermal producers must live with include:

1. Competitive fuels are too cheap and available.
2. Competitive fuels can be transported to areas of use.
3. Reserves cannot be adequately measured for less than \$50-\$60M per 200 MW.
4. Coal, oil, and gas field reserves can be measured for a fraction of the cost.

NEW DEVELOPMENTS

Economics of hot water flash to steam projects continue to be impressive in the areas outside of the USA. Cerro Prieto's development is very encouraging as exploratory work confirms this development can exceed 500 MW. The improvement in heat recovery with double flash units would reduce the cost of electricity and increase the reserve size significantly.

The Republic of Nicaragua's Mototombo field development has progressed rapidly under its new management instituted in 1974. By the end of 1975, seven wells with a capacity of 26 MW had been completed. Two of these were non-commercial and may provide utility as an injection well. At the end of 1976, 15 wells had been completed, and the capacity had been increased to 45 MW. By December of 1977, 26 wells had been completed, and one well was drilling. Eight wells have been drilled that failed to confirm commercial power potential. These may be useful for field performance observations disposal, or injection wells. DeGolyer McNaughton, the international consulting firm, has completed its examination of all the field test data from Mototombo. Test using bottom hole pressure detecting devices in selected wells were combined with full field flowing tests. The firm concludes that double flash turbines can produce 96 MW for more than 30 years using the portion of the reservoir now developed. Turbine specifications are now being prepared to have 80 psig first stage and 20 psig second stage. The power plant

for this 225°C field may have two 45 MW units in operation by mid 1980 or sooner. The estimated cost for the electricity generating plant installed will be \$460/KW for these modern double flash units. In the State of the Union Address by President Somoza on December 1, 1977, it was announced that the development of 100 MW at Mototombo would be completed. This would provide an increase in revenues of 34 million dollars. A savings of 26 million dollars in foreign exchange would be the result of this development. This will be strong competition for oil fired generation in Nicaragua.

SUMMARY

As you review presentations on geothermal resources, remember the field costs and the resulting costs to generate electricity are affected by a list of interrelated variables. These are:

Table VII

GEOHERMAL FIELD COSTS

Variables

- Temperature of fluids
- Composition of fluids
- Geology of reservoir
- Cost drilling
- Flow rate per well
- Well spacing
- Turbine system
- Operating costs

For this reason, it is difficult to present a specific cost of electricity produced by the broad types of resource. The following table presents the probable range of prices for electricity generated from steam and hot water reservoirs today. Prices in 1980 will be higher.

Table VIII
GEOHERMAL GENERATION
ELECTRICITY PRICE

	<u>Mills/KWH</u>
Steam 450°F and above	22.5 - 24
Hot water flash - Below 400°F	36 - 50
Above 400°F	25 - 30
Binary	40 - 48

Geothermal energy can compete with the other types of energy now being used in the U.S. To do so, the energy must be available from its reservoir at a temperature above 400°F. Below this temperature, operating cost rise significantly as the number of wells to produce and reinject the fluid increases. The cost of the plants rise rapidly as the temperature decreases as the volume of fluid moving thru the system increases rapidly. There are economic limits established by temperature that must be recognized. If the BTU content of a ton of coal drops, there is a point where it is not useable for power production. The same is true for oil and gas fluids as their associated water or inert gas ratio increases. Geothermal fluids quality and usefulness is also dependent upon its BTU content per unit volume.

Research must continue on making temperature below 400°F useful. The technology is now mature. There are vast quantities of heat in this resource awaiting the solution to the economic problems of using this low grade heat.

Bob Greider/cm

THE U.S. GEOTHERMAL INDUSTRY IN 1978

Robert W. Rex
Republic Geothermal, Inc. *

INTRODUCTION

The geothermal industry in the United States has been growing rapidly and undergoing significant change from its early orientation focused on The Geysers dry steam field in California. As can be expected, the first commercial field in the United States has set the pace for the geothermal industry. Technology and environmental problems, economics and operating practices, have all been shaped by The Geysers field which has grown steadily in capacity over the past twentyfive years. It should exceed the 1,000 Mw production figure by about 1980 or 1981 (Figure 1). The growth of this capacity appears to be sustainable for at least another 1,000 Mw and geophysical exploration suggests that several thousand Mw of capacity are possible. Significant step-out drilling in the central and northern parts of The Geysers KGRA should be done in the next three years, and then we will be able to better evaluate the contribution of the probably extensive hot water resources in the area, and more clearly define the areal extent of the dry steam field.

INDUSTRY CAPACITY

One measure of geothermal production capacity is the amount of steam production currently being sold and contracted to be

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sold. The principal operator in The Geysers field is the Union Oil Company, who operates for the joint venture that includes Magma Power and Thermal Power (Natomas). Union has a 50% working interest in the project, with Magma and Thermal each having a 25% working interest. The Union-Magma-Thermal group is presently the only supplier of steam that is being sold, and the Pacific Gas & Electric Company (PG&E) is using that steam to supply their 502 Mw of installed capacity. Aminoil USA, Inc., successor to the Burmah Oil Company and Signal Oil interests, is scheduled to have 135 Mw of capacity on line with sales to Pacific Gas & Electric Company starting in approximately another year (Figure 2).

Hughes Aircraft Company's Thermogenics, Inc. should have 55 Mw on line in approximately another year and a half, also selling steam to the Pacific Gas & Electric Company. The Shell Oil Company expects to have sales in the early 1980's to the Northern California Power Association, and the McCulloch Oil Corporation intends to have significant capacity on line for sale to the California Department of Water Resources in the mid 1980's. Several other operators are actively drilling for steam and hot water in The Geysers. These companies include Occidental Petroleum, Standard Oil Company of California (Chevron), Phillips Petroleum Company, Republic Geothermal, Inc., and AMAX Exploration, Inc., with the probable addition of several others.

Other than The Geysers, there is no commercial production of geothermal resources under way in the United States. However,

several other commercial projects are now under construction. Probably the first of these to go into production, at a commercial level, will be the 48 Mw hot water/wet steam facility that is located on Federal leases in the East Mesa field in the Imperial Valley. This particular project, which Republic Geothermal has under construction, utilizes a nearly fresh water resource that has no corrosion, scaling, nor hydrogen sulfide problems. The power cycle for this plant will use conventional dual flash steam technology. The second commercial project will probably be a 50 Mw dual flash steam power plant on the Federal leases in the Roosevelt KGRA in Utah, near the town of Milford. Here, the Phillips Petroleum Company, in a joint venture with Rogers International, will be producing wet steam and converting it into electricity for sale to the Utah Power and Light Company. This project will utilize a low salinity water that also is relatively free of corrosion and hydrogen sulfide problems. Roosevelt has one of the hottest geothermal resources yet discovered in the U.S., and other than its distance from markets, it could be one of the more economically attractive geothermal fields in the country. Unfortunately, it is distant from major markets and it will have to compete with old, low cost, coal-fired facilities, making it economically somewhat handicapped compared to projects closer to rapidly growing load centers such as Southern California.

Several other commercial wet steam/hot water power projects are now under way in the Imperial Valley, some with initial 10 Mw facilities, to be followed by full-scale 50 Mw plants. These include a Magma Power Company 10 Mw experimental binary fluid facility at East Mesa, which should be in operation by 1979, and a 10 Mw facility supported by the Union Oil Company at the North Brawley field. Standard Oil Company of California and the Southern California Edison Company have announced a 50 Mw project at Heber in the Imperial Valley which would probably come on line in the 1982 to 1984 time frame. The Union Oil Company, Southern Pacific Land Company and the Southern California Edison Company have announced a project to develop the hypersaline corrosive brine at the Salton Sea for power. They have announced that they will first build a 10 Mw facility to be followed by a commercial 50 Mw power plant. The demonstrated success of the existing DOE/SDG&E test facility at Niland makes it probable that the Union project will be successful (Figure 3).

In Nevada there appear to have been several discoveries made, by Phillips, the Union Oil Company and the Standard Oil Company of California, of hot water/wet steam resources in temperature ranges appropriate for commercial development of power. It now appears that Nevada may contribute significant amounts of electricity from geothermal resources starting in the mid-1980's.

Union Oil Company has projected 400 Mw of potential from their discovery in the Valles Caldera within the Jemez Volcano in New Mexico. The aggregate contribution from the California, Nevada, Utah, and New Mexico discoveries could easily amount to 1,000 megawatt centuries of proven reserves by the late 1980's. Further expansion of this figure could be accelerated by a lightening of the heavy tax burden which geothermal energy carries.

DRILLING ACTIVITY

The relative activities of geothermal operators in the U.S. can be characterized by considering the amount of drilling that they have done in the past three years. An index of this drilling is the actual footage drilled, which is available from public records (Figure 4). The leader has been the Union Oil Company with over 435,000' of drilling, acting for itself and as operator for Magma and Thermal. The number two company is Aminoil with over 180,000' drilled over the past three years, all of it in The Geysers. The number three company is Republic Geothermal with nearly 128,000' drilled in California, Utah and Nevada. The number four company is the Shell Oil Company with nearly 100,000' drilled, all of it in The Geysers. The number five company is Phillips with over 65,000' drilled, primarily in Utah but also with some activities in Nevada and California. The number six company is Chevron (Standard of California) with nearly 52,000' drilled in Nevada and California. The number seven is McCulloch with nearly 47,000' drilled primarily in California, and the

number eight company is Magma with nearly 42,000' drilled in their own name in Nevada and California. However, it should be remembered that Magma has a one quarter participation in Union's activities at The Geysers and although not an operator there, it does have a quarter working interest and that, therefore, the position as an operator does not truly reflect Magma's actual position in the industry. Several other companies, while not all comparably active over the past three years, still have been significant in the past and can be expected to become important again in the future. These include Hughes Aircraft Company (Thermogenics), Occidental Petroleum, Natomas, Geothermal Kinetics, Hunt Energy, Getty Oil Company, and others.

