Idaho Geothermal Report

BIG CREEK HOT SPRINGS

SITE SPECIFIC DEVELOPMENT ANALYSIS

IDAHO OFFICE OF ENERGY
John V. Evans, Governor

Prepared for the United States Department of Energy, Division of Geothermal Energy

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By

William B. Eastlake
and
Alex Sifford

With a Section on

Resource Evaluation

by

Debra Struhsacker

University of Utah Research Institute

IDAHO OFFICE OF ENERGY
OFFICE OF THE GOVERNOR

GOVERNOR JOHN V. EVANS

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

BIG CREEK HOT SPRINGS

SITE SPECIFIC DEVELOPMENT ANALYSIS

PREFACE

Big Creek Hot Springs, Idaho are located in central Idaho, approximately 3.2 kilometers (2 miles) south of the Salmon River on Salmon National Forest Land. The unsurveyed Section 22, Township 23N, Range 18E, in Lemhi County, Idaho contains these springs, the second hottest springs in Idaho. Temperatures as high as 93°C (200°F) have been recorded at the site.

Big Creek Hot Springs was selected for a site specific development analysis because: it is one of very few sites in Idaho with electrical generation potential, the newly developed Blackbird Cobalt Mine nearby at Cobalt, Idaho is interested in evaluating the electric power generating potential of Big Creek, and the Earth Science Laboratory at the University of Utah Research Institute requested assistance from the Office of Energy.

1.0 Introduction

A site specific development analysis is a qualitative and quantitative analysis of technical, economic, environmental, and institutional factors which influence the scale and timing of geothermal development. The analysis is based on current information available in the literature and reflects the intent of the development interest at Big Creek Hot Springs (H.S.), Idaho. This study summarizes known information, estimates economic risk, and outlines institutional parameters which are site specific to the Lemhi County area. The Big Creek H.S. Specific Development Analysis involves locating a binary cycle generation facility near Big Creek H.S. and transmitting electricity to the Blackbird Cobalt Mine.

A review of current socio-economic data was conducted to determine the nature of the regional economy and the potentials for growth. Resource data for the Lemhi County area was provided by the Idaho Department of Water Resources, the U.S. Geological Survey, and the Idaho Bureau of Mines and Geology. Detailed resource geochemical information was compiled from reports issued by the Idaho Department of Water Resources.

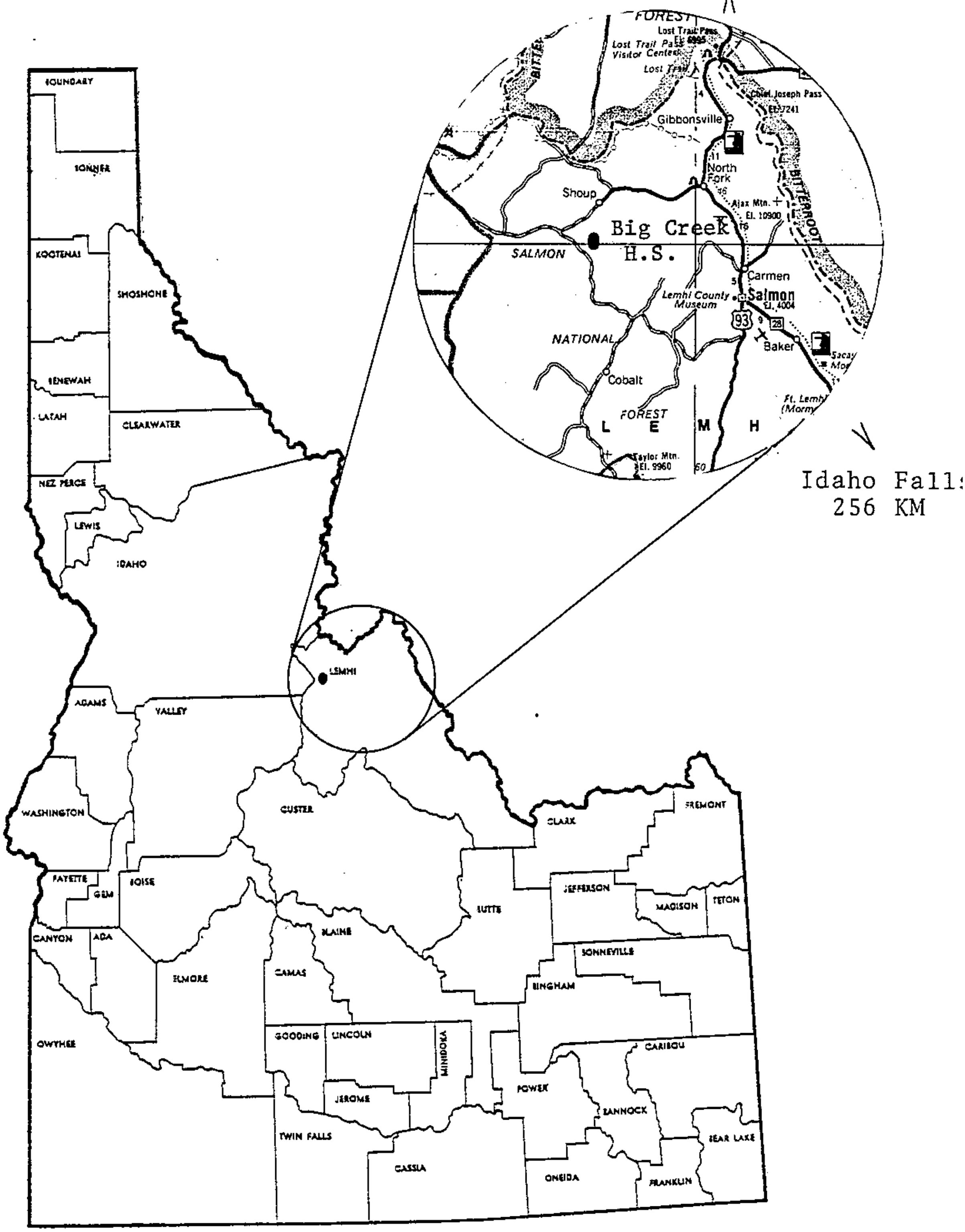
The resource temperatures are expected to range from a minimum of 93°C (200°F) to a maximum of 149°C (300°F) for drilling depths of less than 1828 meters (6,000 feet). Temperatures predicted by geochemical thermometers seem to indicate that thermal waters in the area ascend along fault zones from an aquifer or reservoir source with temperatures from 137°C (279°F) to 173°C (344°F). These higher temperature resources may be circulating to depths approaching 900 meters to 3048 meters (3000 to 10,000 feet).

2.0 Site Description

2.1 Location

Big Creek Hot Springs, Idaho in Lemhi County, is approximately 40 kilometers (25 miles) northwest of Salmon, Idaho and 168 kilometers (105 mi.) south of Missoula, Montana, The area

Figure 2.1
LOCATION OF BIG CREEK
HOT SPRINGS, IDAHO



is remote, although not roadless. Figure 2.1 shows the location of Big Creek Hot Springs.

The springs are located high in the Hot Springs Creek drainage, a tributary of Panther Creek, which in turn empties into the Salmon River. The rugged topography is characterized by flat-topped mountains and moderate to steep V-shaped canyons. Altitudes range from 982 meters (3220 ft.) at the Salmon River to 1317 meters (4320 ft.) at Big Creek H.S. to 2162 meters (7093 ft.) at nearby Copper Mountain.

2.2 Demographics

As the closest towns to Big Creek H.S. have very small, stable populations, the demographic characteristics of Lemhi County will be examined.

The estimates of the future population of Lemhi County are made on the basis of past trends. Many changes in circumstances, especially in economic conditions, can change these trends. The local city and county population changes can vary from the experience of a larger area, such as the state. However, the usual situation is for the smaller area to follow a pattern set by the larger region.

Population change in Lemhi County is related to federal and state estimates. Three estimates, high, medium, and low, were made for the population of Idaho until 1990. All of these are based on preliminary and published estimates made by the U.S. Census Bureau and the Idaho Department of Water Resources. Population projections for Lemhi County are based on the medium series of estimates of state growth.

Growth in Lemhi County is predicted to occur in two ways: first, along the Salmon River valley and the Lemhi River valley, including the towns of Salmon and Leadore. Secondly, growth will occur as a direct result of increasing mining activity. In August of this year Noranda Mining Inc. announced plans to reopen the Blackbird cobalt mine, located 65 kilometers (42 mi.) west of Salmon, on a trial basis. The company townsite of Cobalt, Idaho had only a caretaker population until recently, and now contains approximately 200 people. With the proposed developments an additional 500-600 persons are expected to move into the area, nearly all to Salmon. The influx of mineworkers will cause a resulting increase in services and service employees, primarily in Salmon.

Table 2.2 shows the population forecast for Lemhi County. None of the sources used in the forecast takes new mine development into account and the forecast may therefore be considered conservative.

