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THE STATUS OF PILGRIM SPRINGS

Topical Report

By
Patricia Kirkwood

MASTER

May 1979

Work Performed Under Contract No. EY-77-C-08-1540

Energy Systems, Inc.
Anchorage, Alaska

U. S. DEPARTMENT OF ENERGY Geothermal Energy

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May, 1979

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THE STATUS OF PILGRIM SPRINGS

The following report has been prepared for the U.S. Department of Energy* to summarize background and current planning for the geothermal resource at Pilgrim Springs, Alaska. The information presented here is that which existed at the time of a meeting held in Anchorage on January 25-26, 1979, by the State of Alaska's Division of Energy and Power Development (DEPD). The meeting was arranged by Energy Systems, Inc. (ESI) to assist the DEPDP in formulating a program of exploration, drilling, and demonstration at Pilgrim Springs. DEPDP is administering a State appropriation of \$245,000 for a geothermal demonstration project at Pilgrim Springs. Participants were as follows:

Richard Atuk, Bering Straits Native Corporation

Neil Basset, United States Bureau of Land Management

John Beebee, Energy Systems, Inc.

Bob Clark, U.S. Department of Energy

Gene Culver, Oregon Institute of Technology

Don Dinkel, University of Alaska Agricultural Station

Bob Forbes, Geophysical Institute, University of Alaska

Dan Hawkins, State of Alaska, Division of Geological
and Geophysical Survey

*This work was performed under Contract EY-77-C-08-1540, for the U.S. Department of Energy.

Patricia Kirkwood, Energy Systems, Inc.

Jay Kunze, Forsgren/Perkins & Associates

Lee Leonard, University of Alaska

William Long, State of Alaska, Division of Geological
and Geophysical Survey

Don Markle, Oregon Institute of Technology

Tom Miller, United States Geological Survey

Will Nebesky, Institute of Social and Economic Research,
University of Alaska

William Ogle, Energy Systems, Inc.

C.J. Phillips, Pilgrim Hot Springs, Ltd.

Clarissa Quinlan, State of Alaska, Division of Energy and
Power Development

Bob Sanders, State Division of Minerals and Energy Management

Ross Shaff, State Geologist, State of Alaska

Charles Sloan, United States Geological Survey

Mort Smith, Los Alamos Scientific Laboratory

Don Turner, Geophysical Institute, University of Alaska

Norman Goldstein, Lawrence Berkeley Laboratory was unable
to attend, but sent his comments and recommendations
which were read and discussed.

During the course of the meeting, existing data and information on the Pilgrim Springs geothermal resource and legal and institutional aspects of its development were discussed, and a tentative work plan was outlined. This outline was the precursor of the work plan which will be carried out during the 1979 field season (as described in the final section of this report).

Pilgrim Springs has been the subject of appreciably more exploration and study than have most other hot springs in the state of Alaska. While hydrothermal exploration in this state has, for the most part, been limited to surveys of surficial geology, surface temperatures, flow rates, and chemical analyses, Pilgrim Springs has been the subject of several more sophisticated field studies, which are discussed later in this report.

GENERAL BACKGROUND

Pilgrim Springs, originally named Kruzgamepa by the Eskimos, has a rich history -- from tales of fortuitous cures of a nomadic Eskimo's ailments to a geothermal bordello and bathhouse site to a well-run Catholic orphanage with buildings heated by hot water from the springs beginning in the early 1920's. The orphanage closed in 1942, and it wasn't until 1968 that a renewed interest in Pilgrim Springs led the present lessor of the site, C.J. Phillips of Nome, and his partners to begin the slow process of attempting to develop this resource.

Pilgrim Springs is located at 65°06' N latitude and 164°55' W longitude on Alaska's Seward Peninsula (Figure 1). Forty miles north of Nome, this *Known Geothermal Resource Area (or KGRA)*, as designated by the U.S. Geological Survey, is situated in the Bendeleben A-6 quadrangle. The hydrothermal upwelling occurs at an altitude close to sea level (10 feet above sea level). In addition to the hot springs, the anomalous heat noticeably warms more than 30 acres of adjacent ground.