INDUSTRY ROSTER

In addition to the operators, a broad spectrum of support services, hardware suppliers and financial enterprises have become active in the area of geothermal energy. Some indication of this activity can be gained from the roster of members of the Geothermal Resources Council (Figure 5). The current participants include a large number of corporate and organizational enterprises. There are 122 operators among the members, whereas support services are represented by 413 organizations. These include everything from well logging firms to environmental contractors. There are 80 hardware and supply company members, 38 that can be considered financial organizations, and some 21 individuals or groups involved in direct applications of geothermal energy, primarily in its use for space heat. In addition there are some 34 members

affiliated with utilities. In total, we have seen an explosive growth of commercial and industrial activity in the geothermal area with the preponderance of the operators coming from the oil, gas, and mining industries. There are only a handful of independents, but several of these have become significant factors in the industry and appear able to hold their own in competition with the larger oil companies.

All the signs are that the industry is healthy and growing, but that it is very sensitive to the tax climate and to the prices of alternative fuels. The extensive ongoing program of the Department of Energy to encourage the development of geothermal technology, support environmental assessments, and assist in the development of financially independent small companies by the use of the loan guaranty program, appears to be developing successfully. The development of geothermal energy in the United States is currently comparable to a young plant shortly after sprouting - it is vigorous, growing rapidly but very sensitive to adverse treatment. It would only take a short period of thoughtlessness with respect to tax treatment of geothermal drilling to completely devastate the industry at this stage of its development. Currently, uranium and coal have significant tax advantages compared to geothermal energy in spite of the fact that they are environmentally much more polluting. It seems as though some of our legislators are so concerned about the broad philosophy of

taxation as a tool of social reorganization that they are willing to risk destroying the geothermal industry in its earliest period of growth before it really has the staying power needed to permit it to carry a heavy tax burden.

One of the most important geothermal developments in the last three years has been the high incidence of discovery of commercial geothermal resources on Federal leases. I can speak from personal experience that Federal leases offer the largest potential for new geothermal discoveries for the next ten years. Consequently, the Federal government will not only obtain a tax return from geothermal development but also will obtain royalty income of at least 10% of the gross revenues. Our economic studies show that the tax benefits, combined with the royalty income, will produce somewhere between \$1 to \$2 billion of revenue to the Federal Treasury over the next thirty years from each 1,000 Mw of geothermal power capacity. When one compares this to the small size of the Federal investment in this energy resource, it is readily evident that the Federal government is getting an extremely high rate of return on its so-called tax expenditures and industry assistance programs.

GENERATING CAPACITY AT THE GEYSERS KGRA

FIGURE 1

PROJECTION OF INSTALLED GEOTHERMAL POWER CAPACITY IN MEGAWATTS

	1977	1978	1979	1980	1981	1982	1983	TOTAL
UNION MAGMA THERMAL }	502	106	110		220		440	1378
AMINOIL			135					135
THERMOGENICS				55				55
SHELL							110	110
McCULLOCH							55	55
REPUBLIC			10	48				58
UNION			10	10				20
MAGMA			10					10
CHEVRON							50	50
PHILLIPS						50		50
TOTAL	502	106	275	113	220	50	655	1921

FIGURE 2

**PROJECTION OF INSTALLED
GEOTHERMAL POWER CAPACITY
THROUGH 1983
IN MEGAWATTS**

GEYSERS	1733
UNION, MAGMA, THERMAL, THERMOGENICS, AMINOIL & SHELL	
IMPERIAL VALLEY	138
REPUBLIC GEOTHERMAL UNION, MAGMA & CHEVRON	
UTAH	50
PHILLIPS	

FIGURE 3

SUMMARY OF GEOTHERMAL DRILLING IN THE U.S.

FOOTAGE DRILLED IN 1975 - 1976 - 1977

FIGURE 4

**GEOHERMAL INDUSTRY
PARTICIPANTS IN 1978**
FROM GEOHERMAL RESOURCES COUNCIL ROSTER

OPERATORS	122
SUPPORT SERVICES	413
HARDWARE / SUPPLY	80
FINANCIAL	38
DIRECT APPLICATIONS	21
UTILITY	34

FIGURE 5

ESTIMATED GOVERNMENT REVENUES FROM FIELD DEVELOPMENT PROGRAM

EAST MESA 48 MW PROJECT

10% FEDERAL ROYALTY PAYMENTS	\$70,200,000
FEDERAL INCOME TAXES	67,110,000
STATE INCOME TAXES	16,590,000
AD VALOREM TAXES	59,700,000
	<hr/>
	\$213,600,000

**ASSUMES:
25 MILS/KWH
30 YEAR PROJECT LIFE
6% ANNUAL INFLATION RATE**

FIGURE 6

ESTIMATED GOVERNMENT REVENUES FROM FIELD DEVELOPMENT PROGRAM

1000 MW PROJECT

10% FEDERAL ROYALTY PAYMENTS	\$1,462,500,000
FEDERAL INCOME TAXES	1,243,750,000
STATE INCOME TAXES	1,398,125,000
AD VALOREM TAXES	345,625,000
	<hr/>
	\$4,450,000,000

**ASSUMES:
25 MILS/KWH
30 YEAR PROJECT LIFE
6% ANNUAL INFLATION RATE**

FIGURE 7

A Synopsis Of

A Presentation Made to the
Geothermal Resources Council
Quality Inn
Capitol Hill Hotel
Washington, D.C.
May 17-18

by

Ben Yamagata
Van Ness, Feldman & Sutcliffe

Formerly
Counsel and Staff Director
Subcommittee on Energy Research and Development
U.S. Senate Committee on Energy and Natural Resources

1-1/2
GEOTHERMAL ENERGY:
WHY NOT A PART OF NATIONAL ENERGY PLAN II?

The Federal government, including the Congress and the Executive branch, has demonstrated a willingness to assist in the development of geothermal resources. Evidence of that willingness is the Geothermal Steam Act of 1970; the Geothermal Research, Development and Demonstration Act of 1974; and the ever-increasing budget for the geothermal RD&D program formerly in ERDA and now in the Department of Energy. Given this apparent enthusiasm from both Washington, D.C. and various State capitols why has there been so little visible progress towards harnessing geothermal resources for space heating or electrical generation?

First, the assumption that geothermal energy development has been sluggish should be questioned. Indeed, one might argue that much has been accomplished since passage of the leasing act in the early 1970's. As lethargic as the research and development program has appeared to date, accomplishments have been registered; as cumbersome as the loan guarantee program can be, some projects are underway with government backing; and, despite the plethora of agency clearances, at both Federal and State levels, several companies

are setting down firm plans to proceed with the construction of pioneer geothermal powerplants. The geothermal industry has grown in the last decade and given the increased demand and the expected rise in the cost of energy, a portion of the energy demand will undoubtedly be supplied by geothermal. However, in speaking of new energy sources, there is a tendency to raise expectations about the potential of energy technologies and associated resources; once those expectations have been raised among policymakers they are not easily dispelled. In fact, if year after year passes with no visible progress, the technology development program and the Federal role in the exploitation of the resource will be subject to less and less support and more and more disfavor. Where development of the resource is dependent upon Federal financial support and the leasing of Federal lands this disfavor should be avoided. This is not to suggest that geothermal is in the process of suffering such a fate. In fact, the honeymoon between geothermal energy and the Federal government has not ended. The geothermal RD&D budget continues to rise and the potential energy contribution of geothermal resources is affectionately referred to in speeches on energy by national policymakers.

But, to those in the business of producing energy the limitations of the Federal leasing program, the hurdles that must be cleared in the regulatory arena, the delays in the loan guarantee program and the inequities in the tax law combine to pose a formidable barrier to rapid development. Even though government support continues there really is no assurance that an industry will grow rapidly around this domestic resource.

If, as many in the geothermal industry claim, this energy resource is on the verge of commercial application, then why is geothermal energy not part of the Administration's National Energy Plan II supply initiatives?

A great deal has been written and said about the institutional, financial and technological barriers which confront the geothermal industry. Little would be gained by a detailed resuscitation of those points. Rather, this presentation outlines a strategy for including geothermal energy in the national energy supply program. If correctly presented to the executive and legislative branches of government a national geothermal initiative could be included under the umbrella of projects which will constitute the energy supply initiatives of the Carter Administration. An opportunity exists to bring about a better governmental and administrative atmosphere for the development of geothermal energy. If the opportunity is not seized there is no assurance that geothermal energy will make a timely and significant contribution to the energy supply picture and there is some risk that Federal involvement in geothermal energy development will subside before the industry can support itself.

STATE GEOTHERMAL LAWS AND REGULATIONS

by

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STATE GEOTHERMAL LAWS AND REGULATIONS

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Introduction

Laws providing for the regulation of geothermal development have been established in each of the fifteen gulf and western states. The states have characterized the resource, identified available lands and the methods for leasing, and provided for statewide regulation of field development and production activities. California and New Mexico enacted geothermal statutes in 1967, and other states followed in the '70s, often patterning their legislation after earlier state geothermal statutes or the federal Geothermal Steam Act of 1970.(Appendix 1)

In most states, administrative agencies have promulgated leasing and development regulations to implement the enacted legislation. Major concerns of state leasing regulations are 1) characteristics of the resource, 2) access for exploration, 3) the manner of granting a lease, 4) rentals and production royalties, 5) lease terms and adjustments, and 6) efficient geothermal operations.

Statewide development regulations have been established to control the geothermal industry's methods of drilling, resource production and waste disposal. Development activities are monitored to restrict environmental degradation and help ensure that geothermal resources are not wasted.