TABLE 2.2

POPULATION FORECAST

	1970	1975	1980	1985	1990	1995	2000
Lemhi County	5560	6400	7289	7990	8590	9020	9310
Salmon	2910	3202	3237	3419	3601	3803	4004
Leadore	111	141	114	116	117	119	120
Cobalt	--	--	250	250	250	250	250

Sources: U.S. Dept. of Commerce, 1970 Census Figures

County Profiles of Idaho, Idaho Division of Budget, Policy Planning and Coordination, 3rd ed., 1978 estimate

U.S. Dept. of Commerce, 1980 Preliminary Updated Census Figures

Population and Employment Forecast - State of Idaho, Series 2 - Projections, 1975-2000, Idaho Department of Water Resources

IOE Forecast Based on 1970-1980 Growth Rate

Lemhi County is a rural county which will continue to grow and that growth primarily will be along the river valleys and in the town of Salmon.

2.3 Regional Economy and Employment

Lemhi County economic activities were analyzed to provide a working knowledge of the present and past economic base, as well as to estimate the type of future activities which could occur. Lemhi County has had a moderately growing economy, particularly in the government, manufacturing, and trade sectors. Table 2.3.1 lists the major economic elements of Lemhi County's economy.

Opportunities for growth in Lemhi County in the near future will be tied both directly and indirectly to new mining operations. As explained in the previous section the reopening of the Blackbird cobalt mine will create 500-600 new jobs in the area. In turn, new service jobs will be created to handle the increased demand for goods and services. Combined with recreation-oriented employment and continued growth in the manufacturing sector, Lemhi County should continue to experience growth in the local economy. Table 2.3.2 lists an employment forecast summary for Lemhi County.

2.4 Climate

The climate of Lemhi County varies with elevation. The lower Lemhi Valley and Salmon River Valley areas have a semi-arid climate with warm summers and moderately cold winters. The mountainous areas are cool in summer and cold in winter with heavy snowfalls.

The average frost-free period for the major agricultural areas is ninety-seven (97) days. Due to the short growing season, crops that are frost tolerant and mature quickly are the most successful. These include grains and hay pasture. A significant percentage of Lemhi County is rangeland.

Climatological data for Salmon, Idaho has been collected for over 58 years. The same data has been collected at the Blackbird Cobalt Mine for over ten years. Although many climatological extremes have yet to be recorded at the mine, variations due to elevation can be seen. Table 2.4 shows climatological data for Lemhi County.

TABLE 2.3.1
ECONOMY - LEMHI COUNTY

Percent of average monthly unemployment - 1978:

Jan. 11.6%	Feb. 12.0%	Mar. 11.0%	Apr. 9.1%	May 6.6%	Jun. 5.7%
Jul. 4.8%	Aug. 4.2%	Sep. 5.0%	Oct. 5.6%	Nov. 7.0%	Dec. 10.2%

Percent of labor force unemployed: 1970 6.0%; 1972 7.3%; 1975 8.9%; 1978 7.6%

Month and percentage of highest unemployment: 1975 Feb. 14.8%; 1978 Feb. 12.0%

Month and percentage of lowest unemployment: 1975 Aug. 5.1%; 1978 Aug. 4.2%

Percent of females (16+) in labor force: 1960 (14+) 28.2%; 1970 28.0%

Employment (B.E.A. data)	1967	1970	1977	1978
Total employment	2,080	2,111	2,674	2,877
Farm proprietors	367	345	294	292
Non-farm proprietors	366	366	379	406
Wage and salary employment:				
Federal civilian	151	153	219	244
Military	--	--	44	43
State & local	244	275	356	366
Manufacturing	177	227	340	428
Mining	(D)	17	14	11
Construction	36	30	50	76
Trans., Comm. & Pub. Util.	37	41	45	48
Trade	259	294	455	466
Finance, Ins. & Real Est.	(D)	25	48	52
Services	184	188	242	249
Other	8	9	22	22
Farm	174	141	166	174

(D) Not shown to avoid disclosure of confidential information.

Average Idaho tax return (county) - 1978: $354

Average Idaho tax return (state) - 1978: $476

Market value of all property - 1979: $100,655,744

Total property tax collected - 1979: $1,290,927

Sales tax: 1974* $398,617 1975* $397,891 1977* $525,827
1979* $708,114
*Fiscal Year

Property tax as percent of market value: County - 1979 1.283%;
State - 1979 1.392%

Highest tax code area and the tax as a % of market value - 1979: Area (6) 2.351%

Per capita income:	1970	$2,578	1978	$6,414
% of national average:	1970	65.0%	1978	81.8%
% of state average:	1970	78.4%	1978	90.7%

Median family income - 1969: $6,902 Median family income*-1976: $10,750
*HUD estimate

Transfer payments (thousands of dollars - county):
1970 $2,272 1974 $3,935 1975 $4,787 1978 $6,906

Number of business establishments - 1978: 186

TABLE 2.3.2

POPULATION AND EMPLOYMENT FORECAST

Lemhi County - 1978

EMPLOYMENT SUMMARY

	1972	1975	1980	1985	1990	1995	2000
Agriculture	740	740	712	683	654	632	610
Mining*	14	16	17	18	19	19	20
Construction	60	44	71	88	107	138	178
Food and Kindred	8	36	39	42	46	50	54
Wood Products	194	138	155	170	187	202	219
Other Manufacturing	6	18	24	28	32	37	44
Trans, Comm, and Utils	42	54	55	55	56	57	58
Whsle and Retail Trade	526	694	817	874	937	1004	1080
Finance, Ins., Real Est	62	60	78	90	103	117	135
Services and Misc.	282	229	257	274	292	314	339
State and Local Govt.	280	322	346	361	377	396	418
Federal Government	165	169	174	183	191	198	206
Total	2379	2520	2751	2871	3006	3169	3366

FORECAST SUMMARY

	1970	1975	1980	1985	1990	1995	2000
Total Population	5560	7030	7540	7990	8590	9020	9310
Total Employment	2370	2520	2750	2870	3000	3160	3360
Labor Force	2260	2900	3120	3250	3410	3590	3800

Source: Idaho Department of Water Resources and
Center for Research, Grants, and Contracts,
Boise State University (1978).

*Forecast excludes Blackbird Mine Development

TABLE 2.4

CLIMATOLOGICAL DATA FOR LEMHI COUNTY

Station	Cobalt Mine	May R.S.	Salmon
Elevation	6810'	5110'	4044'
Years of Record	10	31	58
Average Daily Temperature (°F)			
January Minimum	6.6	4.1	6.2
January Maximum	26.3	29.3	29.7
July Minimum	41.7	45.7	47.1
July Maximum	75.1	84.9	88.8
Lowest Temperature of Record	-26	-40	-37
Highest Temperature of Record	91	102	106
Average Annual Days			
Maximum of 90° or more	19	13	35
Minimum of 32° or less	243	202	205
Growing Season*	53	76	97
Average Precipitation (inches)			
Annual Precipitation	20.17	7.54	8.93
Annual Snowfall	164.2	19.9	19.7
January Precipitation	1.44	0.46	0.56
July Precipitation	.86	.65	.81
Average Annual Number of Days with Precipitation			
.10 inches or more	59	38	30
.50 or more	14	5	3
Degree Days	10701	8259	7707

* The average number of days between mean last 32° temperature in spring and mean first 32° in fall, that is the average freeze free period.

Source: Idaho Climatological Summary Data by Counties. National Weather Service Climatology in cooperation with the Idaho Department of Commerce and Development, Boise, Idaho. October, 1971.

3.0 Resource Evaluation

Under the U.S. Department of Energy technical assistance program, prospective geothermal users may apply for free engineering and geological assistance. Noranda Mining Inc. made a request under this program to the Earth Science Laboratory, University of Utah Research Institute for geological assistance. The resulting preliminary report is published herein in its entirety.

PRELIMINARY INFORMATION

PRELIMINARY EVALUATION OF THE GEOTHERMAL RESOURCE POTENTIAL OF BIG CREEK HOT SPRINGS, LEHMI COUNTY, IDAHO AND A SUGGESTED GEOTHERMAL EXPLORATION STRATEGY

by

Debra W. Struhsacker

EARTH SCIENCE LABORATORY DIVISION
UNIVERSITY OF UTAH RESEARCH INSTITUTE
420 Chipeta Way, Suite 120
Salt Lake City, Utah 84108

Prepared for
Noranda Mining, Inc.

TABLE OF CONTENTS

ILLUSTRATIONS

PART I. GEOTHERMAL RESOURCE POTENTIAL OF BIG CREEK HOT SPRINGS

Introduction

The geothermal potential of Big Creek Hot Springs is largely unknown and remains to be tested by geologic and geophysical investigations. However, the available data do allow some speculation as to the type of geothermal system present at Big Creek, and the temperature potential at depth. Exploration methods to assess the system are suggested in Part II of this report.

Regional Setting and Background Information

Big Creek Hot Springs (T. 23N, R. 18E, Sec 22, Lemhi County, Idaho) is the second hottest hot spring in Idaho. The location of this system is somewhat anomalous since most of the geothermal systems in Idaho are concentrated along the Snake River Plain. Likewise, many of the geothermal studies in Idaho have focused upon the Snake River Plain region; very little is known about most other systems in the state.

