GL01170

Geothermal Power Corporation

POST OFFICE BOX 1186
NOVATO, CALIFORNIA 94947
PHONE (415) 897-7833

May 24, 1977

United States Energy Research and
Development Administration
Nevada Operations Office
P. O. Box 14100
Las Vegas, Nevada 89114

RE: GEOTHERMAL RESERVOIR ASSESSMENT
CASE STUDY, SUBMITTAL

Gentlemen:

Enclosed for your serious consideration are ten copies of Geothermal Power Corporation's proposal for cost sharing on a six phase exploration and development program on leases located within and immediately adjacent to the Roosevelt Hot Springs K.G.R.A.

We would like to have your support on all phases of our program. However, we have submitted our program in six phases and we would be willing to negotiate for your support on any or all phases separately.

We would request that you keep the information contained in our proposal confidential and that you will return our proposal at the appropriate time.

Thank you.

Respectfully submitted,

Frank G. Metcalfe

Frank G. Metcalfe
President

Enclosures
FGM:wps

Reprint from: Phillips Petroleum Company
1975 Annual Report

Steam rising from Phillips first geothermal discovery indicates the energy potential of a well testing a large underground reservoir in southwestern Utah.

A
Proposal
to the
United States
Energy Research and Development Administration

"Geothermal Resevoir Assessment Case Study -
Roosevelt Hot Springs K.G.R.A."

Submitted
by

Geothermal Power Corporation
Novato, California 94947

May 27, 1977

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Section 1.

Introduction

INTRODUCTION

Proposed ERDA Georthermal Resevoir Case History Program as presented at the January 27, 1977 Meeting, Salt Lake City Hilton.

Background: Because so few geothermal systems have been exploited, a great deal remains to be learned about this resource. Not only are the characteristics of different types of reserviors poorly known, but also the kinds of geophysical reservior assessment techniques that will succeed in different geological settings are not well understood. As a result, the risk of a "dry hole" is unduly high in an exporation program. Even a successful exploration well, however, does not yield a return on investment unless the existence of an economic reservoir can be established. Unfortunately, the reservoir engineering techniques and methodology required to establish the suitability of such a reservoir are still under development, and investment capital for field development is accordingly hard to attract.

Proposed Program: As an important way in which to reduce the risk and cost of exploration and reservior assessment, and the uncertainty of reservoir engineering, the Division of Geothermal Energy of ERDA proposes to document and publish case histories of reservoirs representative of the different geothermal resource types. Through the offering of "bottom hole money," information on the results of drill holes in these reservoirs will be sought. The concept of bottom hole money, which generally applies to the geological information supplied by a well, will be extended to include a wide range of exploration and engineering information. That is, negotiations may be entered into to obtain, where necessary, additional surface geophysical data, subsurface logging and coring data, as well as the results of flow/pressure tests of a completed well. Through such "case history" contributions, a complete picture of different reservoirs will be obtained and disseminated to the industry at large. The principles illuminated by these case histories can then be applied to the discovery of new geothermal reservoirs, reducing the risk and cost of developing geothermal energy.

An additional benefit of this program will be the stimulation of geothermal exploratory drilling which will result from Government participation in the case history program.

Section 2.

The Company

THE COMPANY

Geothermal Power Corporation (the "Company") is primarily engaged in exploring, acquiring (directly or indirectly) and developing geothermal properties for the generation of electric power.

At present, the Company does not engage in the production of electrical power through the use of geothermal steam resources. It does, however, have working interests in geothermal properties covering approximately 20,480 acres of Federal land and 1920 acres of State land in Beaver County, Utah. The company also holds assignments of all rights under applications pending with the United States Secretary of the Interior and applications for prospecting permits with the State of California, covering a total of approximately 23,600 acres of land in California and New Mexico. In addition, the Company has a 66% working interest in 26,150 acres of Private land in Modoc County, California (Kelley Hot Springs Prospect). The company drilled a deep geothermal well (Kelley Hot Springs #1) in 1974. Presently, the company has a joint venture with Thermal Power Company to further explore and develope this prospect.

The Company was incorporated under the laws of the State of Delaware in December 1971. Its offices are located at 1127 Grant Avenue, Suite #6, P. O. Box 1186, Novato, California 94947 and the telephone number is (415)897-7833.

Section 3.

Management

MANAGEMENT

The names and addresses of the directors and executive officers of the Company are as follows:

Frank G. Metcalfe
President, Treasurer and Director
1127 Grant Avenue, No. 6
Novato, California 94947

John Papini
Vice President, Secretary and Director
985 Moraga Road
Lafayette, CA 94549

Christian Baldenhofer II
Vice President, Controller and Director
3235 Sacramento Street
San Francisco, CA 94115

Ian G. Purves
Financial Vice President and Director
127 Grenfell Boulevard
Winnipeg, Manitoba
Canada R3P OB6

Cecil J. Folmar, M.D.
Director
2020 Hospital Circle, Suite B7
Westminster, California 92683

Robin V. Davis
Geologist
7547 Healdsburg Avenue
Sebastopol, California 95472

Mr. Metcalfe is a Registered Professional Engineer with a Mechanical Engineering Degree from the University of Manitoba, Canada. For the past seventeen years he has held a variety of management, engineering and marketing positions in the energy industry. Prior to founding Geothermal Power Corporation in 1971, he was Vice President of National Energy Systems Corporation, a privately held power and energy generation concern. National Energy finances, owns, operates and maintains stationary power plant systems. During this period he was also Vice President of American Mobile Power Corporation. American Mobile Power rents heavy mobile power generation equipment to utilities, construction, oil and mining companies. From 1965 to 1969, Mr. Metcalfe was employed by Southern California Edison Company, the nation's sixth largest utility. He was Supervisor of Marketing Engineering and an Applications Engineer in which capacity he was responsible for in-depth studies on applications and economics of all types of energy systems, including geothermal. Prior to 1965, Mr. Metcalfe was employed for several years as a Staff Engineer for the Southern California Gas Company. He is a member of the Geothermal Resources Council.

Mr. Papini is a founder and managing partner of Lafayette Investment Research, an investment management firm in Lafayette, California. Mr. Papini was graduated from the University of California, Berkeley in 1963 with a B.S. Degree in Engineering. He also received an Masters of Business Administration Degree in 1969 from the Stanford Graduate School of Business.

Mr. Baldenhofer has an A.B. Degree in economics from Hamilton College, Clinton, New York, and received a Masters of Business Administration Degree from the University of California at Berkeley in 1971. Presently, Mr. Baldenhofer is a Financial Analyst with Bechtel Corporation, San Francisco. From 1973 to 1974, he was associated with Levi Strauss & Co., Inc., as Production Administrator of the Panatela Division and as Manager of Operations Budgeting in the Controller's Department. From 1971 to 1973, he was associated with Dean Witter & Co., Inc., as Manager, Financial Planning and Control. Prior to 1971, he was a cost accountant for Trans World Airlines at the Kennedy Space Center, Florida, and a Lieutenant (J.G.) in the U.S. Navy.

Mr. Purves graduated from the University of Manitoba in 1958, receiving a Bachelor of Science degree in Mechanical Engineering. From 1958 to 1964 he served as Wholesale Manager of Purves Motors in Winnipeg, Canada. For the past fourteen years he has been an Account Executive with Greenshields Incorporated, a large stock brokerage firm located in Canada.

Dr. Folmar is a graduate of Pomona College (B.A., 1957) and the University of Southern California School of Medicine (1961). He is a Diplomate of the American Board of Otolaryngology. Since 1969 he has been a private practitioner of otolaryngology in Westminster, California.

Ms. Davis is a graduate of California State College with a Bachelor of Science degree in Geology. Prior to joining the Company as geologist and well logger, Ms. Davis conducted geohydroligic studies for the State of California, Department of Water Resources. In 1974, Ms. Davis conducted mineral analyses for NASA - Ames Research Center, Space Science Division Moffett Field, California.

In the past, much of the Company's exploration work has been performed by consultants hired as independent contractors. The Company anticipates carrying out the program outlined in this proposal in this manner.

Some of the independent consultants previously retained by the Company and whom the Company expects to be able to retain to carry out the exploration and development program are:

GeothermEx, Berkeley, California (Geology)
Hathaway Engineering, Sacramento, California (Drilling Consultant)
Gene M. Skinner, Yorba Linda, California (Drilling Spvr)
Haskins & Sells, San Francisco, California (Accountant)
Orrick, Herrington, Rowley & Sutcliffe, San Francisco, CA (Legal)

Resumes of the qualifications of these consultants are included for ERDA's inspection and approval.

The Company would also employ contractors for drilling and logging operations such as Loffland Brothers Company or Big Chief Drilling Company, Schlumberger Limited or Welex, Haliburton, etc.

Section 4.

Utah Leasehold Properties

UTAH LEASEHOLD PROPERTIES

The Company holds assignments on geothermal leases on 20,480 acres of land in Beaver County, Utah. In addition, the Company has state leases and a federal lease application on 2,731 acres of land in Beaver County, Utah.

The following tables contain certain information concerning the geothermal leases in which the Company has an interest.

I. STATE LEASES AND NONCOMPETITIVE FEDERAL LEASE APPLICATIONS

Beaver County, Utah (Roosevelt Hot Springs)

Lessor	Gross Acreage	% Working Interest	% Royalty	Anticipated Annual Rental
USBLM (1)	811	100%	10%	$ 811.17
State (2)	640	100%	10%	640.00
State (2)	1,280	100%	10%	1,280.00
	2,731			2,731.17
	24,801			$26,001.17

*U.S. Bureau of Land Management

(1) With respect to the acreages listed, the applicant stands in a priority position. Issuance of leases depends on completion of federal environmental impact statements and in some cases on submission of acceptable development plans by the applicant, and on other administrative requirements of the Bureau of Land Management.

(2) State of Utah Lease provide for a 10-year primary term (and and continue thereafter as long as geothermal steam is being produced) and a 10% royalty. Expiration date of the primary term is January 12, 1986.

II. FEDERAL LEASES IN BEAVER COUNTY, UTAH (ROOSEVELT HOT SPRINGS)

Lessor		Gross Acreage	% Working Interest	% Royalties	Expiration Date of Primary Term (1)	Annual Rentals (Pro-rata Share)
USBLM*	(1)	1,200 (2)	100%	10%	Sept. 1, 1985 (3)	$2,400.00
USBLM	(1)	1,284	100	10	July 1, 1985 (3)	1,284.00
USBLM	(1)	1,920	100	10	July 1, 1985 (3)	1,920.00
USBLM	(1)	1,949	100	10	July 1, 1985 (3)	1,949.00
USBLM	(1)	1,920	100	10	July 1, 1986 (3)	1,920.00
USBLM	(1)	802	100	10	July 1, 1986 (3)	802.00
USBLM	(1)	2,560	100	10	July 1, 1986 (3)	2,560.00
USBLM	(1)	2,048	100	10	July 1, 1986 (3)	2,048.00
USBLM	(1)	2,507	100	10	July 1, 1986 (3)	2,507.00
USBLM	(1)	2,040	100	10	July 1, 1986 (3)	2,040.00
USBLM	(1)	2,560	100	10	July 1, 1986 (3)	2,560.00
USBLM	(1)	1,280	100	10	July 1, 1986 (3)	1,280.00
		22,070 (4)				$23,270.00

* U.S. Bureau of Land Management

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(1) The Lessee has executed an assignment of the lease to the Company. The Company is in the process of fulfilling the administrative requirements of the Bureau of Land Management so that the leases can be formally transferred to the Company.

(2) This lease is located in the Roosevelt Hot Springs K.G.R.A.

(3) Lease renewable for up to 40 years if producing.

(4) Because of the 20,480-acre limitation on leaseholdings in one state, the Company will ultimately obtain additional leases on no more than 20,480 acres of this total.

Section 5.

GeothermEx Summary Report*

* See Full Report Section 11

GeothermEx 901 MENDOCINO AVE.
BERKELEY, CA. 94707

JAMES B. KOENIG (415) 524-9242
MURRAY C. GARDNER (503) 482-2605

GEOTHERMAL POTENTIAL OF LANDS LEASED BY GEOTHERMAL POWER CORPORATION, ROOSEVELT HOT SPRINGS, UTAH

BY

GEOTHERMEX, INC.

March 1977

901 MENDOCINO AVE.
GeothermEx BERKELEY, CA. 94707

JAMES B. KOENIG (415) 524-9242
MURRAY C. GARDNER (503) 482-2605

This report gives a preliminary assessment of the geothermal potential of several parcels of land leased by Geothermal Power Corporation in the northern Mineral Mountains of Beaver and Millard Counties, Utah. This assessment is based upon extensive published and unpublished geological, geophysical and hydrological data, as well as the results of drilling at Roosevelt Hot Springs, Utah.

A commercially producible geothermal field has been discovered by Phillips Petroleum Company in T 27 S, R 9 W, and is confirmed by wells drilled in adjacent sections by Thermal Power Company (Natomas Company). Geothermal Power Corporation leases several sections of land that might be within the Roosevelt Hot Springs geothermal field. Of most interest are sections 13, 24, 25, 33 to 35 in T 27 S, R 9 W; section 25 in T 26 S, R 9 W; and section 19 in T 27 S, R 8 W. Exploration results in the area to date suggest that drilling will proceed to the east and southeast, entering higher elevations of the Mineral Mountains. Thus, the lands in T 27 S, R 9 W, and the southern part of T 26 S, R 9 W, lie directly in the path of exploration. Lands held elsewhere by GPC have a lower priority for exploration.

It is unlikely that further attractive acreage can be leased in the area. However, farm-outs, joint ventures and/or pooling of acreage with other small companies appear to be useful exploration strategies.

The Mineral Mountains are located in the transition zone between two geologic provinces, each with a distinct character and history. The area underwent a long period of sedimentation, lasting from Cambrian through Jurassic time, with some differences in the type of sedimentation between the Utah-Nevada province on the west and the Colorado Plateau province on the east. During Cretaceous time, the province west of the project area underwent deformation that included extensive low-angle thrust faults with horizontal displacements of tens of miles; while the Colorado Plateau province to the east underwent less-intense deformation, including folding and minor thrusting. In early Cenozoic time, the region was the site of deposition of extensive fluvial and lacustrine sediments. This was followed, in upper Eocene through Miocene time, by the eruption of thick ash-flow tuffs of regional extent in the province west of the project area. The later Cenozoic igneous history of the Mineral Mountains is dominated by intrusion of the granitic stock which makes up the bulk of the range.

Late in Cenozoic time, there was a major episode of normal faulting in the region, resulting in the development of the present fault-block ranges and graben valleys.

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The central part of the Mineral Range, where Geothermal Power Corporation's leases are located, and where exploratory drilling has been done by Phillips and Natomas, essentially consists of three types of rocks. They are: *(1)* Precambrian metamorphic rocks, including schists and gneisses, that may be about 1.8 billion years old; *(2)* a very large granite intrusion, that may be 9 to 15 million years old; and *(3)* very young volcanic rocks of rhyolitic composition. These volcanic rocks are about 800,000 to 500,000 years old, and were erupted onto the surface of the granite. To the west, on the sloping floor of Milford Valley, is an accumulation of unconsolidated sediment of varying thickness. This probably covers Precambrian rocks at depth of several hundred to a few thousand feet.

All of these rocks have virtually no primary porosity. For a significant reservoir with porosity and permeability to exist in this area, the rocks must have been pervasively shattered.

Youthful north-trending faults are present along the west front of the Mineral Mountains. One of these controlled the location of Roosevelt Hot Springs (now dry) and other, pre-historic, thermal springs that formed large deposits of siliceous sinter. Several east-trending faults cross the central part of the Mineral Mountains; some of these east-trending faults influence the presently known geothermal system, whereas others apparently do not. Deep drilling by Phillips Petroleum Company has encountered an east-dipping shear zone:at depths of 2,000 feet and deeper this is productive of geothermal fluid. Whether fracturing sufficient to create a reservoir has occurred within the central part of the Mineral Mountains presently is unknown.

All of the granite exposed in the Mineral Mountains is much too old to provide heat to a geothermal system. However, the rhyolitic volcanic rocks may be the surface expression of an intrusion that is sufficiently hot and sufficiently large to drive a large convective geothermal system.

Gravity data for the Mineral Mountains have been interpreted as showing the existance of a quasi-molten body at depths of only a few miles beneath the surface. This, or a larger body assumed present at greater depth, is postulated as the source of heat for the geothermal system. Temperature gradients were measured in holes drilled to several hundred feet at numerous locations in the valley and on the mountain flanks. These gradients reveal a high-temperature anomaly centered slightly downslope from the geothermal field, as presently defined by drilling. It is interesting to note that the gravity anomaly is offset from the temperature-gradient anomaly, which in turn is offset from the area of productive wells. This suggests that the wells drilled to date do not completely define the geothermal field at depth.

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As far as is known, the fluid in the Roosevelt geothermal field is hot water. Of the wells drilled by Phillips or Natomas, 5 or 6 are prospective producers, and have water temperatures ranging from somewhat above 400°F to more than 500°F. The quantity and enthalpy of steam flashed from the water varies from well to well. However, average yields of 1 million pounds per hour, with about 20 percent steam flash, are reported. This would be adequate for about 10 mW of electric power per well, under present-day technology. Numerous wells produce lower quantities (or lower quality) of fluid, either because of restricted permeability in the reservoir rock, or because of unsatisfactory well completion.

The concentration of ions dissolved in the water and the composition of the dissolved ions are different from the concentration/composition of the shallow ground-water that is used for irrigation in Milford Valley, which seems to indicate there is little or no connection between the two hydrologic systems. Water from the deep wells averages 9,000 parts per million of total dissolved solids, mostly sodium chloride. This means that the water cannot be disposed of on the ground surface, and injection wells will be required for waste disposal. Some of the unsuccessful exploration holes may be convertible to disposal wells.

The geologic and hydrologic data sketched above indicate that the three indispensible components of a commercial geothermal system (reservoir, water and heat) do exist in at least part of the Roosevelt area. The areal limits of the commercial system have not yet been defined. However, geophysical data (principally gravity and heat-flow data) and the distribution of very young rhyolite domes at the surface suggest that at least twice as large an area as the present-day well field may be productive ultimately. This could be adequate for several hundred mW of electric generating capacity.

This lends encouragement to continued exploration of Geothermal Power Corporation's leasehold.

As a relatively quick and direct method of evaluating the various parcels of land in the Geothermal Power Corporation leasehold, at least 10 (and preferably 15 to 20) geothermal gradient holes should be drilled to depths of 200 to 300 feet. Sites for these holes have been recommended to GPC for sections of land south, east and northeast of the proven well field. Auxiliary geologic work, such as radiometric age-dating of volcanic rocks and logging of cuttings from the gradient holes, is recommended to help interpret the gradient data. Two or three deep gradient holes (perhaps to 2,000 feet) then may be warranted depending on results from the shallow gradient survey.

JAMES B. KOENIG (415) 524-9242
MURRAY C. GARDNER (503) 482-2605

Trade of gradient and age-dating data or other proprietary information with other companies is recommended as a means of optimizing value received for exploration dollars.

Selection of a deep drill-site would follow upon the steps outlined above. Such a hole might go to as much as 8,000 feet in depth, depending upon observed gradients, the results of test drilling elsewhere, and the financing available. Probably more than one deep hole should be considered when planning exploratory drilling. Costs for drilling and completion are at least $80 per foot in 1977 dollars.

Section 6.

Drilling Program, Total Estimated Costs, Proposal —

ERDA Participation

DRILLING PROGRAM

Phase 1 - Approximately 15 Heat Flow Holes, 300-500 Feet Deep (5,000 ft. total)

Phase 2 - One 2,000-foot Observation Hole

Phase 3 - One 2,000-foot Observation Hole

Phase 4 - One 7,000-foot Production Hole

Phase 5 - One 7,000-foot Production Hole

Phase 6 - One 7,000-foot Production Hole

TOTAL ESTIMATED COSTS

Phase 1 - $25,000 ($5/foot)

Phase 2 - $130,000 ($65/foot) See Hathaway Engineering Cost Estimate

Phase 3 - $130,000 ($65/foot) See Hathaway Engineering Cost Estimate

Phase 4 - $682,000 ($97.43/foot) See Hathaway Engineering Cost Estimate

Phase 5 - $682,000 ($97.43/foot) See Hathaway Engineering Cost Estimate

Phase 6 - $682,000 ($97.43/foot) See Hathaway Engineering Cost Estimate

PROPOSAL - ERDA PARTICIPATION

Phase 1 - $10,000 ($2/foot) or (40% cost sharing)*

Phase 2 - $43,333.33 ($21.67/foot) or (1/3 cost sharing) *

Phase 3 - $43,333.33 ($21.67/foot) or (1/3 cost sharing)*

Phase 4 - $204,600 ($29.23/foot) or (30% cost sharing)*

Phase 5 - $204,600 ($29.23/foot) or (30% cost sharing) *

Phase 6 - $204,600 ($29.23/foot) or (30% cost sharing) *

* ERDA can participate on either on a footage basis or a percentage of actual cost basis.

CONTRACT PRICING PROPOSAL

(RESEARCH AND DEVELOPMENT)

Office of Management and Budget Approval No. 29-RO184

This form is for use when *(i)* submission of cost or pricing data (see FPR 1-3.807-3) is required and *(ii)* substitution for the Optional Form 59 is authorized by the contracting officer.

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NAME OF OFFEROR: GEOTHERMAL POWER CORPORATION

HOME OFFICE ADDRESS: 1127 Grant Avenue, #6
P. O. Box 1186, Novato, CA 94947

SUPPLIES AND/OR SERVICES TO BE FURNISHED: Phase 1
Approx. 15 temperature gradient holes, heat flow calculations and report.

DIVISION(S) AND LOCATION(S) WHERE WORK IS TO BE PERFORMED: Roosevelt Hot Springs KGRA & adjacent land

TOTAL AMOUNT OF PROPOSAL: $ 25,000.00 X 40%

GOV'T SOLICITATION NO.: (RFP) No. EY-R-08-0007

DETAIL DESCRIPTION OF COST ELEMENTS

1. DIRECT MATERIAL *(Itemize on Exhibit A)*				EST COST ($)	TOTAL EST COST[1]	REFERENCE[2]
a. PURCHASED PARTS pipe 5,000 feet @ $.50 foot				$2,500		
b. SUBCONTRACTED ITEMS						
c. OTHER—(1) RAW MATERIAL						
(2) YOUR STANDARD COMMERCIAL ITEMS						
(3) INTERDIVISIONAL TRANSFERS *(At other than cost)*						
TOTAL DIRECT MATERIAL					$2,500	
2. MATERIAL OVERHEAD[3] *(Rate %X$ base=)*						
3. DIRECT LABOR *(Specify)*	ESTIMATED HOURS	RATE/HOUR		EST COST ($)		
Robin V. Davis, Geologist				$2,500		
TOTAL DIRECT LABOR					$2,500	
4. LABOR OVERHEAD *(Specify Department or Cost Center)*[3]	O.H. RATE	X BASE =		EST COST ($)		
TOTAL LABOR OVERHEAD						
5. SPECIAL TESTING *(Including field work at Government installations)*				EST COST ($)		
TOTAL SPECIAL TESTING						
6. SPECIAL EQUIPMENT *(If direct charge) (Itemize on Exhibit A)*						
7. TRAVEL *(If direct charge) (Give details on attached Schedule)*				EST COST ($)		
a. TRANSPORTATION						
b. PER DIEM OR SUBSISTENCE						
TOTAL TRAVEL						
8. CONSULTANTS *(Identify—purpose—rate)*				EST COST ($)		
Vic's Drilling 5,000 feet @ $3.00 foot				$15,000		
Geotherm Ex				$ 5,000		
TOTAL CONSULTANTS					$20,000	
9. OTHER DIRECT COSTS *(Itemize on Exhibit A)*					-0-	
10. *TOTAL DIRECT COST AND OVERHEAD*					$25,000	
11. GENERAL AND ADMINISTRATIVE EXPENSE *(Rate % of cost element Nos.)*[3]					-0-	
12. ROYALTIES[4]					-0-	
13. *TOTAL ESTIMATED COST*					$25,000	
14. FEE OR PROFIT					-0-	
15. *TOTAL ESTIMATED COST AND FEE OR PROFIT*					$25,000	

OPTIONAL FORM 60
October 1971
General Services Administration
FPR 1-16.806
5060-101

This proposal is submitted for use in connection with and in response to *(Describe RFP, etc.)* RFP No. EY-R-08-0007

GEOTHERMAL RESERVOIR ASSESSMENT CASE STUDY

and reflects our best estimates as of this date, in accordance with the Instructions to Offerors and the Footnotes which follow.

TYPED NAME AND TITLE	SIGNATURE
FRANK G. METCALFE, President	Frank G. Metcalfe

NAME OF FIRM	DATE OF SUBMISSION
Geothermal Power Corporation	5-27-77

EXHIBIT A—SUPPORTING SCHEDULE *(Specify. If more space is needed, use reverse)*

COST EL NO.	ITEM DESCRIPTION *(See footnote 5)*	EST COST *($)*

I. HAS ANY EXECUTIVE AGENCY OF THE UNITED STATES GOVERNMENT PERFORMED ANY REVIEW OF YOUR ACCOUNTS OR RECORDS IN CONNECTION WITH ANY OTHER GOVERNMENT PRIME CONTRACT OR SUBCONTRACT WITHIN THE PAST TWELVE MONTHS?