State laws and regulations bear on every phase of geothermal development, from initial exploration and financing to final utilization and waste disposal. Exploration and private appropriation of the resource are affected by state permitting requirements and statutory definitions of geothermal resources; state lease provisions determine the security of a leasehold and influence its profitability; and statewide development regulations impinge on the economic value of resource discoveries. State securities

regulations, taxation policies and utility regulations also have important consequences for geothermal developers.¹

In many cases, established laws and regulations are unresponsive to the needs of geothermal development. Current policies largely derive from state water laws or petroleum statutes, and past experience with these resources often have been misleading when applied to geothermal development. Established policies as a result frequently present obstacles rather than encouragement to the geothermal industry.

Neglected policy areas also may impede development. Currently, state geothermal regulations are tailored principally to the production of electricity. Policymakers have given comparatively little attention to the legal and institutional foundations required for direct use of geothermal resources in agricultural production, industrial processing and heating and cooling of buildings. Geothermal heating districts have been authorized in Oregon, providing contracting and bonding authority and the power of eminent domain.² Similar policies, at a minimum, need to be adopted in other states for geothermal heating to realize its full potential. On the legislative agenda, remedies for such policy vacuums should rank equally with removal of poorly drafted or misconceived regulations.

OWNERSHIP AND DEFINITION

Geothermal resources form an ambiguous entity, resembling water, minerals and gas physically and in aspects of their development and use. As a result, considerable disagreement--including litigation--has arisen over the essential nature of the resource and assignment of ownership rights.³

Most legislatures and the U.S. Congress have avoided any statutory assignment of ownership rights. Exceptions are Hawaii (mineral); Oregon (surface); Idaho, Montana

and Washington (sui generis); and Wyoming (groundwater).⁴ According to the designations of Idaho, Montana, Washington and Wyoming, geothermal energy is a public resource. Colorado has declared that geothermal resources are not mineral, but stopped short of identifying the proper resource category. The Colorado statute reads: "Reference to minerals in any conveyance shall be presumed not to include geothermal resources unless specific reference is made to such resources in the conveyance."⁵

Two Definitions

While a majority of states have skirted the ownership question, all states have attempted to list the identifying characteristics of geothermal resources. Two accounts of the resource--which appear as "definitions" in the California Geothermal Resources Act of 1967 and the federal Geothermal Steam Act of 1970--have served as models for most other states.⁶

Definition 1: California Geothermal Resources Act

"Geothermal resources" shall mean the natural heat of the earth, the energy, in whatever form, below the surfact of the earth present in, resulting from, or created by, or which may be extracted from, such natural heat, and all minerals in solution or other products obtained from naturally heated fluids, brines, associated gases, and steam, in whatever form, found below the surface of the earth, but excluding oil, hydrocarbon gas or other hydrocarbon substances.

Definition 2: Federal Geothermal Steam Act

"Geothermal steam and associated geothermal resources" means (i) all products of geothermal processes, embracing indigenous steam, hot water and hot brines; (ii) steam and other gases, hot water and hot brines resulting from water, gas, or other fluids artificially introduced into geothermal formations; (iii) heat or other associated energy found in geothermal formations; and (iv) any byproduct derived from them.

"Byproduct" means any minerals (exclusive of oil, hydrocarbon gas, and helium) which are found in solution or in association with geothermal steam and which have a value of less than 75 per centum of the value of the geothermal steam or are not, because of quantity, quality, or technical difficulties in extraction and production, of sufficient value to warrant extraction and production by themselves.

The resource definitions of Hawaii, Idaho, Montana and New Mexico (and recently Maryland) follow the California language. Utah and Wyoming use the California definition in their administrative regulations, although no physical description of the resource is given in their statutes. The federal model was followed by Arizona, Colorado, Louisiana and Texas, while Alaska and Oregon incorporated both the California and federal definitions. (Appendix 1)

Departures from the Federal Model

When adopting the federal language, Arizona, Louisiana, Oregon and Texas made substantial modifications. Louisiana and Texas sought to bring the elements of geopressed reservoirs (heat, fluid pressure, dissolved natural gas) clearly within their definitions. Louisiana stipulated that geothermal resources include:

- (a) All products of geothermal processes, embracing indigenous steam, hot water, hot brines and geopressed waters excepting, however, water produced incidental to oil or gas exploration or production;
- (b) Steam and other gases, hot water and hot brines resulting from water, gas or other fluids artificially introduced into geothermal and/or geopressed water formations;
- (c) Heat, natural gas dissolved in formation water or which was dissolved in formation water and is produced at the geothermal and/or geopressed well bore, or other associated energy found in geothermal and/or geopressed water formations;
- (d) Any byproduct derived therefrom.

Oil and gas continue to be excluded as byproducts.⁷

With the same purpose, Texas provided that geothermal energy and associated resources include "all products of geothermal processes, embracing indigenous steam, hot water and hot brines, and geopressed waters." The language of the federal definition is maintained thereafter until "byproduct" is defined. The Texas statute reads: "The term 'byproduct' means any element found in a geothermal formation which when brought to the surface is not used in geothermal heat or pressure inducing energy generation."⁸

Arizona eliminated the "byproduct" section when adopting the federal model and simply included as part of the geothermal resource any "mineral or minerals, exclusive of fossil fuels and helium gas, which may be present in solution or in association with geothermal steam, water or brines." Artificially-induced energy also was made part of the resource under the third clause of the Arizona geothermal definition: "Geothermal resources means--(3) Heat or other associated energy found in geothermal formations, including any artificial stimulation or induction thereof."⁹

The Oregon statute adds minimum temperature and well-depth thresholds to the distinguishing features of geothermal resources. Fluids from wells less than 2,000 feet deep with bottom-hole temperatures less than 250°F. must be developed under state water law.¹⁰ Low-temperature fluids from shallow wells are not considered a geothermal resource.

Departures from the California Model

Of the eight states--California, Hawaii, Idaho, Maryland, Montana, New Mexico, Utah and Wyoming--which follow the California definition, Maryland has made the most substantial departures in its recently enacted geothermal statute.¹¹ The state defines geothermal resources as:

the natural heat of the earth higher than 120 degrees Fahrenheit or 49 degrees Centigrade, or the energy, in whatever form, below the surface of the earth present in, resulting from or created by, or which may be extracted from, this natural heat, the natural or artificial medium containing that heat, and all minerals in solution or other products obtained from naturally heated fluids, brines, associated gases, and steam, in whatever form, found below the surface of the earth, but excluding oil, hydrocarbon gas, and other hydrocarbon substances. (Emphasis added.)

Maryland limits geothermal resources to temperatures exceeding 120°F., and it considers produced fluids--other than hydrocarbons--as part of the geothermal resource.

The fluids may be naturally present or artificially introduced, as would be the case when developing hot dry rock reservoirs. In the other seven states, fluids produced from geothermal reservoirs are not part of the resource, and rights to them must be obtained through separate water appropriation procedures.

Two Other Definitions

Of all the states which have enacted geothermal legislation, only Nevada and Washington have not made use of the California or federal resource characterizations. Nevada defines geothermal resources as "heat or other associated geothermal energy found beneath the surface of the earth."¹²

Washington characterizes geothermal resources in terms of their use. Geothermal resources are restricted to:

only that natural heat energy of the earth from which it is technologically practical to produce electricity commercially and the medium by which such heat energy is extracted from the earth, including liquids or gases, as well as any minerals contained in any natural or injected fluids, brines and associated gases, but excluding oil, hydrocarbon gas and other hydrocarbon substances.

Any other use of naturally heated fluids--whether "byproduct water resources" from geothermal electric generation, or the production of wells not suitable for electric generation--must be authorized through the state's water appropriation procedures.¹³ Such fluids are considered water resources by virtue of their use.

Problems for Developers

No consensus has been reached on what geothermal resources are and who owns them, as is evident from the relevant state statutes. This uncertainty hampers geothermal development. Under these circumstances, all potential ownership rights need to be secured by developers to protect their investments.¹⁴ This can require a great deal of time and talent (if even possible), which diminishes the resource's

economic value. Without that protection, however, the threat of litigation may preclude any major development expenditures.

The hybrid character of geothermal resources also leads to overlapping regulatory jurisdictions. In most states, for example, developers are subject both to water allocation procedures and separate geothermal development regulations. Multiple permitting requirements of this kind cause delays, create uncertainty and generally impede development.

For geothermal development to proceed expeditiously, ownership rights must be settled in each state. The relationship of geothermal to other resources, particularly water, also needs to be clear. Appropriation of the resource hinges on these two issues, which makes them central concerns in the formulation of state geothermal policies.

STATE LEASING

The fifteen gulf and western states have all authorized geothermal leasing for state lands. Two-tiered, non-competitive/competitive systems have been established by most states and by the federal government. Exceptions are Arizona, Hawaii, Montana and Washington, which require competitive bidding for all geothermal leases.

A two-tiered leasing procedure allows non-competitive access for areas with low or unknown geothermal potential, but requires competitive bidding for particularly valuable or known geothermal resource areas (KGRAs). Factors which may be bid for competitive leases include cash bonuses, annual rentals, production royalties, profit shares and work commitments. In most cases, both competitive and non-competitive leases impose annual rentals and production royalties.¹⁵

Two types of non-competitive access are granted for geothermal resources. Alaska, California and Wyoming issue exclusive short-term exploration permits for non-KGRA lands. The permittee is allowed to convert areas under permit to development leases upon discovery of geothermal resources or reclassification of the area for other reasons as KGRA. (Fig.1)

The other states with two-tiered leasing simply issue non-competitive leases for non-KGRA lands unless they are being offered for the first time. Competitive bidding or a public drawing generally is required for newly offered lands. (Fig. 2)

The second tier of the leasing system is engaged when lands not leased or under permit are determined to have significant geothermal value (KGRA). Developers may obtain leases for those lands only through competitive bidding, the terms of which vary among the states.