There is virtually no published information on Big Creek Hot Springs. Bennett's (1977) map of the Blackbird Mountain-Panther Creek area shows the hot spring and a northeast-trending fault, Hot Springs Fault, running through the system, but does not discuss the geothermal potential of the area. Mitchell and others (in press) list chemical and geothermometry data for the system, note the presence of carbonate and siliceous deposits around active vents, and remark that the hot springs occur on the ridge top rather than along the base of the ridge as is the usual case in a fault-controlled system. Published gradient and heat flow maps for the state (Brott and others, 1976) show no thermal measurements for the Big Creek area. More recent investigations have not obtained data for this part of Idaho (Mitchell, verbal communication).

Heat Source for the Big Creek Hot Springs Geothermal System

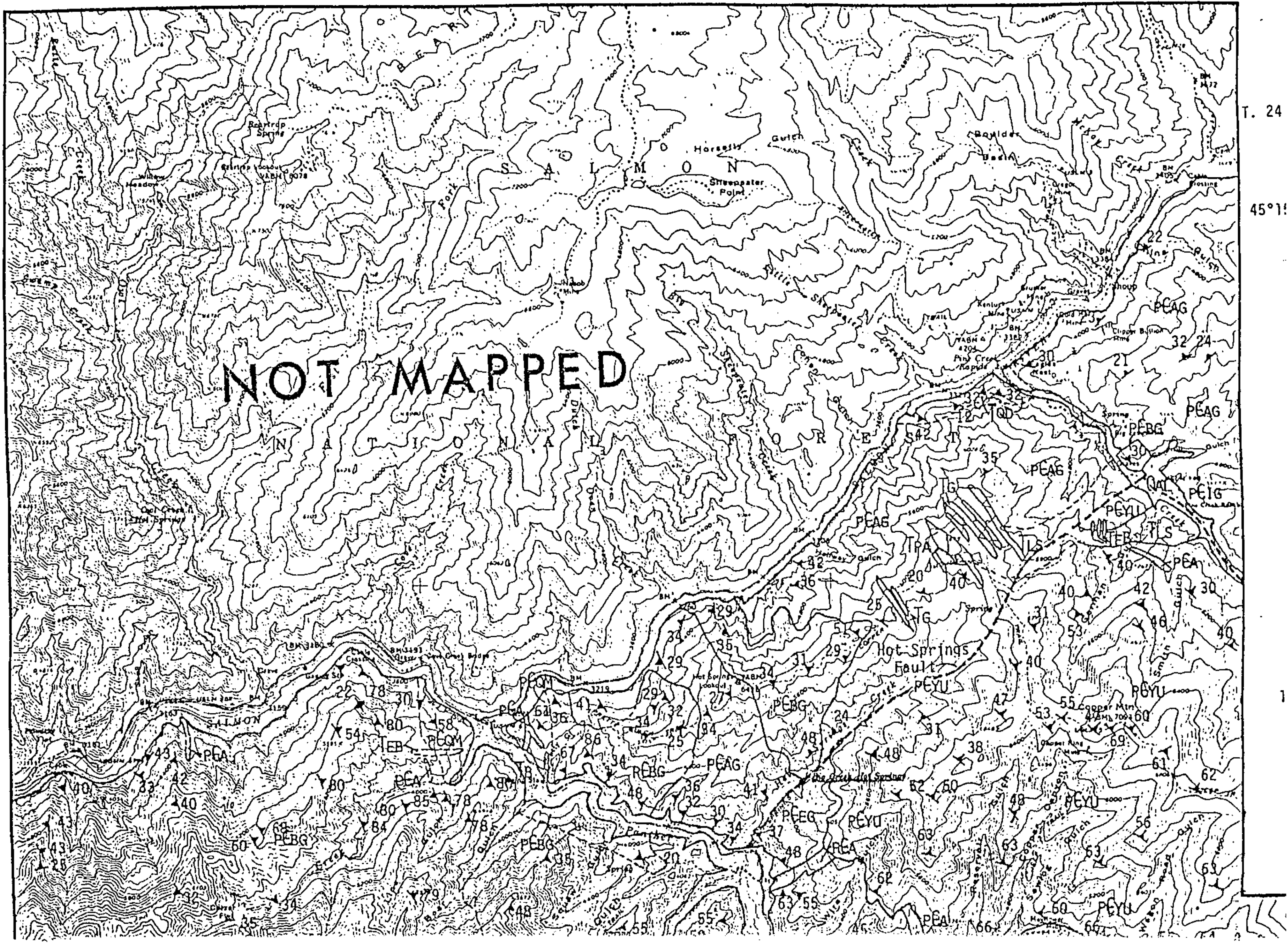
There are two models of hydrothermal geothermal systems commonly used to describe geothermal systems in the western United States. The first type is the magma-driven system in which a magma body or a very young intrusive mass acts as the geothermal heat source. The magma-driven systems are restricted to areas of recent (generally less than one million years old) volcanism, and are characterized by very high reservoir temperatures. The Geysers field north of San Francisco, portions of the Imperial Valley geothermal district in southern California, and the Roosevelt Hot Springs system in southwestern Utah are examples of geothermal systems with magmatic heat sources. The lack of recent igneous activity in the Big Creek area suggests that a magmatic heat source for this system is extremely unlikely.

The second type of system is the fault-controlled variety in which cold, meteoric water seeps downward, is heated by conduction of heat due to the local geothermal gradient, and rises along faults where it may be exposed at the surface as a hot spring, geyser or fumarole. The temperature attained by fluids in a fault-controlled system depends upon the depth of fluid circulation and the local geothermal gradient.

Most of the geothermal systems in the western United States are fault-controlled. The traditional setting for a fault-controlled geothermal system is the basin and range where thermal features commonly occur along range-front faults. Figure 2 is a schematic illustration of a basin and range, fault-controlled system. (It should be added that fluid circulation in fault zones is also important in geothermal systems with magmatic heat sources).

Although Big Creek Hot Springs is not in a traditional basin and range setting, the coincidence of Hot Springs Fault with the geothermal systems (Bennett, 1977) strongly suggests that the Big Creek system is fault-controlled. Figure 1 is

Figure 1. Geologic map of the Big Creek Hot Spring area (Bennett, 1977).



EXPLANATION

QAL	Alluvium
QLS	Landslide deposits
QGL	Glacial terrace deposits
QT	Terrace gravels
TA	Late Tertiary ash
TI	Interbeds
TCV	Undifferentiated Challis Volcanics
TPA	Porphyritic andesite
TED	Undifferentiated Tertiary dikes
TEB	Basalt dikes
TG	Gabbroic dikes
TQD	Orbicular quartz diorite
TCP	Crags pluton
TLS	Late Cretaceous - Tertiary Leesburg stock
pЄQM	Quartz monzonite orthogneiss
pЄAG	Augen Gneiss Complex. Augen gneiss (pЄAG)/Ellipsoidal gneiss (pЄEG)/gneiss intermediate between pЄAG and pЄEG = pЄIG
pЄIG	
pЄEG	
pЄA	Amphibolite dikes
pЄHU	Hoodoo Quartzite pЄHU, upper unit may be equivalent to Ruppel's (1975) Apple Creek Formation. pЄHL, lower unit is probably equal to Ruppel's (1975) Big Creek Formation.
pЄHL	
pЄYU	Yellowjacket Formation pЄYU-upper dark gray, impure quartzite member and pЄYL-lower phyllite member.
pЄYL	
pЄQB	"Mixed unit" Consists of quartzites, schists, phyllites and argillites, which are probably Yellowjacket Formation at a higher metamorphic grade.
pЄGS	Garnet schist Probably Yellowjacket Formation units at a higher metamorphic grade
pЄBG	Undifferentiated schists and other metamorphic rocks - Probably Yellowjacket

a geologic map of the area showing Hot Springs Fault.

The nature of Hot Springs Fault is presently unknown, and must be identified in order to understand the Big Creek system. The temperature potential of the Big Creek system will depend upon the local geothermal gradient, and the depth to which fluids can circulate along Hot Springs Fault. A high-angle fault will permit greater depths of circulation than a low-angle structure. The permeability of Hot Springs Fault will also influence depth of fluid circulation.

Temperature Potential of the Big Creek Hot Springs Geothermal System

The geothermometer estimates of base reservoir temperature for Big Creek Hot Springs range from 137°C (chalcedony conductive geothermometer) to 179°C (Na-K-Ca geothermometer). Table 1 summarizes the geothermometry data for the system.

Table 1. Geothermometry Estimates of Base Reservoir Temperature for Big Creek Hot Springs, Idaho.

Geothermometer	Mitchell and others (in press)	Muffler (1979)
Quartz Conductive	161°C	157°C
Quartz Adiabatic	152°C	149°C
Chalcedony Conductive	137°C	N.A.
Na-K-Ca	173°C	179°C

Muffler (1979) reports that the most likely geothermometer estimate of reservoir temperature is 157°C.

The various silica geothermometers listed in Table 1 are applicable in different geologic circumstances. As a rule, the chalcedony geothermometer is best applied in systems with reservoir temperatures of less than 100°C, although it may be useful in some situations with temperatures as high as 150°C (Fournier, 1972). The quartz conductive geothermometer assumes no steam loss due to boiling and is probably the best geothermometer for the Big Creek system. In contrast, the quartz adiabatic geothermometer assumes maximum steam loss. The Na-K-Ca geothermometer is useful in many situations in which equilibrium with feldspars has been attained and in which no calcium has been lost due to precipitation of $CaCO_3$.