☐ YES ☒ NO *(If yes, identify below.)*

NAME AND ADDRESS OF REVIEWING OFFICE AND INDIVIDUAL	TELEPHONE NUMBER/EXTENSION

II. WILL YOU REQUIRE THE USE OF ANY GOVERNMENT PROPERTY IN THE PERFORMANCE OF THIS PROPOSED CONTRACT?

☐ YES ☒ NO *(If yes, identify on reverse or separate page)*

III. DO YOU REQUIRE GOVERNMENT CONTRACT FINANCING TO PERFORM THIS PROPOSED CONTRACT?

☐ YES ☒ NO *(If yes, identify.)*: ☐ ADVANCE PAYMENTS ☐ PROGRESS PAYMENTS OR ☐ GUARANTEED LOANS

IV. DO YOU NOW HOLD ANY CONTRACT *(Or, do you have any independently financed (IR&D) projects)* FOR THE SAME OR SIMILAR WORK CALLED FOR BY THIS PROPOSED CONTRACT?

☐ YES ☒ NO *(If yes, identify.)*:

V. DOES THIS COST SUMMARY CONFORM WITH THE COST PRINCIPLES SET FORTH IN AGENCY REGULATIONS?

☒ YES ☐ NO *(If no, explain on reverse or separate page)*

See Reverse for Instructions and Footnotes

CONTRACT PRICING PROPOSAL

(RESEARCH AND DEVELOPMENT)

Office of Management and Budget Approval No. 29-RO184

This form is for use when *(i)* submission of cost or pricing data (see FPR 1-3.807-3) is required and *(ii)* substitution for the Optional Form 59 is authorized by the contracting officer.

PAGE NO. 1 | NO OF PAGES

NAME OF OFFEROR: GEOTHERMAL POWER CORPORATION	SUPPLIES AND/OR SERVICES TO BE FURNISHED: Phase 2 or Phase 3 Drilling of a 2,000 foot geothermal observation hole, well logging and abandonment.
HOME OFFICE ADDRESS: 1127 Grant Avenue, #6 P. O. Box 1186, Novato, CA 94947	
DIVISION(S) AND LOCATION(S) WHERE WORK IS TO BE PERFORMED: Roosevelt Hot Springs KGRA & adjacent land	TOTAL AMOUNT OF PROPOSAL: $ 130,000.00 X 33.3% / GOV'T SOLICITATION NO.: (RFP) No. EY-R-08-0007

DETAIL DESCRIPTION OF COST ELEMENTS

1. DIRECT MATERIAL *(Itemize on Exhibit A)*			EST COST ($)	TOTAL EST COST[1]	REFERENCE[2]
a. PURCHASED PARTS					
b. SUBCONTRACTED ITEMS					
c. OTHER—*(1)* RAW MATERIAL					
(2) YOUR STANDARD COMMERCIAL ITEMS					
(3) INTERDIVISIONAL TRANSFERS *(At other than cost)*					
TOTAL DIRECT MATERIAL					
2. MATERIAL OVERHEAD[3] *(Rate %X$ base=)*					
3. DIRECT LABOR *(Specify)*	ESTIMATED HOURS	RATE/HOUR	EST COST ($)		
TOTAL DIRECT LABOR					
4. LABOR OVERHEAD *(Specify Department or Cost Center)*[3]	O.H. RATE	X BASE =	EST COST ($)		
TOTAL LABOR OVERHEAD					
5. SPECIAL TESTING *(Including field work at Government installations)*			EST COST ($)		
TOTAL SPECIAL TESTING					
~~6. SPECIAL EQUIPMENT *(If direct charge) (Itemize on Exhibit A)*~~					
7. TRAVEL *(If direct charge) (Give details on attached Schedule)*			EST COST ($)		
a. TRANSPORTATION					
b. PER DIEM OR SUBSISTENCE					
TOTAL TRAVEL					
8. CONSULTANTS *(Identify—purpose—rate)*			EST COST ($)		
See Hathaway Engineering Estimate			$130,000		
TOTAL CONSULTANTS				$130,000	
9. OTHER DIRECT COSTS *(Itemize on Exhibit A)*				-0-	
10. *TOTAL DIRECT COST AND OVERHEAD*				$130,000	
11. GENERAL AND ADMINISTRATIVE EXPENSE *(Rate % of cost element Nos.)*[3]				-0-	
12. ROYALTIES[4]				-0-	
13. *TOTAL ESTIMATED COST*				$130,000	
14. FEE OR PROFIT				-0-	
15. *TOTAL ESTIMATED COST AND FEE OR PROFIT*				$130,000	

OPTIONAL FORM 60
October 1971
General Services Administration
FPR 1-16.806
5060-101

CONTRACT PRICING PROPOSAL *(RESEARCH AND DEVELOPMENT)*	Office of Management and Budget Approval No. 29-RO184	
This form is for use when *(i)* submission of cost or pricing data (see FPR 1-3.807-3) is required and *(ii)* substitution for the Optional Form 59 is authorized by the contracting officer.	PAGE NO. 1	NO. OF PAGES

NAME OF OFFEROR	SUPPLIES AND/OR SERVICES TO BE FURNISHED	
GEOTHERMAL POWER CORPORATION	Phase 4, or Phase 5, or Phase 6 Drilling of a 7,000 foot deep geothermal test well and completion	
HOME OFFICE ADDRESS 1127 Grant Avenue, #6 P. O. Box 1186, Novato, CA 94947		
DIVISION(S) AND LOCATION(S) WHERE WORK IS TO BE PERFORMED Roosevelt Hot Springs & adjacent land	TOTAL AMOUNT OF PROPOSAL $ 682,000.00 X 30%	GOV'T SOLICITATION NO. (RFP) No. EY-R-08-0007

DETAIL DESCRIPTION OF COST ELEMENTS

			EST COST ($)	TOTAL EST COST	REFERENCE
1. DIRECT MATERIAL *(Itemize on Exhibit A)*					
a. PURCHASED PARTS					
b. SUBCONTRACTED ITEMS					
c. OTHER—*(1)* RAW MATERIAL					
(2) YOUR STANDARD COMMERCIAL ITEMS					
(3) INTERDIVISIONAL TRANSFERS *(At other than cost)*					
TOTAL DIRECT MATERIAL					
2. MATERIAL OVERHEAD *(Rate %X$ base=)*					
3. DIRECT LABOR *(Specify)*	ESTIMATED HOURS	RATE/HOUR	EST COST ($)		
TOTAL DIRECT LABOR					
4. LABOR OVERHEAD *(Specify Department or Cost Center)*	O.H. RATE	X BASE =	EST COST ($)		
TOTAL LABOR OVERHEAD					
5. SPECIAL TESTING *(Including field work at Government installations)*			EST COST ($)		
TOTAL SPECIAL TESTING					
6. SPECIAL EQUIPMENT *(If direct charge) (Itemize on Exhibit A)*					
7. TRAVEL *(If direct charge) (Give details on attached Schedule)*			EST COST ($)		
a. TRANSPORTATION					
b. PER DIEM OR SUBSISTENCE					
TOTAL TRAVEL					
8. CONSULTANTS *(Identify—purpose—rate)*			EST COST ($)		
See Hathaway Engineering Estimate			$682,000		
TOTAL CONSULTANTS				$682,000	
9. OTHER DIRECT COSTS *(Itemize on Exhibit A)*				-0-	
10. *TOTAL DIRECT COST AND OVERHEAD*				$682,000	
11. GENERAL AND ADMINISTRATIVE EXPENSE *(Rate % of cost element Nos.)*				-0-	
12. ROYALTIES				-0-	
13. *TOTAL ESTIMATED COST*				$682,000	
14. FEE OR PROFIT				-0-	
15. *TOTAL ESTIMATED COST AND FEE OR PROFIT*				$682,000	

OPTIONAL FORM 60
October 1971
General Services Administration
FPR 1-16.806
5060-101

STANDARD FORM 19-B
OCTOBER 1969 EDITION
GENERAL SERVICES ADMINISTRATION
FED. PROC. REG. (41 CFR) 1-16.401

REPRESENTATIONS AND CERTIFICATIONS
(Construction Contract)
(For use with SF 19 and 21)

REFERENCE (*Enter same No.(s) as on SF 19/21*)

NAME AND ADDRESS OF BIDDER (*No., Street, City, State, and ZIP Code*)

Geothermal Power Corporation
1127 Grant Avenue, #6 - P. O. Box 1186
Novato, CA 94947

DATE OF BID

May 27, 1977

In negotiated procurements, "bid" and "bidder" shall be construed to mean "offer" and "offeror."

The bidder makes the following representations and certifications as a part of the bid identified above. *(Check appropriate boxes.)*

1. SMALL BUSINESS

He [X] is, [ ] is not, a small business concern. *(For this purpose, a small business concern is a business concern, including its affiliates, which (a) is independently owned and operated, (b) is not dominant in the field of operation in which it is bidding on Government contracts, and (c) had average annual receipts for the preceding 3 fiscal years not exceeding $7,500,000. For additional information see governing regulations of the Small Business Administration.)*

2. CONTINGENT FEE

(a) He [ ] has, [X] has not, employed or retained any company or person (other than a full-time bona fide employee working solely for the bidder) to solicit or secure this contract, and *(b)* he [ ] has, [X] has not, paid or agreed to pay any company or person (other than a full-time bona fide employee working solely for the bidder) any fee, commission, percentage or brokerage fee, contingent upon or resulting from the award of this contract; and agrees to furnish information relating to *(a)* and *(b)* above as requested by the Contracting Officer. *(For interpretation of the representation, including the term "bona fide employee," see Code of Federal Regulations, Title 41, Subpart 1-1.5.)*

3. TYPE OF ORGANIZATION

He operates as an [ ] individual, [ ] partnership, [ ] joint venture, [X] corporation, incorporated in State of Delaware

4. INDEPENDENT PRICE DETERMINATION

(a) By submission of this bid, each bidder certifies, and in the case of a joint bid each party thereto certifies as to his own organization, that in connection with this procurement:

(1) The prices in this bid have been arrived at independently, without consultation, communication, or agreement, for the purpose of restricting competition, as to any matter relating to such prices with any other bidder or with any competitor;

(2) Unless otherwise required by law, the prices which have been quoted in this bid have not been knowingly disclosed by the bidder and will not knowingly be disclosed by the bidder prior to opening, in the case of a bid, or prior to award, in the case of a proposal, directly or indirectly to any other bidder or to any competitor; and

(3) No attempt has been made or will be made by the bidder to induce any other person or firm to submit or not to submit a bid for the purpose of restricting competition.

(b) Each person signing this bid certifies that:

(1) He is the person in the bidder's organization responsible within that organization for the decision as to the prices being bid herein and that he has not participated, and will not participate, in any action contrary to *(a)*(1) through *(a)*(3) above; or

(2) (i) He is not the person in the bidder's organization responsible within that organization for the decision as to the prices being bid herein but that he has been authorized in writing to act as agent for the persons responsible for such decision in certifying that such persons have not participated, and will not participate, in any action contrary to *(a)*(1) through *(a)* (3) above, and as their agent does hereby so certify; and (ii) he has not participated, and will not participate, in any action contrary to *(a)*(1) through *(a)*(3) above.

(c) This certification is not applicable to a foreign bidder submitting a bid for a contract which requires performance or delivery outside the United States, its possessions, and Puerto Rico.

(d) A bid will not be considered for award where *(a)*(1), *(a)*(3), or *(b)* above, has been deleted or modified. Where *(a)*(2) above, has been deleted or modified, the bid will not be considered for award unless the bidder furnishes with the bid a signed statement which sets forth in detail the circumstances of the disclosure and the head of the agency, or his designee, determines that such disclosure was not made for the purpose of restricting competition.

THE FOLLOWING NEED BE CHECKED ONLY IF BID EXCEEDS $10,000 IN AMOUNT.

5. EQUAL OPPORTUNITY

He [ ] has, [X] has not, participated in a previous contract or subcontract subject to the Equal Opportunity Clause herein, the clause originally contained in Section 301 of Executive Order No. 10925, or the clause contained in Section 201 of Executive Order No. 11114; he [ ] has, [X] has not, filed all required compliance reports; and representations indicating submission of required compliance reports, signed by proposed subcontractors, will be obtained prior to subcontract awards. *(The above representation need not be submitted in connection with contracts or subcontracts which are exempt from the clause.)*

NOTE.—Bids must set forth full, accurate, and complete information as required by this invitation for bids (including attachments). The penalty for making false statements in bids is prescribed in 18 U.S.C. 1001.

6. PARENT COMPANY AND EMPLOYER IDENTIFICATION NUMBER

Each bidder shall furnish the following information by filling in the appropriate blocks:

(*a*) Is the bidder owned or controlled by a parent company as described below? ☐ Yes ☒ No. *(For the purpose of this bid, a parent company is defined as one which either owns or controls the activities and basic business policies of the bidder. To own another company means the parent company must own at least a majority (more than 50 percent) of the voting rights in that company. To control another company, such ownership is not required; if another company is able to formulate, determine, or veto basic business policy decisions of the bidder, such other company is considered the parent company of the bidder. This control may be exercised through the use of dominant minority voting rights, use of proxy voting, contractual arrangements, or otherwise.)*

(*b*) If the answer to (*a*) above is "Yes," bidder shall insert in the space below the name and main office address of the parent company.

NAME OF PARENT COMPANY	MAIN OFFICE ADDRESS *(No., Street, City, State, and ZIP Code)*

(*c*) Bidder shall insert in the applicable space below, if he has no parent company, his own Employer's Identification Number (E.I. No.) *(Federal Social Security Number used on Employer's Quarterly Federal Tax Return, U.S. Treasury Department Form 941)*, or, if he has a parent company, the E.I. No. of his parent company.

EMPLOYER IDENTIFICATION NUMBER OF	PARENT COMPANY	BIDDER
		94-230-3047

7. CERTIFICATION OF NONSEGREGATED FACILITIES

(Applicable to (1) contracts, (2) subcontracts, and (3) agreements with applicants who are themselves performing federally assisted construction contracts, exceeding $10,000 which are not exempt from the provisions of the Equal Opportunity clause.)

By the submission of this bid, the bidder, offeror, applicant, or subcontractor certifies that he does not maintain or provide for his employees any segregated facilities at any of his establishments, and that he does not permit his employees to perform their services at any location, under his control, where segregated facilities are maintained. He certifies further that he will not maintain or provide for his employees any segregated facilities at any of his establishments, and that he will not permit his employees to perform their services at any location, under his control, where segregated facilities are maintained. The bidder, offeror, applicant, or subcontractor agrees that a breach of this certification is a violation of the Equal Opportunity clause in this contract. As used in this certification, the term "segregated facilities" means any waiting rooms, work areas, rest rooms and wash rooms, restaurants and other eating areas, time clocks, locker rooms and other storage or dressing areas, parking lots, drinking fountains, recreation or entertainment areas, transportation, and housing facilities provided for employees which are segregated by explicit directive or are in fact segregated on the basis of race, color, religion, or national origin, because of habit, local custom, or otherwise. He further agrees that (except where he has obtained identical certifications from proposed subcontractors for specific time periods) he will obtain identical certifications from proposed subcontractors prior to the award of subcontracts exceeding $10,000 which are not exempt from the provisions of the Equal Opportunity clause; that he will retain such certifications in his files; and that he will forward the following notice to such proposed subcontractors (except where the proposed subcontractors have submitted identical certifications for specific time periods):

NOTICE TO PROSPECTIVE SUBCONTRACTORS OF REQUIREMENT FOR CERTIFICATIONS OF NONSEGREGATED FACILITIES

A Certification of Nonsegregated Facilities must be submitted prior to the award of a subcontract exceeding $10,000 which is not exempt from the provisions of the Equal Opportunity clause. The certification may be submitted either for each subcontract or for all subcontracts during a period (i.e., quarterly, semiannually, or annually).

NOTE: The penalty for making false statements in offers is prescribed in 18 U.S.C. 1001.

U.S. GOVERNMENT PRINTING OFFICE 1969 OF—350-456 (13-E)

8. CERTIFICATION OF EMPLOYMENT OF HANDICAPPED

The offeror certifies with respect to the Employment of the Handicapped clause as follows:

a. He / / has, /X/ has not previously been awarded a contract which included the clause. *(If affirmative, execute b.)*

b. The time specified for contract performance / / exceeded 90 days, / / did not exceed 90 days. *(If more than 90 days, execute c.)*

c. The amount of the contract was / / less than $500,000, / / more than $500,000, and he / / has, / / has not published his program for the employment of the handicapped. *(If more than $500,000, execute d.)*

d. He / / has, / / has not submitted the required annual report to the Assistant Secretary of Labor for Employment Standards.

e. He /X/ has, / / has not made a good faith effort to effectuate and carry out his affirmative action program.

f. He will not award subcontracts to persons or concerns that have not published programs and submitted annual reports as required by the clause.

9. AFFIRMATIVE ACTION PROGRAM

The following paragraphs are added:

a. The bidder or proposer represents that he (a) / / 1. has developed and has on file, / / 2. has not developed and does not have on file at each establishment an affirmative action program as required by the rules and regulations of the Secretary of Labor (41 CFR Part 60-1 and 60-2), or that he (b) /X/ has not previously had contracts subject to the written Affirmative Action Program requirement of the Secretary of Labor.

If such a program <u>has not</u> been developed, the bidder will complete the following:

The bidder does / /, does not /X/ employ more than 50 employees and has / /, has not /X/ been awarded a contract subject to Executive Order 11246 in the amount of $50,000 or more since July 1, 1968. If such a contract has been awarded since July 1, 1968, give the date of such contract, but do not list contracts awarded within the last 120 days prior to the date of this representation.

b. The bidder or proposer represents (a) that a full compliance review of the bidder's employment practices / / has, /X/ has not been conducted by an agency of the Federal Government; that such compliance review / / has, /?/ has not been conducted for the bidder's known first-tier subcontractors with a subcontract of $50,000 or more and having 50 or more employees and (b) that the most recent compliance reviews were conducted as follows:

NAME OF CONTRACTOR	DATE	FEDERAL AGENCY
(include known first-tier sub-contractors)		

c. The bidder or proposer represents that if the bidder has 50 or more employees and if this Contract is for $50,000 or more, and that for each subcontractor having 50 or more employees and a subcontract for $50,000 or more, and if he has not developed one, a written affirmative action plan will be developed for each of its establishments within 120 days from commencement of the Contract. A copy of the establishment's plan shall also be maintained at the establishment within 120 days from the date of commencement of the Contract.

The Affirmative Action Compliance Program will cover the items specifically set out in 41 CFR Part 60-2 and shall be signed by an executive of the Contractor.

d. Where the bid of the apparent low responsible bidder is in the amount of $1 million or more, the bidder and his known first-tier subcontractors which will be awarded subcontracts of $1 million or more will be subject to full, preaward equal opportunity compliance reviews before the award of the Subcontract for the purpose of determining whether the bidder and his subcontractors are able to comply with the provisions of the equal opportunity clause.

e. The bidder or proposer, if he has 100 or more employees, and all subcontractors having 100 or more employees are required to submit the Government Employer Information Report SF 100 (EEO-1), within 30 days after award, unless such report has been filed within 12 months preceding award. The EEO-1 report is due annually on or before March 31.

10. CLEAN AIR AND WATER CERTIFICATION

(Applicable if the bid or offer exceeds $100,000 or ERDA has determined that orders under an indefinite quantity contract in any year will exceed $100,000, or a facility to be used has been the subject of a conviction under the Clean Air Act (42 USC 1857c-8(c) (1)) or the Federal Water Pollution Control Act (33 USC 1319 (c)), and is listed by EPA, or is not otherwise exempt.)

The bidder or offeror certifies as follows:

a. Any facility to be utilized in the performance of this proposed contract has / / has not /X/ been listed on the Environmental Protection Agency list of violating facilities.

b. He will promptly notify the Contractor, prior to award, of the receipt of any communication from the Director, Office of Federal Activities, U. S. Environmental Protection Agency, indicating that any facility which he proposes to use for the performance of the Contract is under consideration to be listed on the EPA list of violating facilities.

c. He will include substantially this certification, including this paragraph c., in every non-exempt subcontract.

11. MINORITY BUSINESS ENTERPRISE

The offeror represents that he / / is /X/ is not a minority business enterprise. A minority business enterprise is defined as a "business, at least 50 percent of which is owned by minority group members or, in case of publicly owned businesses, at least 51 percent of the stock of which is owned by minority group members." For the purpose of this definition, minority group members are Negroes, Spanish-speaking American persons, American-Orientals, American-Indians, American-Eskimos, and American-Aleuts.

12. DISCLOSURE STATEMENT--COST ACCOUNTING PRACTICES AND CERTIFICATION

Any subcontract in excess of $100,000 resulting from this solicitation except (1) when the price negotiated is based on (a) established catalog or market prices of commercial items sold in substantial quantities to the general public, or (b) prices set by law or regulation, or (2) subcontracts which are otherwise exempt (see 4 CFR 331.30(b) and FPR §1-3.1203(a)(2)) shall be subject to the requirements of the Cost Accounting Standards Board. Any offeror submitting a proposal, which, if accepted, will result in a subcontract subject to the requirements of the Cost Accounting Standards Board must, as a condition of contracting, submit a Disclosure Statement as required by regulations of the Board. The Disclosure Statement must be submitted as a part of the offeror's proposal under this solicitation (see (I) below) unless (i) the offeror, together with all divisions, subsidiaries, and affiliates under common control, did not receive net awards exceeding the monetary exemption for disclosure as established by the Cost Accounting Standards Board (see (II) below); (ii) the offeror exceeded the monetary exemption in the Federal fiscal year immediately preceding the year in which this proposal was submitted but, in accordance with the regulations of the Cost Accounting Standards Board, is not yet required to submit a Disclosure Statement (see (III) below); (iii) the offeror has already submitted a Disclosure Statement disclosing the practices used in connection with the pricing of this proposal (see (IV) below); or (iv) postaward submission has been authorized by the Contracting Officer. See 4 CFR 351.70 for submission of a copy of the Disclosure Statement to the Cost Accounting Standards Board.

CAUTION: A practice disclosed in a disclosure statement shall not, by virtue of such disclosure, be deemed to be a proper, approved, or agreed to practice for pricing proposals or accumulating and reporting contract performance cost data.

CHECK THE APPROPRIATE BOX BELOW:

( ) I. Certificate of Concurrent Submission of Disclosure Statement(s)

The offeror hereby certifies that he has submitted, as a part of his proposal under this solicitation, copies of the disclosure statement(s) as follows: (i) original and one copy to the cognizant contracting officer; and (ii) one copy to the cognizant contract auditor.

DATE OF DISCLOSURE STATEMENT(S)	NAME(S) AND ADDRESS(ES) OF COGNIZANT OFFICER(S) WHERE FILED
______________________	______________________
______________________	______________________

The offeror further certifies that practices used in estimating costs in pricing this proposal are consistent with the cost accounting practices disclosed in the disclosure statement(s).

(X) II. Certificate of Monetary Exemption

The offeror hereby certifies that he, together with all divisions, subsidiaries, and affiliates under common control, did not receive net awards of negotiated national defense prime contracts totaling $30 million or more during Federal Fiscal Year 1971; and did not receive net awards of negotiated national defense prime contracts subject to Cost Accounting Standards totaling more than $10 million in any of the Federal Fiscal Years 1972, 1973, 1974, or 1975; and net awards of negotiated national defense prime contracts and subcontracts subject to Cost Accounting Standards totaling more than $10 million in Federal Fiscal Year 1976, or in any subsequent Federal fiscal year preceding the year in which this proposal was submitted.

CAUTION: Offerors who submitted or who currently are obligated to submit a Disclosure Statement under the filing threshold established by the Cost Accounting Standards Board for a Federal fiscal year prior to the one immediately preceding the year in which this proposal was submitted may be eligible to claim this exemption if they have received notification of final acceptance of all deliverable items on all their prime contracts and subcontracts containing the Cost Accounting Standards clause.

( ) III. Certificate of Interim Exemption

The offeror hereby certifies that (i) he first exceeded the monetary exemption for disclosure, as defined in (II) above, in the Federal fiscal year immediately preceding the year in which this proposal was submitted, and (ii) in accordance with the regulations of the Cost Accounting Standards Board (4 CFR 351.40(f)), he is not yet required to submit a Disclosure Statement. The offeror further certifies that if an award resulting from this proposal has not been made by March 31 of the current Federal fiscal year, he will immediately submit a revised certificate to the Contracting Officer, in the form specified under (I) above or (IV) below, as appropriate, to verify his submission of a completed Disclosure Statement.

CAUTION: Offerors may not claim this exemption if they are currently required to disclose because they exceeded monetary thresholds in Federal fiscal years prior to Fiscal Year 1976. Further, the exemption applies only in connection with proposals submitted prior to March 31 of the year immediately following the Federal fiscal year in which the monetary exemption was exceeded.

( ) IV. Certificate of Previously Submitted Disclosure Statement(s)

The offeror hereby certifies that the Disclosure Statement(s) were filed as follows:

DATE OF DISCLOSURE STATEMENT(S)	NAME(S) AND ADDRESS(ES) OF COGNIZANT OFFICER(S) WHERE FILED

The offeror further certifies that practices used in estimating costs in pricing this proposal are consistent with the cost accounting practices disclosed in the Disclosure Statement(s).

13. ADDITIONAL COST ACCOUNTING STANDARDS APPLICABLE TO EXISTING CONTRACTS--CERTIFICATION

a. Cost accounting standards will be applicable and effective as promulgated by the Cost Accounting Standards Board to any award as provided in the Federal Procurement Regulations Subpart 1-3.12. If the offeror presently has contracts or subcontracts containing the Cost Accounting Standards clause, a new standard becomes applicable to such existing contracts prospectively when a new contract or subcontract containing such clause is awarded on or after the effective date of such new standard. Such new standard may require a change in the offeror's established cost accounting practices, whether or not disclosed. The offeror shall specify by an appropriate entry below, the effect on his cost accounting practice.

b. The offeror hereby certifies that an award under this solicitation / / would, / / would not, in accordance with paragraph a.(3) of the Cost Accounting Standards clause require a change in his established cost accounting practices affecting existing contracts and subcontracts.

