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GEOTHERMAL NEWS

GEOTHERMAL COMMERCIALIZATION OFFICE

P.O. Box 4096, University Station, Laramie, WY 82071
(307)766-4820 Toll-free in Wyoming 1-800-442-8334

Vol. 2, No. 5 May, 1981

STEPS INVOLVED IN GEOTHERMAL ENERGY USE

The steps involved in getting geothermal energy out of the ground and into an actual application are as follows:

Geological evidence is the first thing to look for. Thermal springs and wells are an indication that a geothermal reservoir may exist.

Exploration and siting begins onee a reservoir has been confirmed, through geological, geochemical, geophysical, and hydrological technologies.

Drilling prognosis precedes the actual drilling. It involves shallow drilling to determine the methods and materials required for each well.

Testing plans based upon hydrology and engineering will determine the usability, behavior and longevity of the well.

Resource evaluation tells the user what the potential uses are for the well, based upon the quantity and temperature of the fluids discovered.

Economic feasibility includes the capital requirements, replacement costs, tax rates, and financing costs.

Methods of financing the geothermal project range from bank loans to state or federal grants or private funding.

Institutional requirements and legal aspects include the rights to site access, leases, easements, and the rights to reservoir use. The GCO has additional information on institutional requirements for the state of Wyoming.

Environmental impacts are a major concern of the federal and state land use agencies. All negative environmental impacts should be solved or mitigated.

Project management is important to the success of each geothermal project. A competent staff should be employed or consulted with at every step of the geothermal development.

GCO TRIP TO CODY, WYOMING

Patti Burgess-Lyon and Karen Marcotte will be travelling to Cody during the second or third week of May to present the results of the Cody SSDA report. An SSDA (Site Specific Development Analysis) has been prepared this spring on the geothermal energy development potential of the Cody region.

Keith Brown of the Physical Sciences Laboratory of the New Mexico Energy Institute, and Henry Heasler of the UW Geology Department have contributed significantly to the research of this report. Mr. Brown and Mr. Heasler attended several public meetings during the GCO trip to Cody in March.

Specific dates and times for the May GCO presentations in Cody have not been set at the time of this writing. Please watch your local newspapers for additional information or call the GCO at 1-800-442-8334 (within Wyoming).

HEAT PIPE BRIDGE IN LARAMIE, WYOMING

The new bridge being installed in east Laramie is nearing completion. This bridge utilizes ground heat to keep the bridge relatively ice-free during winter months. A detailed description of the bridge design was presented in a past issue of the Geothermal News. The bridge is scheduled to be completed this summer.

GEOTHERMAL FLUID DISPOSAL OPTIONS SUMMARY

The following is a list of disposal options for geothermal energy developers. Method of disposal is dependent upon specific site parameters and the quality of the water encountered.

- °Discharge to surface waters
- °Evaporation ponds
- °Secondary uses
- °Injection at varying depths

MATERIALS AVAILABLE THROUGH THE GCO

The following is a list of printed materials available through the GCO:

- --The Thermopolis/East Thermopolis Site Specific Development Analysis (xerox of draft report at this time)
- --The Cody Site Specific Development Analysis (xerox of draft report only at this time)
- --Preliminary Data from Six Temperature Gradient Holes near Cody, Wyoming
- --Fremont County Area Development Plan
- --Big Horn Basin Area Development Plan
- --Converse and Natrona Counties Area Development Plan
- --Institutional Handbook for the State of Wyoming
- --Rules of Thumb for Geothermal Direct Applications
- --Geothermal Application Technologies
- --Geothermal Greenhouse Heating Pamphlet
- --Federal Cost Sharing for Exploration of Hydrothermal Reservoirs for Direct Applications
- --Geothermal Energy in Wyoming:Site Data Base and Development Status
- --Hydrothermal Commercialization Baseline for the State of Wyoming
- --All previous issues of the Geothermal News

SUMMARY OF GEOTHERMAL PROJECTS BEING CONSIDERED FOR DEVELOPMENT IN WYOMING

- --potential district heating systems for three Wyoming towns
- --ethanol plant using oil field waste heat and heat pump technology
- --greenhousing and aquaculture project near Midwest
- --geothermal greenhouses near Thermopolis
- --several individual domestic space heating applications in the Big Horn Basin
- --potential small domestic heating districts south of Cody
- --possible small industrial park application near Midwest

GCO PERSONNEL

Rick James, Program Director
Karen Marcotte, Research Associate
Patti Burgess-Lyon, Graduate Research Assistant
Keith Bray, Work Study Student
Ruth Tebbutt, Senior Secretary

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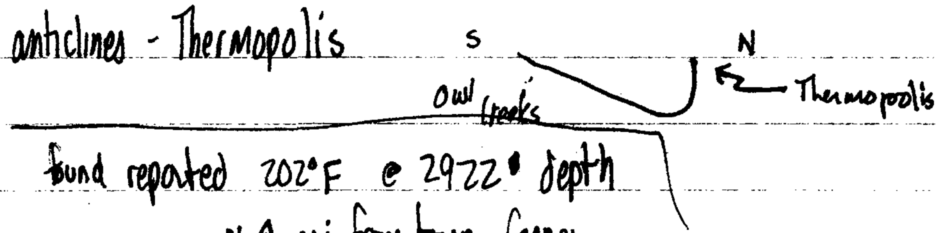
LARAMIE WYO

Duncan Foley, Geologist
Earth Science Laboratory
UURI, 391-A Chipeta Way
Salt Lake City, UT 84108

13 Feb 80 (1)

w/ Ed Decker

anticlines - Thermopolis



found reported 202°F @ 2922' depth
~ 4 mi from town Casper

planning saturation mapping + collection of well temps.
also some "semi site-specific"
big push

has lots of thermopolis data on wells, temps, geol setting

proposal
extension request
letter to J on Wyo program

UNIVERSITY OF UTAH RESEARCH INSTITUTE

UURI

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420 CHIPETA WAY, SUITE 120
SALT LAKE CITY, UTAH 84108
TELEPHONE 801-581-5283

1 June, 1981

MEMORANDUM

TO: Henry Heasler

FROM: Duncan Foley Duncan

RE: Thermopolis report

Carl Ruscetta and I have reviewed the Thermopolis report; our comments are on the enclosed copy. Overall I like it, but I do have some specific comments. You are as an author, of course free to accecpt or reject these as you see fit.

I like the model, it looks sound. I do wonder, however, if there are other data sets not included that might help your case. Is there any available gravity or other geophysical data? With all the well drilling in the area, can you at least get a look at a seismic line across the anticline, to see if your fault shows up? Have you had the report looked at by anyone from the oil patch?

The hydrologic data, as far as it goes, looks very good. I did find myself, however, wishing there were data from aquifer tests included; are any available?

I notice that the geochemical data are compiled from existing sources, and that with the exception of the analyses from Breckenridge and Hinckley, elements useful in geochemical thermometry calculations (Ca, Na, K, Mg, SiO_2) are missing. Do thermometry estimates on the samples you have support your interpretations? If the waters are all mixing, there should be good reflection of the base temperature of the system. If they are different, you could be looking at dilution or flow phenomena. Geothermometers are among the first data that developers look for; I think some discussion of them should be included.

Did anything come out of the Rocky Mountain Groundwater Conference in Laramie that helps your understanding of the system?

I have indicated several places where I think the style could be improved, as well as colloquialisms or first person references that might be changed. These suggestions should, of course, be dealt with appropriately to meet your style and Wyoming Geological Survey publication requirements.

I would suggest that, especially to meet the DOE needs of addressing potential users, either the abstract be expanded to provide a more general introduction, or a first chapter synthesis, similar to your summary section, be included. In this manner, user needs of general results can be addressed, and consultant needs of data are not neglected.

I have kept a copy of the report with my comments on it for our files. It will not have any public circulation, but will serve instead to refresh my memory if you have any questions or don't understand why I've said things.

Happy reading, and keep up the good work.

A SUMMARY OF GEOTHERMAL POTENTIAL AND DEVELOPMENT IN WYOMING

By

Henry P. Heasler
Department of Geology and Geophysics
University of Wyoming

Prepared for
The Interstate Oil Compact Commission
Midyear Meeting
June 28-30, 1981
Casper, Wyoming

INTRODUCTION

The Department of Geology and Geophysics at the University of Wyoming is investigating the geothermal potential of Wyoming and bordering areas. This research is supported by the United States Department of Energy with earlier funding from the National Science Foundation. Department of Energy funding began in December of 1978 with total funding from the D.O.E. amounting to $588,984.00.

Geothermal research has focused on detailed studies of low-temperature resource areas, compilations of regional geothermal data, and syntheses of pertinent geology and geophysics. Compilations of geothermal data include oil well bottom hole temperatures which are used to construct thermal gradient and contour maps, field measurements of temperature profiles in drill holes, and the measurement and computation of the amount of heat flowing through specific rock layers. As part of the heat flow computation, laboratory measurements of rock thermal conductivity are made and interpretated with field measured temperature data. Heat flow values are then used to model the type of geothermal system in an area and predict its maximun temperature.

This report presents a brief summary of current research results. It is divided into sections on the characterization of the resource in Wyoming, on specific areas with potential low-temperature resources, and on present and planned geothermal uses. The data on geothermal uses in Wyoming are from the Wyoming Geothermal Commercialization Office located at the University of Wyoming.

Throughout the text, temperatures are given in °F or °C (°F = 1.8°C + 32), geothermal gradients are given in °F/1000 feet or °C/km (°F/1000 feet = 1.82 °C/km) and depths are reported in feet or meters (1 foot = .305 meters). The flow of heat within the earth is given in heat flow units abbreviated HFU where 1 HFU = 1×10^{-6} calories/cm^2 - sec = 41.8 milliwatts/m^2.

GEOTHERMAL CHARACTERIZATION OF WYOMING

Geothermal systems in Wyoming can be classified into three main catagories as volcanic-plutonic systems, deep sedimentary basin systems, or shallow to moderate depth hydrothermal convective systems. Each of these three systems can be further subdivided into high temperature (greater than 150°C (302°F)), moderate temperature (90-150°C (194-302°F)), or low temperature (less than 90°C (194°F)) resources.

Volcanic-Plutonic Systems

Volcanic-plutonic geothermal systems result from localized heat sources where molten rock is close to the surface of the Earth. The more recent and widespread the volcanic activity the more likely a high temperature geothermal resource will be present. In Wyoming, Yellowstone National Park is the only confirmed high temperature geothermal system of this kind. A research drill hole by the U.S. Geological Survey encountered a temperature of 237°C (458°F) at a depth of 330 meters (1,080 feet) in the Norris Geyser Basin of Yellowstone (White et al., 1975). The Yellowstone National Park area has more than 10,000 identified hot springs, geysers, and steam vents which are surface manifestations of the large amount of heat energy present. However, since the area is a National Park, the exploitation of geothermal energy is not allowed.

Two other volcanic-plutonic systems in Wyoming are young enough to possibly contain some useable geothermal resources. These two areas are portions of the Black Hills in northwestern Wyoming and the Leucite Hills located in the northern portion of the Rock Springs Uplift in southeastern Wyoming (see Figure 1). Evidence for a possible thermal anomaly in the Black Hills is discussed in a paper by Decker et al., 1980. At present the anomally is poorly defined due to the lack of drill holes available for temperature and heat flow determinations. The presence of a thermal anomally in the Leucite Hills has not been verified to date also due to a lack of drill holes accessible for thermal measurements.

Deep Sedimentary Basins

Deep sedimentary basins constitute the second type of geothermal system present in Wyoming. Moderate temperature waters (90°-150°C (194-302°F)) are found in the deeper portions of most of Wyoming's major structural basins. These basins include the Bighorn Basin, Wind River Basin, Green River Basin, Powder River Basin, Great Divide Basin, and Washakie Basin (see Figure 1). Hot water is found in these basins due to the Earth's normal increase in temperature with increasing depth (the increase in temperature with depth is called the geothermal gradient). Certain water-bearing rock units in these basins are folded deep enough (usually over 3 km (10,000 feet)) such that the surrounding rocks heat the water.

This type of geothermal system exists only in the deep central portions of the basins where drilling for a moderate temperature geothermal resource is uneconomical. However, since many of the water bearing rocks such as the Madison Limestone, Tensleep Sandstone, or Mesaverde Formation also sometimes contain oil, deep holes are drilled into these rock units. If hydrocarbons are not encountered, the drill holes are plugged even if hot waters are found. What would be extremely useful in Wyoming is a streamlining of regulations that would easily allow the transferring of these oil exploration holes to municipalities or individuals for hot water utilization.

Shallow to Moderate Depth Hydrothermal Convective Systems

The third type of geothermal system in Wyoming is the shallow to moderate depth hydrothermal convective system. Low temperature resources (less than 90°C (194°F)) are usually associated with this type of system. Also, most of the hot springs located across Wyoming (Figure 2) are the surface manifestations of hydrothermal convective systems. With this type of geothermal system,water circulates in porous rock units to moderate depths (1500 to 2000 meters (5000 to 6500 feet)) where it is heated by the Earth's normal increase in temperature with depth. The warmed water then circulates upwards near the surface of the Earth by either an upwarp of the water-bearing rock units or a porous fault system. In the area of the upwarp warm waters can be found at relatively shallow depths. An example of this type of system is shown in Figure 3 which is a representation of a portion of the Thermopolis hydrothermal system. Figure 3 illustrates how water in the Madison Limestone can be heated to 72°C (161°F) at a depth of 1900 meters (6200 feet) and then brought to within 760 meters (2500 feet) of the surface. This type of geothermal system is relatively easily explored and the resources found can be used for direct heating purposes. Discussions of identified low-temperature resource areas of this type of geothermal system are contained in the next section on site specific areas.

SITE SPECIFIC AREAS WITH POTENTIAL LOW TEMPERATURE RESOURCES

The Thermopolis Area

Temperatures, gradients and regional geology have been compiled for a 1800-1900 mi^2 area that is roughly centered on the town of Thermopolis (Figure 2). The results demonstrate that the thermal anomaly occurs all along the central part of the Thermopolis anticline, occupying a 20 mile long by 3 mile wide area that strikes west-northwest between the southwestern part of T. 43 N., R. 93 W. and the southeastern part of T. 44 N., R. 96 W. Within this zone, calculated gradients are in the range 43-300°F/1000 ft (78-547°C/km) and tabulated bottom hole temperatures range from 90°F (32°C) to 160°F (70°C) at depths less than 2000 ft (∿ .6 km). Inasmuch as downward continuation of the lower gradients predicts 60+°C temperatures at depths between 3500 and 4000 ft (1.1-1.2 km), we consider all of the region to be a "viable" low temperature, hydrothermal resource area.

The Red Springs Anticline area in T. 43 N., R. 93 W. may be a "marginal" resource area. Here the calculated gradients are in the range 24-59°F/1000 ft (43-107°C/km). Consequently, 45°C waters might be encountered at 3900-4500 ft depth (1.2-1.3 km).

A tightly folded syncline is located immediately south of the Thermopolis anticline. We believe that waters from the Owl Creek Mountains are heated at the bottom of this syncline. Subsequent upward movement of these waters along the northern flanks of the syncline could explain the high gradients in the anticline. The thermal waters are most likely to be in the Tensleep and/or Madison Formations -- two formations with porosities and permeabilities sufficient to yield the flow rates (∿ 2800 gpm; Breckenridge and Hinckley, 1978) of the spring system in Hot Springs State Park. Within the central part of the anticline, the "tops" of the Tensleep and Madison range from 200-2800 ft (.06-.85 km) and 800-3450 ft (.24-1.08 km), respectively. It is possible, therefore, that these aquifers could be reached with economical drilling in some parts of the structure (see Figure 3).

Referring to "practical" aspects of resource development, one question that must be answered is whether drilling and large scale development would change temperatures and flow rates of the Thermopolis hot springs. Lack of data on porosities and permeabilities of the regional subsurface units also could impede development, as could the data for the springs which suggest that regional thermal waters would contain large amounts of total dissolved solids (2300 ppm; Breckenridge and Hinckley, 1978). Finally, minor structures along the crest of the anticline should be carefully considered during drill site selection; for example, numerous faults cross-cut the northwest-southeast trend of the anticline, and a heretofore unmapped fault is evident on air photos of the structure.

The Cody-Horse Center Anticline System

This potential resource area is bounded by the DeMaris hot springs (27-39°C (80-96°F) 1700 gpm) just west of Cody and the Horse Center anticline about 7 miles to the south (Figure 2). The first evidence for a low-temperature resource was provided by the 29-205°C/km (27-112°F/1000 ft) gradients calculated using bottom hole temperatures in eleven dry oil wells in the anticline. Down hole measurements by Wyoming personnel agree with the oil well data. For example, least-squares gradients and maximum temperatures based on measurements in five shallow oil wells are in the ranges 96-190°C/km (52-104°F/1000 ft) and 38.4-47.5°C (101-117°F), respectively, at subsurface depths in the range 185-500 m (607-1640 ft).

Data from six shallow temperature gradient wells drilled by the Department of Geology in early 1980 suggest that the area of greatest potential use is in T. 52 N., R. 102 W., S ½ of section 2, and W ½ of section 11. In this area warm waters (34°C (93°F)) can be reached at shallow depths (51 to 300 meters (168 to 1,000 feet)). The maximum temperature of this system may approach 55 to 65°C (131 to 149°F) at depths of 260 to 500 meters (853 to 1640 feet). Warm waters will be found at the shallower depths in the more western portions of this potential use area (see Heasler, 1980).

The main aquifers for the Cody-Horse Center hydrothermal system are the Tensleep Sandstone, Madison Limestone, and Bighorn Dolomite. These formations are reported to have good porosities and permeabilities with flows in the Madison Limestone and the Bighorn Dolomite sometimes exceeding 1,000 gallons per minute (Lowry, 1976). However, the water flow of wells drilled into these aquifers may vary greatly between wells due to secondary fracture permeability, secondary silica cementation of the Tensleep Sandstone, and the cavernous nature of the Madison Limestone and Bighorn Dolomite.

The Rattlesnake anticline is between Cody and the Horse Center anticline. As seems to be the case elsewhere in the area, the Chugwater Formation in this anticline appears to be an impermeable cap rock that overlies porous, permeable and perhaps water-bearing units in the Tensleep and Madison Formations. It is believed that waters are heated at depth in a syncline that is to the southwest of the Rattlesnake anticline. Subsequent upward movement of the water along the northeastern flank of the syncline through the Tensleep and Madison Formations results in the warm temperatures at shallow depths.

The Casper-Midwest-Douglas Area

Because of much local interest in utilization of hydrothermal resources in projected housing development, considerable effort has been spent researching these areas. Present data consist of more than 2,000 bottom hole temperature points, from which combined temperature gradient and geologic maps are being prepared.

Most of our data are for areas near Midwest. These results clearly show that the Salt Creek Oil Field is a conspicuous thermal anomaly. Within this 10-12 mi^2 field, bottom hole temperatures between 1000 and 4500 ft (.3-1.4 km) are in the range 120-170°F (49-77°C), and maximum calculated gradients are between 40 and 100°F/1000 ft (72-182°C/km). Additionally, water injection wells that penetrate the Madison Formation produce 160-175°F (71-79°C) waters that flow to the surface at rates exceeding 7,000 gallons/min. There can be little doubt, therefore, that Salt Creek Field could be used to produce hydrothermal fluids for direct-heat applications in the vicinity of Midwest. The major impedences to resource development could be the relative values of hydrocarbon and geothermal resources, the high concentrations of solids in the nonpotable waters, and the question of whether AMOCO Production Co., Wyoming, or the federal government owns the geothermal resource.