Geothermometers are a valuable tool in predicting reservoir temperature conditions provided that the following assumptions are met (Fournier and others, 1974):

1. Temperature-dependent reactions at depth control the concentration of the constituents used in the geothermometer.
2. The reservoir contains an adequate supply of the reactants.
3. Water-rock equilibrium is established in the reservoir.
4. The constituents used in the geothermometer do not reequilibrate with the confining rock as the water flows to the surface.
5. Mixing of thermal and nonthermal groundwater does not occur.

A comparison of geothermometer values with measured downhole temperatures for numerous systems in the Basin and Range (primarily southwestern Utah and northern Nevada), suggests that geothermometers provide a reliable estimate of reservoir temperature. In general, the geothermometer-predicted temperatures come within $20^{o}C$ of the measured downhole temperatures (unpublished Earth Science Laboratory report).

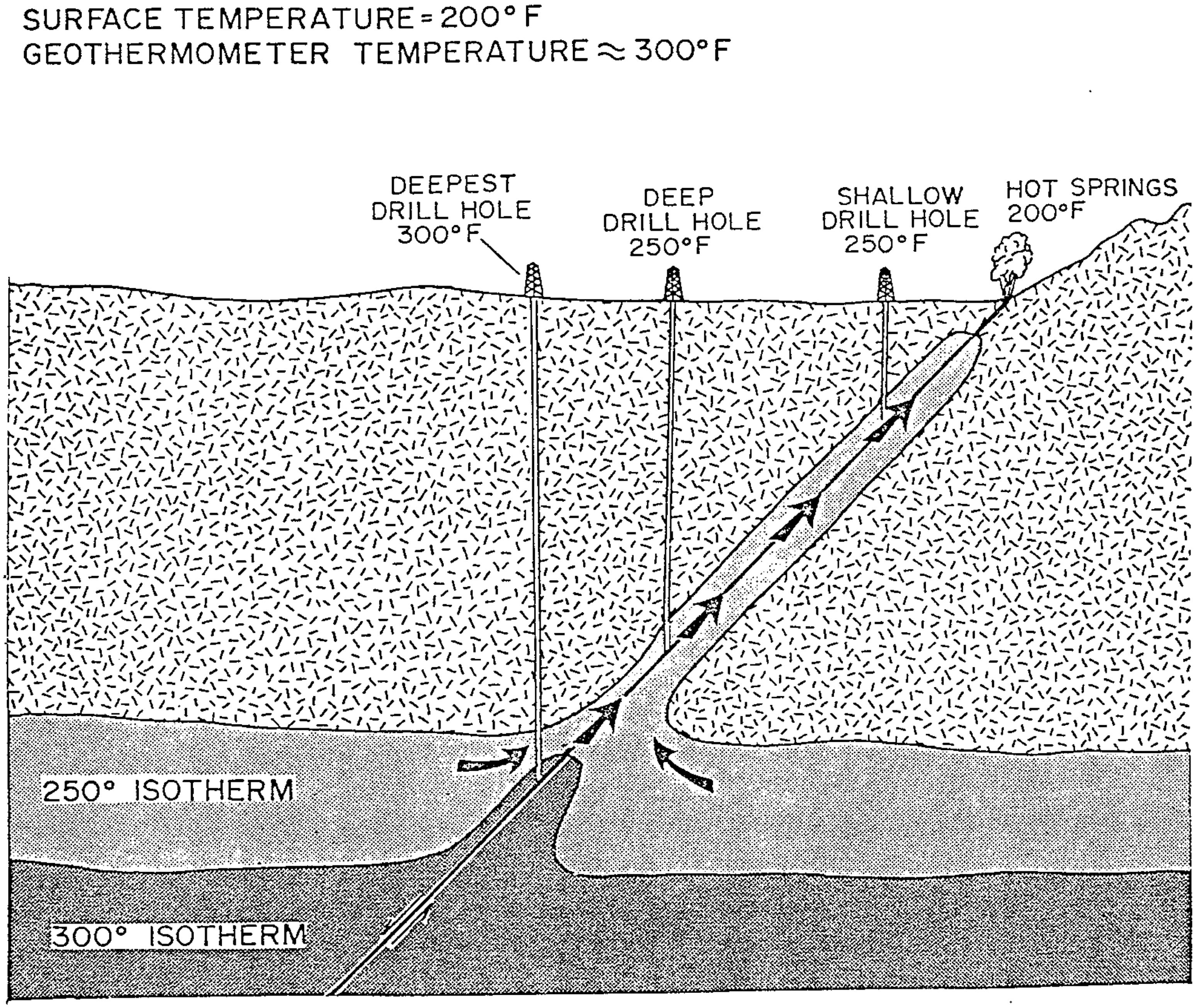
It must be stressed, however, that geothermometers do <u>not</u> predict temperature at a given depth. In some systems the predicted reservoir temperature may only exist at great depth, beyond the economic limits of a drill hole. Thus, the geothermometry data do not permit estimation of the depth at which $157^{o}C$ fluids might be found in the Big Creek geothermal system. However, projection of the geothermal gradient to depth does give a maximum depth at which a predicted target temperature might exist. Since there are no gradient data available for the Big Creek area, an average normal geothermal gradient of 35°C/km will be assumed. (Future thermal gradient measurements might reveal a higher gradient.) In order to attain a target temperature of 157°C (the most likely geothermometry estimate), meteoric fluids in the Big Creek geothermal system must circulate to a depth of 4.48 km (14,718 ft) provided that conduction of heat due to the geothermal gradient is the only heat source.

Assuming that Big Creek hot springs is a fault-controlled geothermal system, 157°C water may be attainable at much shallower depths due to upward circulation of geothermal fluids along Hot Springs Fault, and the attendent upward-bowing of isotherms along the fault as illustrated in Figure 2. It should be noted that fault-controlled geothermal systems are commonly characterized by isothermal zones at depth along the fault. In these isothermal zones, temperature remains relatively constant with depth. Thus for the hypothetical system shown in Figure 2, moderate-temperature (250°F) water is obtainable at a relatively shallow depth along the fault zone. However, the 250°F isotherm persists to considerable depth. Relatively deep wells are required to intersect the 300°F isotherm along the fault, thereby reaching the target temperature as predicted by the geothermometers. Much greater drilling depths would be required to intersect the 300°F isotherm outside of the fault zone.

Flow Potential of the Big Creek Hot Springs Geothermal System

Unfortunately there are no techniques that estimate the fluid flow potential of a geothermal system. Moreover, there is no guarantee or way to predict that fluids will be available at the depth required to attain a target temperature.

Figure 2. Generic Model of Isothermal Circulation Along a Fault Zone



As such, the production characteristics of systems for which no pre-existing drilling and flow testing data are available represent the largest unknown and risk-laden factor in geothermal exploration. It should be noted that the production potential of individual wells within one geothermal field can be quite variable due to the quality of the site drilled (dry holes exist in producing fields), and the drilling and completion techniques employed.

The permeability of most fault-controlled geothermal systems is commonly limited to fracture zones and fracture intersections. Thus, fault zones and fault intersections are usually the primary drilling targets.

Additional Available Information

Lineament Study

Figure 3 is a modification of Bennett's (1977) linear map for the Blackbird Mountain-Panther Creek area. The northeast-trending linear labelled "Hot Spring" corresponds to a portion of Hot Springs Fault. This feature parallels the Salmon, Clear Creek and numerous other NE-trending linears. The prevalence of northeast-trending lineaments suggests that a northeast orientation may reflect a regional structural grain. The northeast-trending Hot Springs Fault may thus have regional tectonic significance and may be a deep-seated structure which might permit fluid circulation to great depths.