With two-tiered access, the states have sought to encourage exploration of unknown lands while retaining the income benefits from ownership is known geothermal areas. This approach permits the entry of small firms into the geothermal industry and provides an incentive generally for exploration. On the other hand, non-competitive leases, and exploration permits with preferential conversion rights, can give developers control of geothermal resources upon state lands for very little cost. Then when a discovery is made, the value of ownership accrues totally to the developers and nearby property holders. Accumulation of geothermal properties is encouraged in this way.

To reduce revenue losses and to discourage accumulation of land for speculation, the states have relied on fixed royalties, acreage limitations, limited lease terms and lease adjustments. (Fig. 3)

Acreage Limitations

Restriction on the size of individual leases and on total lease holdings permitted for any one party are required for orderly resource development. Minimum area limitations prevent excessive fragmentation, and maximums inhibit monopolization of the resource.¹⁶ To be effective, however, acreage bounds must recognize the exigencies of resource development.

The states generally have set quite small lease sizes for geothermal resources. Four states hold individual leases to a maximum of 640 acres; another four use this as a minimum and set 2,560 acres as the maximum lease size. The larger of these two figures is itself small. A field capable of supplying 200 megawatts of electric power generally will span a number of 2,560-acre leases. A developer would need 20-30 such leases to cover a 1,000-megawatt reservoir.

Lease sizes that are too small diminish the value of geothermal development by reducing the expected financial return on investments for exploration and development. Discoveries are more likely to be lost in part to competing developers who hold nearby leases.

The time and financing necessary to procure adequate leaseholdings also increases with undersized leases. Before discovering a 200 megawatt reservoir 150,000 to 500,000 acres on the average will first have been examined and approximately 80,000 to 240,000 acres leased.¹⁷ Even if each lease is 2,560 acres, 80-90 leases will be required. Such large numbers of leases are difficult to obtain in a timely manner and in the desired locations.

Alaska, California, Hawaii and Idaho also impose limits on total state leaseholdings. Idaho disallows interest in more than 50 township-and-ranges. Thirty-six sections of 640 acres--or 23,040 acres--constitute a township-and-range. The Idaho limit therefore prevents checkerboard speculation, rather than

large acreage holdings. Hawaii prohibits the accumulation of more than 80,000 acres of non-producing leases; no acreage limit is imposed on productive holdings.

The total acreage limits set by Idaho and Hawaii should not impede geothermal development. Those of Alaska and California are more restrictive, however. Both states forbid state holdings in excess of 25,600 acres. The federal government similarly limits federal lessees to 20,480 acres/state.¹⁸ These limitations confine developers to at most two or three sites of 7,500 to 10,000 acres, an area just large enough for a 200-300 megawatt reservoir. And since productive acreage is not exempt, the limits set by Alaska, California and the federal government may force successful developers out of states in which they have producing leases.

Rentals and Royalties

State leases generally provide for production royalties (10-15%) and minimal rentals (\$1-\$2/acre). Annual rentals are a small charge for the opportunity to undertake intensive use of public lands. They help primarily to defray regulatory costs. Royalties on production, along with cash bonuses for competitive leases, act to hold a portion of the public resource value in the public treasury.

Royalties, in contrast to cash bonuses, involve no risk for the geothermal developer and are not a barrier to small development firms. Royalties simply become part of production costs. With increased production costs, however, marginal resources become unproducable. This is a prime weakness of royalty charges. Their deleterious effects may be reduced by employing only low rates, except that low royalties fail to retain public ownership value for lucrative geothermal reservoirs.¹⁹

Profit sharing is an alternative to royalties which avoids suppressing the development of marginal resources. Profit shares to the lessor are calculated as

a percentage of net profit, rather than gross income. California has employed profit-shares bidding to lease state geothermal development rights at The Geysers. Winning bids received were 28% and 47.77% of net profits.²⁰

Lease Terms and Adjustments

One method of limiting land speculation and losses due to unreasonable lease arrangements is to restrict the effective life of a lease and to allow for adjustment of its various provisions. Primary lease terms of 5, 10 and 20 years have been selected by different states, allowing for renewal if producible geothermal resources are discovered during that period. Renegotiation of the lease typically is allowed after 20 years.

An important characteristic of geothermal resource development is the need for on-site use. This involves large capital investments in powerplant facilities and transmission lines or industrial facilities which require 20 to 40 years for amortization. In addition, field development generally will proceed in increments of 55-110 megawatts, so that new facilities are added late in the lease term.

The prospect of lease termination or adverse adjustments within 5, 10 or even 20 years consequently figures quite differently in geothermal development than in the development of other energy resources. Uncertain tenure due to short lease terms and frequent renegotiation compounds the risks already inherent to geothermal development. Care should be taken, therefore, that these techniques of resource control are not improperly applied.

DEVELOPMENT REGULATIONS

In each of the fifteen states, public agencies have been given the authority to regulate drilling and production of geothermal resources. These agencies are

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DEVELOPMENT REGULATIONS

In each of the fifteen states, public agencies have been given the authority to regulate drilling and production of geothermal resources. These agencies are

production restrictions and provisions for the unit operation of reservoirs. Geothermal regulatory agencies also have been granted at least one of these powers. Statewide well-spacing requirements predominate, with fewer states adopting production restrictions and mandatory unitization. (Fig. 4) To the extent, though, that water rights are required for geothermal development, state water allocation procedures also would appear to control geothermal production.

Well spacing. A spacing plan for wells sets the minimum distance allowed between a well and other wells, property lines and established roads or buildings. Well spacing limits the total number of wells that may be drilled into a reservoir and therefore the maximum rate of withdrawal. Buffer zones are created along property lines, as well, and these help protect competing interests--or correlative rights--in the reservoir.²²

Production restrictions. Direct restrictions on the rate of fluid withdrawal from a reservoir may be used to protect correlative rights and ensure the most efficient recovery of the resource. For this purpose, the regulatory agency first determines the maximum efficient withdrawal rate for a reservoir and then prorates production by area to the development interests. Production may be allocated to wells in the reservoir, rather than to the areal holdings themselves, and in this case a coordinate well-spacing program is needed to block excessive drilling.

Production allowances also may be set according to appropriative rights. This is the principle of "first in time, first in right." Wyoming has defined geothermal resources as groundwater, and Nevada has submitted geothermal development directly to its water appropriation procedures.²³ Both states therefore

rely on prior rights in the allocation of geothermal production. Production restrictions in the other states follow the principle of correlative rights, although as already noted, water appropriation procedures indirectly control geothermal production wherever water rights are necessary for development.

Unitization. Unitization is an agreement between ownership interests to cooperatively develop a shared reservoir, with benefits allocated according to the principle of correlative rights.²⁴ The regulatory value of unitization is that it removes the competitive drive to overproduce the reservoir. With unitization each interest in the reservoir benefits from improved efficiency. As a result, proper well spacing and production rates are actively pursued, rather than enforced by the state.

Unitization reduces the regulatory burden, since producers voluntarily seek to eliminate waste. Unit operation also gives geothermal developers a larger and more assured resource supply and, therefore, a stronger bargaining stance with industrial or utility consumers.

Voluntary unitization agreements may not always be possible. Unit operation may be blocked by blind stubbornness or parties in a position without unitization to exploit the resource to the detriment of other resource interests. To manage such instances, some states have granted their regulatory agencies the power to mandate unitization. A minimum percentage of development interests may need to agree before the state will mandate unit operation (Arizona: 63%), but this proviso generally is not made.

Environmental Protection

Irresponsible geothermal operations can pose clear dangers to public health and local environments through air and water pollution, noise, subsidence or

solid waste mismanagement.²⁵ Each of the states has regulatory authority and established agencies to eliminate such actions. Geothermal operators must obtain permits to site and drill wells. Methods for well drilling, casing and cementing are prescribed to protect underground aquifers and prevent blowouts. Production and disposal techniques must be approved, and permits are required to plug and abandon a well. Developers also must file surety bonds to insure compliance with regulatory standards at each stage of development. (Appendix 1)

Like other electric generation facilities, geothermal powerplants and transmission lines are sited under state regulation.²⁶ Geothermal production as a whole is subject to state solid waste, air and water pollution control standards. Few states have set specific emission standards for the geothermal industry, however, because development activity has not been sufficiently great.

AREAS FOR NEW INITIATIVE

The importance of state policies for the geothermal industry extends beyond regulations for field development and leasing. State tax policies, direct appropriations, securities regulations, bond authority, construction programs and utility regulatory policies can be applied either to stimulate or impede geothermal development.

The states have not given a great deal of attention to these policy areas, although in some cases important initiatives have been taken. Income tax deductions or property tax exemptions are granted in several states for residential geothermal energy facilities. Some states provide substantial funding for research and development of geothermal and other emerging energy sources.

Arizona now assesses geothermal properties on the basis of gross proceeds. The state also extends geothermal developers a percentage depletion deduction and allows current expensing of exploration and development expenditures.

California, Hawaii and Oregon have sought to enhance geothermal development through areas of utility regulation.

These various policy initiatives are listed in Appendix 2 under the heading of financial incentives. They represent preliminary steps in areas that can help substantially in bringing geothermal development to its full potential.

FIGURES

<u>State</u>	<u>Manner Awarded</u>	<u>Term</u>	<u>Annual Rental</u>
Alaska	By application	3 years, possible 2-year extension	variable: \$1/acre minimum
California	By application	3 years, possible 2-year extension	\$1/acre
Wyoming	a) Public drawing* b) By application	3 years, possible 2-year extension	\$1/acre

*When lands are newly offered for exploration, a period is set of at least thirty days and applications received during that period are awarded permits by public drawing.