Scant data exist for the Casper region because fewer oil tests have been drilled in the area. The available data do suggest, however, that most of the region within a 10-15 mile radius of the city is not thermally anomalous. Calculated gradients are generally in the range 14-16°F/1000 ft (25-29°C/km) and temperatures are in the range 100-135°F (38 to 57°C) at depths of 3,500-4,500 feet (1,070-1,370 meters).

Two reliable heat flow values are now available for the Douglas area (Figure 2). The values are in the range 2.0-2.2 HFU. These drill holes are in an area where the underlying Madison Formation is dipping up to shallower depths from the north, northeast. Perhaps upward circulating waters in the Madison explain the observed above-normal flux. More reliable definition of the suggested resource area will require additional research with shallow drill holes.

Gradients in 5 shallow holes near Torrington are in the range 23-29°C/km (13-16°F/1000 ft). In the Wright area to the north, measurements in 10 holes suggest that the undisturbed regional gradient is between 19 and 29°C/km (10-16°F/1000 ft). The meaning of these data is obscure, but one interpretation is that the eastern part of the Powder River Basin is characterized by a complex pattern of normal to high heat flow and perhaps shallow low-temperature hydrothermal reservoirs in isolated areas. We cannot be more specific without more geothermal data for the Basin.

Research in the Casper-Midwest-Douglas area is continuing in an effort to locate potential resource areas and to better define heat sources and hydrothermal water movement.

The Gas Hills Area

Research before 1979 revealed the presence of high gradients (42-100°C/km) at 8 isolated drill holes on the Beaver Rim, in the Gas Hills east of Lander. Recently compiled data consist of 20 bottom hole temperatures and temperature measurements in 31 holes that were drilled during uranium exploration. Maps of heat flow, gradient and regional geologic data are in various stages of compilation.

The present data are consistent with a complex pattern of gradient and flux in the Hills. Briefly, observed gradients range from 20°C/km to 100°C/km (11-55°F/1000 ft) and estimated heat flows are in the range 1.2-3.4 HFU. From combined geothermal and geologic data, one hypothesis is that faults control the gradient and heat flow patterns. Thus, any development of geothermal resources is likely to require careful mapping of the local geologic structure to delineate fault zones that could yield waters with potential for direct-heat applications. We hope to conduct more studies in the area because the great interest in subsurface uranium could lead to local settlements and because one deep oil test in the Hills is reported to have encountered high temperature waters in the Madison (J. D. Love, personal communication, 1980).

The Saratoga Valley Thermal System

Our DOE cooperative agreement has allowed us to establish a gradient and heat flow profile that extends from the eastern edge of the Washakie Basin to the Laramie Mountains (Figure 1). Gradients and preliminary heat flow values along this profile are in the ranges 7-30°C/km (4-16°F/1000 ft) and .9-1.6 HFU, respectively. Two holes on the profile are near the hot springs in the town of Saratoga (Figure 2). The gradient in the hole about 1 mile west of the springs is 20°C/km (11°F/1000 ft), and that in the hole about 1 mile to the east is 30°C/km (16°F/1000 ft). Both gradients may be considered "normal", and so these observations suggest that the Saratoga hot springs ($\sim$ 50°C (122°F); Breckenridge and Hinckley, 1978) are not surface manifestations of a subsurface hydrothermal system with large dimensions. The narrow width of the system, in turn, suggests that the springs could be flowing from faults in this part of the Saratoga Valley. This view is supported by geologic evidence for a fault zone near the spring system (Montagne, 1955). Like the Gas Hills, development of geothermal resources in the Saratoga area may require additional research on the correlations between faulting, subsurface temperatures and heat flow in the region.

We may speculate that moderate or higher temperature resource areas could be present at shallow depths in the region between the Saratoga

Valley and the southern Rocky Mountains in northern Colorado. From our new data, the heat flow is normal or low (.9-1.6 HFU) in the Saratoga Valley-Sierra Madre Mountains-Medicine Bow Mountains region in Wyoming, whereas the flux is high ($\geq$ 2.4 HFU) at Hahns Peak and Northgate, Colorado, about 50-60 km (31-38 mi) to the south. Interpreted in terms of steady or transient heat sources, the width and magnitude of the transition suggest that the excess flux in northern Colorado is partly due to high temperature heat sources at shallow depths in the crust and/or upper mantle. This view, in turn, is consistent with geothermal reservoirs in the transition zone and the high heat flow area immediately to the south.

EXISTING AND PROPOSED GEOTHERMAL USES

The existing use of geothermal resources in Wyoming is low-temperature direct-use projects. The greatest single use is in swimming pools and spas such as The State Bath House in Thermopolis. One greenhouse and three private homes are geothermally heated. The Wyoming Highway Department has constructed two heat pipe bridges (one near Laramie and one near Wheatland) that use geothermal heat to help keep the bridges ice free. Also, the town of Frannie in the northern Bighorn Basin utilizes 32°C (90°F) well water for their domestic water supply and minor heating purposes.

Proposed geothermal projects within the State also deal with the direct use of low-temperature resources. The U.S. Department of Housing and Urban Development has recently funded a $50,000.00 geothermal district heating feasibility study for the town of Thermopolis. Also in the Thermopolis area two geothermal greenhouses (34 feet by 90 feet each) are being built. In the Cody area interest has been expressed in geothermally heating two subdivisions containing 220 homes. One proposed small ethanol plant in the Bighorn Basin is considering using oil field treater water as a heat source. Other known potential uses of geothermal resources in the State include a greehouse and aquaculture facility near the town of Midwest, possible district heating of Midwest, and use by an ethanol plant or cheese plant near the town of Thayne.

CONCLUSION

Reports are in various stages of completion for the Bighorn Basin, the Great Divide-Washakie Basins, the Thermopolis area, and the Cody area. Additional work is planned for the Wind River Basin, Green River Basin, Laramie Basin, and the Thrust Belt of Wyoming. Studies will also continue in identified resource areas. Public input has been very useful in past studies in supplying information on thermal springs, wells available for logging, and areas of potential resource use. Continued input of this type is strongly encouraged. The Wyoming Geothermal Resource Assessment Group can be contacted at P. O. Box 3006, Department of Geology and Geophysics, University of Wyoming, Laramie, Wyoming 82071 (307-766-4888).

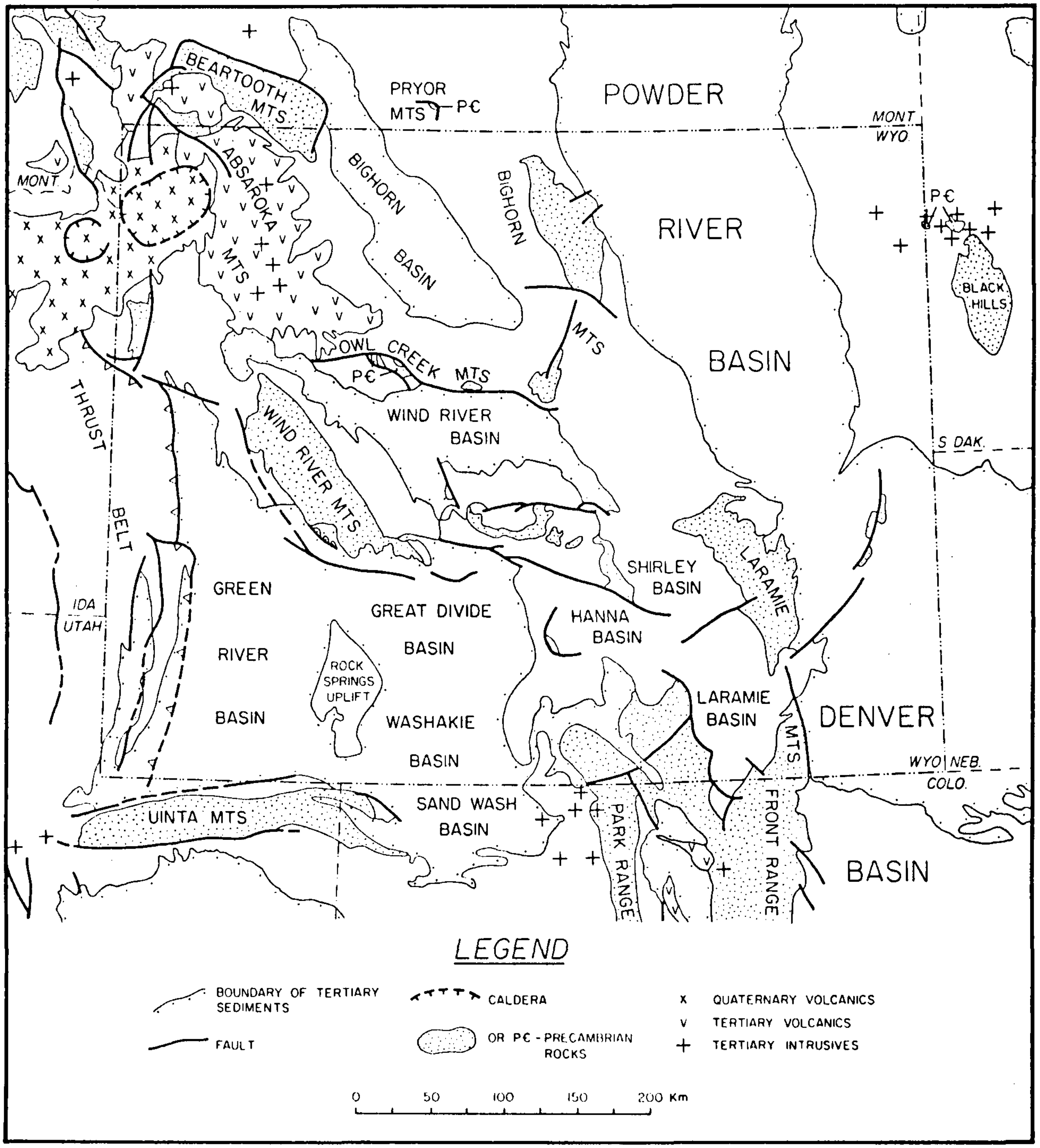

Figure 1. Generalized geology of Wyoming showing major structural features and locations of basins.

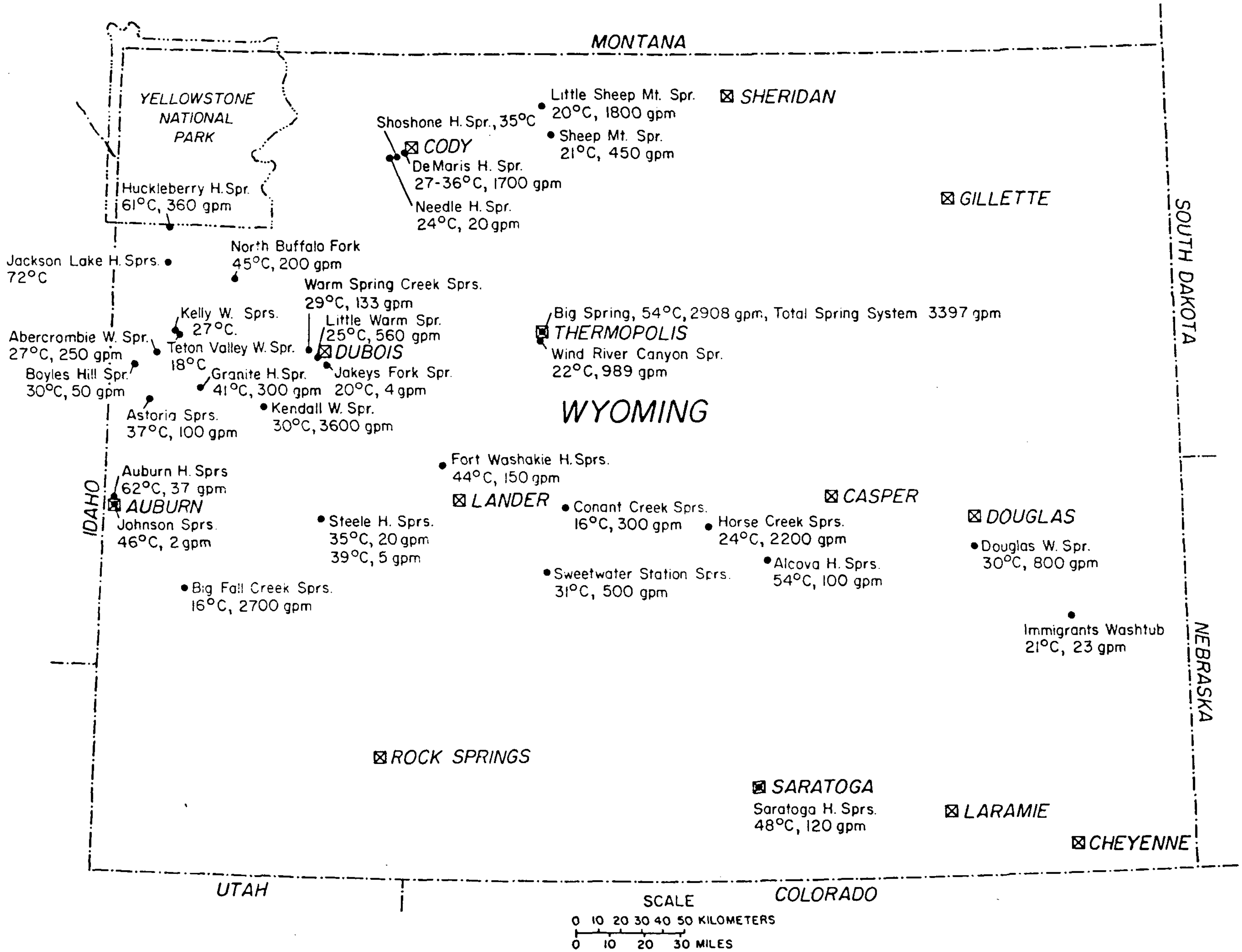

Figure 2. Thermal springs of Wyoming exclusive of Yellowstone National Park. Data primarily from Breckenridge and Hinckley, 1978.

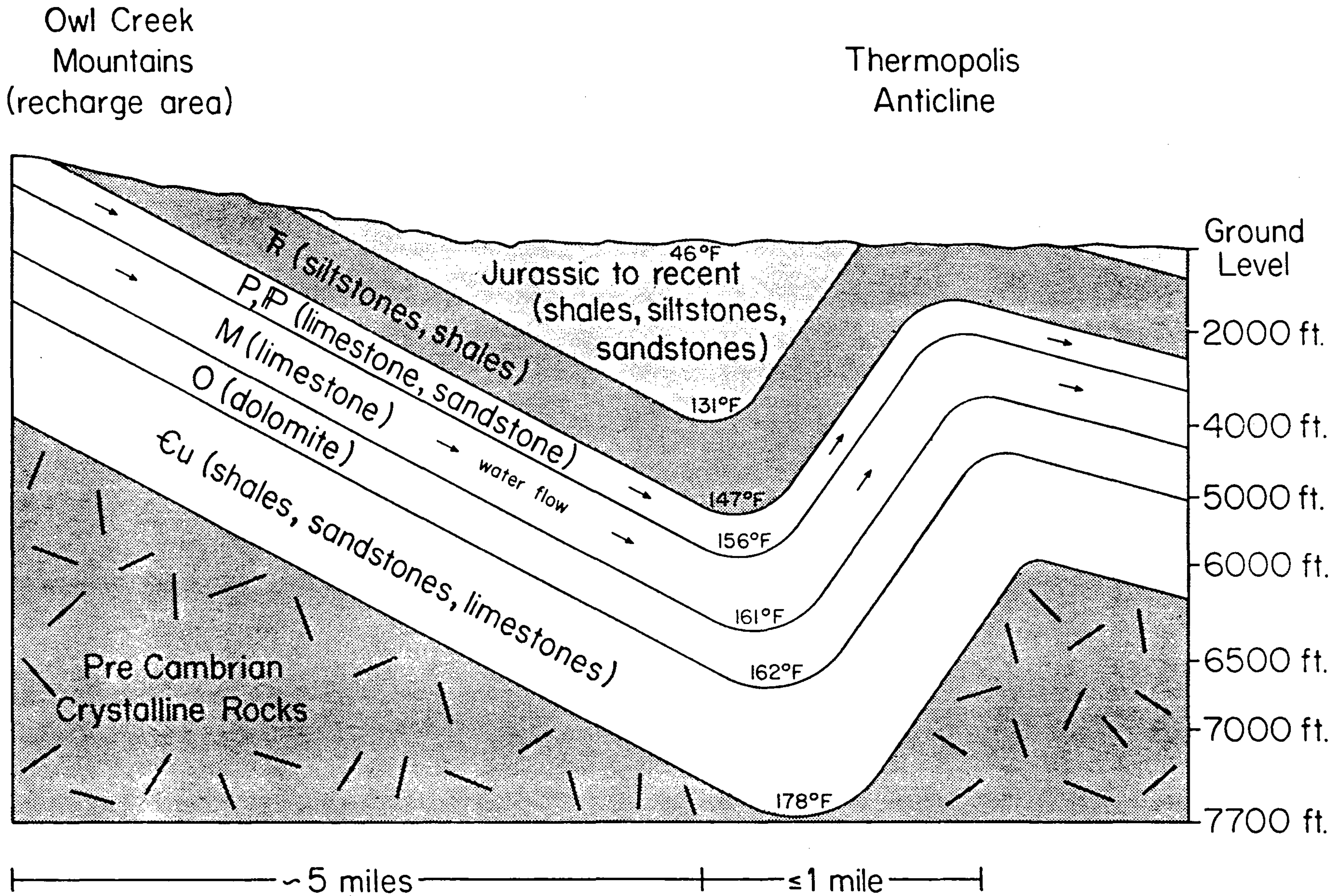

Figure 3. Cross-section of the Thermopolis low-temperature hydrothermal system illustrating how warm waters in the Madison Limestone are brought close to the surface.

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SC Theater Co

2 Feb 79

Rick James
Pet Eng Dept. @ Univ.
Amoco, Midwest Wyo
flowing @ 14 k gpm
200°F
2ndary water flooding

may be used in many other sites of Madison

@ Casper PRDA
nothing may be done wi PRDA, may have come in too late to be considered

PRELIMINARY DATA FROM SIX TEMPERATURE GRADIENT HOLES NEAR CODY, WYOMING

by

H. P. Heasler and E. R. Decker

Date Published - October, 1980

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Prepared for the
DEPARTMENT OF ENERGY
DIVISION OF GEOTHERMAL ENERGY
UNDER COOPERATIVE AGREEMENT DE-FC07-79ID12026

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PRELIMINARY DATA FROM SIX TEMPERATURE GRADIENT HOLES NEAR CODY, WYOMING

INTRODUCTION

Six holes were drilled near Cody in northwest Wyoming in an effort to define a low- to moderate temperature hydrothermal resource. The holes were drilled during January, February, and March of 1980. The total depths of the holes ranged from 116.0 meters (380.5 ft.) to 56.4 meters (185.0 ft.). The project was financially supported by Cooperative Agreement DE-FC07-791-D12026 between the U.S. Department of Energy and the University of Wyoming. This report briefly summarizes the mechanical details of the drilling and casing, and presents preliminary geothermal data for the holes.

EVIDENCE FOR HYDROTHERMAL SYSTEM

The DeMaris Hot Springs, a group of at least seven vents ranging in temperature from 24° to 37° C are one mile west of Cody in northwest Wyoming (see Figure 1). The springs occur on the southeastern flank of a large anticline, the Rattlesnake anticline, where the impermeable Chugwater Formation has been eroded through by the Shoshone River. Within 1000 feet of the hot springs a well that passed through the Chugwater Formation yeilds 208 gallons per minute of water at $34^{\circ}C$. This well and the hot springs appear to define the northern boundary of the hydrothermal system.