NOTE:

If the offeror has checked "would" above, and is awarded the contemplated contract, he will also be required to comply with the clause entitled "Administration of Cost Accounting Standards."

Firm: Geothermal Power Corporation

Frank G. Metcalfe

Name: Frank G. Metcalfe Date 5-27-77

Title: President

Section 7.

Reasons for ERDA's Serious Consideration of Proposal

REASONS FOR ERDA'S SERIOUS CONSIDERATION OF PROPOSAL

The Company believes there are two main reasons for ERDA's support of its program: (1) to significantly expand the Roosevelt Hot Springs steam field; and (2) to test the heat source.

1. Geothermal Power Corporation leasehold contains 1,200 acres within the Roosevelt Hot Springs K.G.R.A.; 7,520 acres adjacent to and immediately south of the K.G.R.A.; 1,440 acres adjacent to and immediately east of the K.G.R.A.; and 3,371 acres adjacent to and northeast of the K.G.R.A.

A successful steam well in any of these directions would significantly expand the scope of the known steam reservoir. A step out production well from commercial wells drilled by Phillips Petroleum in one of three directions (1-1/2 miles to the east -Sec. 25 T26 S R9W; 2 miles to the east - Sec. 13, T27 S R9W; or 2-1/2 miles to the south - Sec. 34 T27 S R9W) is presently contemplated. The results of the heat flow wells will serve to site the deep test.

2. The GeothermEx report (Page 20) under "Heat Source" states that the existence of a significant volume of Pleistocene silicic volcanics in the Mineral Mountains suggest that a buried pluton is the most likely heat source. D. D. Blackwell (Southern Methodist University) has estimated a 3.5 square mile pluton centered about two miles directly south of the southern-most productive geothermal well.

A differing view held by Dr. S. H. Ward and associates Dr. R. B. Smith and W. P. Nash of the University of Utah is that an intrusive center covers some 3.5 square miles in the Mineral Mountains from Bearskin Mountain to North Twin Flat Mountain. As postulated by Dr. Ward, in a paper presented at Golden, Colorado (September 1976), "There is a good possibility of a magma chamber in the Mineral Range between Bearskin Mountain and North Twin Flats." Dr. Ward said to Frank G. Metcalfe in personal communication, that they were 90% sure that this area is the heat source supplying the Roosevelt Hot Springs geothermal field. Dr. Ward's theory on heat source is indicated by published data of Nash; Olsen and Smith; Crebs and Cook (Petrology report, Volume 1, (Nash); and Earthquake Survey Report, Volume 4, (Olsen and Smith); and also Gravity and Ground Magnetic report, Volume 6, (Crebs and Cook).* For either theory (GeothermEx and Dr. Blackwell - or the University of Utah's - Dr. S. H. Ward), acreage held by Geothermal Power Corporation falls on or is immediately adjacent to the center of the presumed heat source. The Company proposes to test one or both of these hypothesis, and believes that deep drilling is warranted.

*Several exerpts from Crebs and Cook are as follows:

1. "Petrologic work has indicated the possible formation of a magna chamber at a depth of 1.6 km in the area near Bearskin Mountain (this depth is with respect to the top mountain, Nash, 1976)"

2. "Olson (1976 personal communications) has noted that a recording station in Ranch Canyon failed to detect well-developed shear-wave phases from 70% of the events with the epicenters at

Cove Fort. It may be important to note that the ray path from Cove Fort to Ranch Canyon passes through a gravity low associated with the rhyolite domes existing in the central part of the mineral range. A magna chamber beneath these volcanic domes may act as a "soft" zone, which would also accentuate the S-wave pattern.

3. A northward-trending residual gravity low (of about 2-mgal closure extending about 7 km southward along a series of volcanic domes including Bearskin, Little Bearskin, North TWin Flat, and South Twin Flat Mountains) which indicates a mass defficiency of about 10^{11}kg with a shallow depth-to-center of about 1.4 km beneath the volcanic domes. This residual gravity low may possibly indicate a low-density, paleo-magma chamber, but more geological and geophysical work is recommended in order to more fully explain this anomalous feature."

Section 8.

Timing of Phases

TIMING OF PLANS

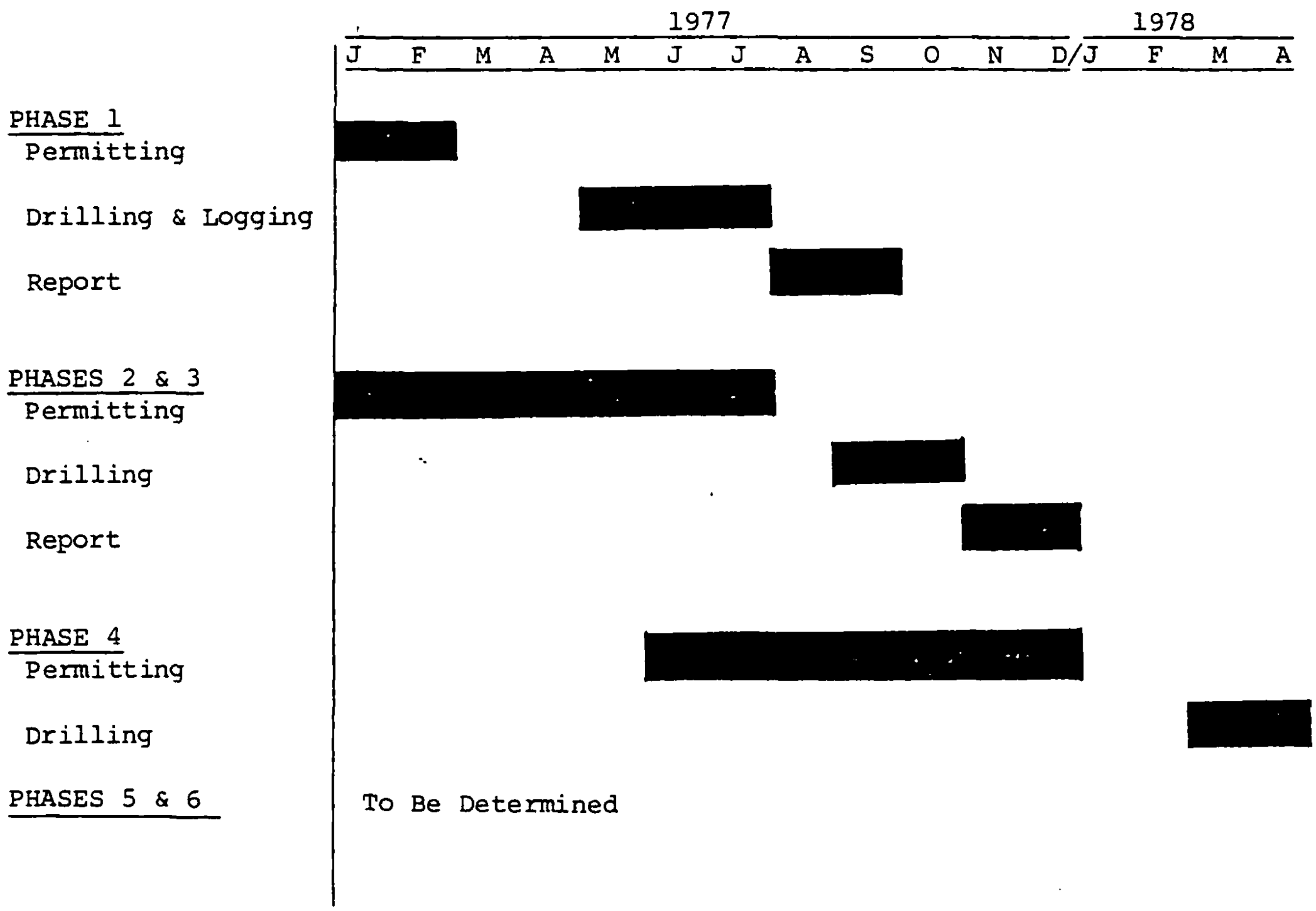
Geothermal Power Corporation is presently conducting Phase I. Vic's Drilling of Beaver, Utah, is at present drilling approximately 15 temperature gradient holes. GeothermEx will measure the temperature gradients. Robin Davis, geologist, is logging the wells. Dr. Dave Blackwell of Southern Methodist University will calculate rock conductivity and heat flow measurements. Calculated results and the final report are expected to be available by August 1977.

The Company has applied to drill two 2,000-foot observation holes in February, 1977 (Phase 2 and Phase 3). Approval of these wells is expected soon, and spudding of the wells should take place in mid-summer, 1977.

Siting of the first deep test hole (Phase 4) is dependent upon the results of the heat flow and observation wells. However, to accelerate the programs, the Company has prepared and will submit applications for approximately six production wells. We believe that the information obtained from Phases 1, 2 and 3 will be encouraging enough to allow a "go ahead" on one (or more) of the six locations previously applied for.

NOTE: Phase 5 and 6 may be either confirmation wells or additional tests if Phase 4 is a dry hole.

Critical Path



Section 9.

Cost Breakdowns

WILLIAM N. HATHAWAY
PETROLEUM ENGINEER
6840 GRANT AVENUE
CARMICHAEL, CA 95608
(916) 944-3884

GEOTHERMAL POWER CORPORATION

Thermal Gradient Hole

Location: Roosevelt KGRA, Beaver County, Utah.

Take all measurements from top KB.
Keep hole full at all times.
Check operation of BOE each round trip or daily.

Drilling Program.

1. Drill 13-3/4" hole to 80'+ to fit 10-3/4" conductor. Cement 10-3/4" conductor at 80'+ with Class B cement treated with 2% $CaCl_2$ to fill annulus to cellar floor. Run 2 centralizers. Use oilfield cementing equipment to mix and displace cement.
2. Land 10-3/4" conductor. Install 10" bag type preventer.
3. Run 9-7/8" bit. Close preventer and test with 100 psig. Drill 9-7/8" hole to 650'+ to fit 7" casing.
4. Cement 7", 20#, K-55, buttress casing at 650'+ with 200 sacks Class B cement premixed 1:1 perlite, 2% gel, 40% silica flour (150% excess). Run guide shoe with insert fillup. Tack weld and Bakerlok bottom 4 collars, weld shoe solid. Use top rubber plug and plug holding head. Bump plug on shoe. Run centralizers 15', 80' & 160' above shoe.
5. After 4 hours (or cement is firm), land 7" casing. Test weld with 1000 psig. Install 6" gate valve, 6" Series 900 Shaffer double hydraulic control gate and Hydril GK. All preventers to be equipped with high temperature rubber. Test each preventer, casing, kelly cock, blowdown line and kill line with 1000 psig. for 5 minutes each. Notify Utah Division of Water Rights to witness preventer tests 3 days in advance of testing (Cedar City 801-586-4231). Enter test results on tour sheets.
6. Drill 6¼" hole to 2000'. Run Induction, Sonic, Density, Temperature build up logs as ordered. Abandon well placing cement plugs as ordered.
7. Install mud logging service at shoe of 10-3/4" conductor. Record continuous mud in and out temperatures, H_2S, CH_4, lithology and drilling rate. Have pit level recorder and intercom to drillers station. Take 2 sets W&D samples every 5'.
8. Run angle survey and maximum thermometers every 200'.
9. Drilling fluid: Milford City water adding gel, weight, lost circulation material, sodium chloride as required.

May 25, 1977

WILLIAM N. HATHAWAY
PETROLEUM ENGINEER
6840 GRANT AVENUE
CARMICHAEL, CA 95608
(916) 944-3884

GEOTHERMAL POWER CORPORATION

Thermal Gradient Hole, Beaver County, Utah

Drilling Cost Estimate

Drilling rig: Move in and out	$ 15,000
10 days @ $3500	35,000
Casing: 80' of 10-3/4"	1,000
650' of 7"	5,000
Wellhead	1,000
Location and clean up	10,000
Drilling mud	5,000
Bits, reamers, stabilizers	6,000
Cement and cementing services	15,000
Mud logging	4,000
Electric and temperature logging	6,000
Water	3,000
Tool rentals	2,000
Trucking	5,000
Supervision	3,000
Contingencies	14,000
Total cost, abandoned	$ 130,000

This estimate is an estimate only and there is no guarantee, either express or implied, that actual costs will be equal to, larger, or smaller than estimated.

REGISTERED PROFESSIONAL ENGINEER
WILLIAM NEIL HATHAWAY
No. 1129
PETROLEUM
STATE OF CALIFORNIA

May 25, 1977

WILLIAM N. HATHAWAY
PETROLEUM ENGINEER
6840 GRANT AVENUE
CARMICHAEL, CA 95608
(916) 944-3884

GEOTHERMAL POWER CORPORATION

Exploratory Geothermal Well

Location: Roosevelt KGRA, Beaver County, Utah.

Take all measurements from top KB.
Keep hole full at all times.
Check operation of BOE each round trip or daily.

Drilling Program

1. Drill 26" hole to 80'+ to fit 20" conductor. Cement 20", 94#, H-40 conductor at 80'+ with Class B cement treated with 2% $CaCl_2$ to fill annulus to cellar floor. Run two centralizers. Use oilfield cementing equipment to mix and displace cement.
2. Land 20" conductor. Install 20" bag type preventer.
3. Run 17½" bit. Close preventer and test with 100 psig. Drill 17½" hole to 650'+ to fit 13-3/8" casing.
4. Cement 13-3/8", 54½#, K-55, buttress casing at 650'+ with 500 sacks Class B cement premixed 1:1 perlite, 2% gel, 40% silica flour (150% excess). Run guideshoe with insert fillup. Tack weld and Bakerlok bottom 4 collars, weld shoe solid. Use top rubber plug only and plug holding head. Bump plug on shoe. Run centralizers 15', 80' & 160' above shoe.
5. After 4 hours (or cement is firm), land 13-3/8" casing. Weld on 12" Series 900 geothermal wellhead. Test weld with 1000 psig. Install 12" gate valve, 12" Series 900 Shaffer double hydraulic control gate and Hydril GK. All blowout preventers on this well to be equipped with high temperature packing elements. Test each preventer, casing, kelly cock, valves and check valve in kill and blowdown lines to 1000 psig. for five minutes each. Notify Utah Division of Water Rights to witness preventer tests 3 days in advance of testing (Cedar City 801-586-4231). Enter test results on tour sheets.
6. Drill 12¼" hole to 1800'+ to fit 9-5/8" casing. Run Induction, Sonic and Density logs as ordered.
7. Cement 9-5/8", 40#, K-55, buttress casing at 1800'+ with 750 sacks Class B cement premixed with 1:1 perlite, 2% gel, 40% silica flour and 0.3-0.4% retarder (200% excess). Run fillup shoe and fillup collar on top of shoe joint. Tack weld top and bottom of bottom 4 collars, weld shoe solid. Use top and bottom rubber plug and plug holding head. Centralize 40' above shoe and every 5th joint thereafter. Have manufacturer install centralizer units in geothermal wellhead prior to cementing.

8. Land 9-5/8" casing. Manufacturer install 12" Series 900 by 10" Series 600 geothermal casing expansion spool. Test packoff with 1000 psig. Install 10" gate valve, two Shaffer double hydraulic control gates, Hydril GK and rotating head. All equipment to have high temperature elements. Test all blowout preventers, casing and valving as before. Test pressure 1000 psig. for 5 minutes each. Notify Utah DWR to witness preventer tests. Enter test results on tour sheets.

9. Drill 8½" hole to total depth, estimated at 6-8,000'. Conventional cores may be taken as ordered. Run wireline logs as ordered. Complete or abandon.

10. Survey hole angle every 2-300' on dull bits. Drillable wing stabilizers are to be run in 12¼" and 8½" holes, and 17½" hole if required. Run drill pipe float valve at all times and have "wet plug" with valve in open position on floor at all times.

11. Install mud logging service at shoe of 20" conductor. Record continuous mud in and out temperature, H_2S, CH_4, lithology and drilling rate. Have pit level recorder and intercom to drillers station. Take two sets W&D samples every 10' above 1800' and every 5' below 1800'. Mail daily copies of the mud log as ordered.

12. Mud program.

Surface-650'.	Water and gel, 8.3-9.0 ppg.
650'-TD	Milford City water. Add sodium chloride, weight material, lost circulation material as required.

13. Run and record maximum recording thermometers on each survey angle run.

May 25, 1977

WILLIAM N. HATHAWAY
PETROLEUM ENGINEER
6840 GRANT AVENUE
CARMICHAEL, CA 95608
(916) 944-3884

GEOTHERMAL POWER CORPORATION

Exploratory Geothermal Well, Beaver County, Utah.

Drilling Cost Estimate

In event of a dry hole

Drilling rig: Move in and out	$ 30,000
45 days @ $4000	180,000
Casing: 80' of 20"	4,000
650' of 13-3/8"	15,000
1800' of 9-5/8"	28,000
Wellhead	20,000
Location and clean up	20,000
Drilling mud	25,000
Bits, reamers, stabilizers	60,000
Cement and cementing services	60,000
Coring	5,000
Electric and temperature logging	20,000
Mud logging	17,000
Water	15,000
Tool rentals	20,000
Trucking	25,000
Supervision	15,000
Contingencies	41,000
Dry Hole Costs	$ 600,000

Completion Costs

Wellhead		$ 50,000
Testing		50,000
Less: Rig time - 2 days	$ 8,000	
Abandon Cement	10,000	(18,000)
Total cost, completed		$ 682,000

This estimate is an estimate only and there is no guarantee, either express or implied, that actual costs will be equal to, larger, or smaller than estimated.

REGISTERED PROFESSIONAL ENGINEER
WILLIAM NEIL HATHAWAY
No. 1129
PETROLEUM
STATE OF CALIFORNIA

May 25, 1977

BIG CHIEF DRILLING COMPANY

May 17, 1977

Mr. Frank Metcalf
Geothermal Power Corporation
P. O. Box 1186
Novato, CA 94947

Re: Steam Well Cost Estimate
Hot Springs Area
Beaver County, Utah

Dear Mr. Metcalf:

In figuring on the estimate on the above captioned test, I assumed the well depth would be 7500' and the rig would be on location for a total of 35 days. The total estimate cost to drill a dry hole or a production well without completion cost would be $382,850.00.

This figure includes rig labor, supervision, moving the rig in and out, contractor's rate for his rig, rat and mouse hole, cellar, conductor hole, drill pipe inspection, drill collar inspection, bits, trucks, cranes, reserve pit, rig fuel, water, corrosion inhibitor, miscellaneous rentals, miscellaneous trucking, casing tools for surface pipe, and casing tools for intermediate pipe.

It does not include conductor pipe, intermediate casing or production casing, cement, and cementing services, mud, well logging, and well supervision and any other items not above mentioned.

I hope this will be of some benefit to you. However, we do not have a rig available and this is not a bid but it is based on today's cost only.

Should you have any questions concerning the above, please advise.

Very truly yours,

BIG CHIEF DRILLING COMPANY

W. A. Glass

W. A. Glass
President

P. O. BOX 14837, OKLAHOMA CITY, OKLAHOMA 73114 PHONE 405/843-5721, TELEX: 74-7150

WAG:psj

VIC'S DRILLING CO., INC.

ROTARY RIG

Victor McCann — Beaver, Utah 84713

Ph. 438-2370 — Box 189 — 20 S. 100 W.

NAME Geothermal Power Corp.

ADDRESS c/o Frank Metcalf

1127 Grant Ave. Suite 6 Riverside Calif.

Date 3-17, 1977 Salesman

DOMESTIC & IRRIGATION WELLS — TEST HOLES — GRAVEL PACKED WELLS

Quantity	Description	Amount
Approx.	15 Holes from 300' to 500 ft deep @ 3.00 per ft.	
	Price includes running 1" plastic pipe	
	to depth specified by Frank Metcalf	

Vic Snelson [illegible]

Frank B. Metcalf

Section 10.

Resumes of Independent Consultants

GeothermEx 901 MENDOCINO AVE.
BERKELEY, CA. 94707

JAMES B. KOENIG (415) 524-9242
MURRAY C. GARDNER (503) 482-2605

GEOTHERMEX, INC.

Resumes

Statement of experience

GeothermEx, Inc.

GeothermEx, Inc. was established in 1973 to supply consultant services for exploration and development of geothermal resources. Its staff consists of geologists, geochemists, geohydrologists and geophysicists, all with large experience in geothermal studies. In addition, GeothermEx has the capacity of drawing on an associated group of geothermal engineers and scientists to supply specific experience for specific jobs.

The staff and associates of GeothermEx have worked on geothermal projects for the United Nations, in Ethiopia, Kenya, and El Salvador, as well as for government agencies in Costa Rica, El Salvador, Mexico, the Azores and the United States. In addition to this, GeothermEx has participated in exploration in all of the major thermal systems of the United States on behalf of numerous industrial and commercial clients. Besides, individual staff and associates have studied geothermal systems in Italy, New Zealand, Indonesia, Egypt and other parts of the world.

GeothermEx supplies its own equipment for geochemical, hydrological and heat-flow surveys of geothermal systems. A large part of this equipment has been specifically designed by the personnel of GeothermEx. This enables accuracy and rapidness in field measurements and in reporting of data.

GeothermEx, Inc.

Here is a partial list of our clients:

U. S. Bureau of Reclamation
U. S. Atomic Energy Commission
Pacific Power and Light Company
Sacramento Municipal Utility District
Northern California Power Administration
Phillips Petroleum Company
Occidental Petroleum Company
Geoscience Institute of the Azores
Anschutz Corporation
Instituto Costarricense de Electricidad
U. S. National Science Foundation
Oregon Institute of Technology
AMAX Exploration, Inc.
Rogers Engineering Company, Inc.
U. S. Fish and Wildlife Service
Cornell, Hayes, Howland & Merrifield
U. S. Environmental Protection Agency
United Nations
Chevron Oil Company
Hunt Oil Company
Sun Oil Company
Shell Oil Company
Pacific Energy Corporation
Thermal Power Company
C. F. E. of Mexico
C. E. L. of El Salvador
Salaverria Duran y Co.
University of California
Dow Chemical U. S. A.
Bechtel Corporation
Aerojet Nuclear Company
LVO Corporation
Weyerhauser Company

Our fields of expertise include:

- selection of target areas
- reconnaissance evaluation
- geological and photogeological mapping
- hydrological monitoring
- geochemical field surveys
- geoelectrical and electromagnetic surveys
- gravity surveys
- microseismic analyses
- thermal-gradient and heat-flow surveys
- planning of drilling programs
- interpretation of drilling logs
- administration of budgets
- environmental analyses
- preparation of reports

GeothermEx, Inc.

Project Description

1. PROJECT

Geothermal Exploration, South-Central Oregon

2. WORK PERFORMED BY GEOTHERMEX

Design of exploration program (30,000 km^2 area)
Geologic mapping of selected areas (1,500 km^2) at 1:62,500 and 1:24,000 scale
Geochemical survey of springs and wells (10,000 km^2)
Isotope survey of selected waters
Electrical resistivity surveys (dipole-dipole, roving dipole, electromagnetic and Schlumberger equatorial) (200 km^2)
Gravity survey of large region (3,500 km^2)
Drilling and logging of thermal gradient wells (over 1,000 meters of drilling)
Analysis and interpretation of all data
Preparations of reports, maps, cross-sections, tables, including specifications for deep drill holes

3. DATE INITIATED

June 1972

4. DATE COMPLETED

March 1976

5. LOCATION OF PROJECT

Klamath Falls, Oregon and vicinity

6. CLIENTS

Pacific Power and Light Company
Weyerhauser Company

7. APPROXIMATE COST

Greater than $500,000

8. PERTINENT FACTS

Project began with detailed literature search and reconnaissance evaluation of an area of 30,000 km^2, within which six targets were selected for detailed exploration; grading criteria were established; priorities set up; and exploration methodology and budget designed for each target.

GeothermEx, Inc.

PROJECT DESCRIPTION

1. PROJECT

Phase 1, Exploration, Guanacaste Geothermal Project, Costa Rica

2. WORK PERFORMED BY GEOTHERMEX

Design of exploration program (500 km^2 area)
Selection and importation of necessary equipment and supplies
Management of exploration time-table
Supervision and review of field work by Instituto Costarricense de Electricidad (geologic mapping at 1:50,000; hydrological survey and geochemical sampling of 500 km^2; gravity survey of 500 km^2; electrical resistivity soundings to 1 km depth; drilling and logging of 35 temperature-gradient holes, totaling 2,700 meters in depth)
Analysis and interpretation of all data
Preparation of final reports, maps, tables, including recommendations for deep drill sites

3. DATE INITIATED

November 1975

4. DATE COMPLETED

October 1976

5. LOCATION OF PROJECT

Las Pailas and Las Hornillas, Guanacaste Province, Costa Rica

6. CLIENT

Instituto Contarricense de Electricidad

7. APPROXIMATE COST

Greater than $400,000

8. PERTINENT FACTS

Project began with establishment of criteria for defining exploration targets; followed by field review of several areas, from which Las Pailas and Las Hornillas were selected for detailed study.

GeothermEx, Inc.

PROJECT DESCRIPTION

1. PROJECT

Geothermal Exploration of Modoc Plateau, California

2. WORK PERFORMED BY GEOTHERMEX

Detailed geologic mapping (250 km^2 at 1:24,000 and 1:10,000)
Geoelectrical surveys (roving dipole and Schlumberger equitorial soundings)
Selection of deep drill sites
Geochemical sampling and analysis (5,000 km^2)
Logging of deep exploratory hole.
Preparation of reports, maps, cross-sections

3. DATE INITIATED

October 1974

4. DATE COMPLETED

January 1976

5. LOCATION OF PROJECT

Northeastern California

6. CLIENT

Dow Chemical, U. S. A.