Fig. 1. Exclusive state geothermal exploration permits with lease conversion privilege after discovery

State	Non-KGRA Lands		KGRA Lands (Competitive Leasing)	
	Newly Offered	Subsequent Leasing	Bidding Factor	Designation Criteria
Alaska	---	---	(A)	(A)
Arizona	Competitive	Competitive	Cash Bonus	All lands awarded competitively
California	---	---	Cash Bonus or other	Producing Well
Colorado	(A)	(A)	(A)	(A)
Hawaii	Competitive (B)	Competitive (B)	(A)	All lands awarded competitively (B)
Idaho	Public Drawing (30-day filing)	By Application	(A)	Producing Well
Louisiana	(C)	(C)	(C)	(C)
Montana	Competitive	Competitive	Cash Bonus	All lands awarded competitively
Nevada	(C)	(C)	(C)	(C)
New Mexico	Competitive (3- day filing)	By Application	Cash Bonus	Determined by Commissioner of Lands
Oregon	Public Drawing (30-day filing)	By Application	Cash Bonus (D)	Geology and/or producing well
Texas	(C)	(C)	(C)	(C)
Utah	Cash Bonus (E) (15-day filing)	By Application	(E)	(E)
Washington	Competitive	Competitive	Cash Bonus (F)	All lands awarded competitively
Wyoming	---	---	(A)	(A)

- (A) Specified by state land commissioners
- (B) Mineral reserve lands may be leased non-competitively to occupier (or assignee) with two-thirds vote by Board of Land and Natural Resources.
- (C) Regulations not finalized
- (D) If no bids received, Division of State Lands may reclassify for non-competitive leasing
- (E) Lands are offered non-competitively by order of application, except when they are newly offered. Newly offered lands are leased by cash bonus bidding.
- (F) Unlike Montana, if a tract receives no bid, it is withdrawn.

Fig. 2. Leasing methods for state lands

State	Primary Term	Re	Acreage Limits
Alaska	10 years	one 5-year term if dri commercial productio	minimum lease: 640 acres maximum lease: 2,560 acres (5,750 for submerged lands) maximum state holdings: 25,600 acres
Arizona*	10 years	2 years if drilling; for production rental	maximum lease: 2,560 acres (4 sections) confined to 6 miles square
California	20 years	so long as geotherma and 10% capable of being pro quantities, up to 99)	minimum lease: 640 acres maximum lease: 2,560 acres maximum state holdings: 25,600 acres (includes acreage under exploration permit)
Colorado	10 years	for duration of comr production, at discre	
Hawaii	10 years	so long as geothe byproducts are pr quantities, up to 5 years with dili out production, or without market	minimum lease: 100 acres maximum lease: 5,000 acres, or 2,560 if length of tract is more than six times the width maximum state holding: 80,000 un- developed acres
Idaho*	10 years	for duration of comr operations to at leas beyond primary term	minimum lease: 40 acres maximum lease: 640 acres maximum state holdings: interest in 50 township-and-ranges
Louisiana	at most 10 years	for duration of comr or development ope	maximum lease: 5000 acres
Montana	10 years	for duration of comr and 5%	maximum lease: 640 acres
Nevada			
New Mexico	5 years	so long as geotherma and 10% capable of being pro quantities and 10% ue)	minimum lease: 640 acres maximum lease: 2,560 acres maximum state holdings: 25,600 acres
Oregon	10 years	10 years, if royalties lized water equalled or exce lease; icted from 5 years, if no produ made or is deem maximum of 50 year	minimum lease: 40 acres
Texas	(no lease terms established)		
Utah	10 years	for duration of comr teeds) terms, in absence of \$5/acre advance roy	minimum lease: 40 acres maximum lease: 640 to 2,560 acres, at discretion of director of state lands
Washington	5 years	so long as drilling net proceeds) commercial discover	minimum lease: 40 acres maximum lease: 640 acres
Wyoming	10 years	so long as geotherm capable of being pr quantities	minimum lease: 640 acres maximum lease: 2,560 acres

* Regulations under review

Fig. 3. State geothermal lease provisions

<u>State</u>	<u>Well-Spacing</u>		<u>Enforced Unitization</u>	<u>Production Restrictions</u>
	<u>Area</u>	<u>Pooling</u>		
Alaska	OG	OG	OG	OG
Arizona	GR	GR	GR, OG	GR
California	GR, OG	OG	OG	GR (only for state leases)
Colorado	GR, OG	GR, OG	GR, OG	GR, OG
Hawaii	GR	--	GR	--
Idaho	GR	GR	GR	--
Louisiana	OG	OG	OG	OG
Montana	OG	OG	--	OG
Nevada	GR	GR	GR, OG	GR(water)
New Mexico	GR, OG	GR, OG	--	GR, OG
Oregon	GR	GR	GR, OG	GR
Texas	GR, OG	OG	--	OG
Utah	GR, OG	GR, OG	GR	GR, OG
Washington	GR	GR	GR, OG	--
Wyoming	GR, OG	OG	--	GR (water), OG

GR = Geothermal Resources

OG = Oil and Gas

Fig. 4. Statewide regulatory powers

Footnotes

1. Sacarto, Douglas M., State Policies for Geothermal Development (Denver: National Conference of State Legislatures, 1976).
2. Oregon Revised Statutes, Section 523.010 et seq.
3. United States v. Union Oil Co., 369 F. Supp. 1289 (N.D. Cal. 1973) rev'd 549 F. 2d 1271 (9th Cir. 1977) cert. den ____ U.S. ____.
- Geothermal Kinetics, Inc. v. Union Oil Co., No. 75314 (Supreme Ct., Sonoma Cty, Cal., 1976)
- Pariani v. California, No. 657-291 (Superior Ct., San Francisco Cty., Cal., 1977)
4. Hawaii Revised Statutes, Sec. 182-1;
Idaho Code, Sec 42-4002;
Montana Revised Code, Sec. 81-2602;
Washington Revised Code, Title 79-76-4;
Wyoming Statutes, Sec. 41-121.
5. Colorado Revised Statutes, Sec. 100-10-103 (6c).
6. California Public Resources Code, Sec. 6903.
- Federal Geothermal Steam Act, P.L. 91-581, Sec. 2.
7. Louisiana Revised Statutes, Sec. 30:801.
8. Texas Natural Resources Code, Sec. 141.003.
9. Arizona Revised Statutes, Sec. 27-651 (5, 10).
10. Oregon Revised Statutes, Sec. 522.025.
11. Annotated Code of Maryland, Sec. 8-8A-09 (Maryland Geothermal Resources Act, S.B. 1154 (1978)).
12. Nevada Revised Statutes, Sec. 534A.010.
13. Washington Revised Code, Title 79-76-3.
14. Gerald J. Kitchen, "Geothermal Leasing Practices", 13 Land and Water Law Review 25, 39-45 (1977).
15. FTC Bureaus of Trade and Economics, Report to the Federal Trade Commission on Federal Land Policy (1975), pp. 221-303.
16. Christopher D. Stone and Jack McNamara, Geothermal Energy and the Law, Vol I. (Los Angeles: University of Southern California Law Center, 1975), pp. 183-187.

Footnotes

17. Sacarto, State Policies for Geothermal Development, pp. 21-23.
18. Federal Geothermal Steam Act, P.L. 91-581, Sec. 7.
19. FTC, Federal Land Policy, pp. 263-278.
20. California Division of State Lands, "Geothermal Resources Program: A Dynamic Approach to Alternative Energy Development" (1977).
21. Stephen L. McDonald, Petroleum Conservation in the United States (Baltimore: Johns Hopkins Press, 1971).
22. Ibid., pp. 45, 150.
23. Nevada Revised Statutes, Sec. 534A.040.
Wyoming Statutes, Sec. 41-121.
24. McDonald, Petroleum Conservation in the United States, p. 199.
Federal geothermal development regulations (30 CFR 271.12) give a standard agreement for unit operations.
25. U.S. Environmental Protection Agency, Western Energy Resources and the Environment: Geothermal Energy (1977).
U.S. Fish and Wildlife Service, Geothermal Handbook (1976).
26. California Energy Resources Conservation and Development Commission, "Geothermal NOI/AFC Regulations (77-SIT-1(1a))" DRAFT (1978).

APPENDIX I

State Laws and Regulations Regarding Geothermal Resources

ALASKA

Statutes: Geothermal Resources Act (1971) AK Stat. 38.05.181
Leasing: Div. of Lands - Regulations & Statutes Pertaining to Coal and Other Leasable Minerals (1974) 11 A.A.C. 84.700...
Drilling: Div. of Oil & Gas - 11 A.A.C. 94.730... (1974)

ARIZONA

Statutes: Geothermal Resources (1972); amend. HB 2257 (1977) A.R.S. 27-651...
Leasing: Land Dept. - Geothermal Resources (1972) T.12C.5.A.21 (under revision)
Drilling: Oil & Gas Conservation Comm. - General Rules & Regulations Governing the Conservation of Geothermal Resources (1972) T.27C.4.A.4

CALIFORNIA

Statutes: leasing - Geothermal Resources Act (1967) Pub. Res. Code 6902...
production - Laws for the Conservation of Geothermal Resources (1967, as amend.) Pub. Res. Code 3700...
siting - Energy Resources Development; Conservation Act (1974) Pub. Res. Code 25000...
Leasing: State Lands Comm. - Leases & Prospecting Permits for Geothermal Resources (1970) C.A.C. 2250...
Drilling: Div. of Oil & Gas - Statewide Geothermal Regulations (1976) C.A.C. 1900...
Siting: Energy Comm. - Provisions Applicable to Geothermal Notices & Applications (1978) DRAFT

COLORADO

Statutes: Geothermal Resources Act (1974) C.R.S. 34-70-101...
Leasing: Board of Land Commissioner - Special Rules & Regulations Relating to Geothermal Resources Leases (1972) SLB #248-1
Drilling: Oil & Gas Conservation Comm. - Rules & Regulations for the Development & Production of Geothermal Resources (1976) G101...