Aeromagnetic Data

Bennett (1977) also includes an aeromagnetic survey as a portion of the Blackbird Mountain-Panther Creek study. Figure 4, the aeromagnetic map for the area, shows a northeast-trending 170 to 200 gamma trough coincident with Hot Springs Fault and Big Creek Hot Springs. Bennett (1977) models this low as expressions of the augen gneiss unit. However, in the vicinity of Big Creek Hot Springs, the aeromagnetic low could also correspond to a zone of hydrothermally

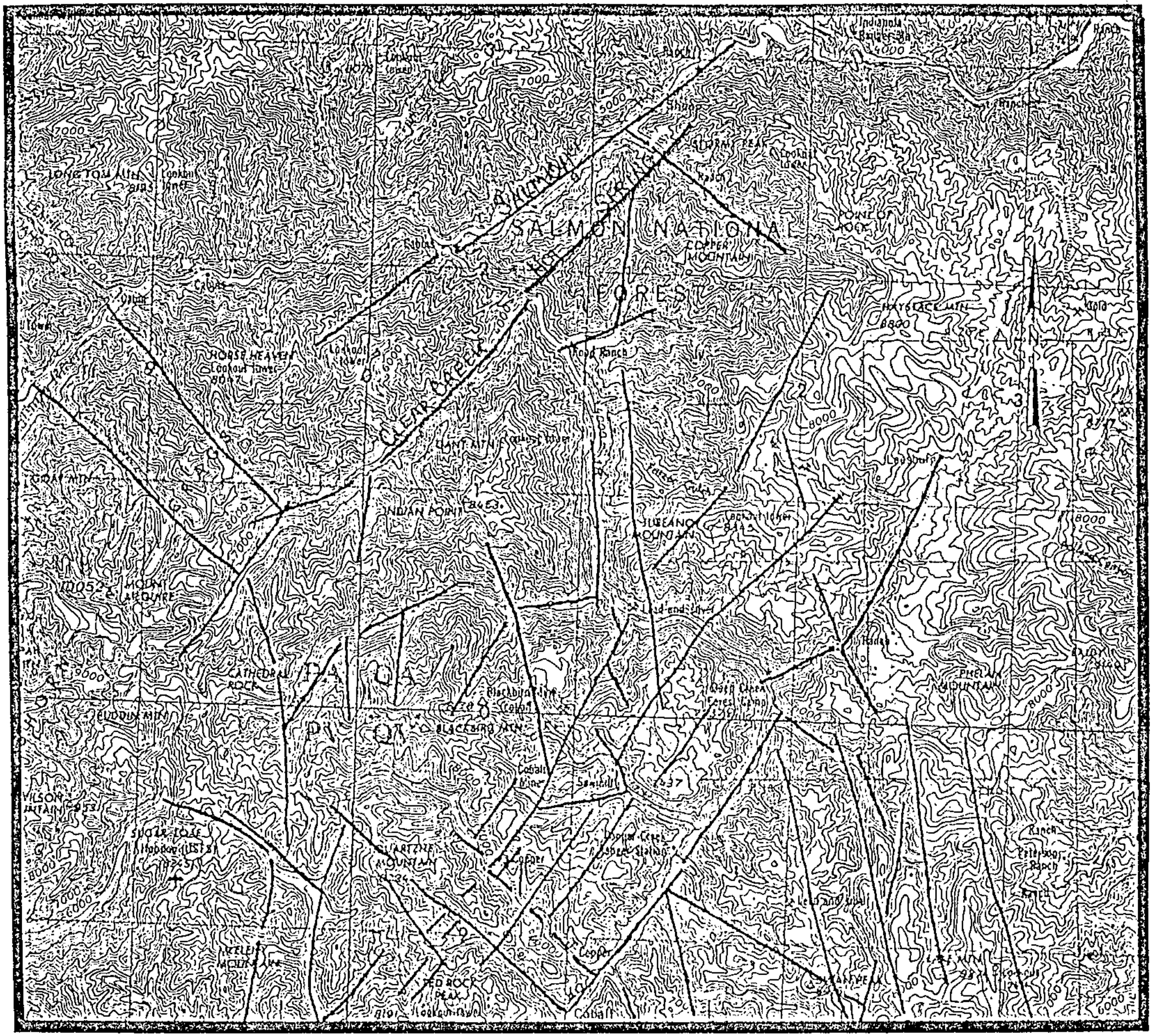


Figure 3. Linear map compiled from LANDSAT, false color, infrared imagery. Topographic base is from the Elk City AMS map (scale 1:250,000). (modified after Bennett, 1977)

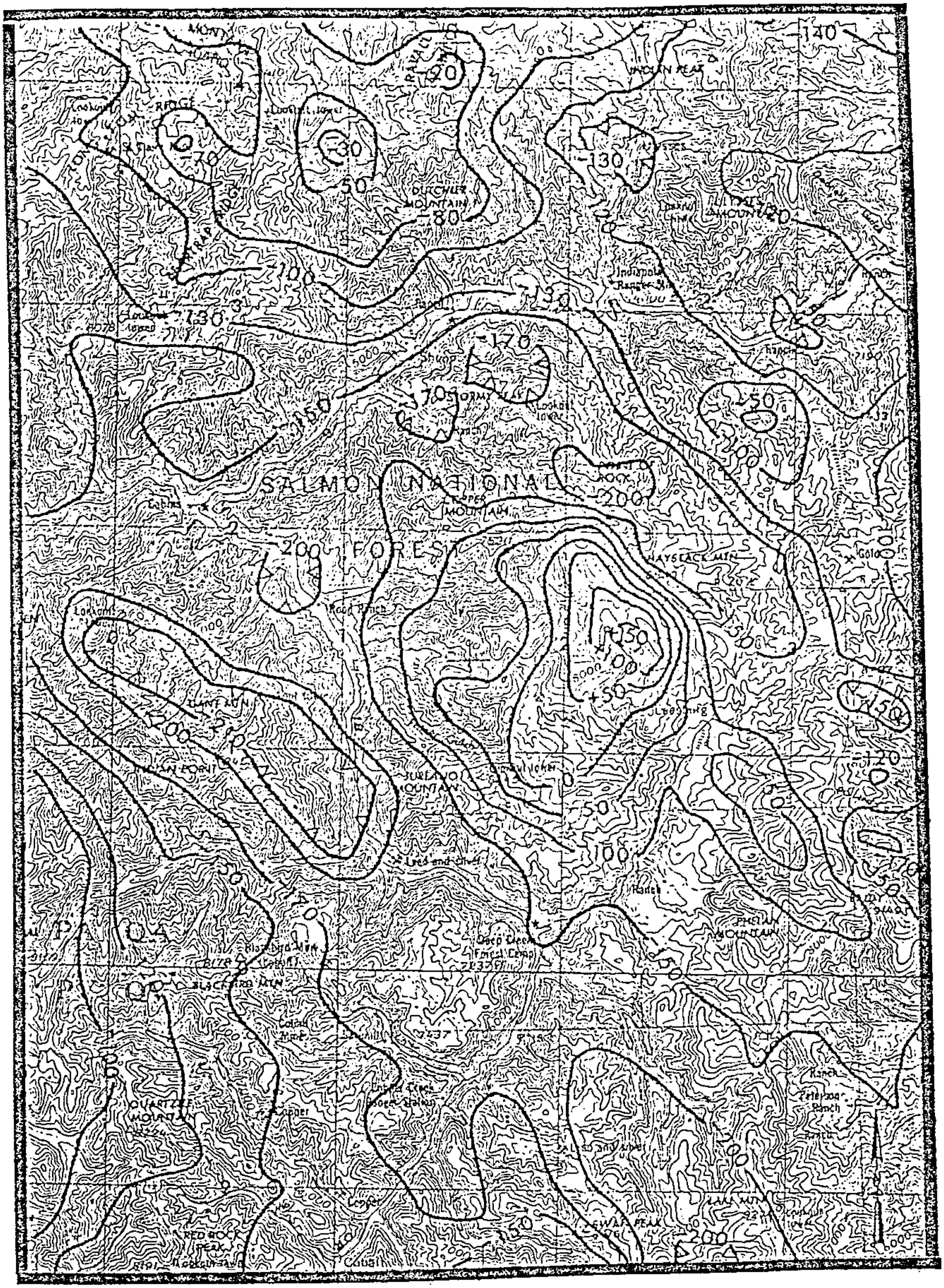


Figure 4 . Aeromagnetic map of the study area (modified from U.S.G.S., 1975). Map is drawn with a 6.17 gamma/mile north and a 3.92 gamma/mile east regional trend removed. Magnetic contours are overlain on topography from the Elk City AMS map (scale 1:250,000). (modified after Bennett, 1977)

PART II. SUGGESTED GEOTHERMAL EXPLORATION PROGRAM FOR BIG CREEK HOT SPRINGS

Introduction

The geothermal exploration program proposed herein for Big Creek Hot Springs is based upon a geothermal exploration strategy developed by Ward and others, 1979, for the Basin and Range. Each step of the suggested exploration strategy is discussed briefly in this report; Ward and others, 1979, should be consulted for further clarification. Where applicable, comments pertaining specifically to exploration at Big Creek Hot Springs have been included. Since Big Creek Hot Springs is not in a traditional Basin and Range setting, the proposed exploration strategy should be modified as necessary once additional geologic data for the Big Creek Hot Springs geothermal system become available. In particular, the selection of appropriate geophysical methods should be based upon the results of geologic studies in the area. The differences in geologic setting, lithologies present and topography between Big Creek Hot Springs and the average Basin and Range geothermal prospect may eliminate the usefulness of standard geophysical exploration tools.

altered rock, marking the course of paleo- and/or recent geothermal fluids. This trough could also be due to topographic effects.

Summary

The Big Creek Hot Springs geothermal system appears to be an excellent geothermal prospect. The geothermal potential of the prospect is, however, presently unmeasured.

The geothermometers for the system suggest that the most likely maximum reservoir temperature is 157°C. The presence of siliceous deposits around the hot spring indicates that at some point in the system water attained a temperature of at least 180°C (the temperature at which silica becomes appreciably soluble in acid to neutral solutions). If siliceous sinter deposits are forming today, the base reservoir temperature may be greater than 157°C.