The lush vegetation seen at Pilgrim Springs, including several areas of dense cottonwood, willow, and alder growth, gives the site the appearance of an "oasis" in the midst of the tundra typical of this latitude (Figure 2) and stimulates visions of an agricultural enterprise developing here to help meet the needs of northwest Alaska.

The hot springs are located on a tract of land owned by the Catholic Church. The surface and subsurface rights are leased to C.J. Phillips who has permission to explore and develop the resource. The surface estate of the surrounding land is the property of the Mary's Igloo Village Corporation, while the Bering Straits Native Corporation has the subsurface rights (Figure 3). The Bering Straits Corporation also owns the surface and subsurface rights to a tract of land between the access road (the Nome-Taylor road) and the hot springs. These factors significantly influence land access to Pilgrim Springs and exploration outside the boundaries of the leased land. Cooperation of three parties -- the lessor of the springs, the village corporation, and the regional corporation -- will be necessary for exploration and development beyond that planned for 1979. Presently, only access to the tract with the hot springs is required, and this access presently exists by air and on the Pilgrim River. The cooperation of the native corporations may be needed if a spur from the existing road to Pilgrim Springs is to be completed (7 miles). Road right-of-way status is currently being investigated.

Transportation is a dominant factor in resource development and economics in Alaska. Pilgrim Springs is conveniently located, compared

Figure 2. Aerial photograph of Pilgrim Springs (Courtesy C.J. Phillips)

to many other Alaskan geothermal sites. The area is within 7 miles of a good (though unpaved) road to Nome (the Nome-Taylor Road). It is possible, though not popular, to travel from Pilgrim Springs by boat along the Pilgrim River to the Nome-Teller Road. There is an "unimproved" airstrip and another smaller landing area at Pilgrim Springs for light aircraft. Presently the easiest access to Pilgrim Springs is via light aircraft from either Nome or from the point nearest Pilgrim Springs on the Nome-Taylor Road, although there is a rugged "cat-trail" between this road and the springs.

Nome is the regional distribution center on the Seward Peninsula and is served by sea transport from Seattle. Nome lacks a deep port, though, forcing loads to be lightered in smaller barges to the dock (or, occasionally, to the shore). The additional handling and small volume leads to high transportation costs for goods in this region. Nome has a large municipal airport with daily scheduled flights by a major Alaskan airline. There is no highway or railroad between Nome and other major Alaskan cities, leaving Nome's road system isolated from the rest of the state.

The Seward Penninsula is sparsely populated by standards applied to the contiguous 48 states but contains the major population center of Nome and numerous small villages. The 1970 census figures showed the Seward Peninsula region (as far north as the Kotzebue and Selawik areas to Stebbeas in the South) to have a population of 9,883, of which 8,371

were native (mainly Eskimo, some Indian) and 1,512 non-native, with a population density of about one person per 6.8 square miles. Four regional centers exist in northwest Alaska (Nome, Kotzebue, Unalakleet, and Pt. Hope) and provide some employment. Figure 4 presents population figures for the Seward Peninsula. Nome, 40 miles south of Pilgrim Springs, has a population of approximately 2,500. Pilgrim Springs presently has no permanent population but is inhabited in the summer months by caretakers and occasional visitors.

The northerly latitude and some maritime influence give this interior location of the Seward Peninsula a harsh climate. In Nome, the warmest summer month is July, which averages 50°F; the coldest winter month is February, averaging 5°F. Nome temperature extremes are -46°F and 86°F. While Pilgrim Springs has no recorded temperature data, it can be assumed that the temperatures there are somewhat colder than in Nome in the winter and warmer in the summer. The region averages 11.5 inches of precipitation annually (including the equivalent of 50" of melted snow). Wind is generally from the east. (No velocity data available.) Figure 5 plots monthly heating degree-days near Pilgrim Springs.

Major factors in heating and agriculture are the amount of available sunlight and its daily duration. Insolation data for Nome (64°30'N) is shown in Figure 6. Similar data is plotted for Boise, Idaho (43°34'N) for comparison. Pilgrim Springs has long summer days and a short growing season, highly suitable for many agricultural products, including cabbage,

Figure 5. Estimated Heating Degree-days for Pilgrim Springs, Alaska
(Based upon climatological data from Nome and Wales, Alaska)

Figure 6. Incident Solar Radiation at Nome, Alaska and Boise, Idaho

potatoes, root vegetables, and others.