7. APPROXIMATE COST

$100,000

8. PERTINENT FACTS

First reconnaissance phase was based upon thorough literature survey and rapid field survey of springs and wells, collecting temperature, temperature-gradient, and chemical data. Included detailed evaluation of existing aeromagnetic and gravity data.

GeothermEx, Inc.

PROJECT DESCRIPTION

1. PROJECT

AMAX Geothermal Mapping Project

2. WORK PERFORMED BY GEOTHERMEX

Mapping of geothermal target areas at 1:24,000 scale
Photogeologic mapping at 1:20,000 and 1:60,000
Sampling of springs, wells and streams for geochemical analyses
Interpretation of data
Preparation of reports, maps, cross-sections, including recommendations for gradient hole sites
Hydrologic monitoring of geothermal systems

3. DATE INITIATED

June 1974

4. DATE COMPLETED

January 1977

5. LOCATION OF PROJECT

The Geysers, California; Calistoga, California; Bieber, California; La Grande, Oregon; Roosevelt Hot Springs, Utah

6. CLIENT

American Metal Climax, Inc. (AMAX)

7. APPROXIMATE COST

Greater than $100,000

8. PERTINENT FACTS

Included compilation of climatologic (rainfall, runoff, evapo-transpiration geologic and hydrologic (recharge areas, major aquifers, porosities, permeabilities of selected rock units, piezometric surface) and water chemistry data for geothermal prospects prior to field investigations.

GeothermEx, Inc.

PROJECT DESCRIPTION

1. PROJECT

Location and evaluation of geothermal anomalies

2. WORK PERFORMED BY GEOTHERMEX

Literature surveys of geologically attractive regions
Rapid field reconnaissance (sampling springs and wells, photogeology, temperature surveys in wells)
Synthesis and integration of data
Preparation of reports, maps, tables, listing and grading targets for exploration

3. DATE INITIATED

September 1972

4. DATE COMPLETED

Still underway

5. LOCATION OF PROJECT

Geothermal regions of Idaho, Oregon, California, Nevada, Utah and Montana

6. CLIENTS

Sun Oil Company
Phillips Petroleum Company
and others

7. APPROXIMATE COST

Greater than $100,000

8. PERTINENT FACTS

Includes large portions of southern California, central Nevada, and adjacent southwestern Utah. Includes reconnaissance report prepared for U. S. Bureau of Reclamation, Salt Lake City, Utah, December 1972, amongst many others.

GeothermEx, Inc.

PROJECT DESCRIPTION

1. PROJECT

Geochemical-hydrological survey, Sao Miguel Island, The Azores

2. WORK PERFORMED BY GEOTHERMEX

Evaluation of geothermal manifestations
Hydrological Surveys (800 km^2)
Geochemical surveys (800 km^2)
Preparation of maps, reports

3. DATE INITIATED

August 1976

4. DATE COMPLETED

December 1976

5. LOCATION OF PROJECT

Sao Miguel Island, The Azores, Portugal

6. CLIENT

Geosciences Institute of the Azores

7. APPROXIMATE COST

Greater than $30,000

8. PERTINENT FACTS

Included compilation of hydrological, climatological and geological data for synthesis and integration with geochemical results. Began with survey of existing literature, reconnaissance selection of targets for sampling. Included sampling of 65 thermal and non-thermal springs, 15 fumaroles and solfatoras.

DR. JAMES B. KOENIG

POSITION: President of GeothermEx, Inc., consultants for exploration and development of geothermal resources. Seventeen years of experience as geologist, twelve of which have been spent in geothermal exploration. Previous work has been with the State of California and the U. S. Geological Survey.

SPECIALTIES:
- Reconnaissance evaluation of geothermal prospects
- Geology of geothermal and volcanic regions
- Interpretation of geothermal exploration data

EDUCATION:
B. S., Brooklyn College, 1954, Geology
M. A., Indiana University, 1956, Geology
Ph. D., University of Nevada, 1972, Geology

PERTINENT EXPERIENCE:

Supervised the geothermal exploration program and selected the sites for deep wells for the Instituto Costarricense de Electricidad, Costa Rica, 1975-76.

Organized and managed a program of geothermal exploration in southern Oregon for Pacific Power and Light Company and Weyerhauser Company, 1972-75.

Performed photogeology and carried out the field geochemical reconnaissance of geothermal resources in the Afar region, Ethiopia, for the United Nations, 1971.

Evaluated the potential for the development of geothermal resources in Ahuachapan, El Salvador, for Salaverria Duran y Cia., 1968-69.

Advised the United Nations on problems concerning geothermal field development, disposal of residues from geothermal wells, El Salvador, 1971.

Geologic mapping, geochemical sampling, and gravity surveys, Coso Hot Springs, California, for the U. S. Navy, 1967-69.

Evaluated the potential of the geothermal exploration sites in sixteen states of the United States for various private companies and government agenies, 1970-75.

DR. JAMES B. KOENIG

Supervised geological mapping, hydrological and hydrogeochemical surveys, and geophysical surveys in the west of the United States for numerous private companies, 1972-75.

Determined the sites of deep exploratory geothermal wells in California, Oregon and Nevada for private companies, 1974-75.

Reconnaissance evaluation of geothermal targets, Central America, Southeast Asia, Eastern United States.

Directed geochemical exploration of Sao Miguel Island, The Azores, for Government of Portugal, 1976.

Participated as speaker in the United Nations Symposium on the Development and Use of Geothermal Resources in Pisa, Italy in 1970 and in San Francisco, California in 1975; invited as speaker to various symposia on geothermics, 1972-76; member of the Editorial Board, Geothermics, 1971-76.

MEMBERSHIPS:

Geothermal Resources Council, Vice President
International Association of Volcanology
American Geophysical Union
Geological Society of America

SELECTED PUBLICATIONS:

Geothermal Explorations in the Western United States: Geothermics, v. 2, pt. 1, 1-13 (paper read at the United Nations Symposium on the Development and Use of Geothermal Resources, Pisa, Italy, 1970)

The Geysers, California, Geothermal Field: California Division of Mines & Geol. Mineral Information Service, v. 22, No. 8, 123-128, 1969.

The Salton-Mexicali Geothermal Province: California Division of Mines & Geol. Mineral Information Service, v. 20, No. 7, 75-81, 1967.

Remote Sensing at the Coso Geothermal Field: U. S. Navy NWC, TP-5233, 1972.

Geothermal Steam Potential of Mount Lassen: Guidebook of the Sacramento Geologic Society, 43-51, 1968.

DR. JAMES B. KOENIG

Worldwide Status of Geothermal Resources Development in "Geothermal Energy: Resource, Production, Stimulation", C. Otte and P. Kruger, eds., Stanford Press, 1973, p. 15-58.

Environments of Geothermal Resources: paper presented to American Association of Petroleum Geologists, May 1976.

Distribution of Mercury in Two Geothermal Fields, Ahuachapan, El Salvador and Coso Hot Springs, California (abstr.): Geol. Soc. Amer. Program with Abstracts, v. 1, No. 5, 1969.

United Nations - Ethiopia Report on the Geology, Geochemistry and Hydrology of Hot Springs in the East African Rift System in Ethiopia, 175-274, 1971.

PERSONAL DATA:

Born November 23, 1932, New York, U. S. A.
Married, 3 children
Reads and speaks Spanish, reads French

DR. MURRAY C. GARDNER

POSITION: Vice President of GeothermEx, Inc., consultants in exploration and development of geothermal resources. Eighteen years of experience as geohydrologist and geochemist, seven of which have been spent in geothermal exploration. Previous work has been with Teledyne Isotopes, Inc., the U. S. Geological Survey, and as an Associate Professor at Southern Oregon College.

SPECIALTIES:

- Geohydrology of volcanic and geothermal regions
- Geochemical field surveys of volcanic and geothermal regions
- Structural geology of the active volcanic regions
- Logging of test holes in geothermal terrain
- Injection tests on geothermal wells

EDUCATION:

B. S., Brooklyn College, 1953, Geology
Ph. D., University of Arizona, 1962, Geology, Geochemistry

PERTINENT EXPERIENCE:

Design and supervision of the geochemical and geohydrological survey program in Guanacaste Province, Costa Rica, for the Instituto Costarricense de Electricidad, 1975-76.

Made hydrogeochemical field surveys in the volcanic and thermal regions of northeastern California and south-central Oregon and interpreted the analytical data, 1971-72, 1975-76.

Made geochemical and geohydrological surveys on the island of Sao Miguel in The Azores for the Geosciences Institute of The Azores, 1976.

Prepared an hydrological analyses of thermal areas in eastern California and Nevada for numerous private companies, utilizing isotopic determinations of $^{18}O/^{16}O$, D/H and Tritium, 1968-71.

Designed and carried out isotope tracer programs as part of the reinjection study in deep wells, Ahuachapan geothermal field, El Salvador, for the United Nations, 1971.

Supervised collection of gas samples following nuclear detonations, Nevada Test Station, for U. S. Atomic Energy Commission and Teledyne Isotopes, Inc., 1956-67.

DR. MURRAY C. GARDNER

Studied the reservoir capacity, geology and geochemistry of volcanic tuffs and lavas, western United States, for the U. S. Geological Survey, 1962-63.

Carried out petrographic studies of thermal gradient well cuttings, Oregon and California, 1962 and 1972.

Mapped portions of the active volcanic regions of Alaska, Oregon and California, 1963, 1967-68.

Logged geothermal wells, Imperial Valley, California, for private companies, 1960-61.

SLECTED PUBLICATIONS:

Effects of Tracer Injection Test and Evaluation of Deep Well Injection of Geothermal Fluids at the Ahuachapan, El Salvador, Geothermal Field: Report to the United Nations, 1971.

Final report on Geochemical Exploration of the Klamath Basin Area, Oregon, 1972: Report to Pacific Power and Light Co. - Weyerhauser Co., January 1973.

Geochemical Parameters in Geothermal Exploration in Oregon: Paper presented to the Oregon Academy of Sciences, April 1976.

Geothermal Hydrology and Chemistry, Goose Lake Basin, California-Oregon: Report to Hunt Oil Company, May 1975.

SELECTED AFFILIATIONS:

Geothermal Resources Council
Oregon Academy of Sciences

PERSONAL DATA:

Born October 5, 1932, New York, U. S. A.
Married, 2 children
Reads French and Spanish

DR. DAVID D. BLACKWELL

POSITION: Associate Professor of Geophysics, Southern Methodist University and Geophysical Associate of GeothermEx, Inc., consultants in exploration and development of geothermal resources. Nine years experience in heat-flow geophysics.

SPECIALTIES:

- Heat-flow studies of geothermal and volcanic regions
- Thermal gradient and conducting measurements in drilled holes
- Interpretation of gravity and magnetic data in geothermal and tectonically active regions

EDUCATION:

B. S., Southern Methodist University, 1963, Geology - Mathematics
M. A., Harvard University, 1965, Geophysics
Ph. D., Harvard University, 1967, Geophysics

PERTINENT EXPERIENCE:

Supervised the drilling program of gradient wells and measurements of thermal gradients and heat-flow, Guanacaste Geothermal Project, Costa Rica, 1975-76.

Explored heat-flow anomaly, Marysville, Montana, by means of drilling and logging thermal gradient and heat-flow holes, 1970-74.

Conducted heat-flow studies in southern part of Mexico, in cooperation with Comision Federal de Electricidad, 1971-75.

Made studies of geothermal gradient in the volcanic plains of Idaho and Oregon under grant from State of Idaho, 1971-74.

Measured head-flow and radioactivity in specially drilled holes, northwestern United States, 1969-71.

Lectured at California Institute of Technology and Southern Methodist University on theory of heat transfer; regional geophysics of North America; interpretation of gravity and magnetic data, 1967-75.

Participated in United States - Italy Geothermal Seminar, 1973; United Nations Symposium on Development and Utilization of Geothermal Resources, 1970; Geological Society of American Symposium on Heat-Flow, Cenozoic Tectonics and Geothermal Power, 1973.

DR. DAVID D. BLACKWELL

Measured heat-flow, Yellowstone Lake, Yellowstone National Park, 1973-75.

Designed thermistor and thermocouple probes for use in thermal gradient studies, 1972-73.

SELECTED MEMBERSHIPS:

American Geophysical Union
Geological Society of America
Geothermal Resources Council

SELECTED PUBLICATIONS:

Heat Generation of Plutonic Rocks and Continental Heat-Flow Provinces: Earth Planet. Sci. Letters, v. 5, p. 1-12, 1968 (co-author).

Heat-Flow in the Northwestern United States: Jour. Geophys. Res., v. 74, p. 992-1007, 1969.

Continental Heat-Flow, in "The Nature of the Solid Earth", E. C. Robertson, ed., McGraw-Hill Book Co., N. Y., p. 506-543, 1972.

Progress Report on Geothermal Measurements in Oregon: Ore. Bin, v. 35, p. 6-7, 1973.

Heat-Flow in a Blind Geothermal Area near Marysville, Montana: Geophysics, v. 38, p. 941-956, 1973.

Thermal Studies of the Boulder Batholith and Vicinity, Montana: Soc. Econ. Geol. Guidebook for the Butte Meeting, p. 1-8, 1973 (co-author).

The Areal Distribution and Geophysical Significance of Heat Generation in the Idaho Batholith and Adjacent Intrusives in Eastern Oregon and Western Montana: Geol. Soc. Amer. Bull., v. 84, p. 1261-1282, 1973 (co-author).

Terrestial Heat-Flow and Its Implication on the Location of Geothermal Reservoirs in Washington, in Energy Resources of Washington: Wash. Dept. Nat. Res. Circular 20, p. 21-33, 1974.

Heat-Flow Studies in Geothermal Areas: Geol. Soc. Amer. Abs. With Programs, v. 6, p. 657, 1974.

Geologic and Geophysical Exploration at Marysville Geothermal Area: National Science Foundation Tech. Rept. NSF-RA-N-740316, 1974 (co-author).

DR. DAVID D. BLACKWELL

PERSONAL DATA:	Born September 10, 1944, Arkansas, U. S. A. Married, 2 children Reads Spanish.

GeothermEx, Inc.

DR. CHRISTOPHER W. KLEIN

POSITION: Geologist with GeothermEx, Inc., consultants in geothermal exploration and development. Two years experience in geochemistry and geology of geothermal systems.

SPECIALTIES:
- Geochemistry of geothermal and volcanic regions
- Temperature logging of geothermal holes
- Petrography of well cuttings and cores

EDUCATION:
B. A., Chemistry, University of California, 1966
Ph. D., Geology, Harvard University, 1975

PERTINENT EXPERIENCE:

Supervision of laboratory procedures, interpretation of analytical data, Sao Miguel Island geochemical project, for Geosciences Institute of The Azores, 1976.

Logging of temperature in wells drilled in Oregon, Nevada and California, 1975-76, private companies.

Geological mapping, volcanic terrain, northern California.

Petrography of cuttings and cores, geothermal regions of Oregon, California and Costa Rica.

Data searches and compilations, geothermal areas of Nevada, 1977.

Sampling of waters and gases in geothermal regions and interpretation of hydrochemical data, California, Oregon and in The Azores.

SELECTED MEMBERSHIPS: Geological Society of America

SELECTED PUBLICATIONS: Chemistry of Thermal and Non-Thermal Waters, Volcanic Lava Plateaus of Northeastern California and Southern Oregon: presented at 2nd EPA Symposium on Geothermal Fluids, Las Vegas, February 17, 1977.

PERSONAL DATA:
Born May 1945, San Francisco, California, U. S. A.
Married, one child
Speaks and reads Spanish, reads German

MR. JAMES R. McINTYRE

PRESENT POSITION: Geologist with GeothermEx, Inc., consultants in geothermal exploration and development, since 1974; a total of six years experience in geothermal exploration.

EXPERTISE: Mr. McIntyre has worked in evaluation of geothermal resources since 1971. He has specialized in geologic field mapping; photogeology of geothermal areas; evaluation of subsurface geologic data; structural geology of the western United States.

EDUCATION: B. A., Geology, Occidental College, 1947
M. A., Geology, University of California, 1950

PAST EXPERIENCE: Mr. McIntyre's earlier experience includes fifteen years (1950-1965) in petroleum exploration, with Standard Oil of California and Franco Western Oil Company, in the western United States, Libya and The Phillipines. His work included regional stratigraphic and structural geology, detailed subsurface geology, and supervision of field parties.

He has also taught geology at Humboldt State College and Southern Oregon College (1965-71).

More recently, Mr. McIntyre served with the Oregon State Department of Geology, mapping and evaluating geothermal areas of southern Oregon, and with Fugro, Inc. and Shannon and Wilson, studying geologic aspects of power plant siting.

EXAMPLES OF PERTINENT EXPERIENCE:

- Photogeologic mapping of geothermal prospects in Oregon, California and Costa Rica.
- Field geology of geothermal areas in northeastern California and southern Oregon.
- Collection and interpretation of geologic and geophysical logs, oil and gas tests in prospective geothermal areas, Oregon, Idaho, Utah, Nevada and California.
- Field reconnaissance of geothermal targets in Nevada, Utah and Idaho.
- Compilation of geologic and geophysical data for Klamath Falls geothermal region.

CAROL ANN PETERSEN

POSITION: Geothermal geologist for GeothermEx, Inc. Ms. Petersen has five years of experience in geothermal exploration and development, mostly with the Utah Geological Survey and the University of Utah.

EDUCATION:
B. A., Geology, University of Oregon, 1970
M. S., Geology, University of Utah, 1975

PERTINENT EXPERIENCE:

Evaluation of geothermal prospects, southern California, for private client, 1977.

Geologist, Research Branch of the Utah Geological and Mineral Survey, 1972-77.

Geologic mapping of Roosevelt Hot Springs area. Helped evaluate potential geothermal resources of the Bonneville Salt Flats area. Designed program for regional assessment of low- and moderate-temperature geothermal resources of State and designed site-specific exploration programs for several prospects.

Represented the State of Utah at the Second United Nations Symposium on Development and use of Geothermal Resources, in San Francisco, May, 1975.

Participated in research on the chemical and physical properties of the lake brines and problems created by rising lake stage, Great Salt Lake.

SELECTED PUBLICATIONS:

Petersen, C. A., 1973, Roosevelt and Thermo Hot Springs, Beaver County, Utah: in Geology of the Milford Area, 1973, Utah Geological Association Publication 3, p. 73-74.

Petersen, C. A., 1974, Summary of stratigraphy in the Mineral Range, Beaver and Millard Counties, Utah: Utah Geology, v. 1, p. 45-50.

Whelan, J. A., and Petersen, C. A., 1974, Bonneville Salt Flats--A Possible Geothermal Area?: Utah Geology, v. 1, p. 71-82.

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CAROL ANN PETERSEN

Whelan, J. A., Nash, W. P., Parry, W. T., and Petersen, C. A., 1975, Design of exploration systems with application to Roosevelt KGRA, Utah (abstr.): Abstracts of the Second United Nations Symposium on the Development and Use of Geothermal Resources, abstract number II-55.

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Petersen, C. A., 1975, Geology of the Roosevelt Hot Springs Area, Beaver County, Utah: Utah Geology, v. 2, p. 109-116.

Whelan, J. A. and Petersen, C. A., 1976, Lithium Resources of Utah: U. S. Geological Survey, Professional Paper.

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PETROLEUM ENGINEER
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CARMICHAEL, CA 95608
(916) 944-3884

Professional Experience of William N. Hathaway

Age: 47 years
Bachelor of Engineering in Petroleum Engineering,
University of Southern California, 1952.
Registered Professional Engineer, State of California,
Petroleum No. 1129.
Member: American Petroleum Institute.
Society of Petroleum Engineers of AIME.
Past President, Sacramento Petroleum Association.

Experience

Consulting Engineer, Sacramento, California. 11 years.
Supervise and design drilling and completion programs for oil, natural gas and geothermal wells. Supervise producing operations. Perform appraisals for sale, purchase or inheritance. Negotiate sales contracts. Analyze and/or originate drilling prospects.

E. L. Doheny, Operator. 4 years.
Division engineer and District manager for California operations of independant oil and gas producer.

Amerada Petroleum Corporation, Rio Vista, California. 7 years.
District engineer in charge of California's largest gas field.

Partial list of clients

United States Government, Beale Air Force Base
Natomas Exploration, Inc.
Hilliard Oil & Gas, Inc.
Dow Chemical Company
Thermal Power Company
Tri-Valley Oil & Gas Company
Cordova Chemical Company (Division of Aerojet General)
E. I. duPont de Nemours & Company
Seaboard Oil & Gas Company
Montara Petroleum Corporation
Hale Brothers and Associates

May 25, 1977

PRESENTATION OF QUALIFICATIONS

GENE M. SKINNER

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RESUME OF QUALIFICATIONS

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OBJECTIVE: o DRILLING ENGINEERING SUPERINTENDENT o

SUMMARY OF QUALIFICATIONS:

Unique background with several years successful experience in Drilling and Exploration Management, Petroleum Production Management, Electronic Design and Systems Engineering. Have effectively been able to use my electronic background in the design and use of sophisticated drilling and petroleum production systems.

Petroleum Industry Experience

Experience in the petroleum industry includes direct supervision of drilling operations (oil, gas and geothermal) . . . consulting functions relative to drilling . . . land base operations . . . off-shore operations . . . both domestic and foreign assignments.

Drilling and Exploration

Experience includes the coordination of wire line surveys . . . pressure and temperature analysis functions relative to zoning and testing . . . land survey . . . the design, writing and implementation of complete programs that encompass start-up operations to completion to final producting testing including fluid and casing programs.

Production

Experience includes work-over oil and gas well service . . . pump changes . . . parted sucker rod, swabbing, and sand pumping . . . remedial programs . . . casing recovery . . . well abandonment . . . operation of REDA and B-J down hole pumps . . . and the set up and check out of REDA and B-J control power panels.

Electronic Design

Electronic Design experience includes digital computer circuit design . . . development of diagnostic software to isolate programming and logic problems . . . system simulation design . . . flow charting sub-routine programs, scaling, binary, octal and decimal conversions.

Performed other functions such as equipment/component evaluation . . . operator training . . . interfaced with production relative to start-up, modification and quality control . . . supervised and coordinated electronic instrumentation installation . . . and more.

Please turn to Page Two ....

SUMMARY OF QUALIFICATIONS: (cont'd)

Systems Engineering Applications
Performed O.E.M. Application engineering functions . . . marketing of O.E.M. . . . training of representatives . . . system analysis . . . feasibility studies piping analysis . . . production process instrumentation analysis . . . pump station analysis . . .

Experienced with transmission systems . . . lact systems . . . metering systems . . . hydraulic systems . . . AC/DC power systems . . . and more.

EMPLOYERS:

7/74 to Present	Drilling Engineering Superintendent	(Major Company)
8/72 to 7/74	Engineering Technical Advisor (Drilling Superintendent)	P.T. COMSERVE Djakarta, Indonesia
11/71 to 8/72	Manager - Design Engineering/ Oil Field Equipment	SOUTHEAST ASIA PETROLEUM SERVICE Singapore
4/69 to 11/71	Manager - Production Process Division	AVERY - LAURENCE Singapore
1958 to 1968	Member - Research & Development	ROCKWELL INTERNATIONAL (Computer & Data Systems Div.)

EDUCATION:

- University of California; Los Angeles, California
  BSEE -- 1963
- National Technical Engineering Schools; Los Angeles, California
  ASEE -- 1958

PERSONAL:

Born: June 6, 1932 . . . 6' 1" . . . 185 lbs. . . Married, 1 child

. . . Excellent Health . . . Willing to Travel/Relocate . . .

REFERENCES:

Excellent personal and professional references available upon request.

Section 11.

GeothermEx Report

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JAMES B. KOENIG (415) 524-9242
MURRAY C. GARDNER (503) 482-2605

GEOTHERMAL POTENTIAL OF THE LANDS LEASED BY GEOTHERMAL POWER CORPORATION IN THE NORTHERN MINERAL MOUNTAINS, BEAVER AND MILLARD COUNTIES, UTAH

for

GEOTHERMAL POWER CORPORATION

by

GeothermEx, Inc.

January, 1977

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ILLUSTRATIONS

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CONCLUSIONS

1. Geothermal Power Corporation has leases on several sections of land with potential to be within the Roosevelt Hot Springs geothermal field. Of most interest are Sec. 13, 24, 25, 33, 34, and 35, T. 27 S., R. 9 W.; Sec. 25, T. 26 S., R. 9 W.; and Sec. 19, T. 26 S., R. 8 W.

2. Other acreage in Milford Valley or on the eastern slope of the Mineral Mountains is frankly speculative, and does not require exploration to the same degree that is warranted for sections listed above or adjacent thereto.

3. The Roosevelt geothermal field is characterized by production of chloride-rich hot water from fractured crystalline gneiss, schist and possibly granite, at temperatures to 260°C (500°F). Holes have encountered this reservoir at depths of 1,250 to 7,500 feet.

4. Both Phillips Petroleum Co. and the Natomas Company have commercially producible wells in the areas. Numerous large and very many small companies have acquired adjacent acreage in a major geothermal exploration boom.

5. Exploration has included geologic mapping, hydrochemistry, seismic, gravimetric, aeromagnetic and geoelectric surveys, and the drilling of numerous temperature-gradient holes. The latter, plus gravimetry and geology, appear to be most useful in determining whether and where to drill deep exploratory holes. However, the shallow thermal-gradient anomaly appears to be displaced downslope slightly from the principal geothermal reservoir.

6. Gravity data suggest the presence of a molten or high-temperature intrusion beneath several square miles of the Mineral Mountains.

7. It is unlikely that further attractive acreage can be leased in the area. Farm-outs or joint ventures, and pooling of acreage with other small companies, appear to be useful exploration strategies. Trade of exploration data is useful.

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8. Electric-power potential found to date by drilling probably is between 50,000 and 100,000 kW. Phillips expects to install 110 mW of generating capacity by 1982.