Big Creek Hot Springs is in an anomalous setting, removed from most of the geothermal systems in the state of Idaho. However, the presence of Owl Creek Hot Springs (T.23N, R.17E, Sec. 10), approximately 8 miles west-northwest of the Big Creek system suggests that this area may be a geothermal district, and may hold considerable geothermal resource potential.

Table 2. Suggested Geothermal Exploration Strategy for Big Creek Hot Springs (modified after Ward and others, 1979)

ACTIVITY	ESTIMATED COST
1) Thermal Gradient Measurements - Existing Holes	$ 30 K
2) Prospect Mapping (1:24,000)	15 K
3a) Shallow Gradient Hole Drilling (20 to 30 holes)	100 K
Temperature Logging	10 K
Down-hole lithologic, mineralogic, alteration studies	5 K
Down-hole fluid and solid geochemical studies	10 K
3b) Dipole-dipole Resistivity Survey	30 K
4) Prospect Evaluation - Target Modeling I	10 K
5) Color Photos / Base Maps	10 K
6) Detailed Prospect Mapping (1:6,000)	20 K
7) Prospect Evaluation - Target Modeling II	10 K
8) Deep Thermal Gradient Hole Drilling (3 holes)	240 K
Geophysical logging	10 K
Down-hole lithologic, mineralogic, alteration studies	30 K
Hydrologic and Down-hole fluid and solid geochemical studies	15 K
9) Prospect Evaluation - Target Modeling III	20 K
10) Production Test Drilling and Brief Flow Testing (3 holes)	3750 K
Geophysical Logging	20 K
Down-hole lithologic, mineralogic, and alteration studies	20 K
Hydrologic and down-hole geochemical studies	15 K
11) Prospect Evaluation - Target Modeling IV	40 K
	$ 4,410,000

DISCUSSION OF SUGGESTED EXPLORATION STRATEGY

1) Thermal Gradient Measurements - Existing Holes

Temperature gradients should be measured in any available, nearby water wells, oil and gas wells and mineral exploration holes. This is a relatively inexpensive way to obtain information on the regional background geothermal gradient, and to highlight any thermal anomalies. This could be very important for the Big Creek geothermal system since the local gradient is unknown. The nearest published gradient and heat flow data (Brott and others, 1976) are about 65 miles south of Big Creek. If any drill holes are available in the Blackbird Mining District or elsewhere nearby, the Earth Science Laboratory might be able to arrange for temperature gradient and heat flow measurements.

2) Prospect Mapping

Prospect mapping at a scale of approximately 1:24,000 should be undertaken at an early stage to aid in siting the shallow thermal gradient holes, to identify possible structural controls for hot water circulation, to help plan geophysical surveys, and to develop preliminary conceptual models of the geothermal resource.

At Big Creek Hot Springs the specific goal of prospect mapping should be defining the nature of Hot Springs Fault (Bennett, 1977) and determining the role that this fault plays in the geothermal system. To the extent possible, surface mapping should identify whether this is a normal, low-angle thrust or high-angle reverse fault, and whether the fault is permeable.

3a) Shallow Temperature Gradient Drilling

Shallow temperature gradient drilling is perhaps the most fundamental aspect of a geothermal exploration program since it provides the primary quantitative data indicating the presence or absence of a geothermal anomaly at depth. It is common to drill 20 to 30 shallow, 50m to 160m (160 ft to 525 ft) holes on a grid covering about 10 square miles. The objective of thermal gradient drilling is to obtain conductive thermal gradient measurements; thus, the majority of these holes should not be drilled into geothermal fluid-bearing structures in which convective, isothermal gradients would be obtained. Cuttings should be retrieved for geochemical and lithologic analyses. Any available down-hole fluids should also be sampled for geochemical studies. In addition to measuring the thermal gradient, it may be useful to make heat flow determinations for some or all of the holes. This will require laboratory measurements of the thermal conductivity of drill cuttings. The rugged topography and poor road access in the Big Creek Hot Springs area may limit the practical number of shallow gradient holes.

3b) Dipole-dipole Electrical Resistivity Survey

A dipole-dipole electrical resistivity survey is commonly used in geothermal exploration to identify buried high-angle structures such as faults. In some geothermal resource areas, low resistivity zones correspond to warm water-bearing structures and/or zones of hydrothermally altered rock. At Big Creek Hot Springs, a resistivity survey may aid in mapping the areal extent of fluid-bearing units. It may be desirable to perform a resistivity survey concurrent with the shallow gradient drilling program. The results of the resistivity survey could then be used to guide the selection of additional thermal gradient hole sites.

4) Prospect Evaluation - Target Modeling I

Following the completion of the shallow thermal gradient drilling and the resistivity survey, all the available data should be integrated and evaluated, and a more precise target model should be defined. At this point the data should indicate whether the prospect merits additional exploration work.

5) Color Photos / Base Maps

In areas with poor base maps and aerial photography, it may be necessary to obtain low-altitude color aerial photography.

6) Detailed Prospect Mapping

It may be desirable to map portions of the prospect area in greater detail than 1:24,000 in order to identify the structural controls for the system.

7) Prospect Evaluation - Target Modeling II

Any detailed mapping data should be integrated with all other available data. The conceptual target model should be refined, and sites for the deep thermal gradient drill holes selected.

8) Deep Thermal Gradient Drilling

Approximately 3 holes ranging in depth from 500m to 800m (1640 ft to 2625 ft) should be drilled to evaluate the thermal regime at greater depths, and to test the viability of the target concept. The average cost for each hole, including logging, is about $80,000. In addition to a temperature log, a minimum of resistivity, SP and gamma logs should be obtained. Cuttings should be retrieved for lithologic and geochemical studies. Lithologic logging should be correlated with surface structural mapping, and cross sections incorporating all available data should be drawn. Information obtained during drilling should also be used in hydrologic studies of fluid recharge for the system and potential production characteristics (porosity and permeability) of the reservoir.

9) Prospect Evaluation - Target Modeling III

The target concept should again be refined, integrating all data with the results of the deep thermal gradient drilling. Drill sites for deep production test drilling should be selected.

10) Production Test Drilling and Brief Flow Test

Approximately three production test wells should be drilled, logged and flow tested. The depth of geothermal production wells varies from system to system, but averages 1525m (5000 ft). Based on the data presently available for the Big Creek geothermal system, 1525m (5000 ft) is a reasonable target depth at which fluids of about 300^{0}F might be encountered (see Part I). The average cost for drilling, logging and briefly testing a 1525m deep well is about $1,250,000. (See Appendix I, Geothermal Production Well Drilling Costs). As outlined in Step 8, lithologic and geochemical studies should be performed on cuttings and fluids obtained from the hole. Hydrologic models should be refined using data gathered during drilling, logging, and testing.

11) Prospect Evaluation - Target Modeling IV

A conceptual model of the geothermal reservoir should be built using all available data. The production potential of the reservoir should now be assessed and tested, if warranted, with long-term flow testing and reservoir engineering.

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4.0 Economic Analysis

Analysis of investment in geothermal facilities must basically answer two questions: first, can geothermal supply energy more cheaply than alternative fuel sources; and second, can geothermal compete with other types of investments.

For investment in a geothermal system the answer to both these questions must be positive. Even if geothermal supplies energy at a cost below that of alternative fuel sources it still needs to compete for scarce investment dollars and must earn a rate of return at least as high as alternative investments.

The analysis that follows takes as given the engineering design and costs developed for Noranda by INEL in "Preliminary Evaluation of an Advanced Binary Power Plant for Big Creek Hot Springs". That evaluation, based on 400,000 lb/hr flow rates and 149°C (300°F) water from a depth of 1830m(6000 ft), predicts an electricity price of 130 mills per KWH from an 11MW binary plant operating at an 80% load factor.

4.1 A Conventional Comparison

Typical analysis of geothermal energy use centers around the cost of providing the geothermal and potential savings to be generated through reduced use of conventional energy sources. A geothermal system typically has large capital costs relative to conventional fuel sources, but these large front-end costs may be offset by low annual operating costs, mainly a relatively small allowance for operation and maintenance expense. For Noranda Mining a $51,796,919 investment in a well field, power plant, and transmission facilities would beget a geothermal electric power source with annual operating expenses of only $1,797,724. Any annual savings generated would be derived by subtracting this annual operating expense from the annual cost of buying electricity elsewhere. Thus the geothermal system would generate a stream of savings over its 30-year life. Evaluation of the worth of that stream of savings could be done in either of two ways. One could simply add up the savings (in either nominal or present value terms) each year to discover how long it takes for the savings to "pay back" the original investment. Or, one can calculate the internal rate of return, that rate of discount which just equates the present value of the savings stream to the original investment cost.

Such a process has been carried out in Figure 4.1. Footnotes to the columns indicate data sources and actual calcualtions performed in making savings projections. The geothermal system in this case does generate some annual savings compared to purchase of electricity at 45 mills (a price quoted to Noranda by an existing public utility for interruptible service).