A series of travertine and sulfur deposits crop out along the eastern flank of the Rattlesnake anticline. The deposits are near the contact of the Chugwater Formation and the underlying rock units. The travertine deposits extend approximately two miles south of the DeMaris Hot Springs. In this area the Rattlesnake anticline merges into a smaller structure known as the Horse Center anticline.

The thermal data for the Horse Center anticline suggest that the regional hydrothermal system extends as much as seven miles south of Cody. The most

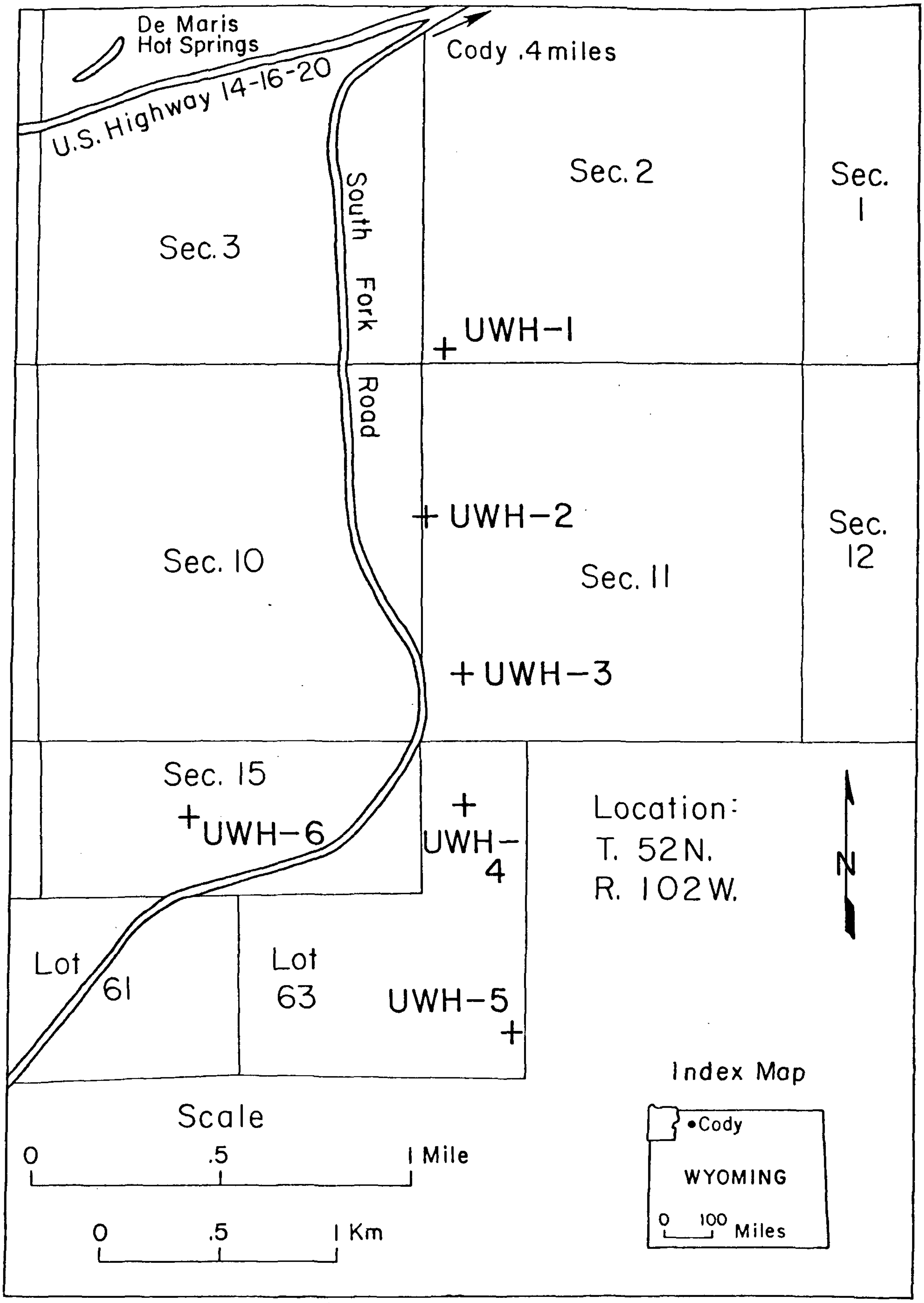

Figure 1. Locations of drill holes (UWH-1 through UWH-6).

convincing data are the thermal gradients of 49 to 205 °C/km in the anticline, based on bottom hole temperatures in eleven oil wells. (Twenty-three "dry" oil wells have been drilled in the structure. Of these, eleven wells yield gradients of 49 to 205 °C/km, five wells yield normal to slightly high gradients of 24 to 37 °C/km, while seven wells had no reported bottom hole temperature).

Our agreement with the U.S. Department of Energy has made it possible for us to log temperatures in three of the five unplugged wells in the Horse Center anticline. The resulting temperature-depth profiles for the wells are plotted in Figure 2. Figure 3 shows the locations of the holes in the area.

Well Letha C-4 may be on the southern edge of the thermal high because the bottom hole temperature of 38.4 °C at 320 meters yields the lowest gradient of 96 °C/km (see Fig. 2). A maximum temperature of 47.5 °C was measured at 500 meters in hole Rose Government 1 (Fig. 2). In contrast, the bottom hole temperature is 45.1 °C at 185 meters in Gains Government C-2 (Fig. 2) and the calculated gradient is 190 °C/km.

Referring to drill hole geology, the three remeasured wells were collared in the Chugwater Formation. Two of the holes ended in the Tensleep Sandstone, with the depth to the Tensleep ranging from 138 to 290 meters.

GEOLOGIC AND DRILLING STRATEGY

The Horse Center - Rattlesnake anticlines geothermal system may be explained by the combined effects of local geology, local hydrology and the regional geothermal gradients. Briefly, we believe that waters in deep porous units are warmed by the thermal gradients outside the middle portions of the anticlines. These waters then quickly gain access to shallower depths by moving upward along the steep limbs of the anticlines. The Chugwater Formation

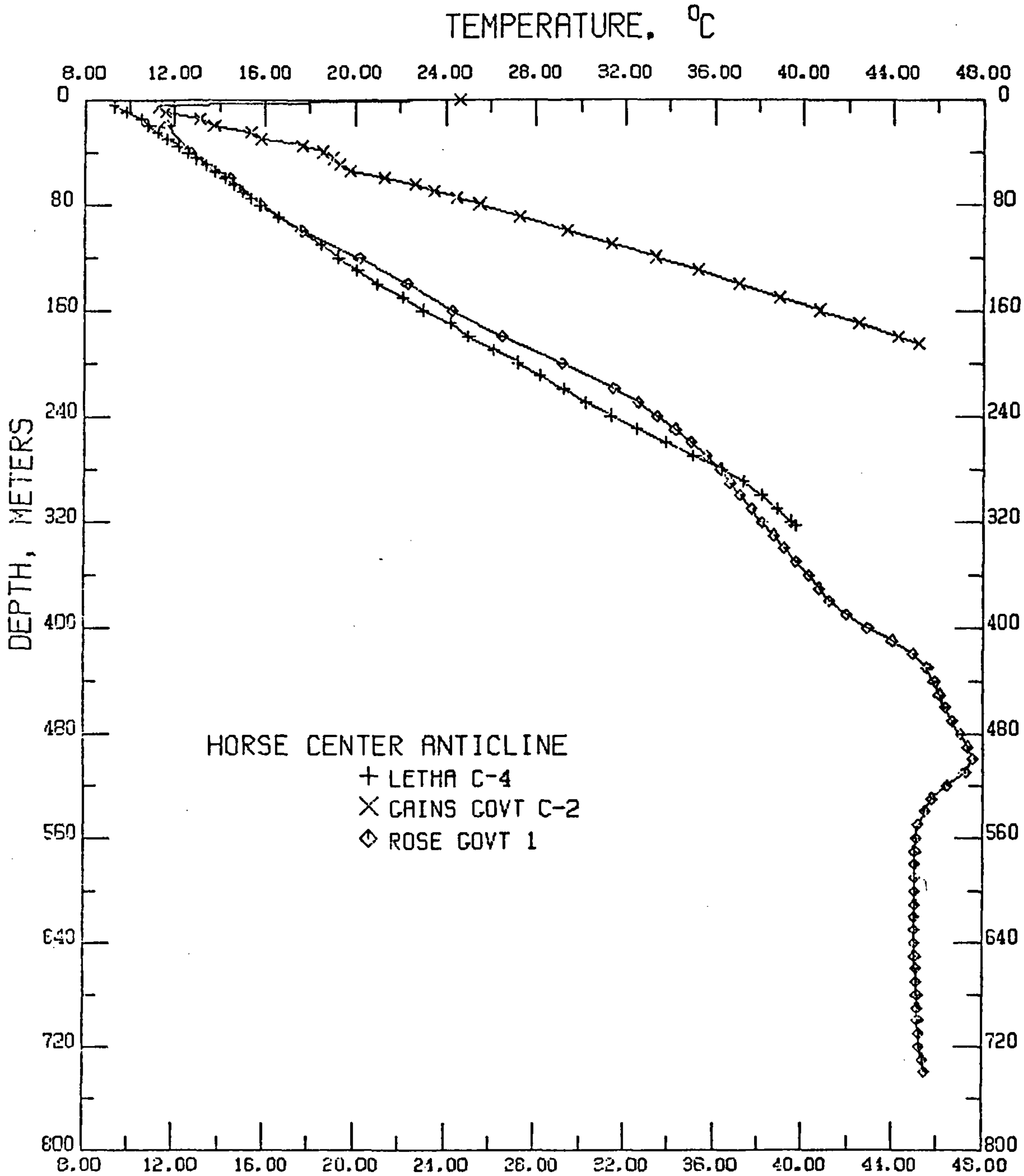

Figure 2. Temperature plots for three oil wells on the Horse Center anticline.

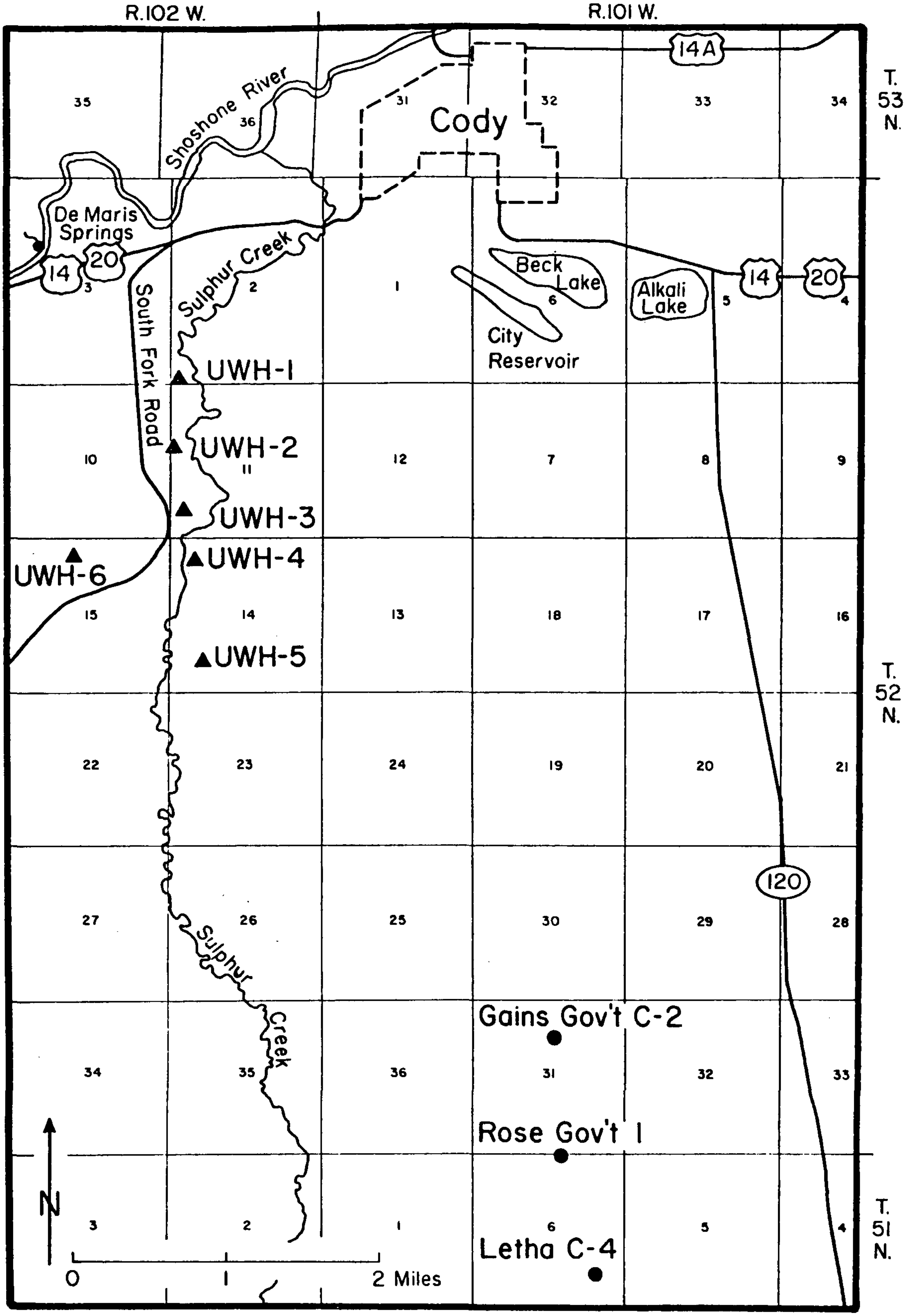

Figure 3. Map showing locations of drilled holes (triangles) and the three thermally logged oil wells (circles).

appears to be an impermeable cap rock above the water bearing units in the central parts of both structures.

The above described model is shown in a general way in Figure 4. The six holes in the Cody-Horse Center region were drilled in the vicinity of a "potential site area" on the southeastern flank of the Rattlesnake anticline.

DRILLING METHODS

The holes were drilled with air or foam using a Frank's Model FJ4HP truck mounted drill rig. The rig was capable of drilling to a depth of 610 meters (2,000 feet). A 5 1/8" tri-cone rotary bit was used to drill the softer units. This bit could not be used for all of holes UWH-3, UWH-4, and UWH-6 because extremely hard units were encountered; therefore a 5 1/8" down hole hammer was used to drill portions of these holes.

The air and foam drilling mediums worked successfully when "dry" fractures etc., were encountered. At some sites, however, water flows or aquifers were encountered and fine sand flowed into the holes as rapidly as drilling proceeded. These "running" sands greatly impeded or prevented further drilling and so cementing was tried to hold the walls of the holes or "stabilize" the sands. The Dowell Company was employed for this grouting, and a special cement was used because the warm subsurface waters had high sulphate contents. This cement gelled in as little as three minutes, and interested readers are referred to the Dowell Company for details on components of the mixture.

The Dowell company was able to cement zones in the upper part of hole UWH-2. When drilling continued downward in this hole, however, other zones of "bad" ground were encountered. These deeper zones could not be cemented because they were either in large caverns or in aquifers with very large volumes of water or high flow rate. A similar problem was encountered at the bottom

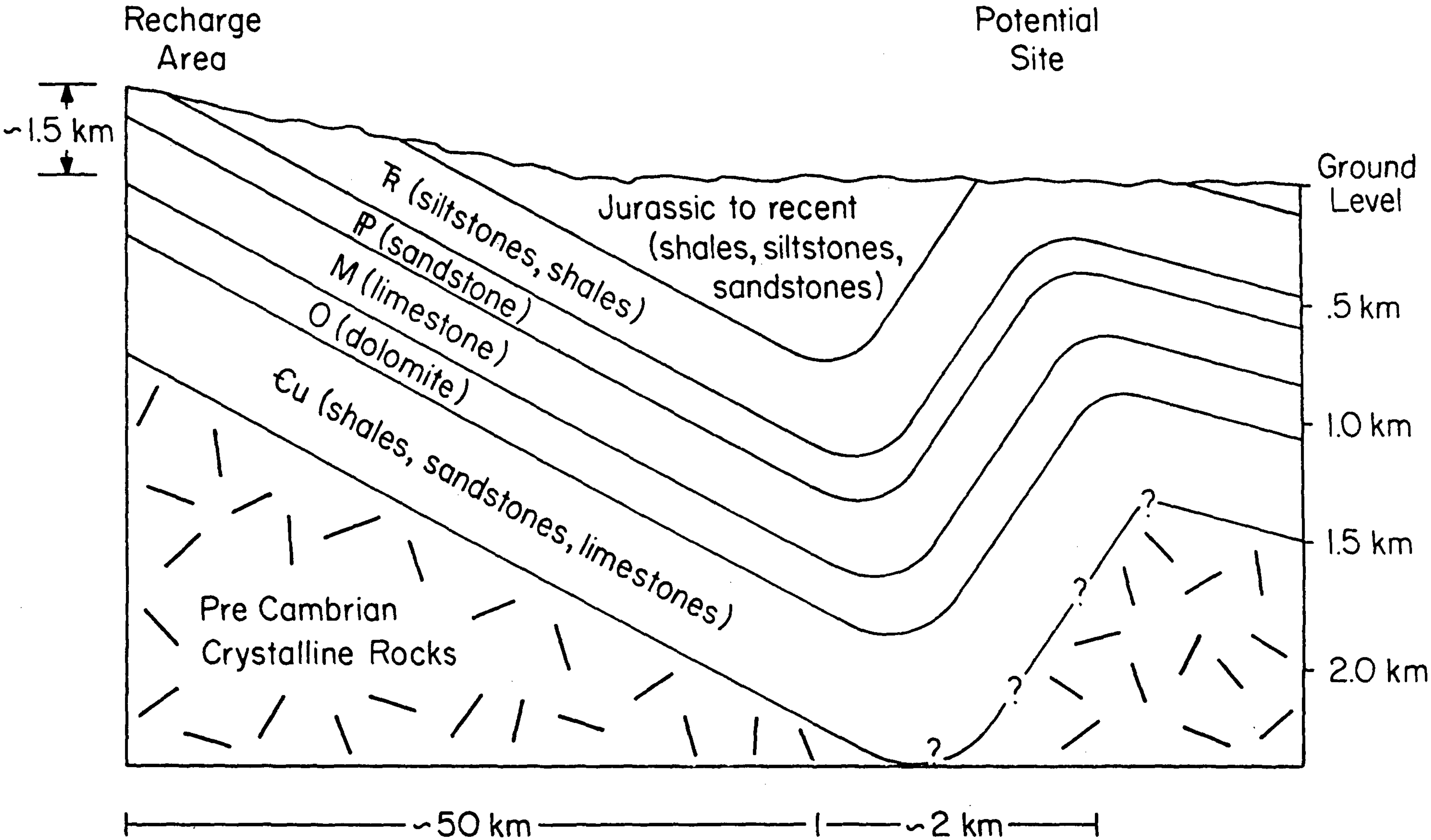

Figure 4. Generalized model of reservoir source and recharge area.

of hole UWH-4. For example only 1.7 meters (5 feet) of "fill up" occurred in UWH-2 when 2.3 $meters^3$ (80 ft^3) were pumped into the bottom of the hole. Consequently, drilling of UWH-2 and UWH-4 was terminated at 123 and 101 meters, respectively, because further drilling was not possible without very costly casing of the troublesome zones.