HAWAII

Statutes: Government Mineral Rights (1974); amend. HB 3033 (1978) H.R.S. 182-1...
Leasing: Dept. of Land & Natural Resources - Regulations on Leasing & Drilling Geothermal Resources (1978) Reg. No. 8
Drilling: Reg. No. 8

IDAHO

Statutes: leasing - Geothermal Resources Leasing Act (1975) ID Code 47-1601...
production - Geothermal Resources Act (1974, as amend.) ID Code 42-4001...
Leasing: Board of Land Commissioner - Rules & Regulations Governing the Issuance of Geothermal Resources leases (1974) (under revision)
Drilling: Water Resource Board - Drilling for Geothermal Resources (1978)

LOUISIANA

Statutes: Geothermal Energy Resources (1976) L.R.S. 30:800...; Geothermal & Geopressure Energy Research & Development Act (1975) L.R.S. 30:681
Leasing: Mineral Board - none (oil & gas model likely)
Drilling: Office of Conservation - pending

Appendix I

MONTANA

Statutes: leasing - Lease of Geothermal Resources (1974) R.C.M. 81-2601...
siting - Major Facilities Siting Act (1975, as amend) R.C.M. 70-801...
filing bottom-hole temperatures - Act to Facilitate the Discovery of
Geothermal Energy Sources (1975) R.C.M. 60-127, 144, 148
Leasing: Dept. of State Lands - Geothermal Rules & Regulations (1975) M.A.C. 26-2.6(2)
Drilling: Dept. of Natural Resources & Conservation - Geothermal Investigation
Reports (1975) M.A.C 36-2.8(14)

NEVADA

Statutes: leasing - An Act Relating to State Lands (1975) N.R.S. 322.030...
production - An Act Relating to Geothermal Resources (1975) N.R.S. 534A.010...
Leasing: Div. of Lands - pending
Drilling: Div. of Water Resources - Regulations Pertaining to Exploration Drilling
(1978)

NEW MEXICO

Statutes: Geothermal Resources Act (1967) N.M.S.A. 7-15-1...
Geothermal Resources Conservation Act (1975) (Chap. 272)
Leasing: State Land Office - Rules & Regulations Relating to Geothermal Resources
Leases (1971)
Drilling: Oil Conservation Div. - Rules & Regulations for Geothermal Resources (1974)

OREGON

Statutes: Geothermal Resources (1975) O.R.S. 522.005...
Geothermal Heating Districts (1975) O.R.S. 523.010...
Leasing: Div. of State Lands - Geothermal Lease Regulations (1975) 75-010...
Drilling: Dept. of Geology & Mineral Industries - Rules, Regulations & Laws
Relating to Exploration & Development of Geothermal Resources (1977) 632-20-005...

TEXAS

Statutes: Geothermal Resources Act (1975) V.A.C.S. Art. 5421s
Leasing: Railroad Comm./Div. of Oil & Gas - none (oil & gas model likely)
Drilling: Railroad Comm./Div. of Oil & Gas - Rules Having General Application
to Oil, Gas, & Geothermal Resource Operations (1976) 051.02.02.000
School Land Board - Rules & Regulations Governing Drilling & Producing
on Permanent Free School Lands (1974) (general)

UTAH

Statutes: Water & Irrigation Laws (1973) U.C.A. 73-1-120
Leasing: Div. of Lands - Rules & Regulations Governing Issuance of Mineral
Leases (1973); Geothermal Steam Lease Agreement (1973)
Drilling: Div. of Water Rights - Rules & Regulations for Wells Used for the
Discovery & Production of Geothermal Energy (1978)

WASHINGTON

Statutes: Geothermal Resources Act (1974) T.79 R.C.W.
Leasing: Dept. of Natural Resources - Geothermal Leasing Policy (1978) DRAFT
Drilling: Dept. of Natural Resources - none

WYOMING

Statutes: Underground Water (1973) WY Stat. 41-121
Leasing: Board of Land Commissioner - Rules & Regulations Governing the Issuance
of Geothermal Resource Permits & Leases (1975)
Drilling: Oil & Gas Conservation Comm. - Rules & Regulations (1975) (general)

APPENDIX 2

State Financial Incentives Applicable to Geothermal Resources

Arizona	H.B. 2257 (1977)	Provides for property tax valuation on gross yield, in lieu of ad valorem assessment, for geothermal production facilities. Extends percentage depletion deduction to geothermal production. Allows deduction (or capitalization) for current exploration and development expenses.
California	S.B. 77 (1976)	Empowers PUC to order public utilities to transmit electricity generated by private producers from non-conventional sources.
	A.B. 4032 (1976)	Higher rate of return allowed for utility investments in renewable energy facilities.
Colorado	H.B. 1519 (1977)	Commercial or residential investments for solar, wind and geothermal energy systems deductible for state income tax.
Hawaii	S.B. 2467 (1976)	Property tax exemption for building improvements to use geothermal energy.
	S.B. 995 (1977)	Exempts nonfossil power generation and transmission facilities from PUC regulation when energy used by producer or sold directly to public utility. Authorizes PUC to require public utilities to purchase surplus power from such facilities.
	S.B. 1581/H.B. 3039 (1978)	Major funding provided for geothermal resource assessment; research and development of non-electric uses; and the rift zone laboratory.
	H.B. 2165 (1978)	Makes rates paid by public utilities to geothermal developers for geothermal steam, or electricity from geothermal steam, subject to PUC regulation.

Hawaii	H.B. 3033 (1978)	Determines the applicability of excise taxes on geothermal gross proceeds. Provides for royalties in lieu of a severance tax. Clarifies utility access.
Idaho	H.B. 468 (1976)	Income tax deduction for investments in residential geothermal energy facilities.
Montana	S.B. 86 (1975)	Applies state coal tax fund to renewable energy projects.
	S.B. 167 (1977)	Tax credit for nonfossil energy systems (may apply to geothermal).
	H.B. 292 (1977)	Tax deduction for residential nonfossil energy generating systems (may apply to geothermal).
Nevada	S.B. 326 (1977)	State energy conservation standards for buildings must allow design and construction latitude to the extent that solar, geothermal, or other nondepletable energy sources are used.
	A.B. 277 (1977)	Property tax credit up to \$2,000 for residential geothermal facilities for heating and cooling.
New Mexico	S.B. 185 (1975)	Created permanent fund for energy research and development and appropriated funds.
	H.B. 395 (1975)	Life-cycle cost analysis of nonfossil energy systems required for new state buildings or major renovations.
	H.B. 2 (1978)	\$200,000 appropriation for establishing geothermal space heating demonstration projects. 100% matching funds required.
	H.B. 199 (1978)	\$2 million appropriation for energy research and development.

Oregon	S.B. 339 (1977)	Income tax credit up to \$1,000 for residential geothermal space heating.
	S.B. 477 (1977)	Loan program for veterans--up to \$3,000 for residential geothermal energy facilities.
	S.B. 572 (1977)	Energy Conservation and Production Fund financed by state bond issues established to assist utility companies and individuals in development of non-nuclear energy resources. Emphasis on geothermal and other resources not currently in widespread use. Oregon Department of Energy authorized to develop alternate energy projects, fix rates and sell energy.
	SJR 32 (1977)	Authorizes issuance of bonds for Energy Conservation and Production Fund (must be approved by voters).
	H.B. 3185 (1975)	Authorizes geothermal heating districts with contracting and bonding authority and power of eminent domain.
	H.B. 2159 (1977)	Authorizes waiver of state bonding requirements for well drilling if operation has bond with federal government.
Texas	HSR 24 (1977)	Requests all state agencies and universities to encourage feasibility studies and demonstration projects for alternate energy use in state buildings.
Utah	SJR 37 (1977)	Interim committee to develop legislation pursuant to Utah energy policy (SCR 1, 1977) for support of solar, geothermal, wind and hydroelectric energy development.

Geothermal Financing

REMARKS OF ^{with}JOSEPH W. AIDLIN, VICE PRESIDENT AND GENERAL COUNSEL OF MAGMA POWER COMPANY
TO THE
GEOTHERMAL RESOURCES COUNCIL MEETING, MAY 18, 1978, AT WASHINGTON, D. C.

On May 8th, ten days ago, "Treasury Secretary W. Michael Blumenthal, in what his aides termed a major policy statement, said at a meeting of the Financial Analysts Federation in Bal Harbour, Florida, that lagging investment was undermining the foundation of future prosperity." This is a quote from the New York Times of May 9th, 1978. In his remarks, the Secretary indicated the Administration's awareness of the need for incentives to encourage additional investment in industry.

Mr. Blumenthal's remarks are very pertinent to the subject assigned to me today because the development and utilization of geothermal energy are directly related to the appropriate financial incentives or financial sources that are available.

The remarks of the Secretary also point up another need--a requirement that is essential to the success of any major public or private enterprise--that is, the need for a clear single direction, a unified national policy, a policy that carries the weight of the Administration and of all of its departments and components.

There is no doubt that the President desires the accelerated utilization of geothermal resources. There is no doubt that the Secretary of the Department of Energy wants to encourage and assist in every way the development and use of geothermal resources. There is no doubt that the Bureau of Land Management, the U. S. Geological Survey, and other branches of the Department of Interior recognize the need for accelerated geothermal development. There is no doubt that Congress, by its various enactments and hearings, wants development and use of geothermal resources to go forward at a much more rapid rate.

But there is something lacking. What is lacking is an ability, a willingness to go beyond the business as usual approach, an ability to cut through the bureaucratic morass that inhibits creative, innovative and more rapid action toward achieving a goal. But most of all, there is the absence of sufficient direction and control within the departments of government so as to avoid or eliminate the thwarting of a national or departmental policy.

Why is it that for years, and to this very day, a segment in the Treasury Department--I believe it is the Office of Tax Policy--has deliberately thwarted the development of geothermal resources by aggressively opposing the tax incentives which are essential to achieve the national goal of accelerated geothermal development and utilization?

How is it that the Treasury Department,

through the Internal Revenue Service, refuses to abide by a final decision of the Federal Ninth Circuit Court of Appeals, a decision which represents the law of a large part of the Western United States, holding that the tax incentives of intangible drilling deductions and depletion apply to certain geothermal resources?