9. Exploration results suggest that drilling will proceed to the east and southeast, entering higher elevations of the Mineral Mountains. Geothermal Power Corporation thus has lands directly in the path of exploration.

RECOMMENDATIONS

1. Sites for 10 to 20 300-foot-deep gradient holes are selected (plate 1) on the more attractive of Geothermal Power Corporation's acreage.

2. Auxiliary geologic work and radiometric age-dating of volcanic rocks is recommended to help interpret results from gradient drilling.

3. A single 2,000-foot gradient hole, or two 1,000-foot holes may be warranted, depending upon results from the shallow gradient survey.

4. Trade of gradient and age-dating data with other companies is recommended as a means of optimizing value received for exploration dollars.

5. Joint venture or pooling of lands is recommended where other companies hold adjoining acreage of similar prospective value. Lands held by Geothermal Exploration Co., Getty Oil Company, and O'Brien Gold Mines are within this classification.

6. Selection of a deep drill site would follow thereupon.

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INTRODUCTION

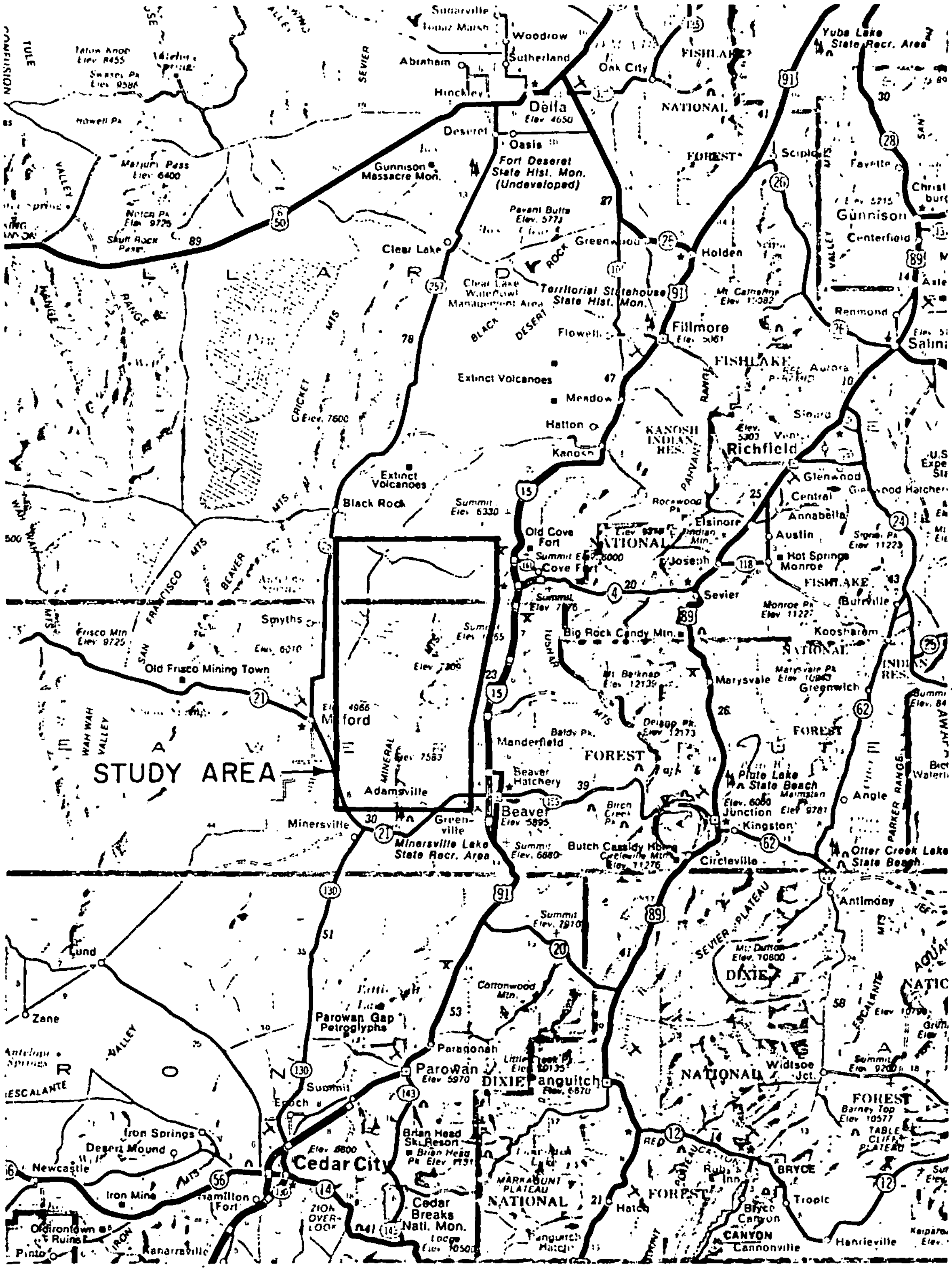
Location

This report deals with the geology, geophysics, and geothermal potential of the northern Mineral Mountains, located in Beaver and Millard Counties, Utah (figure 1). More specifically, it concerns the commercial geothermal energy potential of lease holdings of the Geothermal Power Corporation, which total some 39 sections (approximately 25,000 acres) spread over some 8 townships (plate 1).

These holdings may be grouped into several separate blocks: parts or all of 17 sections are located on the west flank of the Mineral Mountains, near Ranch and Corral Canyons and extending westward to the bottom of Milford Valley, around Milford; 5 sections are within the range, between Bailey and North Twin Flat Mountains; and 12 sections are on the east side of the mountains, in the northwest arm of Beaver Valley. In addition, nearly a dozen contiguous sections extend across the northernmost Mineral Mountains, from 5 to 8 miles north of the southern block.

Milford, with a population of about 1,500 people, is the most important town in the area. The main line of the Union Pacific Railroad traverses Milford Valley en route between Los Angeles and Salt Lake City, and passes through the town. The area is also served by State Highway 21, connecting Beaver, Minersville, and Milford. Highway 257 connects Milford and Delta. Numerous farm roads, mine roads and desert tracks also traverse the lowlands and lower slopes of the mountains. Because of past mining and present-day geothermal exploration, access into the higher elevations is good, except during winter.

Electric utility service is provided to the Milford area by the Utah Power and Light Company. Their line passes within a few miles of the project area. California-Pacific Utilities Company serves an extensive area farther south. If significant amounts of power were to be generated in the project area, it could be transmitted to distribution centers outside the area via moderate to high-voltage lines extending from Sigurd, Utah, 50 to 70 miles away.



LOCATION OF STUDY AREA

FIGURE 1

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Physiography, Climate, and Land-Use

The project area is in the eastern part of the Basin and Range province. The main physiographic features of the area are north-trending, fault-bounded, Mineral Mountains; the Milford Valley section of Escalante Desert, which flanks it on the west; and Beaver Valley on the east. Basically, the physiographic framework was defined by Late Cenozoic normal faulting. It has been modified by both constructional and erosional features. Rhyolite domes and flows have been extruded through the Mineral Mountains, in the area between Bearskin Mountain on the north and Twin Flat Mountain on the south. The drainage pattern within the range is one of numerous intermittent streams flowing in steep-sided canyons trending mainly east or west from the crest. Streams are longer on the west than on the east flank. Erosion has caused the western range front to recede by a mile or more from the western range-bounding fault zone. The fault zone along the east front seems to be closer to the present topographic escarpment (plate 1).

Extensive coalescing fans on the range flanks lead down into the adjacent valleys on the east and west. During Pleistocene time, an arm of Lake Bonneville intermittently occupied the Milford Valley up to an altitude of about 5,120 feet. During high-water phases, deltas, bars and spits were built into the lake. However, the most notable of these lie outside the area of this report.

Holocene faulting along the eastern edge of Milford Valley has formed a system of small horsts and grabens in fan materials in Ranch Canyon and Negro Mag Wash. Total vertical displacement reaches 150 to 200 feet, along a 3-mile reach. The width of the grabens is less than a quarter of a mile (Mower and Cordova, 1974). Ranch Canyon, and to a lesser extent Negro Mag Wash, have been incised into the fan gravels at the front of the range. This is probably a result of both uplift of the range and fluctuations in base level with that of Lake Bonneville.

Hot springs have built low mounds of siliceous sinter and silica-cemented gravel along the range front. The most notable of these mounds is near the center of the north line of section 16, T. 27 S., R. 9 W. This and other hot-springs deposits lie along the Dome fault, one of the recently active faults mentioned above (Petersen, 1975).

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Elevations within Milford Valley range from about 4,900 feet at the Beaver River to about 6,000 feet at the valley edge. Beginning at the range front, relief is high, rising to a general summit elevation of 7,000 to 8,000 feet within a distance of 3 or 4 miles. The maximum elevation is 9,582 feet, at Milford Needle.

The chief stream in the region is the Beaver River, which rises in the Tushar Mountains east of Beaver Valley. It flows westward across that valley and through the gap between the southern Mineral Mountains and the Black Mountains, to Minersville. It then flows northward through the Milford Valley, past Milford, to Beaver Bottom. Here, any remaining water is lost to underflow. Due to the diversion of water for irrigation, the river usually is dry below Minersville.

The climate of the study area is characterized by warm, dry summers and cool winters. Mean annual temperature at Milford is 49°F. Annual precipitation is less than 10 inches in the valleys, but ranges up to about 25 inches in the higher mountains. Precipitation occurs principally as snowfall in winter, but there are occasional summer thunderstorms.

Stock raising is the principal land-use in the area, although there is irrigated farming in the valley around Milford. Mining was of some limited importance in the past, but no mines now are active in the Mineral Mountains. The Union Pacific railroad maintains extensive facilities in Milford.

GEOLOGY

Regional Setting and History

The project is located in the transition zone between two geologic provinces, each with a distinct character and history. The basic tectonic framework of the region was established in Precambrian time. West of the project area, Precambrian rocks of the Utah-Nevada province comprises a thick sequence of slightly metamorphosed quartzite, carbonate rocks and argillite ranging in age from 1.0 to 0.6 billion years. To the east, beneath the Colorado Plateau, Precambrian basement of the Churchill province consists of crystalline schist, gneiss, and other high-grade metamorphic rocks; ages in this suite range

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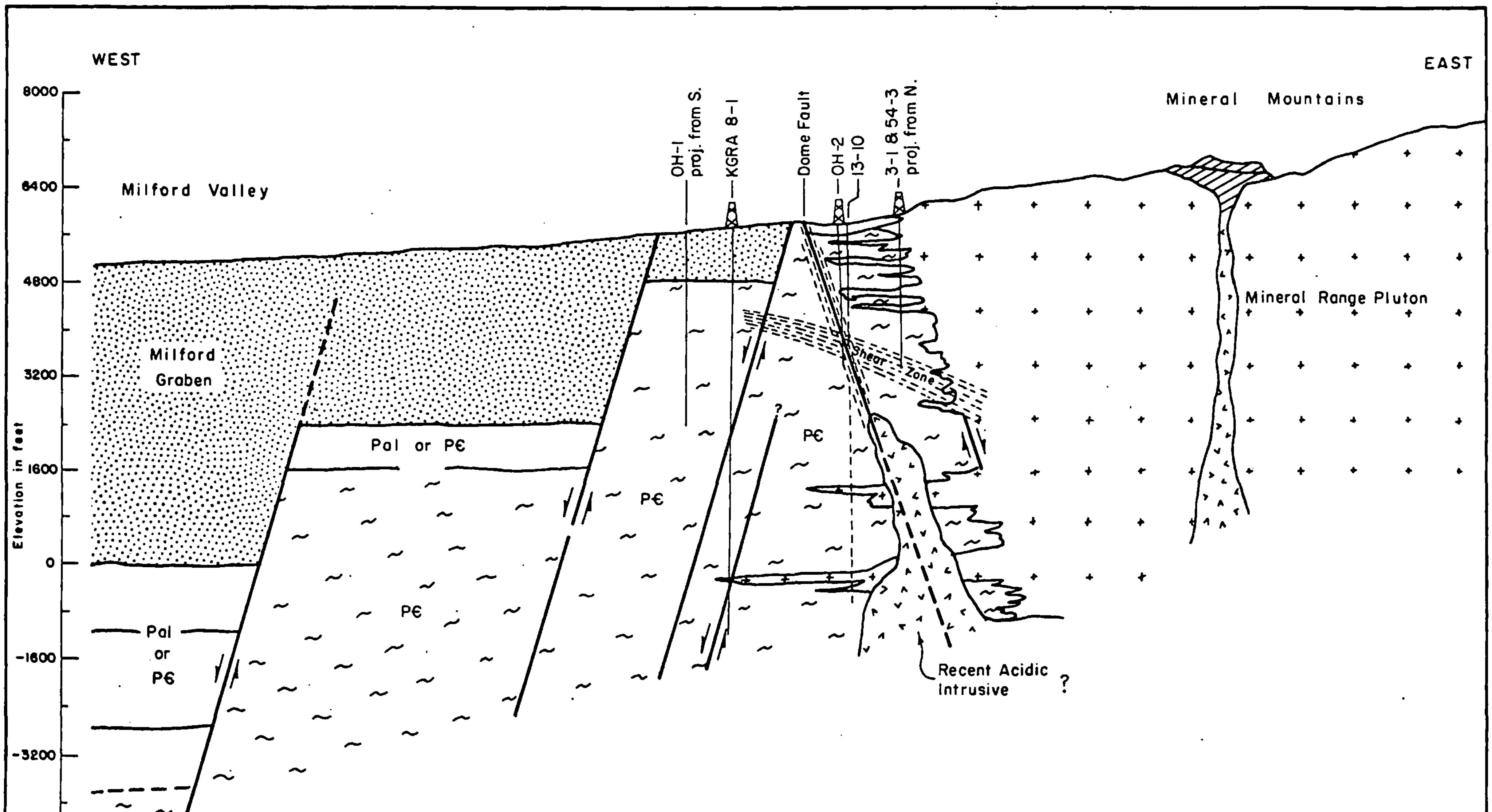
fron 1.8 to 1.6 billion years. Rocks of probable Precambrian age in the Mineral Mountains appear to belong to the Colorado Plateau province, on the basis of lithology, and may represent the western edge of that province.

From Cambrian to Triassic time, the main regional tectonic provinces were the cordilleran miogeosyncline in eastern Nevada and western Utah, and a crational area to the east, under the Colorado Plateau. Stratigraphic sections (table 1) in both the Mineral Mountains and Star Range indicate that the project area lay within and immediately east of the transition zone between these two provinces (figures 2 and 3 and plate 2). Depositional history during this long time-span comprises episodes of marine transgression, during which sedimentation extended eastward over the craton; and of regression, when deposition was confined to the axial regions of the geosyncline. The most extensive deposits are those of Cambrian, Upper Devonian, Lower Mississippian, Pennsylvanian, Permian and Triassic time; the least extensive deposits are those of Ordovician, Silurian, Lower and Middle Devonian and Upper Mississippian time.

Throughout this long Paleozoic-Early Mesozoic interval, the main rock types deposited were limestone, dolomite and quartz arenites. Shales were laid down only during brief intervals.

Based on very limited deep drilling for oil and gas in the region, it appears that most of the Paleozoic sedimentary rocks in this interval lack primary porosity. Any significant porosity now existing is likely the result of fracturing, or solution-channel development (in carbonate rocks). Furthermore, the limited amounts of shale in the section would seem to be insufficient to form cap rocks or to break hydraulic continuity within the carbonate sequence. Thus, it is likely that fluid storage capacity exists throughout the entire section, and there is no reason to anticipate that one part of this sequence has more attractive reservoir potential than another. Rather, reservoir may be best developed where there is most active tectonism.

By Middle Triassic time, deposition in both the miogeosynclinal and cratonal areas had become continental in type. A short-lived seaway was established in Middle to Late Jurassic time.



GEOLOGIC CROSS-SECTION THROUGH THE MINERAL MOUNTAINS AND ROOSEVELT HOT SPRINGS GEOTHERMAL FIELD

Redrawn from Phillips Petroleum Co., Sept., 1976, Field Guide to Roosevelt Hot Springs.

FIGURE 2

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Table 1. Stratigraphy of the Mineral Mountains
(adopted from Condie, 1960)

Period	Epoch	Thickness (ft)	Formation
Quaternary		0 - 3,500	lake beds, terrace gravels, alluvium
		0 - 2,000	Ranch Canyon Volcanics - rhyolite flows & tuffs
Tertiary	Oligocene	0 - 2,500	andesite flows & agglomerate; quartz latite tuffs, flows & agglomerate
	Eocene	--	Claron Formation - conglomerate
Jurassic	Upper	570	Carmel Formation - argillaceous limestone
	Middle	1,540	Navajo Sandstone - massive cross-bedded
Triassic	Lower	600 - 1,000	Moenkopi Formation (upper member - red (ss, sh, siltstone
		570	Moenkopi Formation (middle limestone
		140	Moenkopi Formation (lower member - sh, (siltstone
Permian	Lower?	700	Kaibab Limestone - massive, cherty
		1,180	Talisman (Coconino?) Quartzite - cross-bedded
Mississippian	Upper	915	Topache (Redwall) Limestone - massive, crinoidal
Lower Paleozoic		2,700+	Undifferentiated limestone & dolomite
Cambrian	Upper & Middle	1,300+	Undifferentiated limestone
	Middle	100	Pioche Shale
	Lower	775	Prospect Mountain Quartzite
Precambrian	Lower?		Whitehorse Canyon Series - biotite schist & gneiss

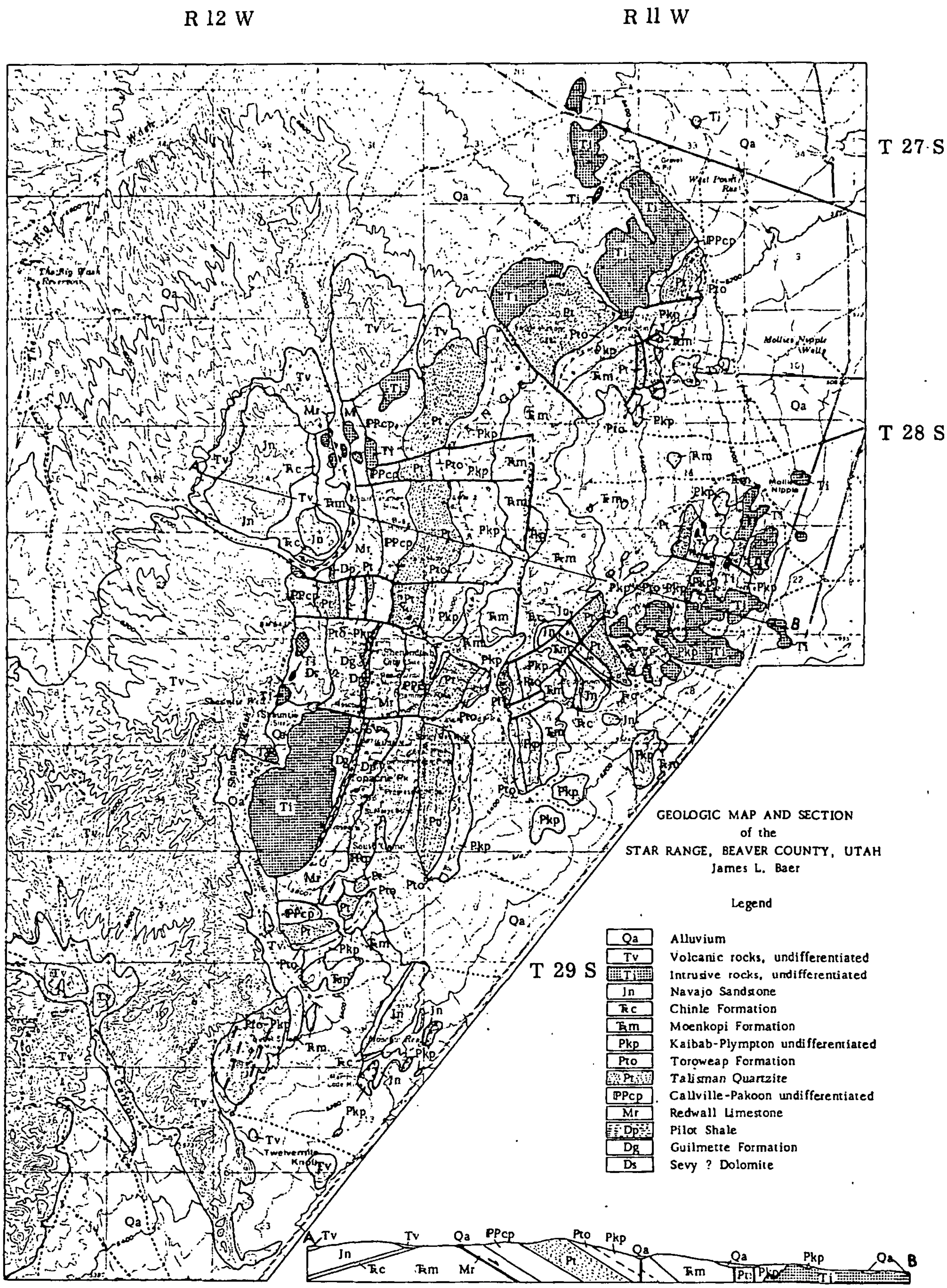

Figure 3. Geologic map and section of the Star Range , Beaver County , Utah . (from Baer , 1973)

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Called the Twin Creek-Arapien Sea, it extended from Montana, through Wyoming and Idaho, southward into central Utah. Deposits of this sea are present in the Mineral Mountains, but have not been recognized farther to the west.

During Cretaceous time the old Paleozoic miogeosyncline to the west of the project area was uplifted and deformed. Some of the major structures developed in this period are extensive low-angle thrust faults, which developed along the transitional zone between the Paleozoic miogeosyncline and the craton. This faulting resulted in the east to southeastward displacement of large sheets of miogeosynclinal rocks over cratonal or transition zone areas. One such fault enters the project area in the northern Mineral Mountains. To the east of the zone of thrusting, less-intense deformation produced folding and minor thrusting in the rocks of the transition zone and foreland (craton). Although obscured by later intrusion and a cover of younger rocks, folding of this period has been recognized in the southern Mineral Mountains (Condie, 1960).

East of the major zone of uplift and deformation in central Utah, a major new seaway was established in Upper Cretaceous time. Large amounts of clastic deposits were transported eastward from the deformed belt into this basin, but none of these sediments have been recognized in the project area.

In Early Cenozoic time, the region was the site of deposition of extensive fluvial and lacustrine sediments. Conglomerates of this age are present in the southern Mineral Mountain and they may be present elsewhere beneath the graben valleys bordering the range. In upper Eocene to Oligocene time, the fluvial and lacustrine phase was followed by onset of the igneous activity which characterizes the later Cenozoic history of the region.

The major Cenozoic volcanic episodes began with the eruption of thick and extensive rhyodacitic welded tuff in Oligocene time (30-28 m.y.). These were followed by tuffs and volcanic breccias of Oligocene-Miocene age (25-19 m.y.). All of these volcanic rocks appear to have originated at eruptive centers outside the limits of the study area. A considerable thickness of these deposits is present at the south end of the Mineral Mountains and in the adjacent Black Mountains. Regionally, these deposits appear to thin in a northerly

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direction. They are not exposed in the northern part of the Mineral Mountains uplift and they may not be present beneath the adjacent graben valleys.

The Cenozoic igneous history of the Mineral Mountains is dominated by intrusion of the granitic stock which makes up the bulk of the range. This is the largest of the exposed Tertiary stocks in Utah. The age of this pluton is variously reported to be 9.2 m.y. (Armstrong, 1970) and 15.5 ± 1.5 m.y. (Park, 1968). However, these ages may be too young, as a result of subsequent reheating during Late Tertiary or Quaternary volcanic phases; if so, the intrusion may belong to one of the intrusive episodes represented in adjacent areas by stocks which were emplaced in the 27-28 m.y. and 20-22 m.y. time intervals. All of the proposed ages of the pluton are too old to permit the known parts of the body to act as a heat source for local geothermal manifestations. Quaternary intrusions at depth have been postulated by geologists with Phillips Petroleum Company and by others, including D. D. Blackwell (oral communication, 1976).

Late in Cenozoic time, there was a major episode of normal faulting in the region, resulting in the development of the present fault-block ranges and graben valleys. The Mineral Mountains are the easternmost of the typical basin-and-range mountain blocks at this latitude. Faulting along the west side of the range has continued at least into the Pleistocene epoch.

Concurrently with the climactic period of faulting, intermontane basins were occupied by lakes and were filled with great thicknesses of fluviatile and lacustrine sediments originating from the erosion of the adjacent range blocks. In Quaternary time, an arm of Lake Bonneville occupied the Milford Valley. These valley-filling sediments contain aquifer gravels as well as fine-grained impervious materials. The latter may serve as cap rocks to potential reservoirs at the valley margin.

Local volcanic activity continued sporadically in the region throughout Late Cenozoic time. Examples in and adjacent to the project area are the basaltic eruptives of Cove Fort and northern Beaver Valley immediately east of the project area, and the rhyolite domes and flows in the Mineral Mountains. The ages of some of these rhyolite eruptives have been determined as ranging in age from 0.78 to 0.49 m.y. (Nash, 1976). The Cove Fort basalts probably range from about one million years to less than 20,000 years (Condie and Barsky, 1971).

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Several general conclusions can be drawn from the regional setting which have a bearing on the geothermal potential of the target.

1. As noted above, most of the pre-Late Cenozoic rocks in the region lack effective porosity and permeability unless they have been fractured. Thus, fractured rocks afford the most probable reservoir locations, and proximity to active fault zones appears to enhance this reservoir potential.

2. Regionally, impervious strata are lacking in parts of the section older than the Late Cenozoic basin fill. Thus, intercommunicating reservoirs may exist in large portions of these older rocks. In areas covered by valley-fill, such reservoirs may be capped by impervious Cenozoic lacustrine sediments.