COMPLETION METHODS

Each well was completed so that temperature gradients could be monitored for an indefinite period of time. This was accomplished by setting an access pipe as deep as possible in each hole. The access pipe is 1¼ inch inside diameter schedule 40 black iron pipe.

The pipe in holes UWH-1, UWH-3, UWH-5 and UWH-6 is grouted with neat cement. The grouting procedure directly followed the methods outlined in Moses and Sass (1979). Grouting was done in an effort to stop vertical flows of water in the annuli between the pipe and the walls of the boreholes. This technique was not used at sites UWH-2 and UWH-2 because both holes bottomed in large cavities and/or very bad ground; therefore, cement would have flowed laterally rather than vertically up around the pipe. Another reason for not cementing pipe in UWH-2 is that it is desirable to deepen this hole in the future, if funding can be obtained.

A latching plug was "chased" to the bottom of the 1¼" pipe in all of the holes. The plug cleaned the pipe and created a tight seal at the end of each string of casing. Each string of pipe was then filled with water, the collars were capped, and each drill site was restored according to the requirements of the State of Wyoming and our agreement with the Department of Energy.

PRELIMINARY RESULTS

Figures 5-10 are plots of the preliminary temperature-depth data for the six holes. A combined plot of these data is in Figure 11. Other measurements in holes UWH-1 - UWH-5 are plotted in Figures 12-17; these measurements were made at times before those shown in Figures 5-9. Tables 1-6 list locations, land owner data, information on drilling, casing and cementing, and generalized lithology for the holes.

Bottom hole temperatures, cased depth, least squares estimates for the gradients in the holes and depth ranges for the gradient calculations are listed below.

Hole	Bottom Hole Temperature	Cased Depth	Gradient	Depth Range
	°C	meters	°C/km	meters
UWH-1	26.6	98.5	156.7	10- 98.5
UWH-2	35.4	116.0	161.4	10- 45
UWH-3	25.3	72.0	181.7	5- 72
UWH-4	13.2	96.7	14.6	5- 96.7
UWH-5	18.3	108.7	78.2	10-108.7
UWH-6	20.4	85.1	108.1	18- 85.1

Rotary chip samples were collected at 3 meter (10 feet) spacings for each hole. The chips were used to determine stratigraphy as drilling progressed. Related geothermal research involves thermal conductivity measurements of the samples. A final report on the resulting heat flow values and regional thermal interpretations for the holes should be fowarded in the next 4-6 months.

PRELIMINARY INTERPRETATION

The Cody-Horse Center hydrothermal system is believed to extend on a line south-southeast from the DeMaris Hot Springs to well Letha C-4 (see Figure 3). The width of this zone varies from one to about two miles.

The area of greatest potential use is in T. 52 N., R 102 W., S½ of section 2, and W½ of section 11 (see Figures 1 and 3). In this area warm waters (34 °C (93 °F)) can be reached at shallow depths (51 to 300 meters (168 to 1,000 feet)). The maximum temperature of this system may approach 55 to 65 °C (131 to 149 °F) at depths of 260 to 500 meters (853 to 1640 feet). Warm waters will be found at the shallower depths in the more western portions of this potential use area.

The main aquifers for the Cody-Horse Center hydrothermal system are the Tensleep Sandstone, Madison Limestone, and Bighorn Dolomite. These formations are reported to have good porositites and permeabilities with flows in the Madison Limestone and the Bighorn Dolomite sometimes exceeding 1,000 gallons per minute (Lowry, 1976). However, the water flow of wells drilled into these aquifers may vary greatly between wells due to secondary fracture permeability, secondary silica cementation of the Tensleep Sandstone, and the cavernous nature of the Madison Limestone and Bighorn Dolomite.

TABLE 1. Drilling and other data for the hole UWH-1

Well Name:	UWH-1
Area:	Cody, Wyoming
Location:	SW¼ SW¼ Sec. 2, T. 52 N., R. 102 W.
Elevation:	5120 ft.
Landowner:	Coy Gail; Cody, Wyoming
Commenced Drilling:	January 2, 1980
Completed Drilling:	January 3, 1980
Total Drilling Depth:	327 ft.
Casing Set:	January 4, 1980
Depth of Casing:	321 ft.
Casing Cemented:	January 4, 1980
Sacks of Cement Used:	60 sacks neat cement with 6 gallons water per sack used to cement casing
Lithology:	0 to 2 feet; surface gravels 2 to 327 feet: Triassic Chugwater Formation; red siltstones, red shales, and fine red sandstone
Notes:	Drilling on this hole progressed smoothly. The formation became moist at 40 feet but never flowed any quantity of water into the drill hole.

TABLE 2. Drilling and other data for hole UWH-2

Well Name:	UWH-2
Area:	Cody, Wyoming
Location:	SW¼, NW¼, Sec. 11, T. 52 N., R. 102 W.
Elevation:	5160 feet
Landowner:	Coy Gail
Commenced Drilling:	January 11, 1980
Completed Drilling:	March 19, 1980
Total Drilled Depth:	403 feet
Casing Set:	18 joints (378 ft.)
Depth of Casing:	378 feet
Casing Cemented:	No. (see notes)
Sacks of Cement Used:	45 sacks neat cement, 80 sacks Dowell 12-3 R.F.C. cement (see notes).

Lithology:

0 to 20 feet:	Travertine; white, powdery
20 to 130 feet:	Triassic Chugwater Formation; red siltstones, red shales and fine red sandstone.
140 to 180 feet:	Triassic Dinwoody Formation; tan and gray siltstone and dolomite. Started making over 5 gallons per minute water at 140 feet.
180 to 200 feet:	No sample return.
200 to 403 feet:	Pennsylvannian Tensleep Sandstone; light gray to tan, sometimes siliceous sandstone. At 220 feet small cubes (1/16 inch) of pyrite were present.

Notes:

The hole was making up to 200 gallons per minute of H_2S smelling water starting at 280 feet. The temperature of the water measured at the surface was 18° C.

Starting at this depth of high water flow, zones of loose, well washed sand were encountered. The hole

Table 2 continued

Notes continued:	would not stay open through these zones. Consequently various cement jobs (a total of 4) were tried. These were successful to a depth of 403 feet where it was decided that further cementing would be too costly. The $1\frac{1}{4}$ inch casing was put in the hole but not grouted in place. It was felt that due to the large, warm water flows in the bottom of the hole the grout would have been washed away.

TABLE 3. Drilling and other data for hole UWH-3

Well Name:	UWH-3
Area:	Cody, Wyoming
Location:	SW¼ SW¼ Sec. 11, T. 52 N., R. 102 W.
Elevation:	5180 ft.
Landowner:	Jerry and John Housel
Commenced Drilling:	January 3, 1980
Completed Drilling:	February 5, 1980
Total Drilled Depth:	333 ft.
Casing Set:	February 5, 1980
Depth of Casing:	13 joints (273 ft.)
Casing Cemented:	February 5, 1980
Sacks of Cement Used:	55 sacks, 6 gals. H_2O/sack
Lithology:	0 to 95 feet: Permian Park City Formation; gray to tan siliceous limestone. At 50 feet there was a strong sulfur odor. 100 to 333 feet: Lost circulation
Notes:	At 180 feet the rock becomes very hard. A hammer is used from this depth on to complete the hole. The 1¼ inch casing was set to 273 feet because of a zone at 275 feet that kept closing off.

TABLE 4. Drilling and other data for hole UWH-4

Well Name:	UWH-4	
Area:	Cody, Wyoming	
Location:	NW¼, NW¼, Sec. 14, T. 52 N., R. 102 W.	
Elevation:	5160 feet	
Landowner:	Dale and Roberta Pike	
Commenced Drilling:	March 7, 1980	
Completed Drilling:	March 18, 1980	
Total Drilled Depth:	333 ft.	
Casing Set:	March 18, 1980	
Depth of Casing:	314 ft.	
Casing Cemented:	No. (see notes)	
Sacks of Cement Used:	50 sacks Dowell 12-3 RFC cement (see notes)	
Lithology:	0 to 90 feet:	Permian Park City Formation; grey to tan siliceous limestone.
	90 to 106 feet:	Poor sample recovery
	106 to 218 feet:	Pennsylvanian Tensleep Sandstone (?); light gray to tan siliceous sandstone with sometimes as much as 20% white silica chips. Small (1/16 inch) quartz spar present at 126 feet
	218 to 333 feet:	Lost circulation.
Notes:	At 218 feet a well washed sand was encountered before circulation was lost. A cement job was done by Dowell at 333 feet but was unsuccessful. Consequently, the 1¼ inch casing was not cemented in place due to the large water flow and/or cavern that was present.	

TABLE 5. Drilling and other data for hole UWH-5

Well Name:	UWH-5
Area:	Cody, Wyoming
Location:	NW¼, SW¼, Sec. 14, T. 52 N., R. 102 W.
Elevation:	5210 feet
Landowner:	Glenn Nielson
Commenced Drilling:	February 27, 1980
Completed Drilling:	February 28, 1980
Total Drilled Depth:	360 ft.
Casing Set:	(17 joints) 357 ft.
Depth of Casing:	354 ft.
Casing Cemented:	February 28, 1980
Sacks of Cement Used:	35 sacks neat cement, 7 gals. H_2O/sack
Lithology:	0 to 360 feet: Jurassic Sundance Formation; green to gray shale, thin brownish limestone and sandstone layers. From 235 feet to 329 feet a red shaley zone was encountered.
Notes:	Drilling on this hole progressed smoothly. The formation became moist at about 100 feet but never flowed water into the drillhole.

TABLE 6. Drilling and other data for hole UWH-6

Well Name:	UWH-6	
Area:	Cody, Wyoming	
Location:	NE¼, NW¼, Sec. 15, T. 52 N., R. 102 W.	
Elevation:	5280 feet	
Landowner:	Carrol Koster	
Commenced Drilling:	February 6, 1980	
Completed Drilling:	February 26, 1980	
Total Drilled Depth:	311 feet	
Casing Set:	9 joints (189') (see notes)	
Depth of Casing:	185 feet	
Casing Cemented:	February 26, 1980	
Sacks of Cement Used:	30 sacks neat cement with 6 gallons H_2O/sack	
Lithology:	0 to 10 feet:	Rounded stream gravel, ½ to 2 inches in diameter.
	11 to 19 feet:	Light tan mud out of hole.
	20 to 269 feet:	Pennsylvanian Tensleep Sandstone; hard silicified sandstone chips dark gray to tan colored. Sporadic, small (less tan 1/8 inch) sulfur veinlets in upper 90 feet.
	270 to 310 feet:	Lost circulation.
	311 feet:	Became stuck in hole.
Notes:	Stuck in hole from Feb. 7 until Feb. 25. During that time the bit was pulled free from 289 ft. up to 186 ft. by injecting 10 gallons diesel fuel in the compressed air. At 186 ft. the bit became plugged. Five gallons 33% HCl acid was put in the drill pipe. Circulation returned 4 hours later when the drill pipe broke free at the downhole hammer. The last 8 joints (164 feet) of drill pipe to come out of hole were covered with a black tarry substance. The substance was extremely black and had a musky to burnt odor.	

Table 6 continued.

Notes continued:

The hammer was stuck in the hole at 186 feet. Consequently the 1¼ black iron pipe was set to that depth and cemented in place with 30 sacks neat cement.

A thermal log of the well was attempted only to find an obstruction in the 1¼ inch casing at a depth of 21 feet. Consequently the only downhole temperature-depth data was that taken during breaks in drilling.

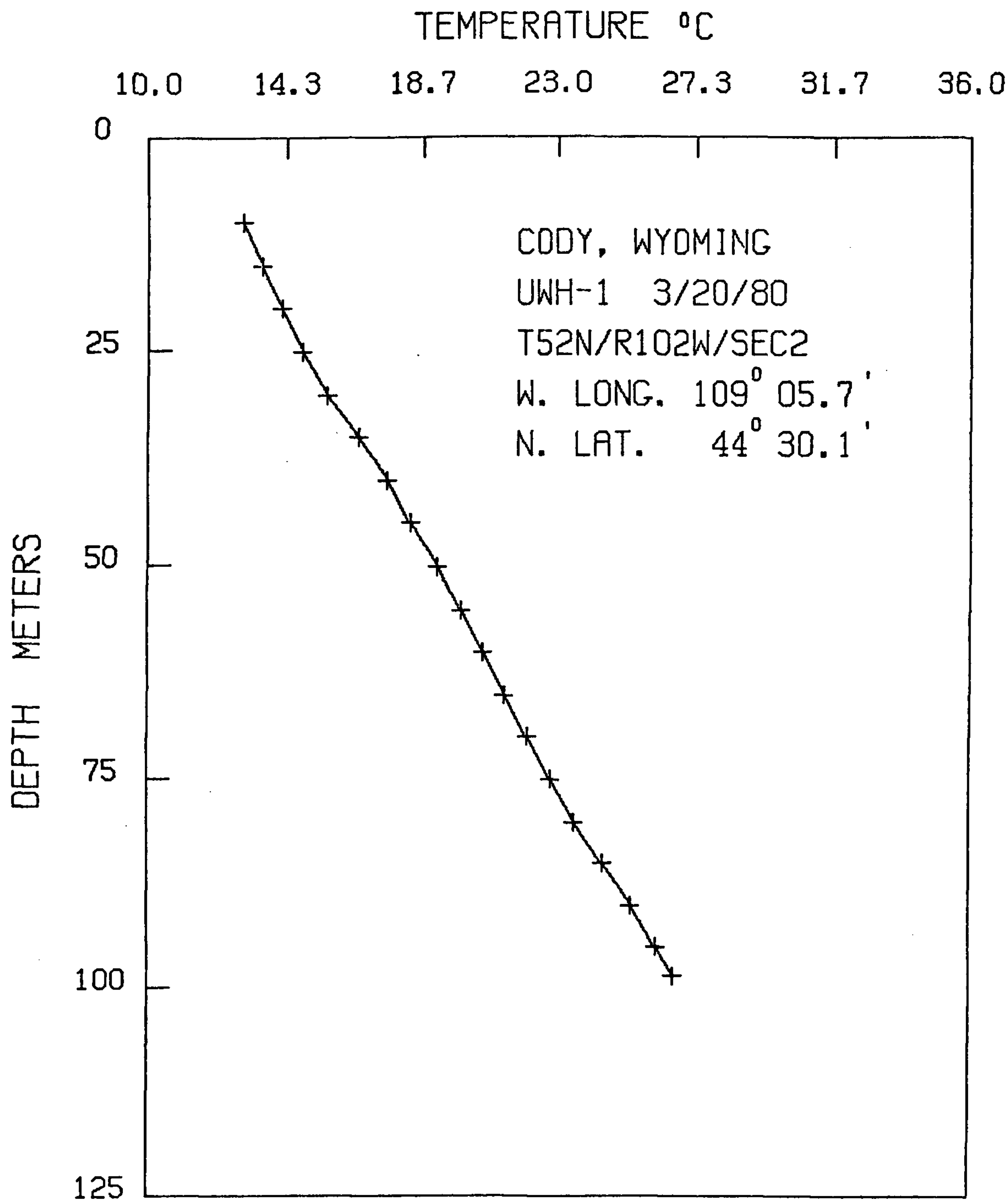

Figure 5. Temperatures as functions of depth in hole UWH-1 (3/20/80).

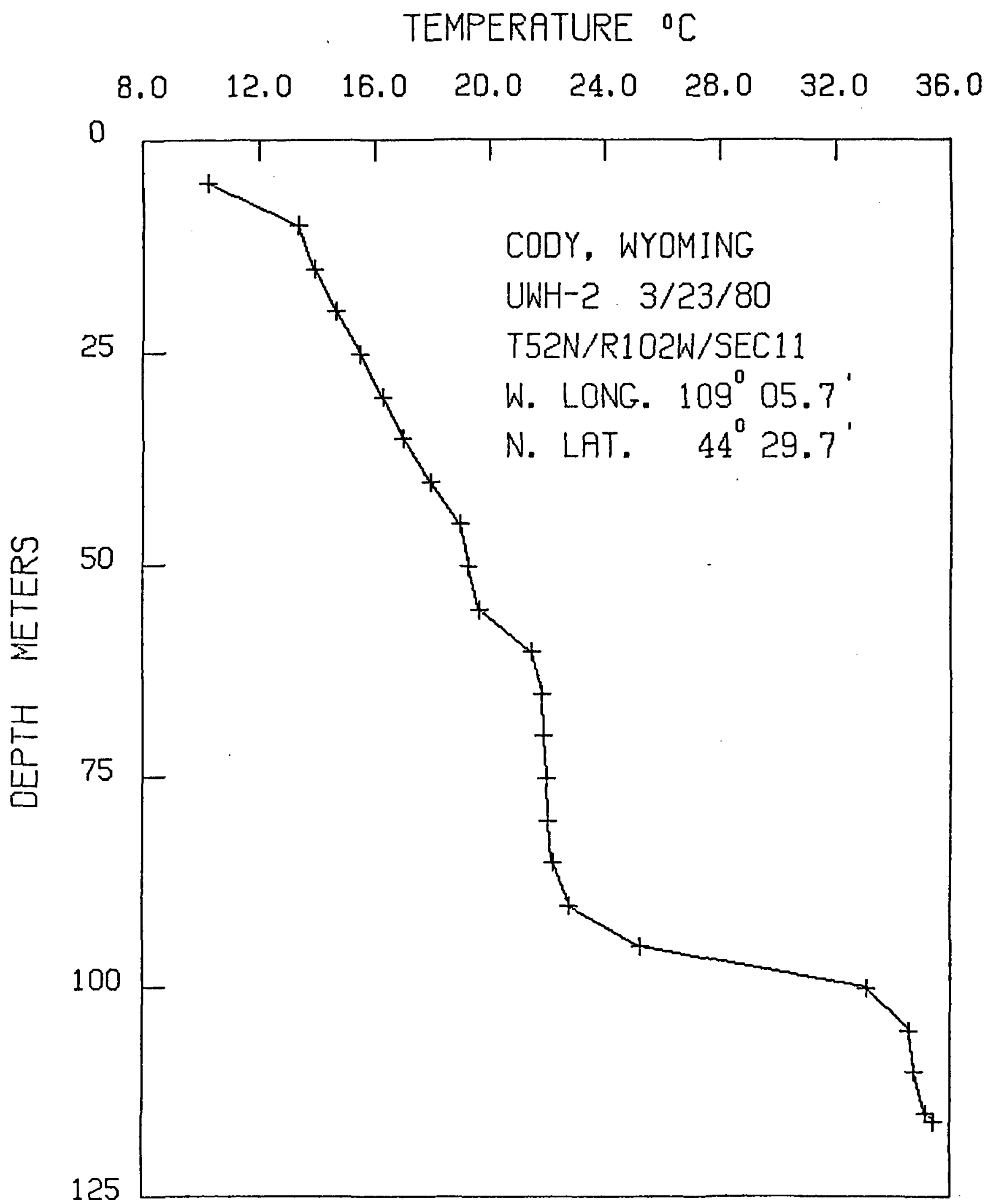

Figure 6. Temperatures as functions of depth in hole UWH-2 (3/23/80).