I believe that Mr. Blumenthal should be distressed that his Office of Tax Policy and his own Internal Revenue Service have policies of their own when it comes to carrying out the broad national policies enunciated by the President or the Department Heads, including the Treasury Secretary. The Congress should be distressed to learn that, although its concerned committees have assumed that the Ninth Circuit Court of Appeals' decision has been obeyed, that is not what is happening, and that a branch of the government is placing itself over the President, the Congress and the Court.

The frustrating intransigence in relation to geothermal resources of the Forest Service, a branch of the Department of Agriculture, is also well known to geothermal developers.

I could list numerous areas of activity where legislative and administrative policy and direction are thwarted by pockets within the system. Anyone concerned with geothermal resources could detail case after case. However, I prefer to deal with our frustrations only to indicate our needs, and I intend here to discuss with you what I know to be the requirements for obtaining and utilizing the financial resources necessary to encourage and sustain the rapidly accelerating development and utilization of geothermal resources.

My comments and recommendations are based on my years of involvement with every aspect of geothermal resources, and on the basic assumption that all tax and other policies of government must advance the public good.

I. What are the tax incentives we need? They are spelled out in the Senate version of the Energy Tax Bill, which is part of the national Energy Legislative Program now awaiting Congressional conference action. The Bill provides for (a) intangible drilling cost deductions, (b) percentage depletion of 22 percent, and (c) an additional ten percent investment tax credit on expenditures for facilities to utilize geothermal resources.

The need for intangible drilling deductions and depletion has been explained many times. The risks of the industry, the inordinate lapse of time between exploration and receipt of income,

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and the need to compete with other more readily profitable energy sources are all well known.

The need for additional tax credit for geothermal facilities has become apparent in recent years. It is now very clear that without an inducement such as the additional tax credit, we will not be able to obtain the necessary capital for construction of plants utilizing geothermal resources, whether for electric generation or non-electric uses. Without this tax incentive, there are other more attractive investment opportunities.

If there is an overriding national policy to accelerate the development and utilization of geothermal energy, the Department of Energy and the Treasury Department should press for enactment of the Senate geothermal tax provisions. If, because of other matters, the total Energy Tax Bill is not acted on by the Congress, then the portions dealing with geothermal resources should be separately enacted. There is no reason for further debate or delay because, without these tax incentives, it will be "business as usual." There will be no incentive to do otherwise, and the public interest will suffer. In the light of Treasury Secretary Blumenthal's recent remarks, perhaps we can hope that his Tax Policy Office will get the message and support all the Senate geothermal tax incentive proposals.

I am aware that there are some in Congress, and in the Treasury Department, who, although supportive of geothermal resource development, believe that these tax incentives will grant unnecessary benefits to major oil companies, and that encouraging or permitting these companies to expand their geothermal holdings would add to their monopolistic control of all energy sources. These persons argue that, rather than granting tax incentives for development of geothermal resources to large oil companies, major and large independent companies should be forced to divest themselves of all geothermal holdings and be prohibited from entering the field. These persons argue that the alternatives of government grants, guarantees of loans, and government's major role in research and development of technology make tax incentives unnecessary.

These views and proposals require consideration and response, so that there shall be no misunderstanding as to the critical need for the tax incentives which I have mentioned. Government guarantees of loans, grants, and support of research are all important, within the limitations and constraints that I will later discuss, in order to make available financial resources for accelerated geothermal operations. But they are not and cannot be a substitute for tax incentives which are the primary need.

As to precluding substantial oil companies from engaging in the development of geothermal resources, I can only say that such a policy would be entirely counter-productive. I am not here as an advocate or apologist for the large oil compa-

nies. They have more eloquent spokesmen who are better informed of their business. I am here, though, as an advocate of the value and promise of geothermal resources, and as one who knows of the vastness of geothermal resources and their potential for supplying a substantial portion of our nation's electrical and other heat energy requirements in a relatively short time if unnecessary barriers are removed and appropriate incentives are provided.

To achieve this objective, the large oil companies and other energy and natural resource companies are essential. They are the only ones who now have the resources, the know-how, and the personnel to move quickly and effectively on a large scale, if encouraged to do so.

The use of available capital for geothermal activities must be made as attractive as the use of capital in other energy fields, and the prospects of a legitimate return must exist. It is hardly logical or fair to expect the oil companies to commit large capital sums in the search for geothermal resources without making such effort at least as financially worthwhile as other fields of activity, and it makes no sense at all to expect these companies to make an all-out effort to explore for and develop geothermal resources while the threat of divestiture exists. If there is truly a national objective to accelerate the development and use of geothermal resources, then we must once and for all grant the incentives which are necessary and remove the cloud of divestiture.

Magma Power Company, the company of which I was one of the founders twenty-three years ago, together with B. C. McCabe, the patriarch of the geothermal industry, and Robert Bering (who died some years ago), is engaged only in the geothermal field. Our interests are only in the fields of exploration, development, and utilization of geothermal resources. We are very small in relation to the large oil companies and natural resources companies now active in the industry. But the presence of these companies in the field has not stunted Magma's growth or limited our operations or opportunities.

Quite the contrary, we are more active and innovative now than ever before. We are even, at this very time, building in Imperial Valley, California, the first plant ever to be constructed to demonstrate that middle-range temperature water can be commercially utilized to generate electric power which is competitive in cost with electricity generated from fossil fuels.

The capital for the Imperial Valley project is coming from our company's receipts from The Geysers in Northern California, where we are engaged in a joint venture with Thermal Power Company, an almost wholly owned subsidiary of Natomas Company, and Union Oil Company of California.

Union Oil Company is the operator for the joint venture. It is our good fortune that Union

is the operator at The Geysers because if it were not so, Magma could not devote the personnel, effort, and capital to the Imperial Valley project. Present-day demands on personnel and resources arising out of the complicated permitting process for every activity; procedures relating to environmental matters; financial, corporate and tax reporting; and the volume of paper work required, in addition to day-to-day operating requirements of engineers, geologists, accountants, field personnel, etc., would require an overhead and personnel beyond our ability to provide and still be free also to engage in the innovative programs with which we have been involved.

With Union as operator, Magma pays only for its share of services rendered, as needed. We are freed of the financially crushing burden of maintaining the staff and facilities on hand at all times, whether needed or not. In other words, Union Oil Company, as operator, is absorbing the full cost of having available the facilities and skills which are needed, and we pay only when we need them.

Union can do this because it is large enough and has a sufficient number of projects. As for Magma, and other small companies in similar circumstances, we are in a sense receiving financial support from our more affluent partner by the avoidance of costs which we would otherwise have to bear. We have found that such joint ventures make good economic sense.

11. What are the other financial sources available to the geothermal industry?

(A) The Loan Guarantee Program is an excellent vehicle to encourage availability of capital. While there are much more geothermal resources to be discovered and developed, I believe that enough resources are already available for use so that the emphasis should be on loans for construction of facilities to utilize the already-discovered sources. The present loan guarantee limits, both as to borrowers and projects, should be increased in the near future because the present limits do not permit sufficiently large projects or a sufficient number of projects by any single borrower.

It is my personal view that loan guarantees are not appropriate for exploratory drilling. I believe that exploration is a risk that the operating company should take if it expects to be entitled to all the fruits of a discovery. However, development drilling after a resource has been discovered and generally outlined might justify the availability of the resource for use.

(B) Direct grants can be made to provide capital for ventures or projects which do not appear now to provide sufficient economic incentives for investment of private capital. The purpose of such grants is obviously to obtain information or to further a project which may have a broad application or value.

I do not favor direct grants for geothermal

exploration or development or for construction of facilities for use, except in unusual cases when the capital costs are high, the economics are obviously not conducive to private investment, and the public gain from the venture is very substantial. The testing of the geopressurized resources is a case in point. But even in such cases, I would prefer that the climate of public opinion and law would encourage large oil and natural resource companies to join together and with smaller companies to invest their own capital for such projects.

Given the proper tax incentives, the prospects of adequate returns would motivate such joint ventures and remove the rationale for subsidizing any private project except in rare cases and when there is an overriding public interest.

(C) Government support of research and development of technology as a source of capital is significant and helpful, but it is not critical. Government-supported research is often expensive and long range. I believe that in terms of capital availability, we must strike a better balance between expenditures for research having possible future application (such as the hot dry rock project) and research which has a more immediate impact. The need today of putting geothermal energy "on line" for generation of electrical power and for non-electric uses, and supporting the activities required to do so, is immediate. I suggest that the capital available is better put to such immediate use.

(D) The availability of private investment of capital in geothermal projects is most of all to be desired. Such capital has been, and continues to be, the basis of our nation's industrial development. To obtain such capital, the geothermal industry must compete with other more established and more familiar suitors.

The Congress has within its power the means of creating the incentives necessary to attract private capital. The vast geothermal resources of our nation await development and utilization. If it is truly our national purpose and policy to accelerate development and use of our geothermal resources, then the incentives and program which I have outlined are essential to achieve our goals.

Geothermal Institutional Barriers

auth
STATEMENT OF DOMENIC J. FALCONE, VICE PRESIDENT
GEOTHERMAL RESOURCES INTERNATIONAL, INC., 4676
ADMIRALTY WAY, SUITE 503, MARINA DEL REY, BEFORE
THE SEMINAR ON GEOTHERMAL ENERGY: A NATIONAL
PLAN, MAY 18, 1978.

I have been asked to say a few words about the institutional barriers to geothermal resource development. Before I get into the governmental barriers, I do think that it is fair to point out that there are other barriers acting to prevent accelerated development of geothermal energy. They are:

1. Universities and colleges which have not developed nor implemented curriculums essential to have capable graduates available for the industry upon graduation. Few, if any, are graduating people with knowledge or skills in the specific requirements of a new resource, namely geothermal. And then,

2. Utilities, which are very conservative, prefer not to contract for geothermal resources at lower costs than other energy sources due to the lack of confidence and knowledge in the extent of the geothermal reservoirs.