3. There are two possible sources of heat in the region, and both may be factors in the project area: deep circulation of water along faults in this area of high regional geothermal gradients; and heating associated with local young intrusions. The first type of heating is probably the source of the minor thermal anomaly near Minersville. The second may be the principal mode at Roosevelt Hot Springs.

Stratigraphy

Only a small part of the stratigraphic column recognized elsewhere in the Mineral Mountains is present in the project area.

Precambrian(?) Whitehorse Canyon Series

These are mainly biotite gneiss, with minor associated schist and phyllite. The gneiss is about 50 percent biotite, 40 percent quartz, 8 percent orthoclase and 2 percent minor constituents. The Precambrian age assignment of these rocks is based on their metamorphic style and grade, and their lack of compositional similarity to any of the Paleozoic or younger rock types of the region.

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Rocks assigned to this series are exposed intermittently along the west side of the Mineral Mountains from the Millard County line southward for a distance of about 18 miles. They are in contact with the west side of the Mineral Mountains stock, and many blocks of gneiss have been engulfed in granite near the contact (Petersen, 1975).

Precambrian(?) rocks are overlain by alluvium along the edge of Milford Valley. Their relationship to and possible presence beneath the Paleozoic rocks elsewhere in the range is unknown.

Cambrian

Two Cambrian sections are present in the north end of the range. One of these is an allochthonous unit carried into the area from the northwest along a major thrust fault. The other section, below this thrust, may be autochthonous, although its relationship to Precambrian(?) and younger units is unknown.

The allochthonous section occurs along the crest of the range (in sec, 23, 28, 35 and 36, T. 25 S., R. 9 W.) as isolated klippen, and comprises a few hundred feet of Prospect Mountain Quartzite. A much more extensive thrust section is exposed in the Beaver Lake Mountains and San Francisco Mountains a few miles to the west of the project area. All of these isolated localities are believed to be parts of a formerly continuous geosynclinal-marginal thrust sheet.

The autochthonous section consists of the following units.

Prospect Mountain Quartzite. This unit is represented by about 775 feet of white to buff-colored, thick-bedded quartzite. The base of the section is not exposed. It is conformably overlain by Pioche Shale.

Pioche Shale. This unit is represented by about 100 feet of grey to greenish grey shale. Its thickness is similar to that encountered in the cratonal area to the east and is considerably less than that found in the geosynclinal areas to the west. This indicates that the section it occurs in is probably autochthonous.

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Undifferentiated Limestone and Dolomite. Limestones and dolomites of Middle and Upper Cambrian age conformably overlie the Pioche Shale. An incomplete section of these rocks is about 1,300 feet thick. Near the contact with the Mineral Range stock these rocks have been metamorphosed to tremolite marble.

Permian

Several small, isolated outcrops of Permian rocks occur along both the eastern and western edges of the Mineral Mountains intrusion, in the southern part of the project area.

Talisman (Coconino?) Quartzite. Outcrops of pure, well-sorted, medium-grained, cross-bedded arenite with siliceous cement occur in two localities in the project area. In the western locality, the base of the unit is covered by alluvium and, in the eastern, it is in contact with the granitic stock. In both localities it is overlain by the Kaibab Limestone. The section is thus incomplete at both localities, but exposures farther south in the range indicate that the complete section is about 1,180 feet thick.

The local name applied to this unit in the San Francisco mining district is the Talisman Quartzite. This is one of several cross-bedded quartz arenites which are apparently correlative with the better known Coconino Sandstone of the Grand Canyon area.

Kaibab Limestone. Overlying the Talisman Quartzite is a dense, bluish-grey, fossiliferous limestone (Kaibab). The section is incomplete in both of the localities noted above, but reaches about 900 feet in thickness in the southern part of the range. In many places, the Coconino-Talisman arenites and the Kaibab Limestone are separated by interbedded sandstone and carbonate rocks of the Toroweap Formation. The Toroweap is recognized in the Star Range, west of Milford, but has not been reported in the Mineral Mountains (Baer, 1973); in the Star Range, it includes gypsum.

The Kaibab Limestone sections in the project area are overlain by alluvium. In well-exposed sections farther south, and perhaps also in the project area beneath the valley fill, the Kaibab is overlain by a thick section of Mesozoic rocks (see plate 2).

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Near the contact with the east side of the Mineral Mountains stock, the Kaibab Limestone locally has been converted to a scheelite-bearing skarn (Hobbs, 1945).

Tertiary

Pliocene(?) Mineral Mountains granite. The central Mineral Mountains are made up largely of granite with composition as follows: 50 percent orthoclase, 25 percent oligoclase, 15 percent or more quartz and 5 percent or more biotite and magnetite (Condie, 1969). In outcrop, the pluton contacts Precambrian rocks on the west and Permian on the east. At its north edge, the granite intrudes Cambrian marble along an east-northeast-trending contact, which is parallel to and partly coincident with a steep aeromagnetic gradient (plate 4).

The age of the granite is reported to be 9.2 m.y. by Armstrong (1970) and 15.5 ± 1.5 m.y. by Park (1968). As noted earlier, both ages are younger than those of any other stocks known in the region, and may be erroneously low. The stock has been cut by numerous faults and dikes, and is intruded and overlain by Quaternary rhyolite.

Post-Intrusion Dikes. Rhyolite (dellenite) porphyry dikes, varying in thickness from 20 to 200 feet, cut the stock but are not known to intrude other rocks. These are composed of up to 65 percent quartz, with subordinate oligoclase and orthoclase. Minor amounts of biotite and magnetite are present in the ground-mass. The phenocrysts are mainly quartz and orthoclase.

The dikes occur both as steeply dipping and nearly horizontal sheets. They have an average strike of N. 45° W. (Condie, 1960). North-striking, steeply dipping, lamprophyre dikes occur throughout the length of the range. Many are porphyritic, containing up to 20 percent plagioclase phenocrysts. Their overall composition is 60 to 65 percent andesine, 20 to 30 percent brown hornblende, 8 to 10 percent magnetite, and minor apatite. The dikes show considerable alteration.

Condie (1960) reported that the lamprophyre dikes occur only along the west side of the pluton, and that the rhyolite dikes are present only on the east and south sides.

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Quaternary

Ranch Canyon Volcanics. These consist of rhyolite plugs, flows, and associated minor tuffs resting upon an erosional surface developed on the Mineral Mountains granite. The main eruptive centers were at North and South Twin Flat Mountain and Bearskin Mountain. Flows extend down the west side of the range from these eruptive centers. The basal part of the section includes local deposits of tuff and pumice up to 1,000 feet thick. These are overlain by rhyolite and rhyolite porphyry flows up to several hundred feet thick, then by obsidian and vitrophyre flows up to 60 feet thick, and finally by more rhyolite tuffs. The total thickness of the section may locally reach a maximum thickness of 2,000 feet (Condie, 1960). The linear distribution of some of the eruptive centers suggests that they occur along one or more fault zones. On the basis of composition, it has been suggested that the source of the rhyolite could be granite remelted at depth (Evan and Nash, 1975). Nash (1976) reported that the ages of these volcanics range from 0.78 to 0.49 m.y., which makes them amongst the youngest rhyolite eruptives in Utah.

Basalt. Basalt occurs in the project area in one isolated locality along the east flank of the range (sec. 36, T. 25 S., R. 9 W. and sec. 31, T. 25 S., R. 8 W.). At the north end of Beaver Valley near Cove Fort, there is a large basaltic andesite volcano of probable Quaternary age.

Quaternary Valley-Fill. The alluvial filling of Milford Valley ranges from coarse-grained alluvial fans on range flanks to sand, silt, and clay of fluvial and lacustrine origin near the center of the valley. In the Milford area, at depths less than about 800 feet, these sediments are not well indurated and contain important shallow aquifers. Induration increases and permeability decreases with depth. The total thickness of valley-fill sediments varies from zero at the mountain front to as much as 4,500 feet in the valley, based on gravity data (Thangsuphanich, 1976). Estimates of fault displacement along the east side of the Mineral Mountains suggest that in excess of 6,000 feet of low-density sediments may be present in Beaver Valley.

The near-surface parts of this thick section are made up of Holocene fluvial deposits and Pleistocene sediments deposited in an arm of Lake Bonneville. The lake had a high-stand elevation

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of about 5,120 feet. Beneath these deposits, the stratigraphy of the Late Cenozoic section is poorly known.

Structure

The only evidence of folding in the study area is found at the north end of the range, where a faulted syncline is centered in sec. 23, T. 25 S., R. 9 W. This syncline involves both Cambrian limestones and a conglomerate unit which is of either Late Cretaceous or Early Tertiary age. Pre-Cenozoic sedimentary rocks beneath Milford Valley also are likely to have been folded by the Late Mesozoic-Early Tertiary orogeny.

Two main ages and types of faulting are present. One is thrusting of Late Mesozoic age. The only feature known definitely to be in this category is a low-angle thrust fault in the northern part of the range. The other and dominant type is normal faulting of Cenozoic age (plate 2 and figure 2).

Several allochthonous klippen of Cambrian Prospect Mountain Quartzite overlie younger Cambrian units in the area extending from sec. 35 and 36 northeast to sec. 23, T. 25 S., R. 9 W., in and beyond the northern part of the study area. These isolated masses are believed to be remnants of a formerly continuous thrust sheet. This thrust may be an extension of the Grampian-Pavant Range line of thrust faults, which themselves are part of a great system of thrust faults that extend for hundreds of miles along the geosyncline-craton boundary zone. Displacement on the thrust system in the project area appears to be in a southeasterly direction. Unless it was removed by Early Tertiary erosion, the thrust sheet is likely to be present in adjacent areas of northern Milford Valley, only a few miles from the Roosevelt geothermal field. The effect of the thrust is to introduce a slab of Early Paleozoic or Precambrian sedimentary rocks into the section immediately beneath the pre-Tertiary unconformity.

The basic structural framework of the area is determined by high-angle normal faults of Late Cenozoic age. The youngest and most important of these faults occur in north-trending zones along the east and west sides of the Mineral Mountains horst. Gravity data indicate that these zones are made up of several sub-parallel faults along which step-like displacements have

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taken place. Total displacement along the western zone is estimated to be about 4,500 feet, and along the eastern side about 6,200 feet (Thangsuphanich, 1976). The horst between the two fault zones appears to be tilted westward.

The range-bounding faults are located valleyward from the major bedrock escarpments and are covered by alluvium. However, detailed photogeologic mapping in the area from Ranch Canyon to Negro Mag Wash, along the west side of the range, shows that Holocene fault scarps are present in the alluvium (Petersen, 1975). The zone in which these scarps occur is as much as 6 miles wide in the Roosevelt Hot Springs area. Trends of these small faults are mainly northerly, but some are northeasterly or northwesterly. The largest of them is the Dome fault, which has a length of about 3 miles. This fault has been the locus of past hydrothermal activity, indicated by the development of a sinter mound and silica-cemented gravels along it. Deposits of this type have been fault-offset by as much as 20 feet in sec. 16, T. 27 S., R. 9 W. (Petersen, 1975). Another area with strongly defined Quaternary fault offsets is in Ranch Canyon (Mower and Cordova, 1974).

A prominent and unusual group of east-trending normal faults is present in this region. Important examples occur in the southern Mineral Mountains between Minersville and Pass Canyon, south of the project area. Other prominent faults of like trend occur in the Star Range, west of Milford. In the project area, probable faults in Negro Mag Wash and in sec. 15 and 22, T. 27 S., R. 9 W. also trend easterly. Long, straight, east-west topographic lineations in the range suggest that jointing or faulting with this trend may be more common than indicated by available reconnaissance mapping. The significance of this fault trend to geothermal prospecting is uncertain. The faults in sec. 15 and 22 may somehow limit the thermal anomaly along the southern Dome fault, and the fault in Negro Mag Wash appears to correlate with a perturbation in temperature-gradient contours.

A prominent zone of cataclastic metamorphism has been described by Condie (1960) in the east-central part of the Mineral Mountains, extending to the southern edge of the project area. This low-dipping shear zone ranges in thickness from about 50 feet in Rock Corral to 200 feet thick in Cave Canyon, to the south. The zone is present along the contact between

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Precambrian gneiss or Tertiary granite and overlying sedimentary rock (figure 2). Believing the Mineral Mountains granite to be Cretaceous in age, Condie (1960) thought the cataclasite probably formed as a result of thrust-fault movements. Since the age of the granite is now thought to be Late Miocene or Pliocene, it is no longer tenable to associate the cataclasite with Cretaceous tectonism. Tertiary intrusives have been described in the Snake Range of western Utah and in other localities in the Basin and Range province. They may be related to "relaxing" of Cretaceous-age thrusts in post-Miocene time.

The cataclasite is a mylonite in which large blocks of Paleozoic rock, Precambrian gneiss and Tertiary granite occur in a matrix of pulverized material from a gneiss or granite source. Quartz is the most abundant mineral, but feldspars, usually altered to clay, also are present.

The significance of the cataclastic zone to geothermal prospecting is uncertain, but such a zone (or zones) may be present along the west side of the range under the alluvial cover in the project area.

GEOPHYSICS

Geophysical data are available from gravity, aeromagnetic, resistivity, microearthquake, and temperature-gradient surveys. They show a major, apparently active, normal-fault zone along the west side of the Mineral Mountains, containing a strong temperature-gradient anomaly. Pronounced vertical zones of high and low resistivity parallel faults in this zone, but have no simple relationship to the geothermal reservoir as presently known.

None of the above-listed surveys is detailed throughout the study area; rather, data densities vary widely across the area. Furthermore, of the available data only gravimetry appears to offer strong evidence for a magma body within a few kilometers of the surface.

Most of the published geophysical data come from the University of Utah, which has had National Science Foundation (NSF) funding continuously since 1974 for detailed earth-science investigations in the Roosevelt KGRA.

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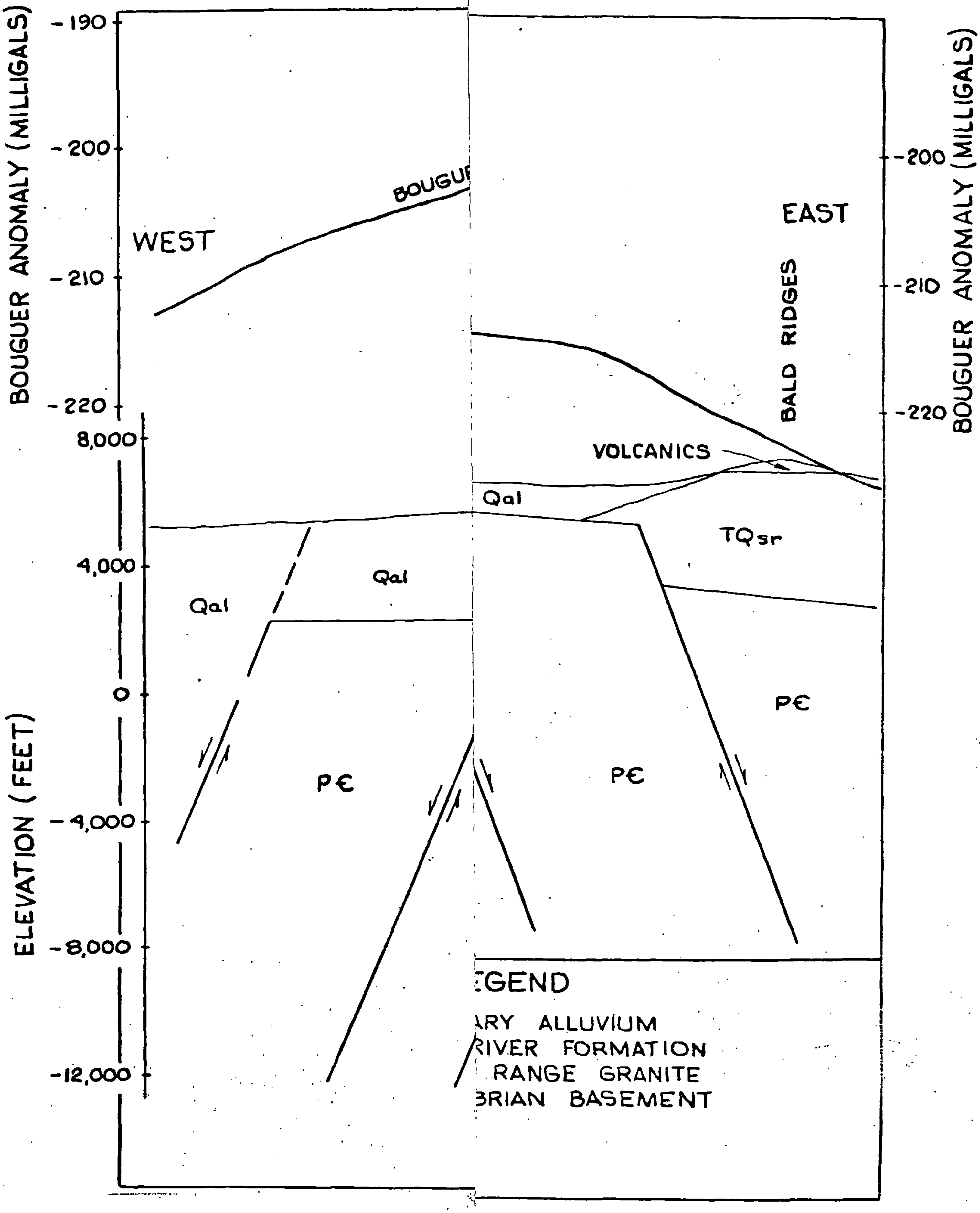
Gravity

Much of the area is covered by a Bouguer gravity map (originally at a scale of 1:250,000) containing some 100 gravity stations within the study area west of longitude 112°45' (Peterson, 1972; Crebs, 1976); their maps are combined and reproduced as plate 3. An unpublished master's thesis (Sontag, 1965) covers the area east of 112°45', but is not reproduced due to strict copyright observance by the University of Utah. However, a gravity map of the State of Utah (Cook et al., 1975) (originally at 1:1,000,000) has been used for the area east of 112°45' on plate 3. Recently, Thangsuphanich (1976) completed a gravity survey of the Mineral Mountains south of latitude 38°25'. His stations are much more closely spaced than those of Peterson. However, the data reveal no significant anomalies not shown by Peterson or by Crebs farther to the north, and therefore have not been reproduced here.

Briefly summarized, gravity measurements show that the Mineral Range is a horst (expressed as a gravity high) flanked by normal faults of major displacement. Escalante Valley is a deep graben (expressed as a gravity low) with pre-Tertiary bedrock as much as 7,000 feet deep near its center. Basement is significantly shallower along the valley margins. Beaver Valley also is a deep graben, and bedrock there has a maximum depth of about 6,000 feet. On both sides of the horst, steep gravity gradients indicate that a series of step faults is present, as diagrammed in figure 4. The data are not detailed enough to show individual faults.

Within the Mineral Range, the Bouguer anomaly varies considerably from north to south along the range axis. At its north and south ends there are closed gravity highs, with maximum values of -178 and -182 mgal, respectively. Near the middle, there is a gravity "saddle" with values as low as -200 mgal. The cause of this large variation is unknown, and cannot be explained readily in terms of surface geology. However, the minimum does coincide approximately with the presumed eruptive center of the Ranch Canyon Volcanics, in the vicinity of North and South Twin Flat Mountains. The coincidence suggests the possibility that a large, relatively low-density intrusion is associated with these young volcanics.

Relative to the gravity field produced by a simple, homogeneous prism of granite, the saddle-anomaly appears as a



BOUGUER ANOMALY (MILLIGALS)
-190
-200
-210
-220
WEST
BOUGUE
EAST
BALD RIDGES
VOLCANICS
Qal
TQsr
PЄ
ELEVATION (FEET)
8,000
4,000
0
-4,000
-8,000
-12,000
EGEND
ARY ALLUVIUM
RIVER FORMATION
RANGE GRANITE
BRIAN BASEMENT

FIGU5

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relative gravity low of about 20 milligals. This can be modeled by a variety of hypothetical low-density mass distributions at depth; for example (D. D. Blackwell, oral communication, 1976), as a horizontal cylinder with a diameter of 5 km and a length of 7 km, with its top about 1-1/2 km below the ground surface, and a density about 7% less than the surrounding granite (figure 4). Were its density still lower, its volume would be correspondingly smaller. In any case, data suggest that the anomalous body may have a volume of some 500 cubic kilometers, and may approach a density corresponding to the melting point for rhyolite.

An elongate Bouguer gravity low in Sec. 17-19, T. 27 S., R. 8 W. may represent a molten or near-molten body (S. H. Ward, oral communication, 1976), perhaps as an apophysis rising from the postulated larger and deeper magma.

Aeromagnetic Data

A detailed aeromagnetic map, prepared for the University of Utah under NSF funding, covers the project area. Originally at a scale of 1:24,000, the map has been reduced to 1:62,500 for this report (see plate 4). The survey was flown at a mean altitude of 1,000 feet above ground level, with a flight-line spacing of 1/4 mile. A pronounced east-west herring-bone effect in the magnetic data is an artifact and must be ignored.

In this area, as throughout western Utah, magnetic grain has prominent north-south and east-west trends. North-south grain reflects Late Cenozoic basin and range structure. East-west grain appears to be related to Precambrian basement-structural trends. There is weak correlation between topographic elevation and magnetic intensity, but this may be safely ignored.

Looked at very broadly, we see that areas of low magnetic intensity and low intensity relief generally are over Quaternary alluvium or pre-Tertiary sedimentary rock; areas of high intensity and high relief are over Cenozoic igneous rocks. Also, north-south alignments of magnetic features (highs, lows, and gradients) occur predominantly in areas of Cenozoic igneous rocks. Therefore, where such alignments occur over sedimentary materials, it is likely that they are underlain by Cenozoic igneous rocks. Thus, the north-trending alignments along the east flank of the Mineral Range suggest that the granitic pluton extends at least one mile east of its surface outcrop.

Several strong anomalies deserve to be identified and treated separately. A north-trending anomaly, comprising a

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paired high and low, coincides approximately with the Dome fault. This feature may simply represent the granite or Precambrian gneiss believed to be present at shallow depth there. Alternatively, and more likely, it could represent a tabular-shaped silicified zone centered on the Dome fault.

A series of weak highs extends some 4 miles north from Negro Mag Wash, and is offset about 1 mile east of the Dome fault. Although this might reflect a northward continuation of faulting and mineralization comparable to the Dome fault, most probably it does not. If both of these high magnetic-intensity alignments represent the same geologic structure, then their offset indicates the presence of a right-lateral fault in Negro Mag Wash, as suggested by several workers. This and several other hypothetical faults based upon aeromagnetic data are shown in plate 5.

Within the Mineral Range, several small, high-relief, east-trending anomalies occur from Bailey Mountain to North Twin Flat Mountain. These are located over eruptive centers of the Ranch Canyon Volcanics, composed of Quaternary high-silica rhyolites containing about 1/2 percent magnetite (Nash, 1976). The Mineral Range granite contains some 5 percent of biotite and magnetite combined (Condie, 1960), and it may be reasonably assumed that not more than 1 percent of whole rock is magnetite. Hence, differences in magnetite content between the rhyolite and the granite are likely not large enough to explain the magnetic anomalies. Condie (1960) reported that inclusions within the granite contain up to 35 percent dark minerals. Possibly, such inclusions may be so concentrated as to produce the observed magnetic highs. Another possibility is that unexposed basic intrusions or pendants of Precambrian gneiss are present.

Finally, the strong north-trending anomaly just west of Shag Hollow is noted. As with the above-described features, no ready explanation can be given. In both cases, magnetite-rich inclusion zones seem to be the most plausible cause, although undocumented.

Geoelectrical Surveys

A number of geoelectrical surveys have been conducted in the project area by both private and public agencies. These include dipole-dipole resistivity surveys, electromagnetic (EM)

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soundings, and magnetotelluric soundings. The only published work is that by the University of Utah, which has done dipole-dipole surveys and preliminary EM soundings in the Roosevelt KGRA under National Science Foundation support (Ward and Sill, 1976; Petrick, 1974). These are described below. A series of magnetotelluric soundings by Geotronics Corporation, under contract to the University of Utah, has been released, and is described below, also. Geoelectrical work has been conducted for several private companies active in exploration in the region, but is unreported. Amongst these, Senturion Sciences performed a magnetotelluric survey for several participating companies in 1976.