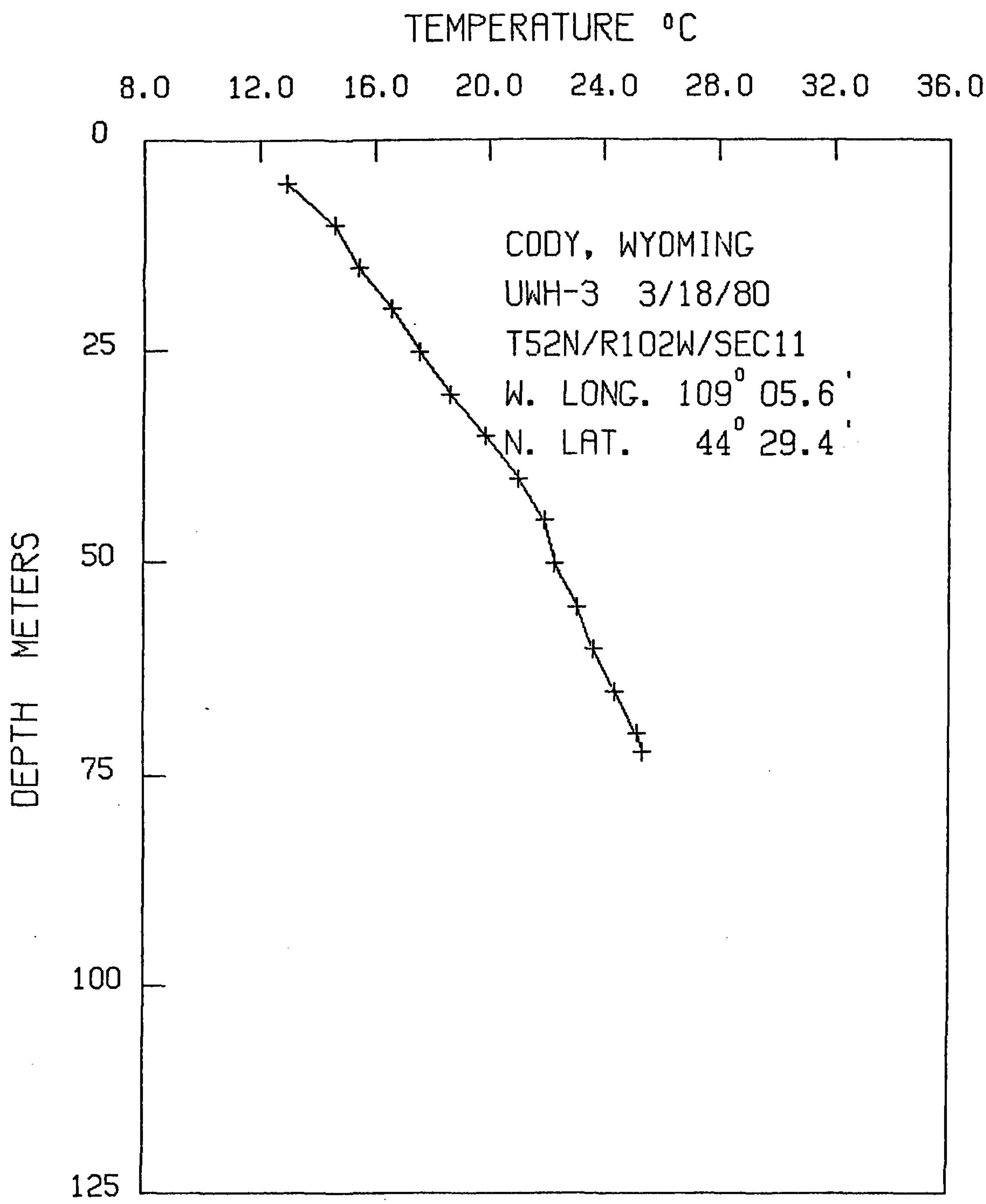

Figure 7. Temperatures as functions of depth in hole UWH-3 (3/18/80).

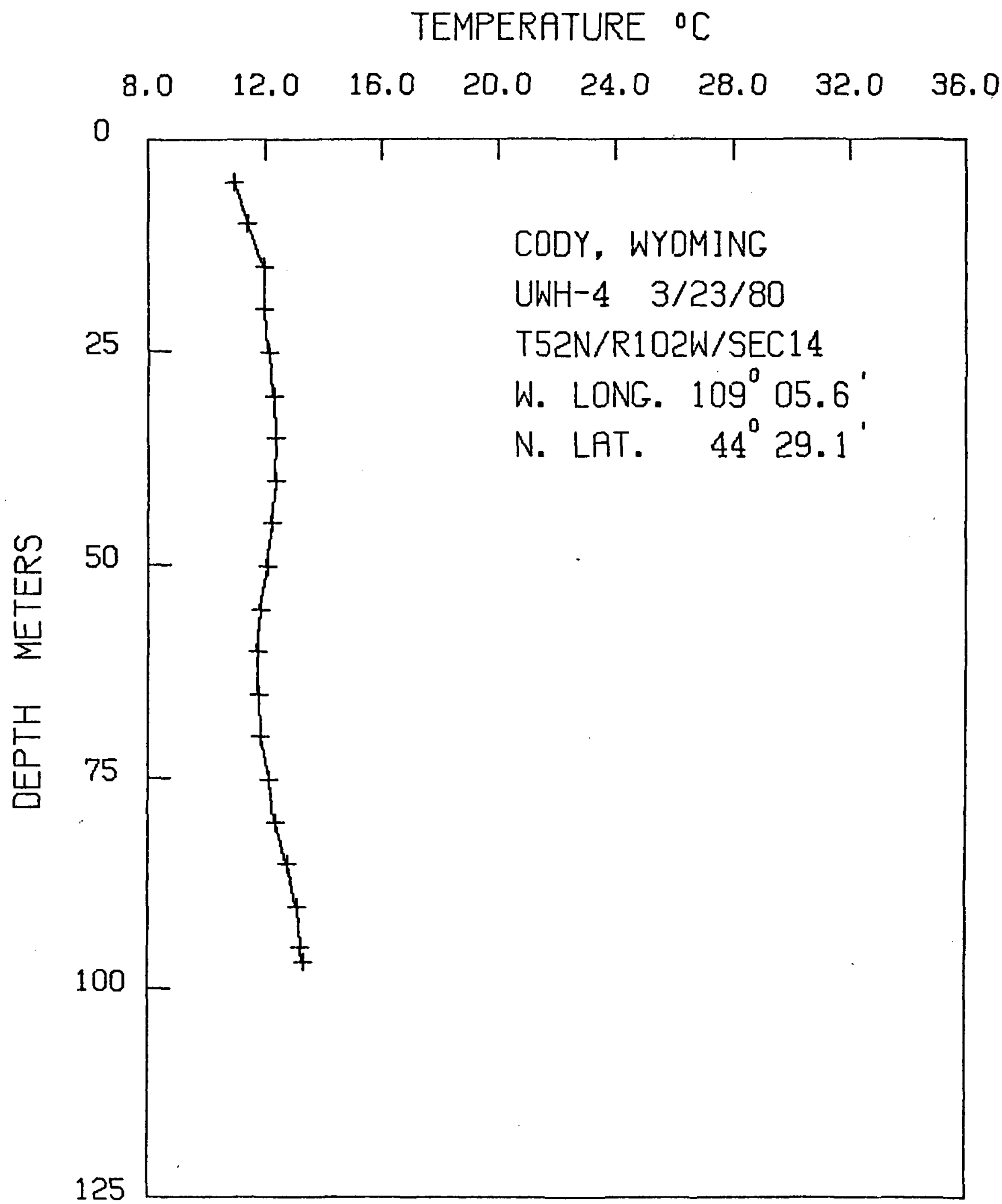

Figure 8. Temperatures as functions of depth in hole UWH-4 (3/23/80).

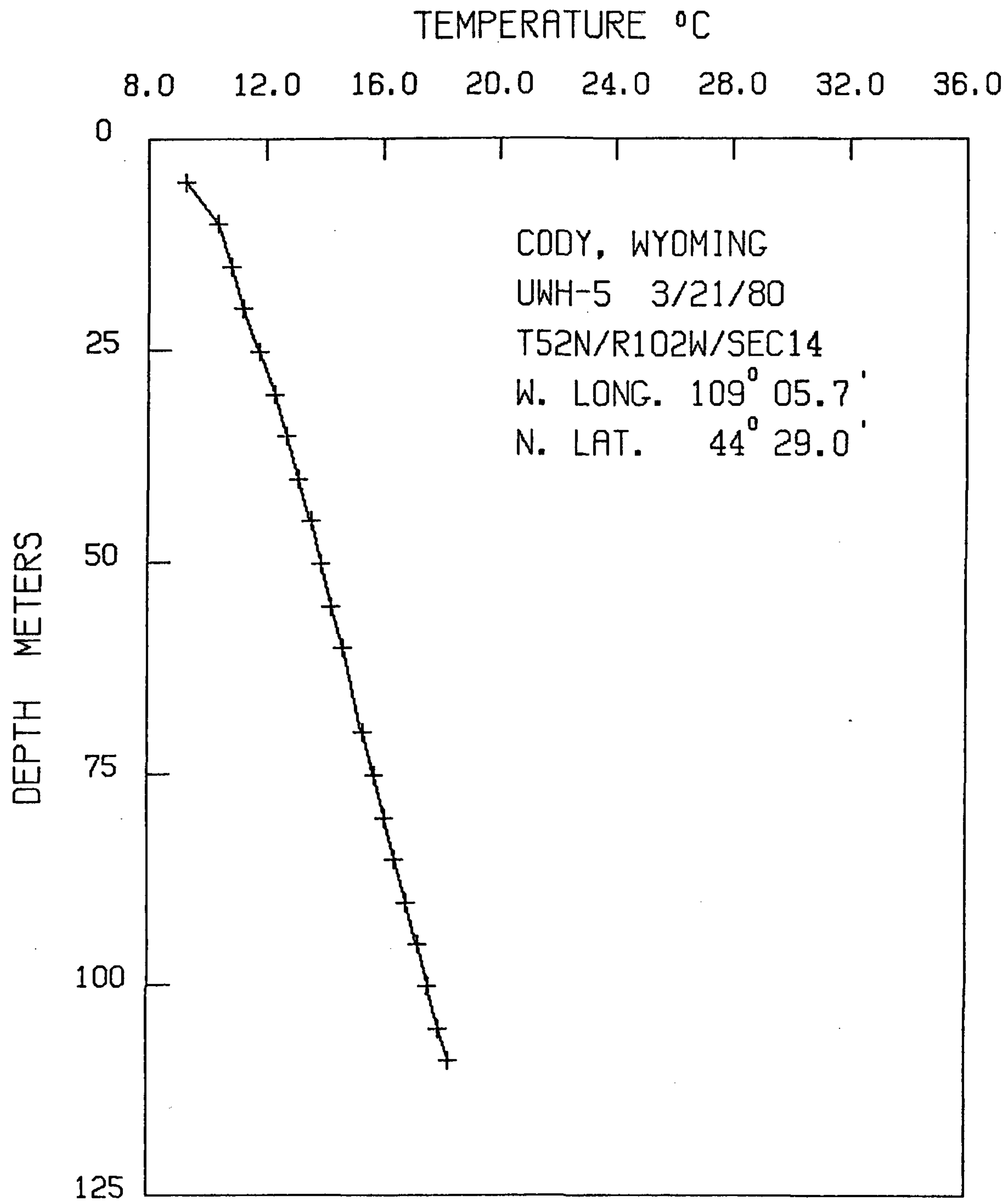

Figure 9. Temperatures as functions of depth in hole UWH-5 (3/21/80).

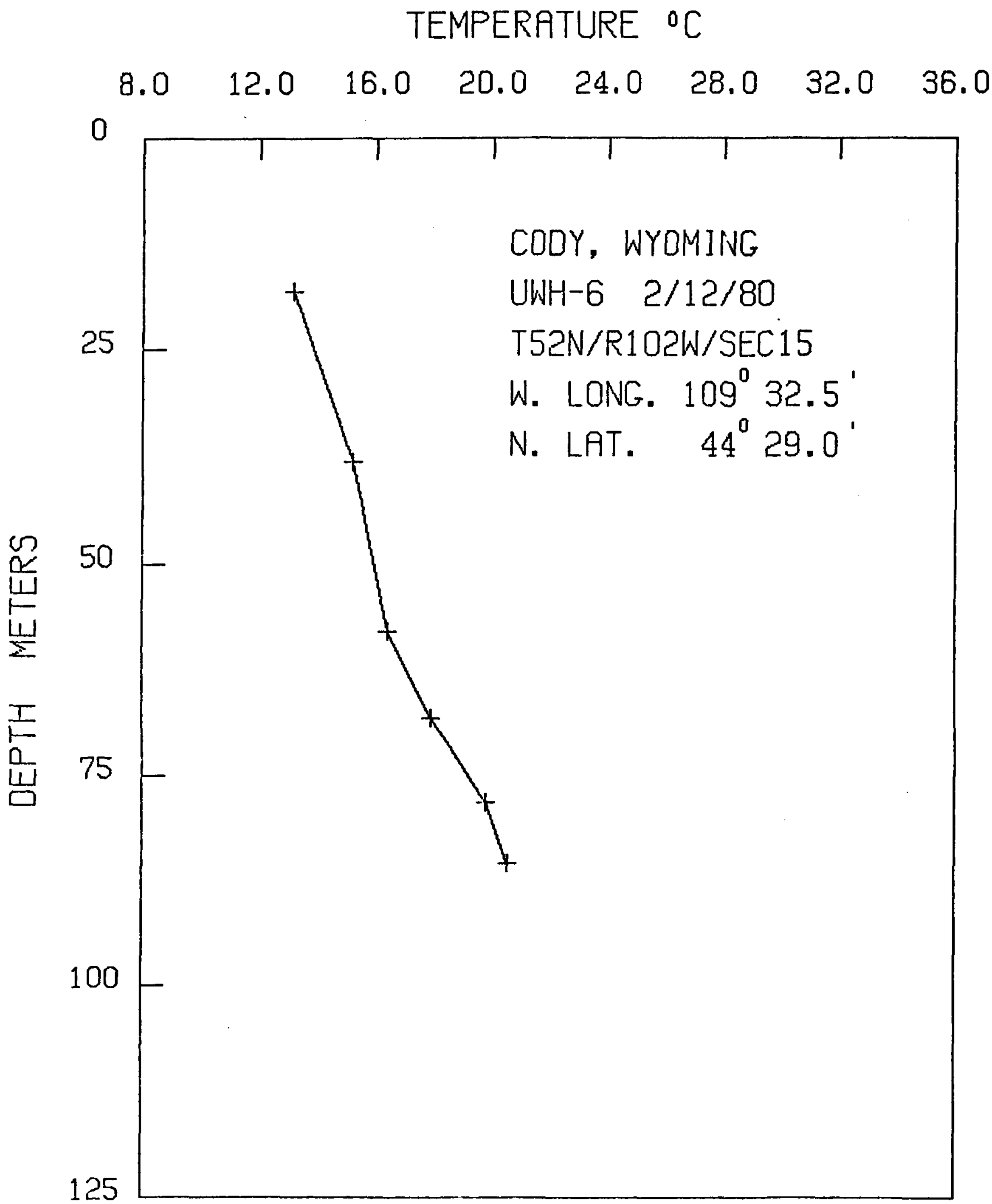

Figure 10. Temperatures as functions of depth in hole UWH-6 (2/12/80).

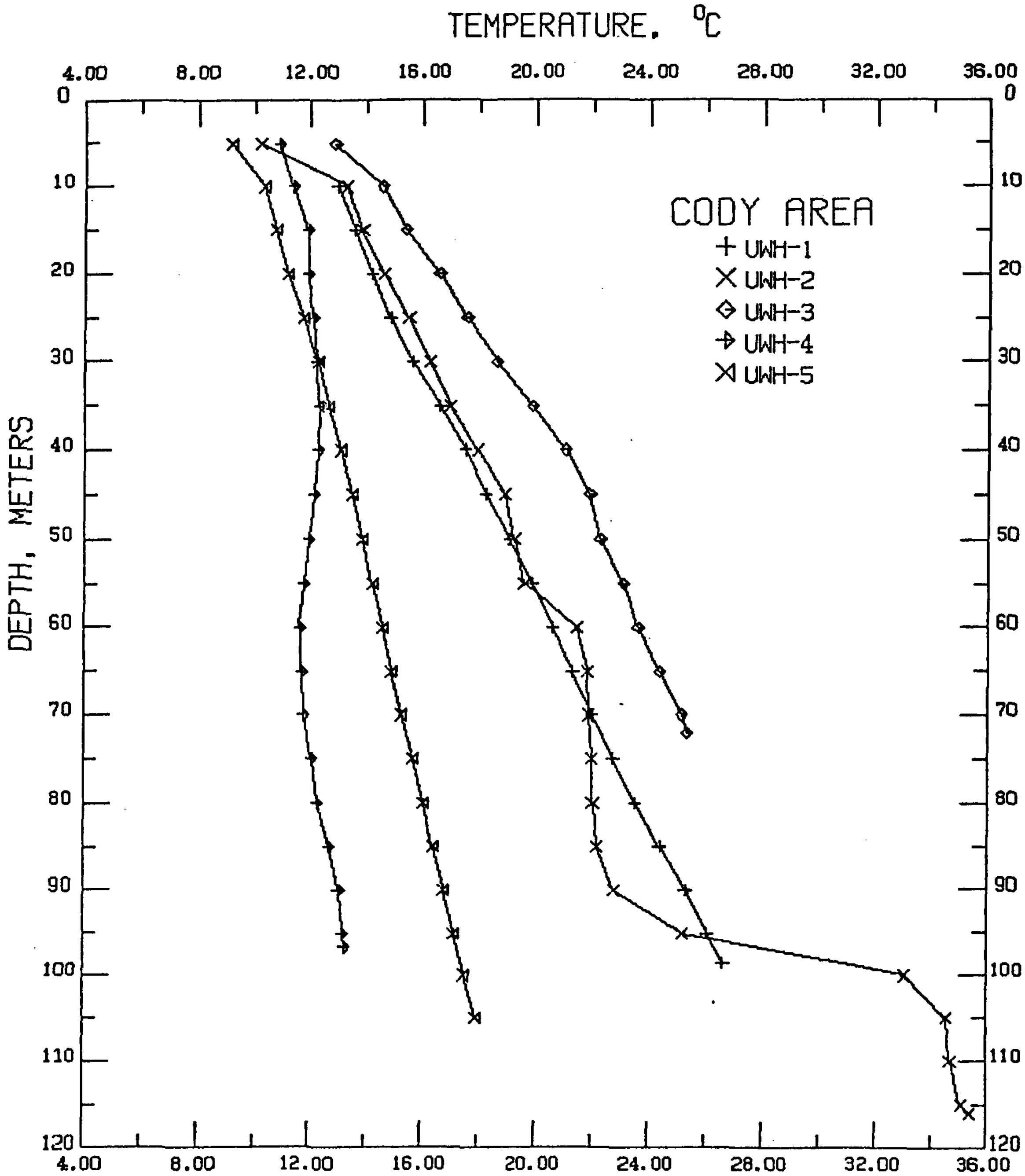

Figure 11. Temperatures as functions of depth in UWH drill holes.