The economy of Nome differs from economies of towns in the contiguous 48 states in several important aspects. A major difference is the fact that the Nome economy is a mixture of cash and subsistence economies. Nearly half of the employment which does exist in Nome is in the form of state and local government jobs, and the remaining employment apportioned to the transportation and communications industries, public utilities, and other services. There is much import of goods, but virtually no export. The cost of necessities uses up a large fraction of the average income in Nome and local people thus forgo amenities important to those in much of the rest of the country. Geothermal heat developed at Pilgrim Springs will probably be able to provide a product for the regional market and possibly even for export. The production, processing, and marketing of such a product could become a significant stimulus to the region's economy.

THE RESOURCE

The feasibility of any geothermal development is dependent upon the characteristics of the resource. Although evidence to date does not indicate an extremely hot geothermal resource, the United States Geological Survey has designated Pilgrim Springs a Known Geothermal Resource Area and estimates a reservoir of 1.05×10^{18} joules (Ref. 1). This section describes the results of geothermal exploration to date.

Geological Reconnaissance

Early literature contains observations of the Pilgrim Springs

resource made by Waring in 1917 (Ref. 2). The regional and local geology of the Bendeleben quadrangle was described by Sainsbury in 1969 (Ref. 3). Figure 7 is Sainsbury's geological map of this area, and may be compared with Figure 3 (same scale) for reference. Miller (Ref. 4) added to the description of the geological setting of this and other hot springs in the region in 1975 and substantiated the close correspondence of hot springs with contacts of granitic plutons here. Forbes (Ref. 5), also in 1975, briefly summarized the surficial geology of the area around Pilgrim Springs.

Resistivity

In October of 1973, Harding-Lawson Associates performed a series of measurements for Stephano & Associates, Inc. (Ref. 6) to obtain data down to 2,000 feet below surface. One set of measurements consisted of deep electrical soundings with an east-west Schlumberger array located midway between the airstrip and the church (Figure 8). A second set of resistivity measurements was taken with an equatorial array north and south of the Schlumberger array (also Figure 8). Data from these geophysical studies are given in Appendix A. Harding-Lawson interpreted their results to indicate that if sedimentary resistivity is constant, bedrock is 100 feet deep to the south of the Schlumberger line and drops off to 600 feet north of the line, with an unfrozen alluvial soil layer underlain by bedrock. The drop line in bedrock from 100 feet to 600 feet is attributed to probable east-west faulting 500 to 1000 feet south of the church.

Figure 7. Surface geological map of the Pilgrim Springs area. (Ref. 3)

Key:

Qc cover
 Qs silt
 Qo outwash
 Qal alluvium
 Qk } terrace deposits
 Qc }
 pOs graphitic siltite
 KgF fine-grained granite
 pEp pegmatite
 pEb biotite-garnite schist
 pEmu metamorphic rocks
 pEgn orthogneiss
 pEcl chloritic schists

--- contacts inferred
 contacts concealed
 TTT thrust fault
 ⊥ strike and dip direction of beds

Figure 8. Geometry of instrumentation arrays for resistivity measurements (from Ref. 6)

Seismic Refraction

In 1974, Forbes et al (Ref. 5) measured the seismic profile of a 2,250 foot strip between the north end of the airstrip and the mission buildings (Figure 9). The total distance was surveyed in three increments all of which were run in two directions. Results of these seismic runs are plotted in Appendix B. (Geophone spacing was at 50 foot intervals, but reduced to 10-15 foot intervals where greater resolution was desired.) Seismic data from this study is diagrammatically presented in Figure 10 and is interpreted by the investigators to indicate four subsurface layers in the vicinity of the springs:

- (1) A " weathered zone" to a depth of about 10'
- (2) A homogenous section (probably fluvial sediments) about 100 feet thick to the north, pinching out to the south
- (3) A third layer of coarse, compacted sediments 125-150 feet thick with two significant breaks which may indicate either faults dropping 35 and 43 feet on the north side or an old stream meander
- (4) Dense material at a depth of 208 feet which may be either
a) tertiary sandstone and conglomerate or highly indurated till (very hard unconsolidated rocks, sand, etc. of glacial origin), or b) alluvial fan gravels which have been thermally cemented into conglomerate

Magnetic Profiling

The Forbes group also ran magnetic profiles during the 1974 measurements. Intervals averaging 100 feet were used, and data was collected along the seismic profile line. A negative deflection occurred near the hot spring (Figure 11). Two interpretations of this deflection were offered. The deflection may indicate 1) thickening of alluvial sand and

Figure 9. Location of shotpoints for seismic profile (from Ref.5.)

NORTH-SOUTH REFRACTION PROFILE OF PILGRIM SPRINGS

SEISMIC WORK BY
L. GEDNEY & D. VANWORMER
SEPTEMBER 20, 21, 1974

Figure 10. Seismic profile (from Ref. 5)

NORTH-SOUTH MAGNETIC PROFILE OF PILGRIM SPRINGS VERTICAL COMPONENT

Figure 11. Magnetic profile (from Ref. 5)

silt (with decreasing underlying glacio-fluvial gravel thickness) at that point, possibly indicative of a former river channel cut in gravels and filled in with sand and silt or 2) a leaching of magnetic minerals in the sands and silt by thermal waters.

Figure 12 is our suggested north-south section diagram for Pilgrim Springs based upon others' interpretations of the resistivity and seismic data and is included here merely as an aid to visualization.

Microseismic Background

Seismic measurements, taken by Forbes et al, with a portable seismograph set upon the concrete step of the church on two consecutive nights at ground-to-record magnifications of 40,000 at 20 Hz and 80,000 at 20Hz, respectively, revealed this to be a relatively quiet area. Forbes interprets these results to indicate that the area is not likely to contain a steam field.

Thermal

Temperature measurements of 38°C and 69°C at the upwellings were reported by Waring in 1917 (Ref. 2). Willey & Presser, USGS, reported 55°C (see Ref. 4). Forbes (1974) used a thermister probe to measure temperatures at the bottom of the pool, and at 6-inch and 8-foot depths in the pool sediment. The maximum measured temperature was 80°C. In one pool a temperature reversal was seen with depth (possibly due to currents from mixing with ground water). Ground water temperatures measured by this group were 17°C. These temperatures were obtained in

Figure 12. Possible section diagram at Pilgrim Springs

the shot holes of the seismic study, all of which were located in warm ground associated with the hot springs. One would expect normal ground water temperatures near Pilgrim Springs to be within a few degrees of freezing.

More recent measurements by Bob Forbes with the assistance of Don Markle during the summer of 1978 gave additional thermal information. The data has not yet been published, but temperatures increasing to 65°C at a depth of 11 feet were found over a large area south and east of the spring. A few probes reached temperatures as high as 70°C within three feet of the surface. (Ref. 7.)

Infrared

Reference has been made to the existence of infrared photographs of this region. Further investigation has revealed that these photos do not cover the Pilgrim Springs area (Ref. 8).

Chemical Analysis

Three different collections and analyses of water samples from Pilgrim Springs are reported here. The first two sets of data (presented in Table I) are from summer samplings by the U.S.G.S. The third sample was collected by Don Markle in late winter of 1979 for comparison with summer samples to attempt to ascertain whether the summer samples were diluted with ground water (which generally has much lower solute concentrations than do the geothermal waters at Pilgrim Springs). Due to time and technical constraints, rigorous sample treatment was not possible.

TABLE I
CHEMICAL ANALYSES OF PILGRIM SPRINGS
WATER SAMPLES

All concentrations in parts per million.