However, the saving is small (even smaller when evaluated in terms of present value) relative to the capital investment required. These savings pay off the original capital cost in 28 years if one ignores present value considerations. If one evaluates that stream of savings in present value terms the capital investment is never paid back. The internal rate of return calculated on the basis of

FIGURE 4.1
30-YEAR PROJECTION OF OPERATING COST SAVINGS

(1) Conventional Fuel Cost	(2) Operation and Maintenance	(3) Geothermal Saving	(4) (10%) Present Value
2,210,000	1,797724	412,276	374,796
2,397,850	1,941,542	456,308	377,114
2,601,667	2,096,865	504,802	379,265
2,822,809	2,264,615	558,194	381,254
3,062748	2,445,784	616,964	383,086
3,323,081	2,641,446	681,635	385,765
3,605,543	2,852,762	752,781	386,296
3,912,014	3,080,983	831,031	387,682
4,244,536	3,327,462	917,074	388,929
4,605,321	3,593,659	1,011,662	390,039
4,996,773	3,881,151	1,115,622	391,019
5,421,499	4,191,643	1,229,856	391,870
5,882,327	4,526,975	1,355,352	392,597
6,382,324	4,889,133	1,493,191	393,204
6,924,822	5,280,263	1,644,559	393,694
7,513,432	5,702,685	1,810,747	394,071
8,152,073	6,158,899	1,993,174	394,339
8,884,500	6,651,611	2,193,389	394,500
9,596,825	7,183,740	2,413,086	394,559
10,412,555	7,758,439	2,654,116	394,517
11,297,622	8,379,115	2,918,507	394,380
12,257,920	9,049,444	3,208,476	394,148
13,299,843	9,773,399	3,526,444	393,827
14,430,330	10,555,271	3,875,059	393,418
15,656,908	11,399,693	4,257,215	392,924
16,987,745	12,311,668	4,676,077	392,348
18,431,703	13,296,602	5,135,101	391,694
19,998,398	14,360,330	5,638,068	390,963
21,698,262	15,509,156	6,189,106	390,158
23,542,614	16,749,889	6,792,725	389,281

(1) 7MW peak load and 80% load factor as estimated by W. Moens, Noranda Mining requires an average yearly usage of 4.91×10^7KWH. A purchase price of 45 mills per KWH generates a yearly electricity bill of $2,210,000. This figure is escalated at the very conservative rate of 8.5% per year suggested by Dames & Moore, Consultants to the Idaho Public Utilities Commission

(2) Estimated in INEL Preliminary Evaluation of an advanced Binary Power Plant for Big Creek Hot Springs. Escalated at 8% per year.

(3) Saving is equal to the difference between conventional fuel cost and geothermal operation cost -- column (1) minus column (2).

(4) Savings in column (3) discounted to present value at a rate of 10%.

the savings generated in column (3) of Figure 4.1 is a meager 1.5%, far too low to attract outside investors.

4.2 A Premium for Uncertainty

The analysis in Figure 4.1 ignores the interruptible nature of the 45 mill per KWH for electricity from a utility. One way to treat the possibility of interruption is to add a premium to the cost of power to reflect the cost of interruption.

Data in Figure 4.1 was recalculated with two premiums, one of 50% and one of 100%. If the cost of power is raised to 67.5 mills the annual cost of purchased electricity starts at $3,315,000 rather than $2,210,000. The internal rate of return rises to 7.6% with the 50% premium and the payback period falls to 17 years. If the premium for interruptible power rises to 100%, 90 mills per KWH, the internal rate of return rises further, to 11.4%, and the payback period falls further, to 13 years.

With the 100% premium added to compensate for the interruptible nature of power supply the investment in a binary power plant looks just competitive in terms of rate of return and payback period. What this means is that electric power purchased from outside at about 90 mills is roughly competitive with power at 130 mills from an owned power plant. Such competitiveness comes from the fact that over the 30 year life of the plant geothermal power will increase in cost at a rate much slower than power purchased from outside since the only source of such increases for geothermal power is operations and maintenance, a relatively small annual expense.

However, it takes this substantial premium to cover the interruptible nature of power supplied from outside to allow the geothermal power to be competitive.

4.3 Looking to the Future

The projected price of 130 mills per KWH is astronomical with respect to present prices of any alternative way of producing electricity. However, today's electric rates, whether for coal, nuclear, diesel, or hydropower, are blended rates whose low level reflects the fact that most utility overhead costs are from a bygone era. Today's sales are still relatively cheap because the plants that produce that electricity were built long ago when they, too, were cheap.

The only fair way to compare geothermal to other ways of producing electric power today is in terms of costs to be undergone now and in the future.

The comparison is not between geothermal electricity at 130 mills and hydropower at 2 mills but between geothermal at 130 mills and the cost of a coal or nuclear or hydro plant to be built at today's costs. While these costs are a matter of some dispute, especially since today's utilities will evidently be forced to buy excess power from cogenerators and small power producers at "avoided" cost and thus utilities want to keep their estimates of "avoided" costs as low as possible, there is a general range of costs to be discovered. Hydro facilities built today may supply electricity at a cost somewhere between 40 and 65 mills depending on the site and, of course, the actual load factor. Idaho utilities estimate a modern coal-fired plant will produce power somewhere around 50 mills per KWH. The various delays associated with public hostility to nuclear plants have raised many estimates of nuclear power to near 80 mills per KWH.

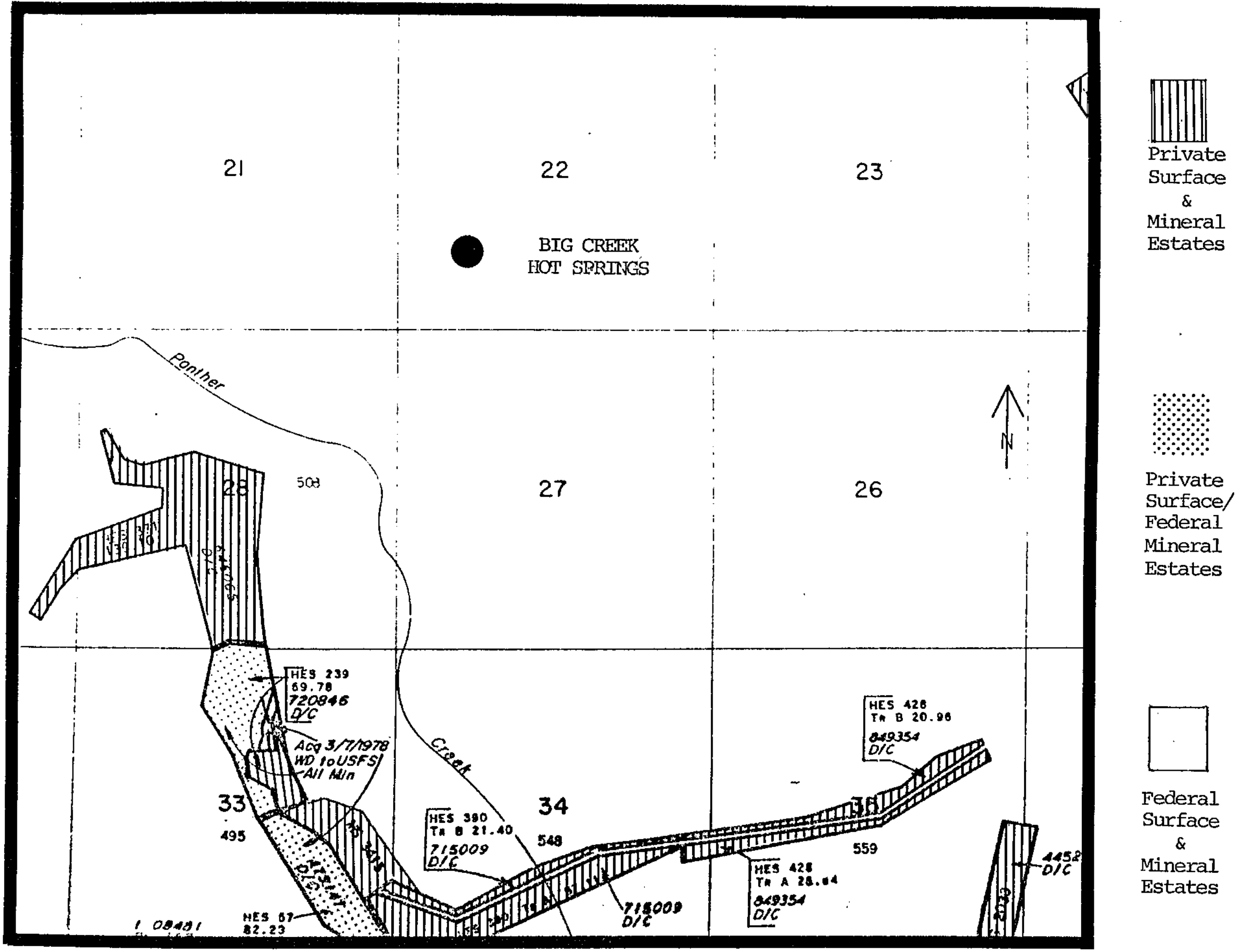
4.4 Conclusion

From the foregoing analysis it appears that alternative sources of electricity generation would have to cost about 90 mills per KWH before geothermal electricity at 130 mills would be a viable economic alternative. Since at this point it appears that most other sources of electric power, however expensive they may seem by historical standards, will be less expensive than 90 mills, it appears that a binary cycle geothermal power plant would not be a viable source of supply for Noranda Mining.