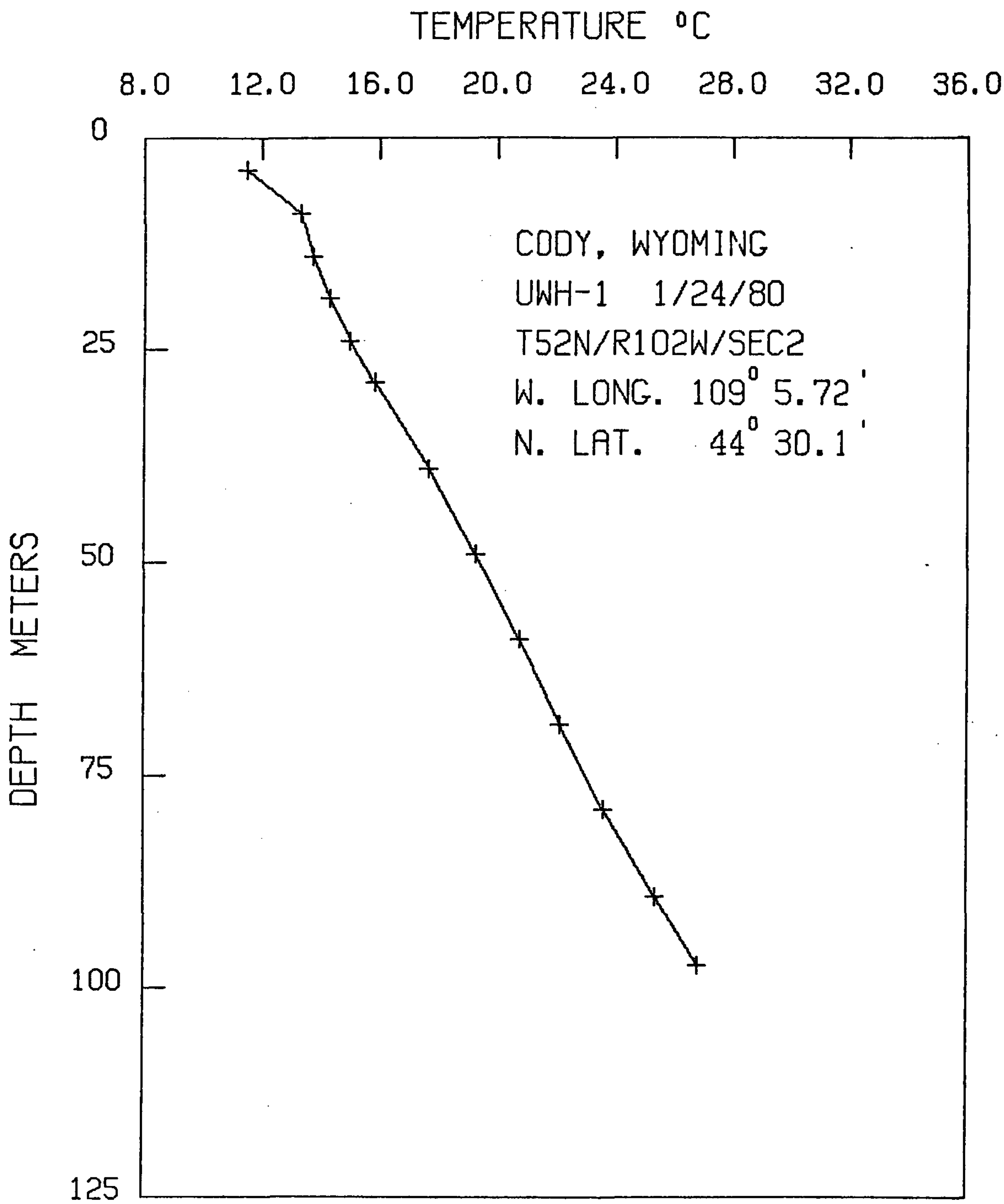

Figure 12. Temperatures as functions of depth in hole UWH-1 (1/24/80).

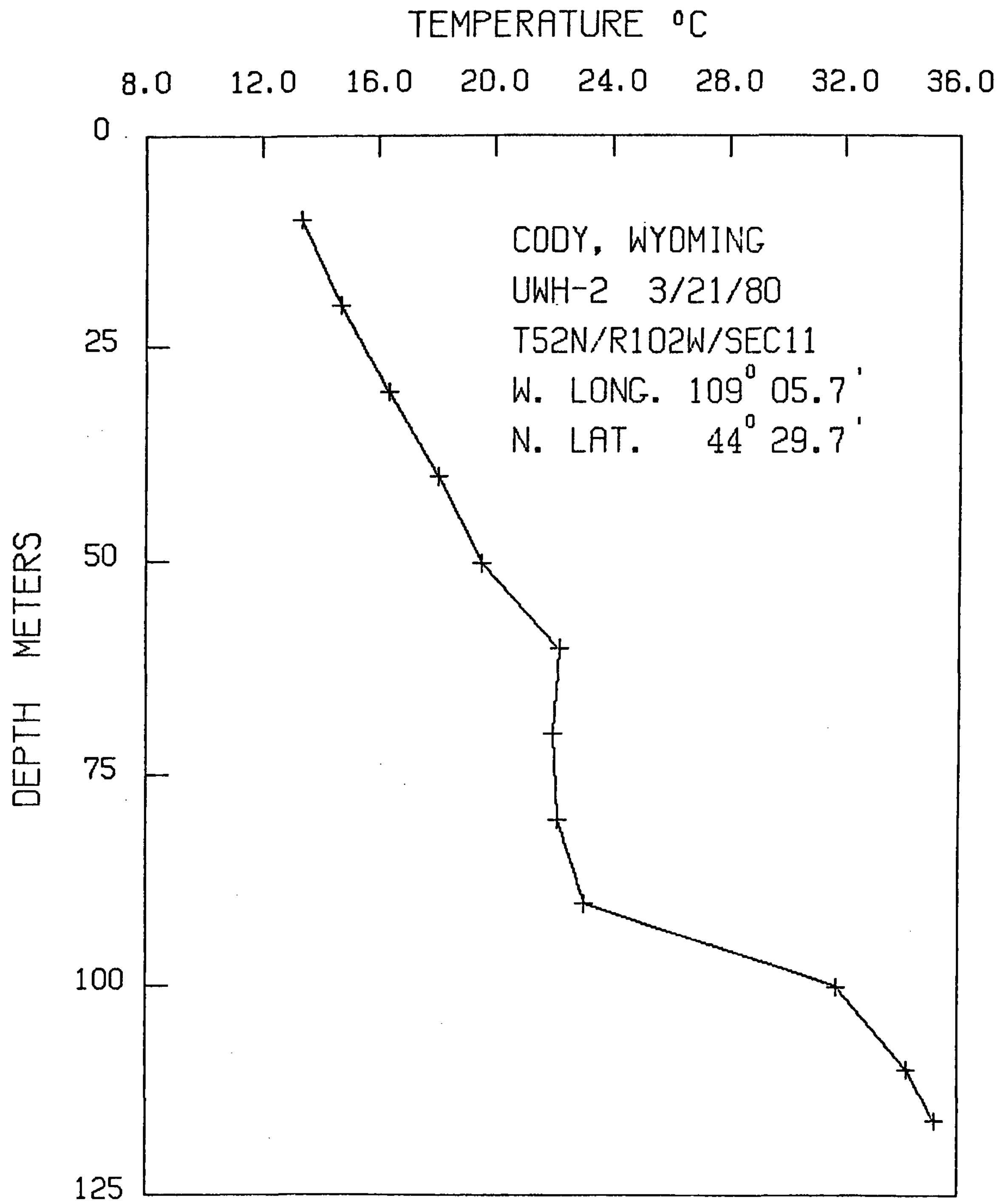

Figure 13. Temperatures as functions of depth in hole UWH-2 (3/21/80).

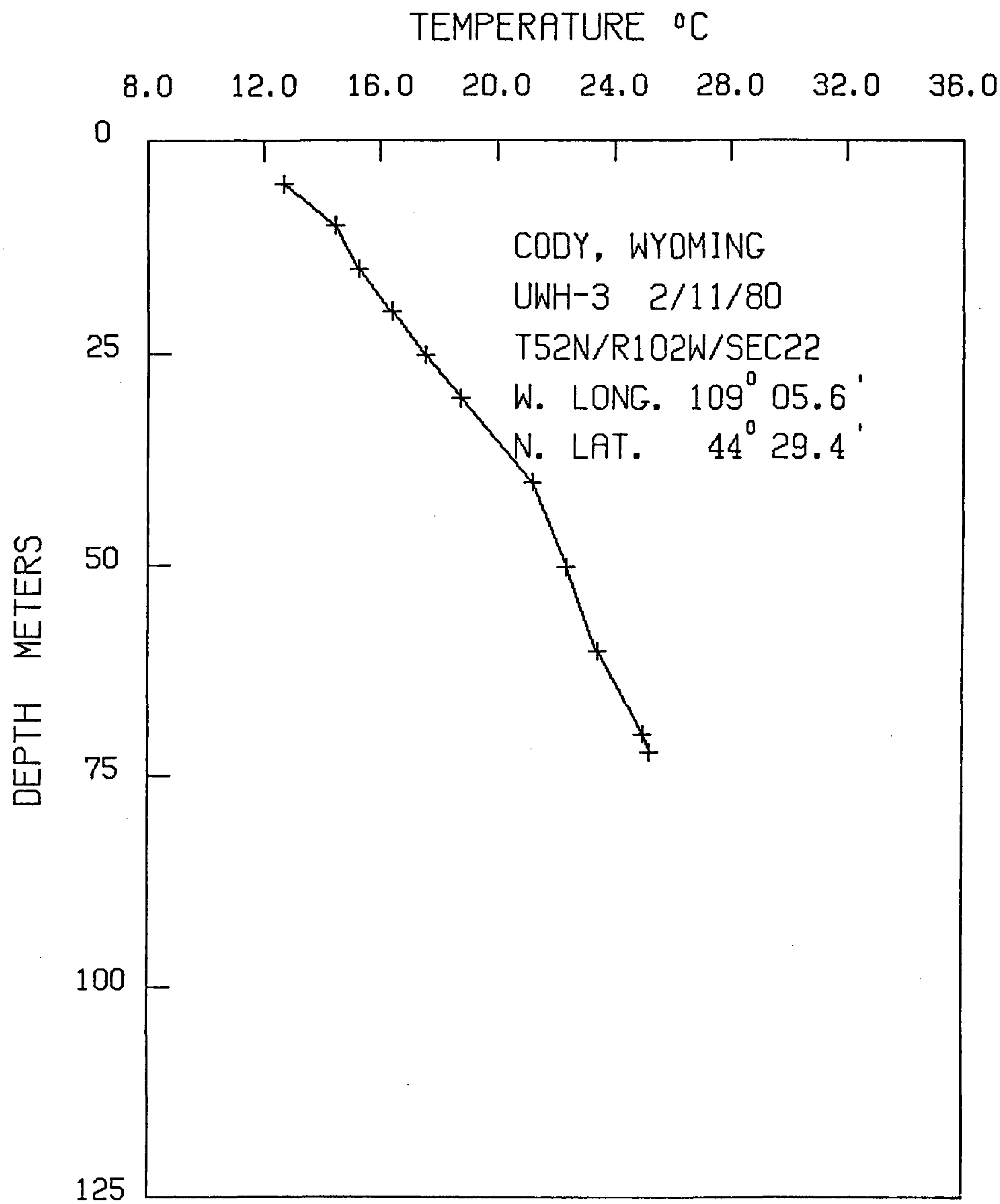

Figure 14. Temperatures as functions of depth in hole UWH-3 (2/11/80).

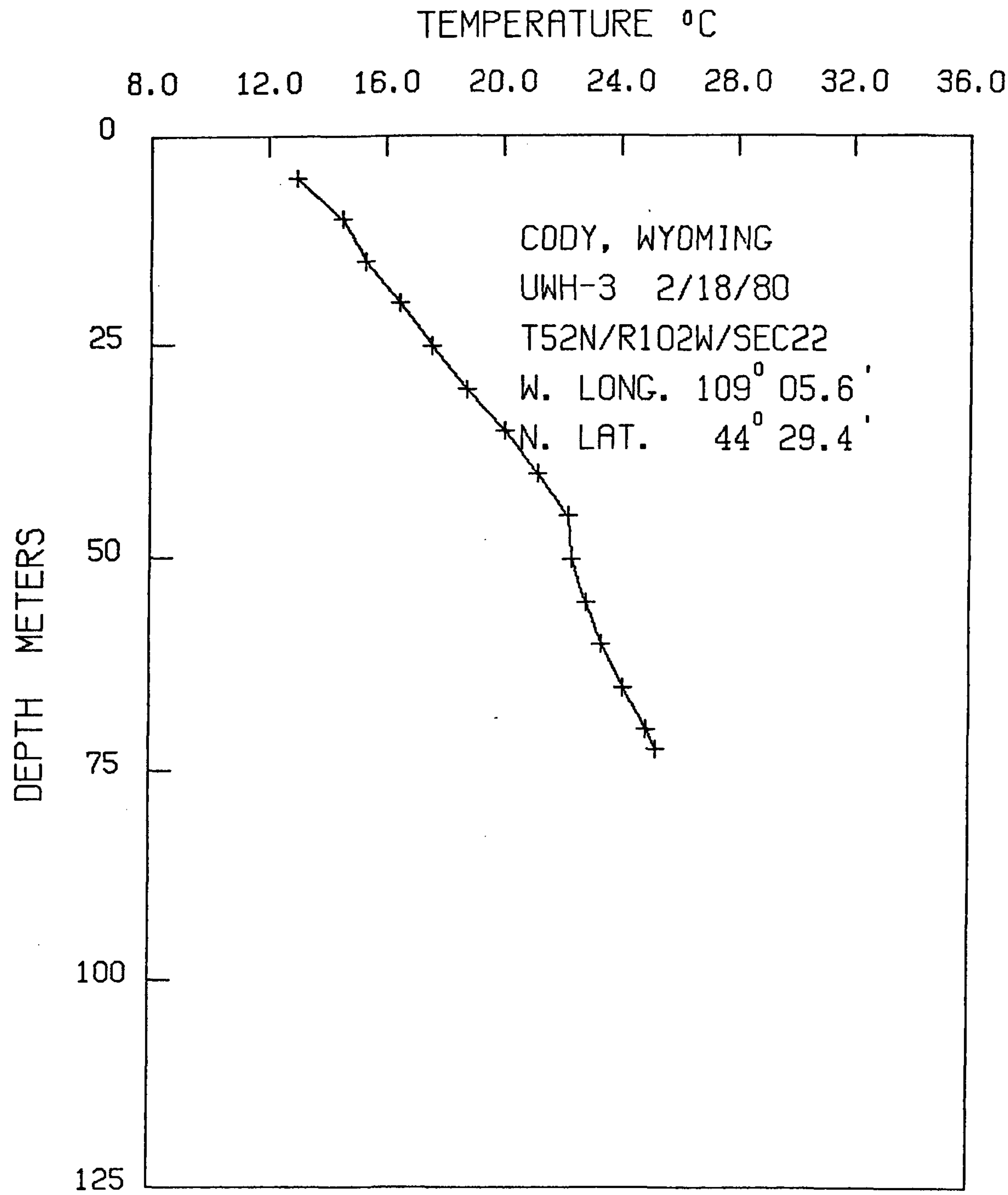

Figure 15. Temperatures as functions of depth in hole UWH-3 (2/18/80).

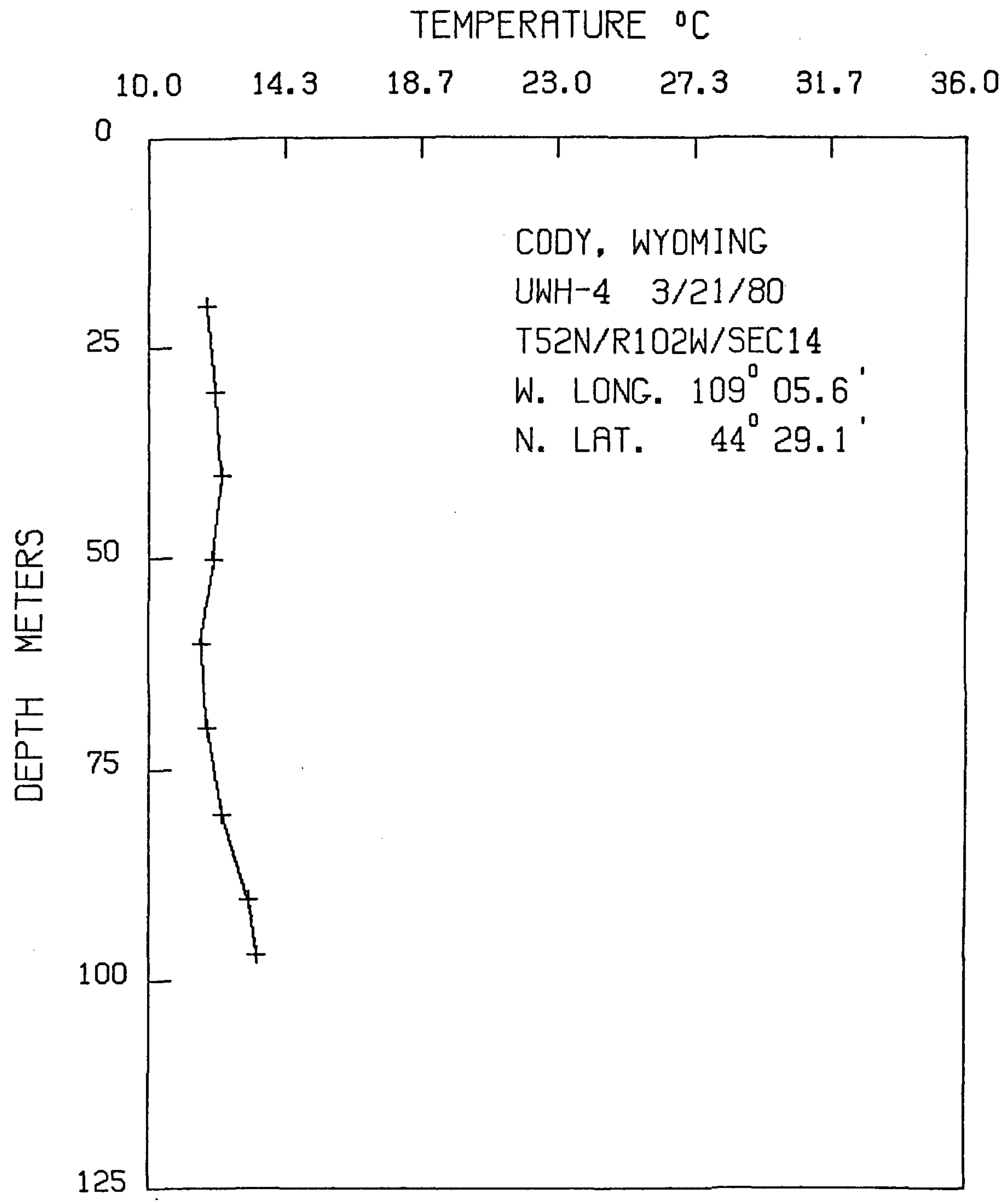

Figure 16. Temperatures as functions of depth in hole UWH-4 (3/21/80).