Once having accepted that the above exists, your imagination can run away with you when you think about the local, state and federal barriers that must exist for this fledgling industry. I think it is well to bear in mind that the geothermal industry requires a long lead time and the barriers discussed merely go to stretch the delays.

I have selected the following theme for discussion:

1. ownership of geothermal resources (yesterday Owen Olpin did an excellent job of pointing out some of the pitfalls in just acquiring a geothermal lease);

2. multiple agency procedures;

3. federal income tax code status (this one is near and dear to us all since it has been fought so long and never brought to fruition for whatever reasons no one can really say except that lack of positive activity on it is a barrier without meaningful substance.

As to Ownership of Geothermal Resources

A primary barrier to prompt geothermal development has been the question of ownership of the resources. This problem typically arises where minerals have been either reserved or conveyed as a separate real property estate.

In the case of Union Oil Company v. United States, several companies had acquired geothermal rights through leases from persons holding title under patents issued under the Stock-Raising Homestead Act of 1916. That Act reserved all "coal and other minerals" to the property of the United States. The Government claimed title to the geothermal resources on the ground that they were reserved minerals. The companies argued that they were non-mineral in character.

At the district court level in California, the United States lost. The Court found that the geothermal liquids were not minerals as defined at the time the Act in question had become law.

On appeal to the Ninth Circuit Court of Appeals, the United States prevailed, and the resources must now be developed under leases from the Government. The Court held that the mineral reservation did, indeed, include the right to produce geothermal energy from the conveyed lands.

It should be carefully noted that the Court specifically defined the geothermal resources as being included within the term "minerals". This legal conclusion may well be significant in the related question of how

to define geothermal resources within the existing provisions of the U.S. Tax Code.

So far as the Ninth Circuit is concerned, geothermal resources must now be considered as "minerals", at least for purposes of construing the Stock-Raising Homestead Act. To such extent, this institutional barrier has been resolved.

One other very important point to remember is that the question of who owned the resources is very old and was not dealt with in the Geothermal Steam Act of 1970. It took a recent court decision on a case which originally was filed in 1972 to resolve the question for now. I would like to think that this barrier was truly put to rest but I know that questions concerning the ownership of the resource outside of the framework of the Stock-Raising Homestead Act of 1916 will come up and another barrier will be constructed. The hope is that appropriate legislation can be passed which will put the issue to rest once and for all and that is what I urge anyone here who cares to spend some of their effort on to try to accomplish.

The Next Barrier Which I Mentioned is the
Multiple Agency Procedures.

A geothermal developer has to deal with a myriad of Federal, State and local agencies. There should be some way to get all of this simplified. Meanwhile, so long as multiple agency procedures are required, each agency should give some kind of prior attention as well as sympathetic treatment to pending applications.

In California, one must report to a county planning commission, the State Division of Oil and Gas, the Regional Water Quality Control Board, the Air Resources Board, the Public Utility Commission, and possibly the Federal Energy Regulatory Commission. If Federal property is involved, one must clear with the Bureau of Land Management and possibly the U.S. Forest Service,

as, well as the U.S. Geological Survey, among others.

In their annual reports for the years 1974 and 1975 Magma Power Company and my company, Geothermal Resources International, Inc. pointed out and obviously has been acknowledged by Congressman McCormack that no fewer than nine permits must be received from at least 44 different applicable federal, state and local governmental agencies in the state of California in order to advance geothermal energy development. We all understand that environmental considerations are of top priority but 44 different agencies all vying for control over one project (as you must certainly appreciate) can do nothing but impede progress. We recommended in that same report that one regulatory agency empowered to issue a single comprehensive permit be approved as soon as possible. If this is too difficult, perhaps fewer permits could be required and issued by a group of agencies working together. Even as was recommended by the Institutional Barriers Panel, the States could let the federal government lead as long as the States trusted the federal government. Two perfect examples of this competition for control are the quarrel between DOE and Interior as to who is responsible for the amended geothermal regulations soon to be produced and the quarrel between the State of California and Lake County as to who will control the zoning for geothermal development. These quarrels could cause incredible delays in progress.

Further, we waited about 8 years while the Congress and the Executive Branch debated over the proposed authorization of geothermal steam leases. Then we waited 3 more years while the proposed administrative regulations were being issued. Then we waited 3 more years before our preferential-right lease was issued, and then it was issued only on BLM land. On national forest land our "grandfather rights" have not yet been honored, despite the statutory

injunction that such rights were to be exercised "at any time within one hundred and eighty days following the effective date of this Act."

The problem of multiple-agency jurisdiction impinges uniquely on geothermal development -- because extraction, refinement and generation of power all occur within the same local area. Whatever the final resolution of this problem, it seems foolish to require the geothermal developer and the public utility to file three or more environmental impact statements for a single local development. Meanwhile at least the agencies concerned should "tool up" to do their work efficiently and effectively.

Now I would like to turn to my favorite and obviously a number of other participant's favorite institutional barrier, The Federal-Income Tax Code.

Uncertainties and adverse or unfair treatment under current interpretations of the Internal Revenue Code are probably the leading institutional barriers to more rapid development of geothermal energy. Added to this is the long history of deferral and delay in the Congress in acting upon urgent requests for remedial legislation.

The Code makes no expressed substantive provision for the income tax consequences of developing and producing geothermal resources, such as is provided for virtually every other kind of energy resource that is in commercial production today.

The present confused situation has included an artificial and unjustified discrimination against geothermal resources in general, as compared with other kinds of energy resources; and against non-"steam" resources. The only satisfactory remedy is legislation by the Congress: and the industry generally prefers provisions in the Senate-passed energy tax bill.

Joe Cullen already has mentioned this however, I shall expand a little bit on it. So far as "steam" is concerned, the Ninth Circuit has held

that the resource is "gas", as in "natural gas". The resource, by virtue of an exception contained in the Tax Reduction Act of 1975, continues to be accorded a depletion rate of 22 percent; and intangible drilling and development costs may be written off against current income. It is said, however, as remarkable as it may sound, that the Internal Revenue Service is unwilling to adopt the lawful determination of the Circuit Court.

So far as the non-"steam" resources are concerned, the law has not been judicially construed.

In the Union Oil Company case (referred to under "Ownership of geothermal resources"), the Ninth Circuit Court of Appeals squarely placed geothermal resources, without limitation, under the term "minerals". The Tax Code provides that any "minerals" not elsewhere expressly provided for shall be accorded a depletion rate of 14 percent. (Sec. 613(b)(7) of the Internal Revenue Code). A case can be made that 14 percent is the currently applicable rate. However, nothing in the Code appears to provide for the current deductibility of intangible drilling and development costs in the case of the non-"steam" resources.

For three successive Congresses, the U.S. Senate has adopted legislation that would accord all geothermal resources a specified depletion rate and allow the intangible costs to be deducted. The most recent of these actions now awaits disposition in the Conference Committee. The House bill omits any depletion allowance, but would accord the intangible costs deduction.

A part of the debate on this matter has involved the factual question: "Do geothermal resources, in fact, deplete?" On this question various elements within the Executive Branch have exhibited remarkable wavering and inconsistency. It is worth our time to take a brief look at this vexing facet of the problem.

I thought that during testimony before the House and the Senate that we had proved conclusively that the resource depletes.

The fact is that since 1971, a total of 23 new wells have had to be drilled to replace wells that had depleted at The Geysers geothermal steam field.

Additional evidence showing that the resources deplete has been presented from Hawaii, where the geologists have estimated the life of a geothermal well will be in the range of some 20 years.

The position of the Executive Branch on this matter seemed to have been resolved on October 11, 1977, when the Division of Geothermal Energy of the Department of Energy wrote to Senator Matsunaga, saying in part:

"I do not believe there is any reasonable scientific doubt that geothermal resources are depletable. It is possible to imagine an extremely unusual formation that might not be depletable, but the scientific evidence clearly shows all known recoverable resources are depletable."

In like manner, in January, 1978, a letter to me from the same source confirmed that geothermal resources are depletable, stating that the Treasury Department's spokesmen had given misleading statements on this point before the Senate Committee on Finance.

Now, however, under date of April 7, 1978, Mr. Alvin L. Alm, Assistant Secretary for Evaluation, Department of Energy, has advised me that the Administration's position is as follows:

(1) geothermal energy is not a depletable resource as that term is used under the provisions of the Internal

Revenue Code, and

(2) while geothermal energy is derived from the immense but theoretically limited amount of heat in the earth's magma, as a practical matter, it is not a depleting resource.

We have asked Senator Matsunaga and others on the "Hill" to examine this latest development as soon as possible, inasmuch as it may have a bearing on the disposition of the current legislation.

Meanwhile, for my own part, I have faith in the strength of the stated factual and scientific evidence. This is in the hands of the Congressional Committees and is well known to many of the tax-bill conferees.

But we must think ahead in terms of failure of the Congress to move ahead on general energy-tax legislation. In such event, we should request urgently that new legislation individually addressing geothermal tax questions be introduced and promptly considered in the two committees.

If no legislation at all is to be forthcoming, the industry will be forced to limp along with the current judicial determination regarding "steam". As to non-"steam", we would have to consider seriously the possibility of claiming a 14-percent rate of exhaustion under the existing Code provision relating to "all other minerals".

All of you who are staff members could help the cause of this industry by suggesting that at very least the tax ramifications should be the same as those received by competitive resources such as coal, nuclear, etc. I urge you to try to put an end to this nonsensical delay. At very least, Treasury should certainly get off the backs of this industry by adhering to the mandates of the courts.

After all, geothermal energy already exists and its future could be bright, but none of this will take place unless those who can move mountains get out and at least remove some of these barriers.