	Waring 1917	Willey & Presser 1972	Winter of 1979*
SiO ₂	87	100	(47)
Al	4.1	0.044	(0.01)
Fe	0.7	---	(0.09)
Ca	545	530	(600)
Mg	7.4	1.4	(1.3)
Na	1,587	1,450	1,500
K	61	61	58
Li	---	4.0	---
NH ₃	---	---	---
HCO ₃	21	30.1	(24)
CO ₃	---	---	---
SO ₄	25	24	---
Cl	3,450	3,346	---
F	---	4.7	---
Br	---	---	---
B	---	2.4	(2.5)
pH	---	6.75	(7.1)

* Values in parentheses must be interpreted cautiously due to sampling technique variation. See text, page 22 (ff).

(There was no chemical analysis in the field; samples were not filtered at the time of collection; and samples were not acidified or otherwise treated in the field.) Energy Systems, Inc. had the samples analyzed by Chemical & Geological Laboratories of Alaska, Inc.

It may be presumed that the determinations of sodium and potassium concentrations from the recent sampling are accurate (Ref. 9). The calcium concentration of this sample may in actuality be higher than that reported here (although there is relatively good agreement with previous sample analyses). Other solute concentrations from the recent sampling are included in Table I and annotated for purposes of interpretation. The close correspondence of the winter sample sodium and potassium concentrations with summer sample values gives no evidence of a seasonal change in mixing of geothermal fluids with ground water.

Using Fournier and Truesdell's Na-K-Ca geothermometry (Ref. 10) with the 1979 data gives a calculated resource temperature of 141.4°C which is within the previously reported range of 140-155°C. It must be noted that this estimate is based upon the following assumptions: 1) no dilution with ground water, 2) no steam losses, 3) sufficient time at depth to reach equilibrium, 4) no significant periods of time in transit to the surface allowing equilibration at cooler temperatures. If the assumptions 1, 3, and 4 should prove to be invalid, the calculated temperature (141.4°C) is lower than the actual resource temperature at depth; if the second assumption is not valid, a lower resource temperature exists than was calculated.

EXPLORATION IN 1979

The State of Alaska has appropriated \$245,000 for a "geothermal demonstration" at Pilgrim Springs, Alaska in 1979. These monies are to be administered by the Division of Energy and Power Development (DEPD) of the state's Department of Commerce and Economic Development.

The program of geophysical and thermal exploration which was outlined at the planning meeting of January 25-26, 1979 will be carried out by the Geophysical Institute of the University of Alaska which is directing \$35-50,000 of its DOE funded geothermal budget to this effort. The state of Alaska will finance the remainder of the exploration. This program will consist of active seismic profiling and additional resistivity studies to locate the possible faults(s) in the vicinity of the church and to locate bedrock; thermal grid measurements using a combination of 8- to 10-foot and 30- to 40-foot depths to map ground water migration and mixing for further elucidation of the distribution of heat in this area; three holes 200 feet deep, to better examine the vertical heat distribution; a local hydrology survey, since little data have been taken in this area and this information will be useful in interpretation of other data; and detailed site geology, including bedrock and surficial mapping. The State Geological Survey has offered to assist with surface geology and petrology. The hydrology branch of the USGS will assist in hydrology studies, water chemistry, and well design.

Exploratory drilling, possibly 500 to 1000 feet in depth, is anticipated in 1979, depending on the results of the geophysical and geologic

studies. The drilling will be contracted and funded by the State of Alaska.

AGRICULTURAL DEMONSTRATION

It is the intent of the State of Alaska to promote the utilization of the geothermal resource at Pilgrim in the development of a local "industry" which would improve the economic base of the region. In order to encourage private entrepreneurs to invest in such development, the State will begin a demonstration project at Pilgrim with planning beginning in 1979. The State intends to direct about \$75,000 of the \$245,000 appropriation to this demonstration. The U.S. Bureau of Indian Affairs has expressed interest in such a project and may be able to supply some additional funding. It became clear during discussions of the cost of the demonstration that even if BIA funding becomes available, further support must be sought from other sources.

Consideration is being giving to various possible direct uses for the available heat. An agricultural demonstration appears to be the first application, but additional uses which may develop in time include food processing and aquaculture. A market for products of such a development appears to exist in the region, particularly in Nome. Agricultural products from Pilgrim Springs have in past years been transported for sale in Nome. The most recent caretakers at Pilgrim Springs are, with little training or equipment, on the margin of making a profit from vegetables grown in the warm ground at Pilgrim Springs (Figure 13).