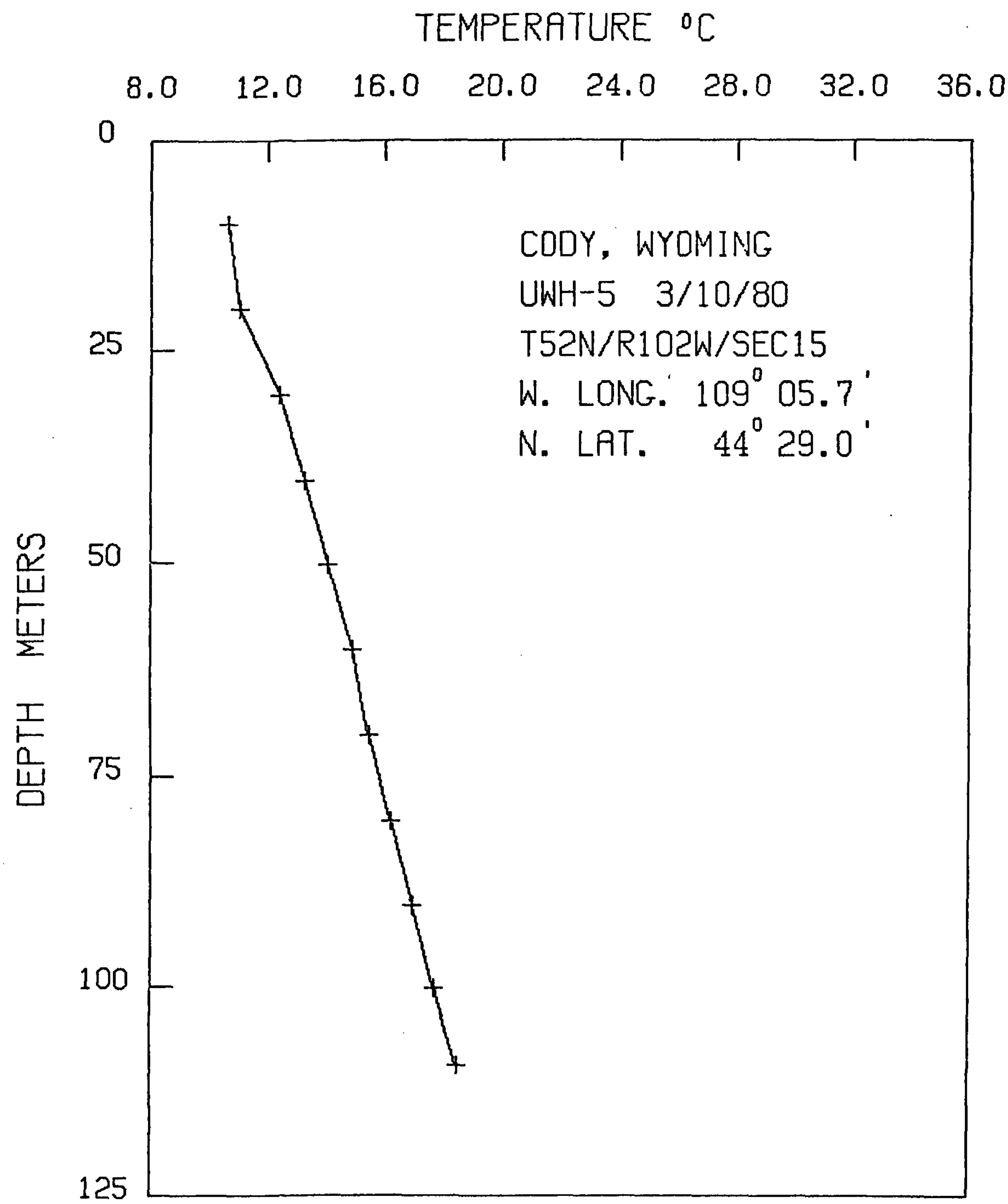

Figure 17. Temperatures as functions of depth in hole UWH-5 (3/10/80).

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A PROPOSAL TO THE UNITED STATES DEPARTMENT

OF ENERGY, IDAHO FALLS,

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GEOTHERMAL ENERGY
BRANCH

for

"HYDROTHERMAL RESOURCE STUDIES IN WYOMING, JUNE 1, 1980-

MAY 31, 1981"

Amount Requested: $154,500

Investigators:

Edward R. Decker — Date
Professor of Geology
056-32-1937

Henry P. Heasler — Date
Research Associate II
520-62-8409

Department Head

R. S. Houston — Date

University Official

Edward H. Jennings — Date
President
University of Wyoming

INTRODUCTION

Our original proposal to the U.S. Department of Energy was submitted in the Fall of 1978, with funding being approved in January of 1979. That program is now in the final stages of completion. It was hoped that hydrothermal resource data would be obtained for at least 600 oil wells, five indicated low-temperature reservoirs, and 12-24 new heat flow sites. Additionally, regional gradient and heat flow maps were to be prepared and interpreted. These objectives have been substantially achieved: >1500 bottom hole temperatures for oil wells have been compiled and analyzed; temperature-depth measurements have been made on >100 drill holes; the Thermopolis, Cody-Horse Center Anticline, and Saratoga spring systems have been studied in detail, as have areas in the neighborhood of Casper, Midwest, and the Gas Hills; new heat flow measurements are being completed for some 30 localities; a site specific drilling program near Cody is in progress; and combined heat flow and geologic maps for the Rocky Mountain region have been prepared. A brief summary of the present state of our work is presented below. The principal question discussed here is our proposal for additional work for the coming year (June 1, 1980-May 31, 1981).

Circumstances to be considered are the following (See Figures 1 and 2 for localities):

1. While our analyses of bottom hole temperatures, subsurface gradients and other geothermal data greatly expand the inventory of hydrothermal resource data for Wyoming, the actual investigated area (∿5000 mi^2) is too small to permit reliable assessment of this 95,000-100,000 square mile region. One important justification for additional work, therefore, is that there is a critical need for data in large, unstudied

areas. We plan to improve knowledge of the resource base in these areas in at least four ways: 1) with measurements of temperature in water wells and other accessible drill holes; 2) from compilations and analyses of bottom hole temperatures in oil wells; 3) with analyses of water composition; and 4) with compilations of regional geology and geophysics.

2. Research to date shows that indicated low temperature resource areas must be examined in detail and on an individual basis, if reliable reservoir models are to be obtained. The Thermopolis, Cody-Horse Center anticline, and Salt Creek Oil Field (Midwest) thermal anomalies (Fig. 1), for example, can be explained by hydrologic circulation in the vicinity of anticlinal structures. In contrast, the hot springs and/or high gradients in the neighborhoods of the Saratoga Valley and the Gas Hills (Figs. 1 and 2) appear to be fault controlled and perhaps related to narrow subsurface reservoirs. The controls are not understood in other areas (Auburn, Alcova, Lander, DuBois, etc.), but studies are in progress. This research is expected to extend into the new year of research. Related studies will focus on water quality, regional porosities and permeabilities, and quantification of indicated resources.

3. Although the present distribution of heat flow is incomplete and irregular, it does suggest interesting possibilities as well as directions for further study. Briefly, more heat flow values are needed for the Powder River Basin, the Owl Creek Mountains-Bridger Mountains area, the Absaroka Mountains and the Southern Rockies in extreme southeastern Wyoming (Fig. 2) because there is new evidence for

(>1.8 HFU ($\pm$ HFU = $1 \times 10^{-6} cal/cm^2 sec = 41.8\ m\ W/m^2$)) and thus buried geothermal reservoirs in parts of these regions. The new low to intermediate heat flow values (.9-1.7 HFU) in parts of the Green River, Great Divide and Laramie Basins and the Medicine Bow-Sierra Madre Mountains area (Fig. 2) imply that they are not "viable" geothermal areas. However, like most of Wyoming, the sites are too few and too widely scattered to permit accurate generalizations for these large provinces. The final resolution of these questions may require comprehensive drilling specifically for heat flow measurements, but considerable amounts of new data can be obtained using holes that were drilled for other reasons. Possible research sites are listed in Table 1; others are likely to become available during the coming year.

4. The relatively large increase in drill hole measurements (108 vs. 20-30) has come mainly through intensive cultivation of working relations with mining and other exploration companies. Additionally, the U.S. Geological Survey, the Wyoming Geological Survey, and State of Wyoming personnel have given their complete cooperation. As a result, we have access to locations for numerous water wells in the region. The general public appears to be similarly enthusiastic; for example, it is not unusual for us to receive letters from people describing previously unknown thermal springs or wells. This cooperation and interest has therefore led to an almost continual stream of information on drill holes, etc., and the number is likely to increase in the next year as exploration for water, uranium and other resources continues its upward spiral. There is little doubt, therefore, that much temperature, water quality and other pertinent data can be obtained if the program is handled by qualified personnel. Because necessary equipment and facilities are

already at the University, continued research and exploitation of facilities, equipment and cooperation depends mainly on funds for salaries, field expenses, supplies and equipment repair and replacement and in some cases contract casing, as discussed below.

5. The program now terminating has created a sizeable group of Wyoming personnel with expertise in various aspects of hydrothermal resource evaluation. Interest is likely to remain high: a M.Sc. thesis on heat flow in southern Wyoming and northern Colorado will be completed by June of 1980 (by K. L. Buelow); an experienced M.Sc. candidate in geophysics (Mr. Eric Medlin) from the University of Florida will join our research team in May of 1980; and a "qualified" Ph.D. candidate (Mr. Doug Hanson) wishes to begin geothermal energy research by June of 1980. Considered together, the principal investigators and these students would be a solid group that could accomplish a large amount of resource identification, if new funds are provided.

In view of the above considerations, another year of research on hydrothermal resources in Wyoming is proposed. Primary emphasis would be placed on an assessment of the low and/or moderate temperature resources with direct-heat applications, by compiling and studying temperatures, heat flow, water qualities and other pertinent geothermal, geologic and geophysical data for large areas of the state. However, moderate or high temperature resources also could be defined because there is evidence for high heat flow zones in the regions that would be studied.

PROCEDURES: ACQUISITION AND AVAILABILITY OF DATA

Research would be conducted by five full-time personnel. We propose to divide the state into four quadrants and require that one full-time researcher manage the resource assessment of an entire quadrant. The principal investigators will oversee all aspects of data acquisition and interpretations to insure that the same quality control and procedures are used during research in each quadrant.

Research in the Summer and Fall of 1980 would focus on area by area measurement of temperatures in water wells, exploration holes, or any accessible and reliable underground opening. Concomitant field work would involve the collection of samples of water from flowing or pumpable wells; these samples would be sent to the University of Utah Research Institute (UURI) for chemical analyses. The program in the Winter and Spring of 1980-81 would focus on analyses of data collected in the previous field season, and compile pertinent geologic and geophysical data for each area. Other work in 1980-81 would involve preparation of maps and final reports.

Interpretations and resource assessments would focus on areas in which subsurface temperatures are in the range 30°-60°C at depths near 1.0-1.5 km. However, we would also compile gradients, depths, etc., for holes in which T $<30^{\circ}$C because these data can yield estimates of the depths to potentially usable low temperature reservoirs. Special attention would be given to areas characterized by high geothermal gradients. Evidence for high gradients and flux in the Gas Hills and Powder River Basin areas was mentioned above; new drilling in both areas should provide a valuable opportunity for more subsurface temperature studies and thus better definition of any resources. Other topics will be investigated; for example, the thermal waters in the Madison Formation in the Big Horn Basin area and the Gas Hills. We cannot be more specific without closer examinations of available data. At present we have access to all of the well logs at the Wyoming Geological Survey and at State offices in Casper. Data for new wells would be examined as records are released and stored in the nearby offices of the Geological Survey of Wyoming.

Water quality data, depths to water, aquifer productivities, regional hydrology and pertinent geology would be compiled for all investigated areas. Water quality must be studied because the environment can be contaminated if certain elements (e.g. Hg, As, S) in some geothermal fluids are not disposed of properly, and because low-temperature heat exchanger systems must be designed according to local water compositions (Wright, 1978). It is equally important to compile specific data or "educated" generalizations on regional aquifer production, hydrology, geologic structure, and proximity of potential resources to communities. It is sufficient to state that a resource is not likely to be developed, if the yield of water is too small, or the market is distant, regardless of the temperature at reasonably shallow depths. Geologic and hydrologic data would be obtained from the literature and records of the U.S. Geological Survey in Cheyenne, Wyoming. Water quality data would be abstracted from the literature, and six previously promised water analyses, and from water analyses provided by UURI.

Regional heat flow and radioactivity studies would be continued throughout the region. We plan to use shallow holes and a limited number of "shut in" oil wells. Thermal conductivities of regional units will be used to determine heat flow in established oil fields, hard rock areas and other regions. Basic heat flow and radioactivity (U, Th, K) data would be collected using well established techniques. To insure acquisition of reliable data in critical areas, selected holes would be cased so that they would remain open for temperature measurements.

DELIVERABLES

All data would be used to update file GEOTHERM of the USGS. Maps for the public and geoscientists would be prepared according to requirements of the Department of Energy, NOA, the USGS, and UURI. All written reports would attempt to quantify reservoirs with direct-heat or other applications.

Short status reports and preliminary results would be submitted to the U. S. DOE on a monthly basis. We expect to furnish the following "hard" deliverables by July, 1981.

1. A compilation of locations, temperatures, depths, gradients, and, if possible, depths to water for the STATE ~~four quadrants~~ of Wyoming. Regional maps of subsurface temperatures and depths would be supplied with the data, as would written reports. Available water quality and aquifer production data would be incorporated into the reports, as would relevant stratigraphy and geologic structure. The maps would show pertinent control points and relevant geology.

2. Regional gradient maps and interpretations thereof would be prepared and delivered. These deliverables would reflect local geology and the thermal properties of local rock units. This would be done because the conductive gradient varies sympathetically with corresponding conductivities of the local rocks. Reports would also summarize available shallow and deep water quality data, aquifer disposition, and aquifer production. We expect to deliver detailed reports and maps for areas that could be prospectively valuable for near term direct-heat or other applications. One of these areas is expected to be the Powder River Basin, where the Madison Formation is known to locally contain thermal waters.

3. The now terminating program will provide reports on the Thermopolis area, the Cody-Horse Center anticline, the Gas Hills area, the Saratoga area, and the Casper-Midwest area. The new program would be arranged so that research on the Saratoga, Casper-Midwest, Auburn and DuBois areas is expanded to include data for regions within a 20-30 mile radius of each suggested resource. This detailed research will be done to better define their lateral extents, and to quantify the magnitude of each reservoir. Other systems would be analyzed in a similar manner as data are located. Reports would directly follow available drill hole data, the geologic and hydrologic literature, and the proximity of resources to population centers.

4. Chemical analyses will be delivered for six heretofore unanalyzed springs or spring systems. These were to be furnished by the now terminating project, but bad weather and the urgency of drilling in the Cody area prevented us from doing such. Water samples and analyses would be accompanied by descriptions of collection sites, local geology and other pertinent geoscience data. From cooperative studies with qualified personnel elsewhere (e.g. the USGS), we expect to deliver preliminary interpretations of the chemical analyses. Following procedures of Breckenridge and Hinckley (1978), these analyses would be done in the laboratory of the Wyoming State Chemist. We also plan to try to collect samples of subsurface waters in areas where gradient data are collected and where existing waters, etc., are flowing or can be pumped. As mentioned above, analysis of these samples will be done by UURI. We believe that 70-75 samples will be sent to UURI for analysis.

5. An updated (1981) regional heat flow map would be delivered, as would detailed maps of gradients and heat flow in prospectively valuable areas. All maps would be interpreted. Both heat flow and available radioactivity data would be used in interpretations. We expect to acquire heat flow data for at least twenty new stations.

One of the tasks of our 1979 program was to contact case about 12,000 feet of drill holes for heat flow studies. This was not possible in many of the suggested areas because of the early onset of winter. It is also true that casing was not needed in many areas because we were able to obtain some 30-35 heat flows, rather than the promised 20. We therefore request permission to carry over $10,000 of 1979 funds so that they can be used to contract case about 5,000 of drill holes (∿5) in 1980-81.

PERSONNEL

Dr. Edward R. Decker, Professor of Geology, would be ultimately responsible for every phase of the research. During the academic year, he would devote 50 percent of his time to research and 50 percent to teaching. The summer of 1980 would be entirely devoted to the proposed research.

Mr. Henry P. Heasler would be co-investigator of the project. He would be in immediate charge of most of the library and field research. He would work intimately with Decker on all aspects of the project. Heasler holds an M.Sc. degree in geothermal studies, and is a co-investigator of the 1979 program.

A new research associate would be employed by June 1, 1980. We expect the associate to be K. L. Buelow, an M.Sc. candidate in geophysics (heat flow), at Wyoming. Buelow is very familar with all aspects of the University's procedures for field and laboratory studies of heat flow.

Other personnel would consist of a half-time secretary, three summer field assistants, and two research assistants for the academic year (September, 1980-May 15, 1981). One part-time assistant would also be employed during the academic year.

FACILITIES

Wyoming's heat flow equipment includes portable and truck-mounted temperature cables (1- 2 km lengths), two pick-up trucks, three divided-bar systems for thermal conductivity measurements, a conductivity sample saturation facility, a temperature calibration facility ($-30^{\circ}C$ to $235^{\circ}C$, $\pm .001^{\circ}C$ control), and a gamma ray system (two 5" x 4" NaI(Tl) crystals) for measurements of uranium, thorium and potassium. The temperature calibration facility is traceable to the U.S. National Bureau of Standards. The gamma-ray system and standards are modeled after those used by C. M. Bunker of the U.S. Geological Survey, Denver Federal Center, Denver, Colorado.

The University has XDS Sigma 7 and CDC Cyber computers with multiple stream batch and time-sharing capabilities. Calcomp and Versatec plotters are connected to the computers. The Department of Geology has three time sharing terminals that are connected to the computers. proposed investigators are experienced computer programmers; so digital data and preliminary maps and figures could be readily prepared at the University. We request funding for computer time or other services because the University recently initiated a charge for computing, etc.

The College of Arts and Sciences in the University has well-staffed electronic and machine shops. Both shops have much experience with construction and maintenance of geothermal equipment. The machine shop also expertly prepares conductivity samples. The Geology Department employs an electronics technician.

The Wyoming Geological Survey occupies offices, etc., in a facility that is connected to the building occupied by the Department of Geology. The U.S. Geological Survey maintains offices in the building of the Wyoming Geological Survey. We enjoy good support and relations with these offices and personnel, and with U.S.G.S. and state personnel in Cheyenne.

PRESENT RESULTS

Our first year of research involved detailed studies of indicated low-temperature resource areas, compilations of regional geothermal data, and syntheses of pertinent geology and geophysics. Compilations of geothermal data directly followed >1500 bottom hole temperatures in oil wells, and measurements of temperatures in more than 100 drill holes. The regional geology and geophysics were synthesized from published articles. Present results are summarized below.

The Thermopolis Area. Temperatures, gradients and regional geology have been compiled for a 1800-1900 mi^2 area that is roughly centered on the Thermopolis hot springs (Figure 1). The results demonstrate that the thermal anomaly occurs all along the central part of the Thermopolis anticline, occupying a 20 mi long by 3 mi wide area that strikes west-northwest between the southwestern part of T. 43 N., R. 93 W. and the southeastern part of T. 44 N., R. 96 W. (Fig. 3). Within this zone, calculated gradients range from 43 to 300°F/1000 ft (78-547°C/km) and tabulated bottom hole temperatures are in the range 90°F(32°C)-160°F(70°C) at depths less than 2000 feet ($\sim$.6 km). Because downward continuation of the lower gradients predicts 60^{+o}C temperatures at depth between 3500 and 4000 feet (1.1-1.2 km), all of the middle part of the structure is considered a viable low temperature resource area.

The Red Springs Anticline area in T. 43 N., R. 93 W. may be a "marginal" resource area. Here the calculated gradients are in the range 24-59°F/1000 ft (43-107°C/km) (Fig. 3). Consequently 60⁺°C waters might be encountered at 3900-4500 ft depths (1.2-1.3 km) here.