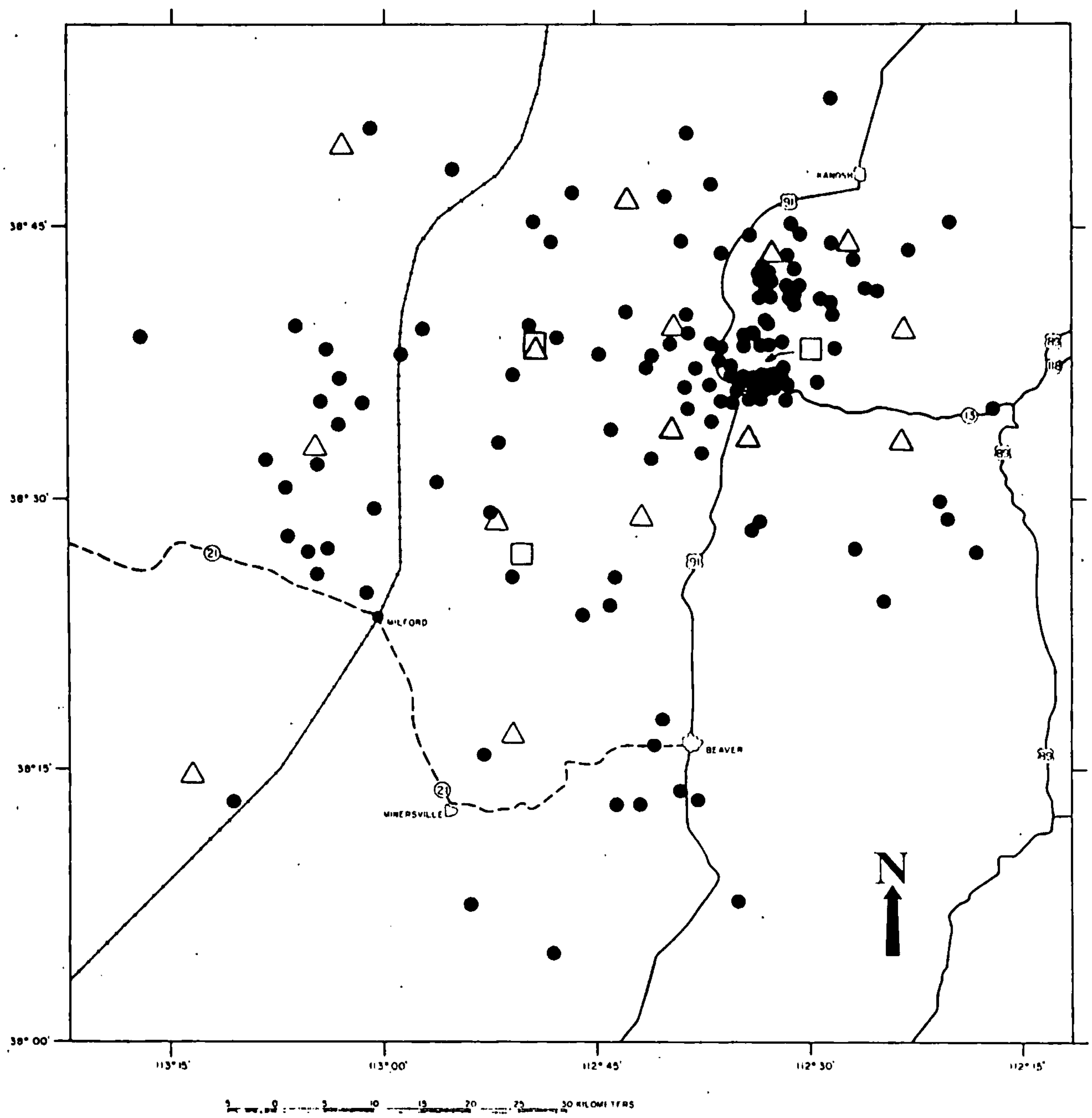
Dipole-Dipole Surveys

Dipole-dipole resistivity surveys by the Department of Geology and Geophysics of the University of Utah cover a long, narrow strip along the west flank of the Mineral Range. This strip is some 13 miles long by 4 miles wide, and runs from Ranch Canyon on the south to latitude 38°37' on the north, near the north end of the Mineral Range. Some 100 km of traverse line were surveyed with 100 m, 300 m, and 1,000 m dipoles.

The data reveal three dense fracture sets in the vicinity of three steam-producing wells; hydrothermal alteration and brines in these fractures produce pronounced resistivity lows at shallow depth (less than 500 m). These fracture sets appear to carry fresh water into, and brine away from, the center of a convective hydrothermal system.

The low resistivities ($\leq$ 5 ohm-meter) of the fractures above 500 m in depth are ascribed to clay and pyrite alteration or to hot brine, or both. The marked increase in resistivity (to 300+ ohm-meter) along fractures deeper than 500 meters is attributed to (1) reduction in alteration, (2) replacement of brine by steam, (3) tightening of the fractures, or (4) lack of resolution of these surveys; alternatives (1) and (4) are believed most likely to be important (Ward and Sill, 1976).

The resistivity data have revealed very little of the deep geothermal system. Therefore, included herein is only a map showing fractures interpreted from shallow dipole-dipole results (figure 6); this plate also shows fractures interpreted from surface geologic mapping, photogeology, and aeromagnetics.



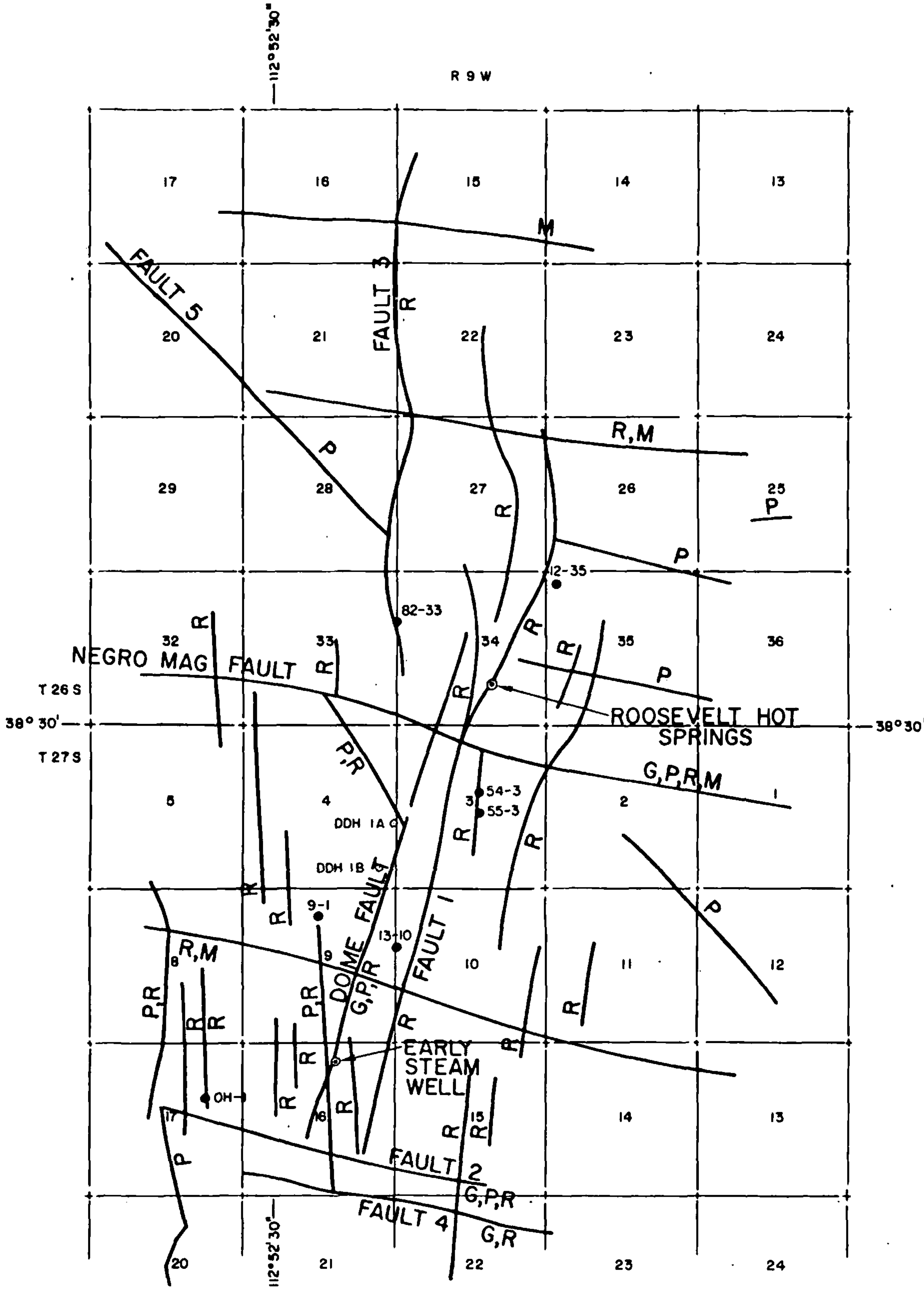
EPICENTER MAP OF MILFORD-BEAVER-COVE FORT AREA OF UTAH. DATA FROM 1974-1975 SUMMER SURVEYS.

● EPICENTER

△ TEMPORARY SEISMOGRAPH SITE

□ PROPOSED PERMANENT SEISMOGRAPH STATIONS

FIGURE 5



FRACTURES INTERPRETED FROM RESISTIVITY AND OTHER DATA ROOSEVELT HOT SPRINGS KGRA

LEGEND

- ——— Interpreted fracture
- G,P,R,M Geology, Photo, Resistivity, Magnetics
- ● Well by Phillips Petroleum Co.
- ⊙ DDH by University of Utah

N 16°

0 1 mile

Scale 1:62,500

Note: See Plate 2 for location within study area.

FIGURE 6

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Maximum depth of dipole-dipole exploration was just over one km. To this depth, the data do not reveal a heat source for the hydrothermal system. More importantly, perhaps, the data do not define that system at depths greater than 500 m. Furthermore, Ward and Sill (1976) reported that large-scale bipole-dipole surveys done by Phillips were no more successful in defining the hydrothermal system at depth.

Magnetotelluric Soundings

Geotronics Corporation of Austin, Texas conducted a series of 25 magnetotelluric (MT) soundings in the area, extending eastward across the Mineral Mountains into T. 27 S., R. 8 W., under contract to University of Utah. This work includes several interpretive resistivity cross-sections.

The cross-sections show apparent resistivities to a depth of 14 kilometers, but it must be pointed out that interpretation of MT data is highly ambiguous in nature. In order to compute resistivities, one must know electric-field skin depths; but skin depths are dependent upon the resistivities of the penetrated rock. Therefore, any MT cross-section must be highly interpretive.

The sections show a deep low-resistivity zone along the Dome fault, dropping to 3 ohm-meters at a depth of 3 km; highest values are about 20 ohm-meters at depths of 500 to 900 m. This fits approximately with the zone of high resistivities observed in dipole-dipole surveys beyond 500 m; however, the values are vastly out of agreement with the characteristic 300+ ohm-meters observed in the dipole-dipole surveys.

These discrepancies cannot be resolved herein, and cast some doubt on the utility of geoelectric surveys in this geologic terrain.

Seismicity

The project area lies within the Intermountain Seismic Belt, which extends along the Wasatch frontal zone in Utah, northward through the Idaho-Wyoming thrust belt, and at least to the vicinity of Helena, Montana.

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During the summer of 1974 and 1975, high-gain portable seismographs were deployed in the Mineral Mountains region by the University of Utah. The networks were centered on the Roosevelt Hot Springs and Cove Fort areas. Calculated magnitudes ranged from -0.5 to +2.8. Focal depths were usually less than 8 km.

As may be seen from figure 5, most of the microseismicity was concentrated in the area from Cove Fort to Kanosh. However, several events occurred on the west flank of the Mineral Range, perhaps along the Dome fault; also, there was a number of events along the east flank of the range (Olson and Smith, 1976).

Activity in the Cove Fort area was characterized by swarms containing large numbers of shocks. The Dog Valley station frequently recorded from 10 to 30 shocks per day, most of which were too small to be recorded at other, nearby stations. By far, this station recorded the greatest number of events. Fault-plane solutions for events in this area indicate normal faulting (with some right-slip) on planes striking northeasterly and dipping northwesterly. Interestingly, unpublished data from Dog Valley and vicinity show thermal gradients of up to 350°C/km (20°F/100 ft.), making it the strongest thermal anomaly in the area outside of the proven geothermal field at Roosevelt Hot Springs.

P-wave delays and S-wave attenuation were also evaluated in the study of local seismicity. If sufficient in magnitude, these parameters can sometimes provide strong evidence of a local magma body which interferes with seismic wave transmission. At the Ranch Canyon station, these parameters may have been significant for travel paths southwest from the Cove Fort area. However, as presented and analyzed by Olson and Smith (1976), the results are far from conclusive. They allow, but do not confirm, the presence of a shallow magma body (depth less than about 10 km) between Cove Fort and Ranch Canyon. Much more collection and analysis of data will be required to answer this question.

Heat Flow

Heat flow and thermal gradients in the Wasatch frontal zone are somewhat higher than average for the western United States. Heat-flow values range from 1.9 HFU at Bingham and

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2.0 HFU at Eureka to 2.2 HFU near Milford; average for the zone is about 2.0 HFU. Background geothermal temperature gradient is probably about 36°C/km (2°F/100 ft.) in consolidated rock of the Milford area. In unconsolidated sediment of lower thermal conductivity, gradient may average 55°C/km (3°F/100 ft.). These elevated thermal parameters correlate with the thin crust (30 km at Delta) and intense Late Tertiary igneous activity which characterize the Wasatch frontal zone. Although temperature gradients between 36° to 55°C/km are not indicative of a commercial geothermal resource, they are encouraging in a regional context. Much higher gradients have been observed in holes drilled in the vicinity of Roosevelt Hot Springs, in rocks having higher thermal conductivities than alluvium. This becomes strongly attractive for exploration (see p. 27-29, below).

HYDROLOGY

Surface Water

Perennial streams are non-existent in the Mineral Range. The Beaver River, which drains the region, rises in the Tushar Mountains and flows westerly through Beaver Canyon and northward into Milford Valley. It is the only perennial stream in the region but, due to diversions for irrigation, is almost perennially dry north of Minersville. A number of intermittent streams drain the Mineral Range on both sides. These have water in them only after thunderstorms and during the spring season of snow melt.

Upon reaching the flanking alluvial fans, water from these ephemeral streams is largely lost to evaporation and transpiration; about one-third of it infiltrates coarse alluvial materials and joins the shallow ground-water reservoirs present in the basin-filling Cenozoic sediments. Diversion of the Beaver River for irrigation has further increased evapotranspirative losses, and therefore reduced infiltration into the Escalante Valley ground-water reservoir.

Some cool springs discharge on the slopes of the southern Mineral Mountains. Their contribution to the regional water budget is trivial.

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Ground Water

In northern Escalante (Milford) Valley, the ground-water reservoir, as it is known and utilized, comprises three zones of high permeability alternating with three of low permeability. The series is penetrated by irrigation and municipal wells at an average depth of 500 to 800 feet. Pumping tests show that all three aquifers are interconnected.

Principal sources of water recharge into this shallow reservoir are major streams, irrigation ditches, irrigated fields, and underflow from rainfall infiltrating into the consolidated rocks of the mountains. Total volume of recharge was estimated at 58,000 acre-feet for the 1970-71 water year; this may be representative of the average annual amount. Discharge occurs principally by evapotranspiration and pumping of irrigation wells, and was 81,000 acre-feet in 1970-71.

Because discharge exceeds recharge, as it has for some 23 years, piezometric water levels have continued to drop in Milford Valley since 1953. Water wells are heavily concentrated in the area between Milford and Minersville. Therefore, largest cumulative water-level declines are in this area, and had reached some 30 feet by 1972. Away from this area, declines were generally less than 10 feet. At 1972 piezometric levels, a 1-foot decline in level represents a change in storage of 84,000 acre-feet. Expressed alternatively, each 10,000 acre-foot deficit in the water-budget corresponds to a level-drop of 0.12 feet per year. Thus, at the present deficit of 23,000 acre-feet per year, the average (valley-wide) level-decline is some 1/4 foot per year.

Interrelationship between this shallow circulation system and the deeper geothermal system probably is slight. Subsurface outflow from the geothermal system moves downslope within the alluvial fans toward the Beaver River channel, becoming dispersed and diluted en route. The minimum depth to the fractured Pre-cambrian(?) gneiss and Tertiary granite of the geothermal reservoir is 1,200 to 1,600 feet in the vicinity of Roosevelt Hot Springs. Production probably will come from twice those depths on the average. Beneath Milford Valley, depth to the geothermal system may be many thousands of feet, if indeed the geothermal system is present. Upward leakage from the vicinity of Dome Fault may enter shallow, cool-water aquifers with time, especially

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if pressures continue to decline in shallow wells as a result of overdrafts for irrigation. However, R. Lenzer of Phillips Petroleum Company estimated (oral presentation, Beaver, Utah, April 29, 1976) that outflow from the geothermal system might take 300 to 700 years to reach shallow wells along the course of the Beaver River several miles north of Milford. It is unlikely that underflow would go southwestward toward the intensively irrigated farmland south of Milford.

At the urging of the South Milford Water Pumpers Association, Phillips has agreed to monitor a number of stock wells, special observation wells, Roosevelt saline seep, and one of its deep but dry holes for evidence of thermal outflow and contamination of potable aquifers.

Long-term effects of production and reinjection cannot be predicted with certainty, given the present-day level of understanding of the hydrothermal system. However, careful monitoring will reveal any abnormalities as soon as they arise, and may lead to a more comprehensive understanding of relationships between the shallow, cool hydrologic system and the geothermal production parameters (locations, amounts, and compositions of fluids withdrawn and reinjected).

Hydrochemistry

Shallow ground water stored in the alluvium of Milford Valley has total dissolved solids (TDS) of about 400 ppm; TDS ranges no higher than 1,000 ppm. Composition is predominantly $Ca\text{-}HCO_3$ and $Ca\text{-}Na\text{-}HCO_3\text{-}SO_4$. Relative abundances of principal ions is: $Ca>Na>Mg>K$; $HCO_3>SO_4\sim Cl$. In both absolute and relative terms, abundances of these species are quite typical of shallow, cool ground waters of the Basin and Range province, and indicate meteoric origin, and subsurface movement measured in months or years. Because of irrigation practice, evaporation and ion-exchange is increased in the near-surface zone. This has led to local enrichment of Na and Cl ions in the cool water aquifer. This might become confused in interpretation with NaCl water derived from the geothermal system.

Chemically, the deep thermal well-waters of the Roosevelt Hot Springs area are NaCl in character, and contain 6,000 to

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8,000 mg/ℓ TDS. Mundorff (1970) reported Roosevelt Hot Springs to contain TDS of 1,040 and 7,800 mg/ℓ. Other chemical concentrations (in mg/ℓ) were: Na (2,500 and 2,080), Ca (19 and 22), K (472 and 488), Cl (4,240 and 3,810), SO_4 (73 and 65), SiO_2 (313 and 405), HCO_3 (156 and 158), B (38), and F (7.1 and 7.5). Minor constituents included Li (0.27), Br (3.3) and I (0.3) mg/ℓ. Mg had nearly completely been combined in low-temperature minerals (0 and 3.3 mg/ℓ). Trace quantities of various metals probably are present, but were unreported.

Clearly, the composition of this fluid is very different from that of shallow, cool groundwater in Milford Valley. The thermal fluids are indicative of a very high temperature reservior, and are generally comparable to fluids found in the Ahuachũpan, El Salvador and Cerro Prieto, Mexico geothermal fields.

A very long residence time is suggested by oxygen and deuterium isotope data reported orally by R. Lenzer of Phillips Petroleum Company. Lenzer's data are suggestive of enrichment patterns observed at other geothermal fields in North America. They are consistent with a model of recharge via infiltration of rainwater or snowmelt into fractured granite of the Mineral Mountains. Travel times and residence at depth may be estimated in decades or centuries.

GEOTHERMAL REGIME

Thermal Springs

Boiling water (to 195°F) discharged from Roosevelt Hot Springs (sec. 34, T. 26 S., R. 9 W.) until about 1963, when either blocking of the spring system by mineral deposition or lowering of the water table caused a cessation of flow. Thereupon, wisps of water vapor at about 205°F issued from warm ground. A tepid chloride-water seep about one-quarter mile north of the former hot spring area probably represents minor upward leakage from the reservoir along the Dome fault. Soil temperature was measured at 204°F at about 4 feet in depth in an auger hole near the former main orofice for Roosevelt Hot Springs. A nearby group of springs in Negro Mag Wash (NW/4 sec. 3, T. 27 S., R. 9 W.) may also have been active to about the same period. Extensive siliceous sinter deposits and elevated temperatures (to about 195°F) are also reported in shallow trenches at Negro Mag Wash.

Deposits of sinter, opal and hematite-stained silicified gravel occur over a distance of about 2-1/2 miles, south of Negro Mag Wash, along the Dome fault. These deposits indicate formerly extensive leakage of thermal water from along the fault. The large deposit in sec. 16, T. 27 S., R. 9 W. is offset by the fault, with vertical displacement of about 20 feet.

Temperature Gradients and Shallow Wells

Two large areas are characterized by temperature-gradient anomalies of 100°C/km (5.5°F/100 ft.) to more than 500°C/km (28°F/100 ft.) in holes of 50 meters to 500 meters in depth. These are on the west flank of the Mineral Range, and in the vicinity of Cove Fort. Available temperature-gradient data for Roosevelt are plotted on plate 5. Unpublished and proprietary data confirm this picture, but extend the anomaly on the north and east.

Several holes were drilled around the opalite deposit in sec. 16, T. 27 S., R. 9 W. in 1968 in the search for gem-quality opal. One of these penetrated to approximately 275 feet and produced low-pressure, water-saturated steam at a temperature of about 270°F before being plugged. This equals 80°F/100 ft., or 1,450°C/km. It obviously represents thermal convection along the Dome Fault. More recently, temperature-gradient holes were drilled in the area by Phillips Petroleum Company, Thermal Power Company of Utah, and other parties. Gradients range from 2.5°F (equivalent to background) to 26.8°F per 100 feet (45°C/km to 485°C/km). The gradient contours outline an elongate north-trending anomaly, the most intense part of which is almost coincident with the Dome fault in sec. 4, 9 and 16, T. 27 S., R. 9 W. and the Bouguer low or saddle discussed above. A magnetic high anomaly in the area changes trend and amplitude to the north of Negro Mag Wash. The anomaly is at least 8.5 miles long (north-south), and 2.5 miles wide (east-west), as contoured on the 100°C/km isograd (plate 5).

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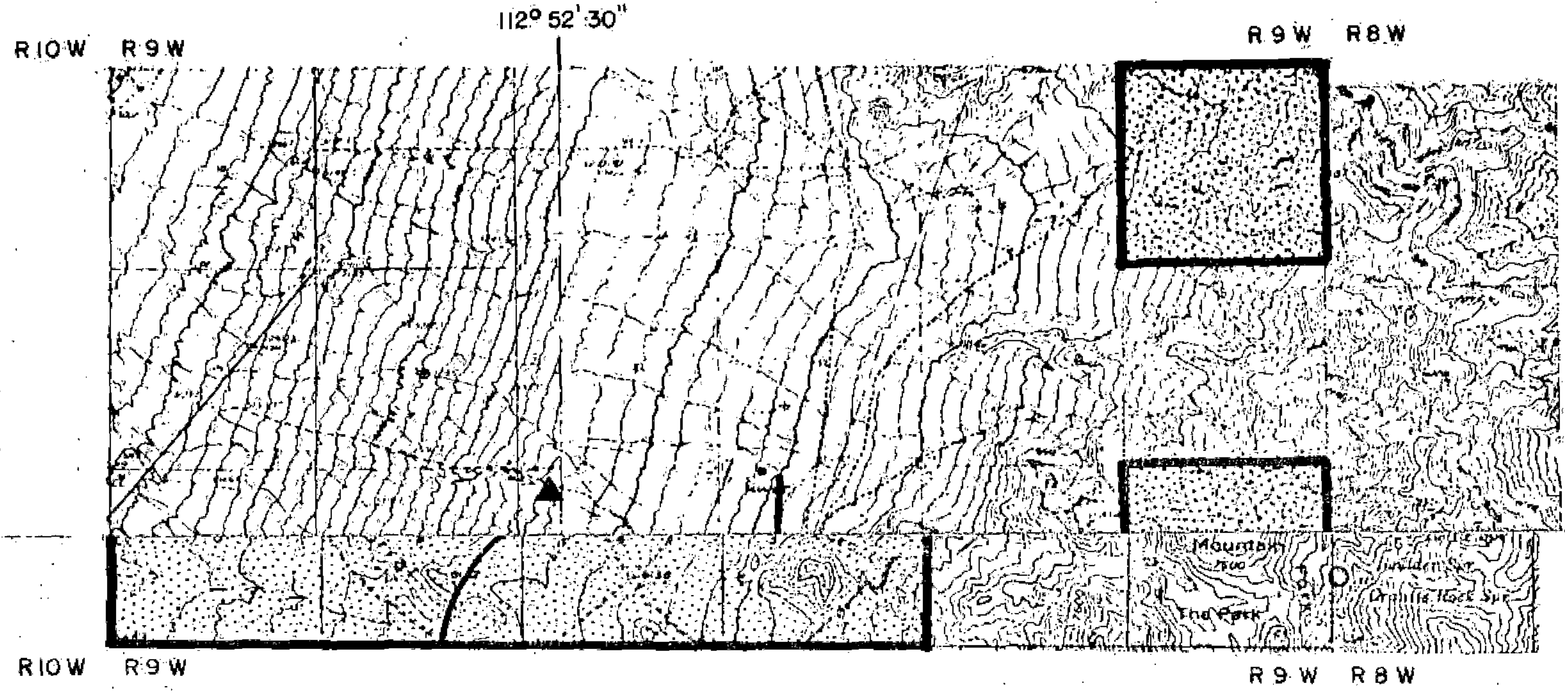
Based on both publishable and proprietary data, gradients drop off equidimensionally and rapidly east and west of the Dome fault. Termination at the north and especially the south ends of the main anomaly is more rapid. A lobe or arm of higher-than-normal gradient extends northwesterly into Milford Valley. This high corresponds to the direction of subsurface thermal outflow from the deep geothermal reservoir, and probably represents a thermal plume from the vicinity of the Dome fault.

The rather abrupt termination of high gradients on the south is based on relatively few drill holes. It probably reflects a fault or other fracture bounding the thermal cell on the south (see plate 5). The lack of publishable gradient data farther south makes it difficult to conclude if another thermal cell is present from Ranch Canyon south. More gradient data definitely are needed in that direction.