Figure 13. A recent garden at Pilgrim Springs (Courtesy C.J. Phillips)

More detailed economic figures are needed before it can be assured that the demonstration will become a self-supporting enterprise; experience obtained from the demonstration will be most useful in obtaining these figures. This project will provide meaningful experience for development in other promising geothermal areas of the state, and should stimulate further utilization of this Alaskan energy resource.

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APPENDIX A

DATA AND CALCULATED APPARENT RESISTIVITIES FOR SCHLUMBERGER AND EQUATORIAL TRAVERSES

Data and calculated apparent resistivities for
Schlumberger traverses (from Ref. 5)

Current Electrode Separation AB/2 *	Potential Electrode Separation MN/2 *	Separation Factor K	Current I	Voltage mV	Apparent Resistivity ρ (Ωm)
(feet)	(feet)				
10	2	2.623×10^1	0.1	36.0	9.6
15	2	5.290×10^1	0.1	19.5	10.3
25	2	1.486×10^2	0.1	7.5	11.2
40	7	1.061×10^2	0.1	9.8	10.4
70	7	3.317×10^2	0.5	16.0	10.6
100	10	4.739×10^2	0.6	14.0	11.1
150	15	7.109×10^2	0.6	14.0	16.6
200	15	1.269×10^3	1.0	17.0	21.6
200	40	4.596×10^2	3.7	146.0	18.1
300	40	1.058×10^3	4.5	115.0	27.0
400	40	1.896×10^3	3.8	65.0	32.4
500	40	2.973×10^3	3.75	51.0	40.4
500	100	1.149×10^3	3.8	122.0	36.9
600	100	1.676×10^3	3.5	96.0	45.9
800	100	3.016×10^3	2.8	56.5	60.9
1000	100	4.740×10^3	0.9	16.0	84.3
1200	100	6.847×10^3	0.65	7.7	81.1
1600	100	1.221×10^4	0.99	5.7	70.3
1600	100	1.221×10^4	2.2	12.0	66.7
2000	100	1.910×10^4	4.3	17.5	77.7

increasing depth

* In the Schlumberger array of four electrodes, AB is the distance between the outer (current) electrodes and MN is the distance between the inner (potential) electrodes.

Equatorial Number 1 (from Ref. 5)

R	Potential Electrode Separation MN/2	$\bar{R}$	Separation Factor K	Current I (amperes)	Voltage mV	Apparent Resistivity ρ_a (Ωm)
1000	100	1887	2.008×10^4	2.2	4.0	36.5
1535	100	2217	3.685×10^4	2.2	2.6	43.5
2000	200	2561	2.522×10^4	2.35	4.6	49.3
3000	200	3400	5.900×10^4	2.4	2.3	56.5
4000	200	4308	1.199×10^5	2.4	1.4	69.9
5000	500	5250	8.759×10^4	2.4	2.0	72.9

AB/2 = 1600, equatorial #1 going north

R is the distance between the center of the current electrode spread and the potential electrode spread

$\bar{R}$ is the equivalent AB/2 Schlumberger spacing for the given equatorial R spacing

Equatorial Number 2 (from Ref. 5)

R	Potential Electrode Separation MN/2	$\bar{R}$	Separation Factor K	Current I (amperes)	Voltage mV	Apparent Resistivity ρ_a (Ωm)
1000	100	1887	2.008×10^4	2.45	17.0	142.0
1500	100	2193	3.158×10^4	2.4	13.5	177.6
2000	200	2561	2.522×10^4	2.4	19.0	191.0

AB/2 = 1600, equatorial #2 going south

R is the distance between the center of the current electrode spread and the potential electrode spread

$\bar{R}$ is the equivalent AB/2 Schlumberger spacing for the given equatorial R spacing

Data plotted (from Ref. 5)

APPENDIX B
SEISMIC TRAVEL TIME CURVES

Seismic travel-time curves A-B (from Ref. 4)

Seismic travel-time curves B-C (from Ref. 4)

Seismic travel-time curves D-E (from Ref. 4)