Perhaps the real question is not about choice of alternative power sources but about the long-term cobalt market and whether cobalt can be produced for a profit when 50 mill power is the cheapest to be found.

FIGURE 5.1

MINERAL OWNERSHIP AND RESERVATIONS



As of September 1, 1980, the Bureau of Land Management (BLM) had not acted to pre-adjudicate these lease applications.

The probable binary power plant site outlined in the preliminary EG&G study is also located on federal forest land. As such, the proposed plant would be subject to the Power Plant Siting Regulations administered by the BLM.

The proposed transmission lines would run thirteen (13) miles along Panther Creek where they would tie-in to the existing Idaho Power grid serving Blackbird mine and the town of Cobalt. Due to the pattern of land ownership along Panther Creek, transmission system development would utilize normal right-of-way procedures on federal lands, and easement acquisition techniques on private land.

5.2 State Permitting Requirements for Geothermal Resources

The groundwaters of the State of Idaho are a public resource. The Department of Water Resources has responsibility for administration of the use of these groundwater resources, and to conserve and protect them against waste and contamination.

Section 42-237a and Sections 42-1601 through 42-1605, Idaho Code, require all flowing wells to be capped or equipped in a manner that will allow the flow of water to be completely stopped when not in use. Flowing and non-flowing wells are to be constructed in a manner as to prevent waste and contamination through leaky well casings, pipe fittings, valves or pumps, either above or below the land surface or through improper or inadequate sealing.

Section 42-238, Idaho Code, gives the Department of Water Resources authority to establish and require compliance with minimum water well construction standards. Every water well constructed in Idaho must be in compliance.

Title 42, Chapter 39, Idaho Code, gives the Department authority to establish and require compliance with standards for construction and abandonment of waste disposal and injection wells.

Pursuant to the provisions of Section 42-238, Idaho Code, Title 42, Chapter 39, Idaho Code, and the provisions of Title 67, Chapter 52, Idaho Code, the Idaho Water Resource Board has established minimum standards for construction of water wells, and minimum standards for construction or abandonment of waste disposal and injection wells.

All wells deeper than 18 feet must be drilled by a well driller licensed to operate in Idaho. Well drillers must conform to the rules and regulations of the Idaho Department of Water Resources when constructing water wells and waste disposal and injection wells.

All water wells shall be constructed in a manner that will guard against waste and contamination of the groundwater resources of the State of Idaho.

All wells constructed for public supply of domestic water must meet all of the requirements set forth by the Idaho Department of Health and Welfare. The well driller and the property owner are charged with the responsibility of taking whatever steps might be necessary in any unique situation to guard against waste and contamination of the groundwater resources. It will be necessary in some cases to construct wells with significant additional controls beyond the minimum standards to accomplish these goals. Casing shall be installed in every well, and for water wells shall extend at least 12 inches above the land surface surrounding the water well, and to a minimum of 18 feet below land surface.

An approved permit from the Department of Water Resources is generally required before work can begin on geothermal wells. The two exemptions to this requirement relate to exploratory well is less than six inches in diameter and less than 1,000 feet deep and is to be used only for collecting geotechnical data, the owner must simply file a notice of intent to drill with the director of the department. Also, as explained in Section 42-4003(e), Idaho Code, wells from which low temperature water is used for such purposes as space heating or fish propagation are exempt from the permit requirement if the owner has obtained an approved water right.

The following permits and bonds are required under the geothermal resources act:

(a) Form 4003-1, Application for Permit to Drill for Geothermal Resources;
(b) Form 4003-2, Application for Permit to Alter a Geothermal Well;
(c) Form 4003-3, Application for Permit to Convert a Well to a Geothermal Injection Well;
(d) Form 4005, Geothermal Resources Surety Bond;
(e) Form 4007, Notice of Intent to Abandon a Well;
(f) Form 4009, Report of Abandonment of a Well

5.3 Public Funding Factors

There are two public assistance mechanisms available to Republic Geothermal Inc. through the Department of Energy (DOE). These are the User-Coupled Confirmation Drilling Program and the Geothermal Loan Guaranty Program.

The DOE initiated the User-Coupled Confirmation Drilling Program (UCCDP) in Spring 1980. The first solicitation period ended September 15, 1980. Present plans call for follow-on solicitations on a 6- to 12-month basis, allowing ninety (90) days for response.

The objective of the User-Coupled Confirmation Drilling Program is to foster economically viable use of direct hydrothermal energy in the United States by absorbing much of the risk associated with confirmation of hydrothermal reservoirs, while developing an experienced group of engineering consultants, contractors, and equipment manufacturers in private industry who will reduce reservoir confirmation risks in the future.

Under terms of the program, the U.S. DOE will share the cost of the exploration, well siting, drilling, flow testing, reservoir engineering, and, if necessary, injection well drilling needed to confirm the desired temperature and flow rate of a hydrothermal reservoir to be used for direct heat application. If the proposer confirms a reservoir with a completely optimum temperature and flow rate, the DOE cost-share will be 20 percent. If the project is completely unsuccessful, the DOE cost-share will be 90 percent.

For the first solicitation, DOE's 90 percent costs for unsuccessful projects which proposed one production well were limited to $2.0 million. The DOE costs for unsuccessful projects which proposed one production well and one injection well (where necessary) was limited to $3.6 million.

DOE's 20 percent costs for successful wells in the first solicitation were limited to $440,000 for projects without an injection well, and $800,000 for projects with an injection well.

Federal cost-share arrangements under this program are in accordance with the variable cost-share formula (based on degree of success) submitted by a proposer.

For more information contact:

EG&G Idaho, Inc.
P.O. Box 1625
Idaho Falls, Idaho 83415
(208) 526-9217

5.0 Institutional Development Process

The development of geothermal energy at Big Creek Hot Springs will require close cooperation between Republic Geothermal, Inc., Noranda Mining, Inc., Salmon National Forest officials, and the Bureau of Land Management. The impacts of developing a binary cycle power plant must include the potential effects of plant construction, electric power transmission, and disposal of the thermal water.

5.1 Resource Ownership

The land containing Big Creek Hot Springs is part of the Salmon National Forest. Much of the area is unsurveyed and remote, although not roadless.

Figure 5.1 shows that portion of the Master Title Plat for T. 23 N., R. 18 E., containing Big Creek Hot Springs. This figure shows the location of federal and private interests; there are no state interests in the area. Exploration on any parcel of land which has federal ownership or a federal geothermal reservation will require a geothermal lease from the Bureau of Land Management. Because the area has not been classified, by the U.S. Geological Survey, as a Known Geothermal Resource Area (KGRA), federal geothermal resources can be leased to the first qualified applicant applying for a lease. Exploration drilling on any parcels under state ownership or parcels under which the mineral estate is reserved to the State of Idaho can occur only if a geothermal lease is acquired from the State Land Board. Exploration on private or municipal lands within the area requires permission from the landowner and the appropriate permits from the State of Idaho.

The probable drilling site outlined in the EG&G preliminary engineering study is located on Salmon National Forest land. Republic Geothermal, Inc., has lease applications in covering the Big Creek area. These are shown below.

#	Order of Processing	Legal Description	Acreage
I-15975	8-30-79	T23N, R18E Sec. 14,15,22,23	2560
I-15976	8-30-79	T23N, R18E Sec. 21,27,28	1788
I-15977	8-30-79	T23N, R18E Sec. 16,26	1280

I-15975 covers the section containing the springs.

The Geothermal Loan Guaranty Program (GLGP) became effective on June 25, 1976 under Title II of the Geothermal Research, Development and Demonstration Act of 1974.

The outlined objectives of the GLGP as stated under this Act are:

(1) To encourage and assist the private and public sectors to accelerate development of geothermal resources in an environmentally acceptable manner by minimizing a lender's financial risk.

(2) To develop normal borrower-lender relationships in order that financing be made available without guarantees at some future time.

Under the terms of the Act, loan guarantees will be granted for up to 75% of project costs, with the Federal government guaranteeing up to 100% of the amount borrowed, and the applicant contributing 25% equity. The amount to be guaranteed is limited to $100 million per project and $200 million per borrower.

The life of the program is 10 years, to terminate on September 3, 1984, but all loans guaranteed up to that time will be honored according to the terms of the loan agreement. The maximum term for any loan guaranty is 30 years or the expected average useful life of any major physical asset to be financed by such loan, whichever is less.

Priorities assigned to different types of projects are as follows:

(1) Projects with promise of rapid energy production from geothermal resources.

(2) Projects designed to demonstrate or utilize new technologies or produce advanced technology components.

(3) Projects that will demonstrate or exploit the commercial potential of new geothermal resource areas.

(4) Lowest priority is given to projects initially proposing geological and geophysical exploration, or the acquisition of lands or leases.

In addition, priority within each of these categories is given first to projects from which the Federal government receives royalty payments and second, to projects undertaken by small companies and private utilities.

For further information about the Geothermal Loan Guaranty Program, write: Loan Guaranty Program, Department of Energy,
1333 Broadway; Oakland, CA 94612
(415) 273-7151

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