To the east, the rapid decrease in gradient in the mountains is surprising, as the principal mass of Pleistocene rhyolite is exposed to the east. The number of available gradient holes probably is inadequate for decisions regarding the deep geothermal regime. It is possible that terrain factors and the higher amount of precipitation in the mountains serve to depress gradients in holes of 50 meters or less. Further, the center of the complete Bouguer minima (described earlier) lies 2 or 3 miles west of the volcanic axis, which is near the crest of the Mineral Mountains (figure 7). Therefore, the center of a presumed intrusion may lie west of the volcanic axis. This is strange, for it means that Pleistocene volcanism expressed itself along the longest, most difficult course, through the granitic pluton rather than along the fractured boundary of the range. This violates the geologic concept of parsimony. Further and deeper drilling may reveal a heated cell to the east beneath the cold-water recharge cap. As evidence to support this, a very high temperature well was drilled by Natomas Company on the east edge of the temperature anomaly of plate 5, near a shallow hole having a calculated gradient of only 69°C/km (sec. 2, T. 27 S., R. 9 W.).

Gradients of course vary inversely with thermal conductivity of the rocks or sediments penetrated. Gradients of 35° to 40°C/km in dense bedrock of the Mineral Mountains might be comparable to 70° to 100°C/km gradients in alluvium of Milford Valley, in terms of heat flow. Values in the bedrock as low as 65° to 70°C/km may thus be attractive for exploration, representing as



EXPLORATORY DRILLING AT ROOSEVELT HOT SPRINGS GEOTHERMAL FIELD

LEGEND

- ▲ Future drilling sites approved for Phillips Petroleum Co.
- N 14-2 (7324) Geothermal well with number and depth (feet); N=Natomas.
- Apparently encountered producible geothermal aquifer.
- Mapped or interpreted faults (Phillips Petroleum Co.), barb on down side.
- Axis and center of Bouguer gravity low.
- Geothermal Power Corp. leases in R 9 W.

N

16°

1 0 1 miles

Scale 1:62,500

FIGURE 7

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they do potential temperatures of 200°C at 3 km (10,000 ft.). By contrast, gradients in unconsolidated sediment should exceed 80° or 90°C/km to be attractive for deep exploration, as the gradient can be expected to drop sharply upon drilling into denser rock at depth. Data are not shown on plate 5 for the Cove Fort thermal anomaly, as it is beyond the scope of this report.

Heat Source

The project area is characterized by high heat flow and Quaternary silicic volcanism. Rock temperatures, therefore, may be significantly above average at any given depth, and may be extremely high in the vicinity of presumed silicic plutons. Meteoric water entering fractured granitic and volcanic rocks of the surface may be heated to temperatures of 200°C (400°F) or more by (1) deep circulation in fault zones under regional gradient conditions; (2) less-deep circulation within fractured zones in the vicinity of buried hot plutons. In the study area, the existence of a significant volume of Pleistocene silicic volcanics in the Mineral Mountains suggests that a buried pluton is the more likely heat source there.

Evans and Nash (1975) determined intrusion temperatures of about 700°C for the Quaternary silicic rocks, with a source region at 13 to 16 km depth below sea level. D. D. Blackwell (unpublished data, 1974) has estimated emplacement of such a silicic pluton at about 4 km beneath ground surface. Its cross-sectional area he estimated at 9 km^2 (3.5 mi^2), which seems minimal when considering the surface distribution of Quaternary rhyolite and the size of the thermal gradient anomaly (over 20 mi^2 within the 100°C/km isograd). This feature extends across Secs. 22, 27 and 34, T.27 S., R. 9 W.; this is 2 miles south of the southernmost productive geothermal well, and is on the southern boundary of high gradient in shallow holes.

More recently, Blackwell (oral communication, January, 1977) has expressed his belief that perhaps 15 square miles (35 km^2) are underlain by young silicic plutons, based upon Crebs' (1976) gravity data. Not all of this mass need be at near-molten temperatures; the average deep gradient across this zone might be 50° to 70°C/km. This would make portions of the area underlain by Quaternary plutons non-commercial for geothermal development.

A differing view, held by Dr. S. H. Ward and associates Dr. R. B. Smith and W. P. Nash of the University of Utah, is that the intrusive center is represented by an elongate Bouguer low centered on Sec. 17-19, T. 27 S., R. 8 W., and covering some

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3.5 square miles. This might represent a molten or near-molten body, according to Ward (oral presentation, Golden, Colorado, September 1976).

In either case, acreage held by Geothermal Power Corporation falls on or immediately adjacent to the presumed Quaternary intrusion (plates 1 and 3), and becomes prospectively more attractive accordingly.

Reservoir

Production in the developing Roosevelt geothermal field is obtained from fracture systems in Precambrian(?) gneiss and possibly the Tertiary granite. Prospectively valuable lands may be sought along the contact zone between the Mineral Mountains granite and Precambrian(?) gneiss, and within deeply fractured zones in the granite. It is possible that highly cemented and fractured sections of Tertiary sediment may serve locally as reservoir in the deeper portions of Milford Valley, but this is not likely. It appears that reservoir potential in all of these rock types is of fracture type. Obviously, the best environment for fracture development is within or near fault zones (see Figure 6). This appears to be borne out by the location of the geothermal field as presently known.

In carbonate rocks, permeability may be enhanced locally by through-going solution activity. However, exposures of carbonate rocks are limited in the region of Pleistocene volcanism and probable intrusion to a zone just south of Ranch Canyon.

In the Roosevelt geothermal system, various factors can be significant in limiting and localizing the reservoir. Deposition of silica, clay, or other minerals may occur around the periphery of the reservoir, thus sealing the fracture systems. In addition, clay-mylonite in fault zones or a zone of so-called cataclastic metamorphism (Condie, 1960) might act as a seal. Finally, fine-grained lacustrine facies of the valley-fill probably are very poorly permeable to the geothermal fluid.

Quaternary, and possibly active, tectonism may serve to re-open sealed fractures and to create additional fracture channels. Therefore, areas along the Dome fault, or cut by other presumed Quaternary faults offer better prospecting possibilities.

It is apparent that the location of the Roosevelt geothermal-gradient anomaly is controlled significantly by the north-trending zone of faulting and fracturing along the west side of the Mineral Mountains. However, it is not apparent whether other individual faults and fractures in this zone have special significance. As stated earlier, east-west faults may terminate or deflect the strike of the Roosevelt anomaly.

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LEASEHOLD EVALUATION

Exploration History and Results

Exploration began with the accidental drilling of the 270-foot-deep hole on the opalite mound in 1968. That event yielded an eruption of 270°F water, and began a leasing rush that is still in progress; this in turn led to the discovery of the Roosevelt geothermal field.

Figure 7 shows the location of deep holes (greater than 400 meters) in the Roosevelt area, and table 2 gives their characteristics. These holes were drilled either by Phillips Petroleum Company or by Thermal Power Company (a subsidiary of the Natomas Company). In addition to this deep drilling, which has reached approximately 7,500 feet in maximum depth, there have been dozens of gradient holes drilled in the broad area from north of Cove Fort to south of Thermo. This has been accompanied by tens of line miles of resistivity and magnetotelluric soundings, several months of microseismic recording, and correspondingly great efforts in hydrogeochemistry, seismic profiling, passive noise recording, gravimetry, aeromagnetometry, photogeology and field geologic mapping, and other exploration techniques.

This work has been accomplished by private companies, members of the U. S. Geological Survey and Utah Geological and Mineralogical Survey, faculty and student researchers at the University of Utah, and private contractors. Relatively little data are in the public domain, although proprietary information does circulate informally by trade or privileged release. These efforts in the Roosevelt Hot Springs area rival those accomplished at The Geysers or in Imperial Valley, California. Phillips Petroleum Company alone acknowledges spending $6 million on leasing, exploration and drilling since beginning work in 1973; they estimate a total outlay of $30,000,000 by 1982, to develop 110 mW of electric power generation (Gary Crosby, oral presentation, September 1976).

Drilling results reveal a hot-water reservoir, with temperatures as great as 260°C (500°F) at depths as shallow as 2,800 feet. Production comes from highly sheared and fractured Precambrian(?) gneiss and schist, and possibly from fractured

Table 2. Geothermal Wells Drilled at Roosevelt Hot Springs, Utah

Well Number	Location	Date Drilled	Depth, ft.	Casing	Results and Status
			Phillips Petroleum Company		
OH-2	SW/4 NW/4, 10-27S-9W	2/2/75-2/15/75	2,250	N.D.	Deep temperature-gradient hole; reportedly high gradient
OH-1 (also 17-1)	SE/4 NE/4, 17-27S-9W	3/3/75-3/12/75	2,321	N.D.	Deep temperature-gradient hole; "high" temperature; low permeability
9-1	NE/4 NW/4, 9-27S-9W	3/13/75-4/8/75	6,885	N.D.	"High" temperature; poor permeability
3-1 (also 55-3)	NW/4 SE/4, 3-27S-9W	4/20/75-5/24/75	2,728	N.D.	Tested at 1.2 million #/hr of hot water
54-3	SW/4 NE/4, 3-27S-9W	7/5/75-8/28/75	2,882	N.D.	∿1 million #/hr of hot water at >500°F and >500 BTU/#; rated as "best" well
12-35	NW/4 NW/4, 35-26S-9W	8/6/75-10/1/75	7,324	7" liner to 4,500'	Suspect shallow-zone cool-water contamination; ∿440°F thermal aquifer now lined off; cannot test satisfactorily
13-10	SW/4 NW/4, 10-27S-9W	10/2/75-11/4/74	5,351	N.D.	Tested above 1 million #/hr of hot water at 75-125 psig
82-33	NE/4 NE/4, 33-26S-9W	11/5/75-12/23/75	6,028	13-3/8" to 575'	>300°F, <350°F; possible future injection well
25-15	NW/4 SW/4, 15-27S-9W	8/26/76-11/12/76	∿7,500	9-5/8" at ∿2,500'	Shallow-zone cool-water contamination; less satisfactory than wells to north
(Note: All Phillips' wells are on Federal lease blocks)					
			Thermal Power Company (Natomas Company)		
Utah State 14-2 (ML27536)	SW/4 NW/4, 2-27S-9W	9/11/76-10/21/76	6,108	9-5/8" at 1,805'	Reported >400°F hot water at ∿4,000'
Utah State 72-16 (ML25128)	NW/4 NE/4, 16-27S-9W	10/22/76-1/5/77	1,254	N.D.	Reported 1 million #/hr of hot water at 432°F and 355 psig

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Tertiary granite. The extent of Precambrian(?) rocks within the range is unknown: it may have been terminated beneath the Mineral Mountains by the Pliocene granitic intrusion or by the younger generation of rhyolite magma represented by the rhyolite domes and flows. Precambrian(?) rocks do crop out farther to the south along the range front, extending at least to the vicinity of Cave Canyon in T. 29 S.

Figure 2 reveals the conceptualization by scientists at Phillips Petroleum Company that pervasively fractured rock, rather than individual fault planes, forms the reservoir. Those holes not cutting the "shear zone" of figure 2 reportedly exhibit low permeability. However, all youthful faults may serve to carry hot fluids toward the surface, thus generating high temperature gradients in shallow holes.

The fault trending east-west across Negro Mag Wash apparently does not terminate the field: high temperature (∿440°F) was reported from hole 12-35, nearly 1.5 miles north of this south-dipping feature (G. Crosby, oral presentation, September 1976). Similarly, the southern boundary of the field is unknown.

Wells drilled very close to the range front commonly exhibit low gradients in their upper positions, reflecting cold-water recharge through fractured rocks of the mountains. Those drilled west of Dome fault exhibit high gradients in their upper portions, because of outflow of thermal fluid up Dome fault or other faults shown in figures 2 and 7. However, deeper gradients may be disappointing, and permeability often is limited.

It is interesting to note that the high gradients (as shown in plate 5) are displaced slightly westward from the proven geothermal field (figure 7). This recharge-discharge effect (described above) imposes a constraint on the use of gradient holes in the siting deep exploratory wells at or beyond the field boundaries. Structural and petrologic geology, results from earlier holes, and gravimetry all should be considered carefully, along with data on seismicity or the electromagnetic field, as these become available in the future.

Reservoir fluid is water-dominated and chloride-rich (∿3,000 mg/ℓ), with TDS of 6,000 to just over 8,000 mg/ℓ, average enthalpy of 500 BTU/pound, and temperature at one kilometer of

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160°C (320°F) to 260°C (500°F). Mass flow in productive wells averages about one million pounds per hour of hot water, at pressures slightly above hydrostatic. Individual well tests up to 1.5 million pounds per hour have been reported, but stabilized flow may be expected to be less than this. An average steam flash of 18 to 20 percent is anticipated, although pressure, mass flow, and therefore percentage of steam flash and steam enthalpy, vary somewhat from hole to hole.

Using "average" conditions, a productive well may be expected initially to yield 200,000 pounds of steam per hour, after flash separation. This should serve to generate 10,000 kW per hour, or 10 mW. This is quite high, and therefore attractive commercially. Ultimately, stabilized flow may be somewhat lower.

It is probable that more than one thermal zone is present, one being a shallow system fed by leakage up faults, and a second being a deeper system of pervasively fractured rock. Differences may be expected in pressure, temperature, enthalpy, and possibly mass flow and well life in these two systems. Because field dimensions are unknown, and because no data are available on long-term well productivity, ultimate generating capacity is unknown. Well spacing probably will be determined empirically, using results of interference tests between existing wells to determine optimum locations.

Reinjection will be required for all waste fluids, and probably for any condensed steam that is not evaporated in the cooling process. Such wells may be located to the northwest and west of the producing field, and a ratio of one injector for two producers is anticipated (G. Crosby, oral presentation, September 1976).

Phillips has applied to drill 21 additional wells to define field boundaries and parameters. Still additional wells will be required for development purposes.

Competitive Interest

A Known Geothermal Resources Area (KGRA) was established at Roosevelt Hot Springs prior to the beginning of leasing in the public domain in January 1974. Therefore, no applications for non-competitive leases were accepted for a zone of 23,000

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acres centered on the former hot spring and the opalite mound. Figure 8 shows the location of the KGRA, and table 3 lists the successful bids entered in the July 30, 1974 competitive lease sale.

The principal bidders at this sale were Phillips Petroleum Company, Getty Oil Company, Union Oil Company (all of whom were successful in varying degree), Gulf Oil Company, Al-Aquitaine Oil Company and American Oil Shale Corporation (all of whom were unsuccessful). Phillips was the major winner, purchasing nearly 19,000 acres for a bonus of $800,000, or $43 per acre, averaged. Actual bids by Phillips ranged up to $128.06 per acre for lease units 6 and 4. This revealed their preference for the western side of the Dome fault; this, of course, was prior to their first deep drill holes.

One parcel of 40 acres was claimed under grandfather rights by A. L. and W. L. MacDonald, of Milford, Utah, for the equivalent of $58.38 per acre, thereby matching Phillips' bid.

On June 12, 1975, 1,200 acres in the KGRA was reoffered, and were bid on (and won by) a private party, Gary Seltzer.

The largest block of fee leases in the area is held by Thermal Power Company of Utah (TPU). Acreage in these leases has been optioned or re-leased to Natomas Company, AMAX Exploration, Inc., and others. In addition to fee leases, several companies and private parties have applied for non-competitive leases to public domain. These include Phillips, Union, Getty, AMAX, American Oil Shale (now American Geothermal Energy Co.), TPU, Davon and Geothermal Exploration Company, among many others. In addition to Seltzer, private applicants include Milton Fisher (associated with American Geothermal Energy), Malcolm Justice, Christopher Marks, Trevor Windsor and Cecil Folmar, to name a few.

Federal acreage held by Seltzer, Windsor and Folmar have been assigned to Geothermal Power Corporation.

Several sections of State land also have been applied for and awarded for lease.

Taken together, these leases and applications cover at least 85 percent of a nearly continuous zone 17 miles long (north-south) and 9 miles wide (east-west).

Leasing extends in discontinuous fashion westward across the floor of Milford Valley; southerly and southwesterly toward

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Table 3. Summary of KGRA lease sales in Utah

ROOSEVELT HOT SPRINGS, JULY 30, 1974

Unit	Acreage	Bids Received: Amount	$/Acre	Bidder
1	2,560	$ 51,994	20.31	Union Oil*
		23,372		Gulf Oil
		13,082		Phillips Petroleum
2	1,640	87,543	53.38	Phillips Petroleum*
		62,090		Union Oil
		14,973		Gulf Oil
3	1,920	9,812	5.11	Phillips Petroleum*
4	2,454	314,199	128.04	Phillips Petroleum*
		93,234		Union Oil
		22,400		Gulf Oil
5	1,644	8,401	5.11	Phillips Petroleum*
		5,877		Aquitaine
6	1,940	248,392	128.04	Phillips Petroleum*
		53,350		Getty Oil
		42,672		Union Oil
		17,709		Gulf Oil
		6,139		Aquitaine
7	1,961	41,856	21.34	Phillips Petroleum*
8	2,273	62,903	27.67	Phillips Petroleum*
		28,412		Getty Oil
		20,747		Gulf Oil
9	1,920	24,000	12.50	Getty Oil*
		17,529		Gulf Oil
		9,811		Phillips Petroleum
		4,992		American Oil Shale Corp.
10	2,560	13,082	5.11	Phillips Petroleum*
11	2,480	12,673	5.11	Phillips Petroleum*
12	40	2,335	58.38	A.L. & W.L. McDonald* (grandfather applicant)
		2,335		Phillips Petroleum

JUNE 12, 1975

Unit	Acreage	Amount	$/Acre	Bidder
1	1,200	2,586	2.16	Gary Seltzer

*indicates bid accepted by Dept. Interior

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and beyond Thermo Hot Springs; and northeastward into the Cove Fort region. The scope and intensity of this leasing operation rivals leasing at The Geysers geothermal field in California, and clearly exceeds activities elsewhere in Utah, or in adjacent Nevada, Arizona, Idaho or Wyoming.

Many companies that have not established satisfactory leasehold positions at Roosevelt have gone farther afield, or have attempted to purchase positions. Therefore, although not listed as active at Roosevelt, the interest of Chevron Oil Company, Hunt Oil Company, Earth Power Corp., Sun Oil Company and Atlantic Richfield Co. should be noted.

It can be said fairly that at this time a market exists for the farm-out, sale or joint venture of all leases and applications within the 150-square-mile zone described above, even though less than one-tenth of that area can be classified as proven geothermal field. Therefore, the acreage held by Geothermal Power Corporation (plate 1 and figure 7) is to a very large degree of interest for farm-out, sale or joint venture, especially acreage in T. 26 and 27 S., R. 9 W., and to a lesser degree T. 28 S., R. 9 W. Further, were Geothermal Power Corporation to drop any leases or applications, it is highly likely that another entity immediately would attempt to obtain leases to those lands.

Because of the very intense competition for attractive acreage, no significant new position can be acquired within T. 26 and 27 S., R. 9 W. without either bonus payments in cash, a commitment to expend money on exploration and deep exploratory drilling, or both.

Undoubtedly there will be unsuccessful holes drilled in the Roosevelt area as exploration proceeds. At that time, the value of various lease blocks will decline, depending upon position relative to these dry holes. Conversely, further drilling probably will expand the perimeter of production, especially eastward, thus raising the value of certain acreage.

At this time, the acreage held by Geothermal Power Corp. in T. 27 S., R. 9 W. prospectively is worth several tens of dollars per acre; that in T. 26 S., R. 9 W., only slightly less. Acreage in T. 28 S., R. 9 W. is worth perhaps half as much, prospectively; and acreage elsewhere may be valued at a few dollars per acre.

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Therefore, it would be realistic to expect another company to be willing to spend several hundred thousand dollars in bonus, exploration and drilling in order to obtain fractional interest on the most favorable of Geothermal Power Corporation's acreage.

Exploration Program

In recent months, very good data on complete Bouguer anomalies and aeromagnetic intensity have become available for the majority of leases held by Geothermal Power Corp. It is not anticipated that further gravimetry or aeromagnetometry will be useful in classifying acreage or siting deep holes.

Chemical data are available for wells drilled in Milford Valley (although not included herein) and for a few springs of the Mineral Mountains. Chemistry of the lowland wells rarely is revealing of the deep geothermal system; data from the highland springs are dominated by precipitation and infiltration. Therefore, no further hydrochemical work is warranted at this time.

Geologic mapping, including photogeology, for the central and western Mineral Mountains is adequate to very good in quality and detail. However, geology of the eastern and northeastern flanks of the Mineral Mountains is less well known, and may benefit from some intensive photogeology. This would have as its goals the recognition of fault and fracture patterns and establishment of volcanic stratigraphy. Probably it would be useful to collect some volcanic rock samples of that area for radiometric age-dating.

Seismic and geoelectrical techniques continue to provide important data for the region, especially in the vicinity of Cove Fort. However, because of work released or in progress by public agencies, and because of the high cost of obtaining additional data, and the uncertainty of collecting and interpreting seismic records, no further seismic or geoelectric work is recommended at this time. However, efforts should be made to obtain data from publically funded surveys as soon as they are released, for integration with other data. Additionally, if private contractors offer to provide data at lower cost to a group of participating companies, or if a trade of private data is suggested by other companies, this should be considered for cost-effectiveness.

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The burden of exploration will have to be borne by gradient drilling and heat-flow calculation. This is so despite the twin constraints of (1) the effects of recharge and outflow on gradients, and (2) the need to convert gradient data to heat flow, to compensate for variations in thermal conductivity between sediment and basement rock. A third possible constraint is the cost of obtaining these data.

Costs for permitting, drilling and logging holes, and for calculating heat flow should not exceed $10 per foot for holes to 100 meters (328 feet) and may be as little as $5 per foot. Holes must be deeper than 200 feet, to penetrate beyond seasonal effects and the effect of cold-water recharge. However, in some areas cold-water recharge may be detected to several hundred meters.

A series of over 20 locations is recommended on plate 1 for 300-foot-deep gradient holes. These are designed to test the acreage held by Geothermal Power Corp. in T. 26-28 S., R. 8-9 W., especially Sec. 13, 24 & 25, T. 27 S., R. 9 W. and Sec. 25, T. 26 S., R. 9 W. The latter, overlying parts of the Quaternary volcanic field, are considered promising for exploration. Also, Sec. 33-35, T. 27 S., R. 9 W. and Sec. 4-5, T. 28 S., R. 9 W. lie within the anomalous Bouguer gravity low (figure 7), and should be tested for gradient.

If anomalies are detected at 100 meters, and sustained by calculation of heat flow, consideration should be given to testing deep heat flow in holes 300 to 600 meters (1,000 to 2,000 feet) in depth. Additionally, if encouragement is received from gradient drilling, it may be advisable to perform further analyses of the gravity, aeromagnetic, seismic and geoelectric data. By encouragement is meant gradients above 100° to 150°C/km in poorly consolidated materials, and over 70° to 80°C/km in crystalline rock.

Costs for a 300-foot-deep hole, including logging, calculation of heat flow, and reporting, should average $1,500 to $3,000. Therefore, a 10-hole program might cost $15,000 to $30,000. This is the minimum number of holes recommended. Fifteen to twenty holes, with a corresponding increase in total cost, is preferable for so large and scattered an acreage position, if budget permits.

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It may be possible to augment this total of gradient data points by conducting trades with other companies active in the region.

It is far too early to predict location of a deep geothermal test on this property. However, it is likely that deep drilling will be warranted, if merely on the proximity to high-temperature, high-yield wells as little as two miles distant. In 1976 dollars, costs for deep holes at Roosevelt have averaged $80 per foot, including completion, but exclusive of extensive testing.

Acreage should be reviewed periodically for retention or release. Acreage undergoing exploration, or scheduled for exploration, should be retained until work is completed and evaluated. Acreage that is judged of lower quality, either as the result of new data or as based upon presently existing criteria, should be offered for farm-out or sale prior to being dropped. Farm-outs, sales and joint ventures should not be considered for the most attractive acreage, unless budgetary constraints force this.

There is little likelihood of leasing new acreage of high quality in the area. Therefore, consideration should be given to pooling acreage with other small companies holding adjoining acreage of high quality, to thereby increase leverage for exploration and drilling. The single section (12, T. 27, S., R. 9 W.) held by Geothermal Exploration Co. obviously fits this concept.

Several sections of land leased by Geothermal Power Corp. are attractive for exploration, and may overlie commercial reserves of geothermal fluid. These should be explored promptly, efficiently and with an adequate budget. Drilling of shallow gradient holes, perhaps two or three deep gradient holes, and supportive geologic and geophysical work probably can be accomplished for $82,500 to $135,000, as follows:

Fifteen 300-foot gradient holes	$22,500 - $ 45,000
Photogeology, radiometric age-dating	5,000
Two 2,000-foot gradient holes <u>or</u> three 1,500-foot holes	$60,000 - 80,000
Reporting, data trade, data interpretation, miscellany	5,000
	$82,500 - $135,000

This would certainly place Geothermal Power Corp. in the position to site one or more deep exploratory holes.

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It is premature to estimate the depth or location of a deep geothermal hole. However, in today's dollars, drilling and completion, exclusive of testing, at Roosevelt Hot Springs costs $80 to $100 per foot. Recent holes there have averaged 6,000 to 7,000 feet in depth. By extension, it is possible to prepare hypothetical budgets, again in 1977 dollars, for holes assumed to be 6,000 to 7,500 feet in depth.

1 hole (7,500 feet), drilled, completed, logged and tested ($80-$120 per foot)	$600,000 - $ 900,000
2 holes (6,000 feet), drilled, completed, logged and tested ($80-$120 per foot)	960,000 - 1,440,000
	$1,560,000 - $2,340,000

If to this is added the costs of drilling and logging gradient holes (see above), $82,500 to $135,000, the total hypothetical cost range is $1,642,500 to $2,475,000. By averaging, this yields a figure of $2,000,000 as a possible cost range for gradient drilling and logging of nearly 9,000 feet, followed by siting, drilling and testing of 3 deep holes with a total of nearly 20,000 feet around the Roosevelt geothermal field.

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