The narrow boundaries of the Thermopolis-Red Springs anticlines anomaly suggest that "thermal waters" would be at shallow depths. The best examples are the changes from 43-300°F/1000 ft (78-547°C/km) gradients from the Thermopolis anticline to the 11-23°F/1000 ft gradients about 5-6 miles (8-10 km) to the north-northwest (Fig. 3). The 10-25°F/1000 ft (18-46°C/km) gradients at five sites 5-10 miles (8-16 km) southwest of the anticline also suggest that shallow sources are responsible for the increased gradient in the middle part of the structure.

A tightly folded syncline is located immediately south of the Thermopolis anticline. We believe that waters from the Owl Creek Mountains are heated at the bottom of this syncline. Subsequent upward movement of these waters along the northern flanks of the syncline could explain the high gradients in the anticline. The thermal waters are mostly likely to be in the Tensleep and/or Madison Formations, two formations with porosities and permeabilities sufficient to yield the flow rates (2800 gpm (Breckenridge and Hinckley, 1978)) of the spring system in Hot Springs State Park. Within the central part of the anticline, the "tops" of the Tensleep and Madison range from 200-2800 ft (0.6-.85 km) and 800-3450 ft (.24-1.08 km), respectively. It is possible, therefore, that these aquifers could be reached with economical drilling in some parts of the structure.

Referring to "practical" aspects of resource development, one question that must be answered is whether drilling and large scale development would change temperatures and flow rates of the Thermopolis hot springs. Lack of data on porosities and permeabilities of the regional subsurface units also could impede development, as could the data for the springs which suggest that regional thermal waters would contain large amounts of total dissolved solids (2300 ppm (Breckenridge and Hinckley, 1978)). Finally, minor structures along the crest of the anticline should be carefully considered during drill site selection; for example, numerous faults cross cut the northwest-southeast trend of the anticline, and a heretofore unmapped fault is evident on air photos of the structure.

<u>The Cody-Horse Center Anticline System</u>. This potential resource area seems to be bounded by the DeMaris hot springs (27-36°C, 1700 gpm) just west of Cody and the Horse Center anticline about 7 miles to the south (Fig. 1). The first evidence for a low-temperature resource was provided by the 49-205°C/km gradients calculated using bottom hole temperatures in eleven dry oil wells in the anticline. Recent down hole measurements by Wyoming personnel agree with the oil well data. For example, least-squares gradients and maximum temperatures based on measurements in five shallow wells are in the ranges 96-190°C/km and 38.4-47.5°C, respectively, at subsurface depths in the range 185-500m.

The Rattlesnake anticline is between Cody and the Horse Center anticline. As seems to be the case elsewhere in the area, the Chugwater Formation in this anticline appears to be an impermeable cap rock that overlies porous, permeable and perhaps water-bearing units in the Tensleep and Madison Formations. From recent detailed geologic mapping, we believe that $\sim$60°C waters might be encountered at ∿300 m depths in the vicinity of the southeastern flank of this structure. Confirmation of a reservoir at such temperatures and depths with adequate flow rates is of great local interest because the resource could be used in two possible projects, a housing development or an alcohol plant.

The inferred most promising area is presently being examined with a drilling program that started in January of 1980. From measurements in four ∿100 m drill holes, the gradients off the flank of the Rattlesnake anticline are in the range 130 to 200°C/km. Concomitant bottom hole temperatures at these depths are in the range 20 to 29°C. We hope to complete at least one 300+ meter hole in the Madison Formation by the end of the third week in March, 1980. Observed temperature, water geochemistry and flow rate studies for this locality would provide data on the base temperature and other important characteristics of the indicated system.

The Casper-Midwest Area. The town of Midwest is about 40 miles north of Casper (Fig. 1). Because of much local interest in utilization of hydrothermal resources in protected housing developments, considerable effort has been spent researching these areas. Present data consist of more than 1000 bottom hole temperature points, from which combined temperature gradient and geologic maps are being prepared.

Most of our data are for areas near Midwest. These results clearly show that the Salt Creek Oil Field is a conspicuous thermal anomaly. Within this 10-12 mi^2 field, bottom hole temperatures between 1000 and 4500 ft (.3-1.4 km) are in the range 120°F-170°F (49-77°C), and maximum calculated gradients are between 40 and 100°F/1000 ft (72-182°C/km). Additionally, water injection wells that penetrate the Madison Formation produce 160-175°F (71-79°C) waters that flow to the surface at rates exceeding 7000 gallons/min. There can be little doubt, therefore, that the Salt Creek Field could be used to produce hydrothermal fluids for direct-heat applications in the vicinity of Midwest. The major impedances to resource development could be the relative values of hydrocarbon and geothermal resources, the high concentrations of solids in the non-potable waters, and the question of whether AMOCO Production Co., Wyoming, or the Federal Government owns the geothermal resource.

Scant data exist for the Casper region because fewer oil tests have been drilled in the area. The available data do suggest, however, that most of the region within a 10-15 mile radius of the city is not thermally anomalous. However, two areas near the city are being examined in greater detail: 1) the Emmigrant Gap Ridge, where 3 bottom hole temperatures are 90-117^{O}F at depths between 1350 and 1550 ft; and 2) the airport area, where a 202^{O}F bottom hole temperature was logged in a 2922 ft. deep well. The 200^{O}F temperature obviously is of particular interest and much effort is being spent to confirm the measurement, find supporting data, and interpret the local geologic structure.

The Gas Hills Area. Research before 1979 revealed the presence of high gradients (42-100^{O}C/km) at 8 isolated drill holes on the Beaver Rim in the Gas Hills (Fig. 1). New data consists of 20 bottom hole temperatures and temperature measurements in 31 holes that were drilled during uranium exploration. Maps of heat flow, gradient and regional geologic data are in various stages of compilation.

The present data are consistent with a complex pattern of gradient and flux in the Hills. Briefly, observed gradients range from 20^{O}C/km to 100^{O}C/km and estimated heat flows are in the range of 1.2-3.4 HFU. From combined geothermal and geologic data, one hypothesis is that faults control the gradient and heat flow patterns. Thus, any development of geothermal resources is likely to require careful mapping of the local geologic structure to delineate fault zones that could yield waters with potential for direct-heat applications. We hope to conduct more studies in the area because the great interest in subsurface uranium could lead to local settlements, and because one deep oil test in the Hills is reported to have encountered high temperature waters in the Madison (J. D. Love, pers. communication, 1980).

The Saratoga Valley Thermal System. The 1979 cooperative agreement has allowed us to establish a gradient and heat flow profile that extends from the eastern edge of the Washakie Basin to the Laramie Mountains (Fig. 2). Gradients and preliminary heat flow values along this profile are in the ranges 7-30°C/km and .9-1.6 HFU, respectively. Two holes on the profile are near the hot springs in the town of Saratoga (Fig. 1). The gradient in the hole about 1 mile west of the springs is 20°C/km, and that in the hole about 1 mile to the east is 30°C/km. Both gradients may be considered "normal," and so these observations suggest that the Saratoga hot springs (∿50°C (Breckenridge and Hinckley, 1978)) are not surface manifestations of a subsurface hydrothermal system with large dimensions. The narrow width of the system, in turn, suggests that the springs could be flowing from faults in this part of the Saratoga Valley. This view is supported by geologic evidence for a fault zone near the spring system (Montagne, 1955). Like the Gas Hills, development of geothermal resources in the Saratoga area may require additional research on the correlations between faulting, subsurface temperatures and heat flow in the region.

We may speculate that moderate or higher temperature resource areas could be present at shallow depths in the region between the Saratoga Valley and the Southern Rocky Mountains in northern Colorado (Fig. 2). From our new data, the heat flow is normal or low (.9-1.6 HFU) in the Saratoga Valley-Sierra Madre Mountains-Medicine Bow Mountains region in Wyoming, whereas the flux is high >2.4 HFU) at Hahns Peak and Northgate, Colorado about 50-60 km to the south.

Interpreted in terms of steady or transient heat sources, the width and magnitude of the transition suggest that the excess flux in northern Colorado is partly due to high temperature heat sources at shallow depths in the crust and/or upper mantle. This view, in turn, is consistent with geothermal reservoirs in the transition zone and the high heat flow area immediately to the south.

The Big Horn Basin, Excluding the Thermopolis and Cody-Horse Center Systems. Bottom hole temperature data have been compiled and analyzed for ∿150 oil wells that are within a triangular area bounded by Worland, Meeteetse and Thermopolis in the southern part of the Big Horn Basin (Fig. 2). The widely scattered data points cannot be interpreted in detail, but one general conclusion is that the geothermal gradients increase between Worland and the Absaroka, Wind River and Owl Creek Mountains to the west, southwest, and south, respectively. Confirmation of this regional variation(?) would be important because it suggests that any low-temperature reservoirs are most likely to exist along the flanks of these mountains.

A new heat flow value of 1.78 HFU has been determined for Meadow Creek Basin in the eastern part of the Absaroka Mountains. This flux and Blackwell's (1969) 1.8 HFU value near Kirwin about 20 km to the south suggest that a large part of the Absarokas is a zone of high flux like the western Great Basin. Additional evidence for Basin and Range type flux in these mountains, in turn, would suggest that low-temperature reservoirs could occur in this part of northwestern Wyoming.

Temperatures have been measured in 15 drill holes in the Bridger Mountains (Fig. 2). Although some of the observed gradients (5.3-12.8°C/km) are consistent with local hydrologic disturbances in these mountains, the most reliable values of 19.0-22.6^{o}C/km support earlier suggestions that the Lysite-Bridger Mountain area is a zone of above-normal heat flow (see Decker and others, 1980). Like the elevated flux in the Absarokas to the northwest, the above-normal regional heat flow may imply the presence of hydrothermal reservoirs locally in the Bridger Mountains.

The Wyoming Basin. New temperature-depth data for seven widely separated localities in the Great Divide-Green River Basins area (Fig. 2) yield gradients in the range 17-30^{o}C. Estimated heat flows near Eden, Wyoming are 1.6-1.7 HFU, values that agree with Sass and others' (1971) conjecture that this locality is in a zone of normal to intermediate flux. New heat flow values (8) in the Rawlins Uplift-Laramie Basin part of the Wyoming Basin (Fig. 2) are low to normal (1.1-1.3 HFU). We, therefore, conclude that there is very little geothermal evidence for shallow reservoirs with direct-heat potential in the eastern Wyoming Basin, although there are very few control points in this province.

The Powder River Basin, Excluding the Casper-Midwest Area. Head and others (1978) have contoured depths and temperatures for the Madison Formation in the Powder River Basin (Fig. 2). The temperatures and assumed permeabilities of this unit suggest that it could yield vast quantities of waters adequate for direct-heat applications. It is also the case, however, that the Madison is at great, perhaps uneconomically drilled depths in many parts of the area. Consequently, our studies of the Basin have focused on shallow temperature, gradient and heat flow measurements.

Two reliable heat flow values are now available for the Douglas low-temperature resource(?) area (Fig. 1). The values are in the range of 2.0-2.2 HFU. These drill holes are in an area where underlying Madison Formation is dipping up to shallower depths from the north -northeast. Perhaps upward circulating waters in the Madison explain the observed above-normal flux. More reliable definition of the suggested resource area will require additional research with shallow drill holes.

Gradients in 5 shallow holes near Torrington are in the range of 23-29°C/km. In the Wright area to the north, measurements in 10 holes suggest that the undisturbed regional gradient is between 19 and 29°C/km. The meaning of these data are obscure, but one interpretation is that the eastern part of the Powder River Basin is characterized by a complex pattern of normal to high heat flow and perhaps shallow low-temperature hydrothermal reservoirs in isolated areas. We cannot be more specific without more geothermal data for these and other parts of the Basin (Fig. 2).

Maps of Regional Heat Flow and Geology. Figures 4 and 5 are maps of heat flow and generalized geology in Southern Rocky Mountain and Northern Rocky Mountain regions, respectively. The maps were prepared shortly after the beginning of our 1979 program using U.S. DOE funds. They are presently in press in Chapter 13 of a new book entitled "Physical Properties of Rocks and Minerals" that is being published by McGraw Hill and Purdue University. The proposed principal investigators are co-authors of the chapter.

The maps permit rather easy visualization of correlations between flux, faulting and/or bedrock geology. Updated versions of the Wyoming part of the Northern Rocky Mountain region map will be submitted to the U.S. DOE in our final report on research in 1979.

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Wright, P. M., 1978, Western States Cooperative Direct Heat Geothermal Program, Technical Document No. 1, U.S. Department of Energy/Division of Geothermal Energy.

BUDGET: Funds are requested for the period June 1, 1980 to May 31, 1981, a period that includes the University's entire academic year.

Salaries	From the U.S. DOE	University of Wyoming
Principal Investigator (Decker)		
13 weeks summer, 1980)	9777.00	
10 weeks, acad. yr 1980-81		9192.00
Co-Investigator (Heasler)		
1 mo. (June, 1980)	1346.00	
11 months (July-May, 1980-81)	16291.00	
Research Associate II-		
12 mo. (June, 1980-May, 1981)	15000.00	
Secretary - Half Time	4000.00	
Graduate Assistants		
Summer 1980 3 people x 13 wk x 40 hrs x $5.45/hr.	8502.00	
Acad. yr 80-81 2 people $4500	9000.00	
Part-time Assistant		
40 weeks x 15 hrs x $5.00	3000.00	
	66916.00	9192.00
Fringe (17% x 54916.00)	9336.00	1563.00
	76252.00	10755.00
Travel		
Field expenses, per diem 250 da x $40	10000.00	
Expenses for permanently consigned field trucks (2), 40,000 mi @ .25	10000.00	
Rental of Univ. Wyo. Car Pool vehicle summer, 1980, 10,000 mi @ .25	2500.00	
Travel to US DOE meetings (Salt Lake City, Idaho Falls, Washington, D.C.	2500.00	
Total Travel	25000.00	
Expendable Equipment		
Replacement of Armoured cable (4000' at $2100 and Portable cables (6000' at $1900 Total	4000.00	
Other costs		
Supplies (thermistors, probe parts, standards, water sample containers, computer cards, tapes, etc.)	4500.00	
American Tel and Tel	2000.00	
Publication chartes (drafting, etc.)	3000.00	
Processing of data, etc. 600 mi/$4.00	2400.00	
Machine and Electronics shop time (prepare conductivity samples, construct and repair equipment, etc.) 800 hrs @ $2.50	2000.00	
Chemical analyses (6 @ $100.00	600.00	
Contract Casing (casing and rig time) 6500feet @ $2	13000.00	
Total Other costs	27500.00	
TOTAL DIRECT COSTS	132752.00	10755.00

continued . . .

TOTAL DIRECT COSTS	132752.00	10755.00
INDIRECT COSTS 48.5%)	32454.00	4458.00
	165206.00	15213.00
Less carry-over from 1979	10600.00	
	154606.00	15213.00
NEW AMOUNT REQUESTED FROM U.S. DOE	154500.00	

TABLE I. Areas in which drilling will occur in 1980-81. Localities may be visited and/or cased for subsurface geothermal measurements.

Locality	No. of Holes, Depth Range	
Absaroka Mtns. (Sunlight Basin)	19,	up to 1000'
Beartooth Mtns. (Cooke City)	2-4,	200-400'
Bighorn Mountains	2-4,	200-300'
Central Part Bighorn Basin	6-10,	<700'
Laramie Mtns, Southern (Diamond Exploration)	6-12,	up to 1000'
Sierra Madre-Medicine Bow Mountains	4-6,	up to 1000'
Saratoga Valley	2-4,	up to 1000'
Laramie and Shirley Basins (Rock River to North)	>10,	700-1000'
Rawlins Area	> 3,	1000+ ft.
Ft. Collins, Colo. Area	12+,	500-700'

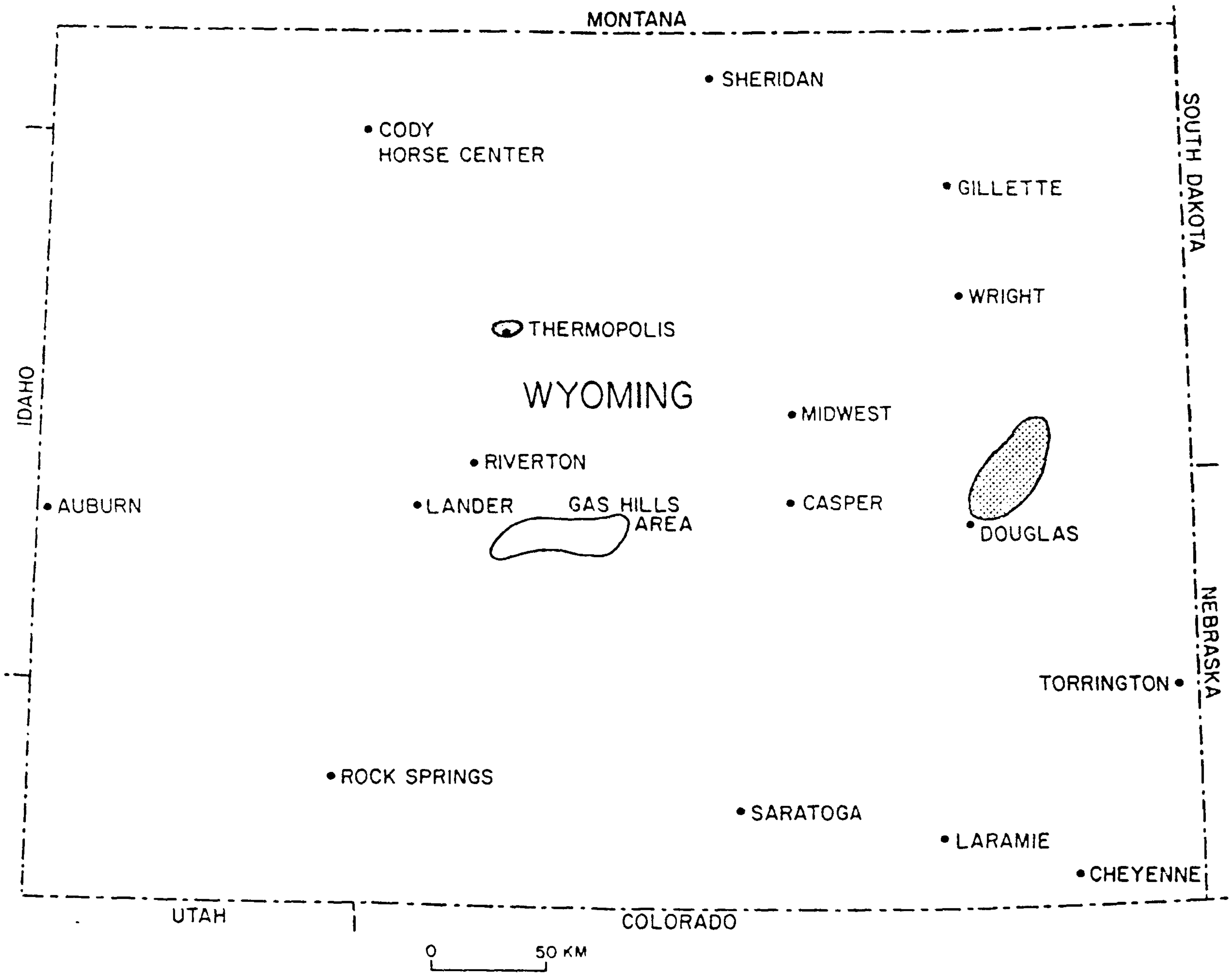

Figure 1. Map showing research localities in Wyoming. Cross-hachured areas may contain low temperature hydrothermal reservoirs.

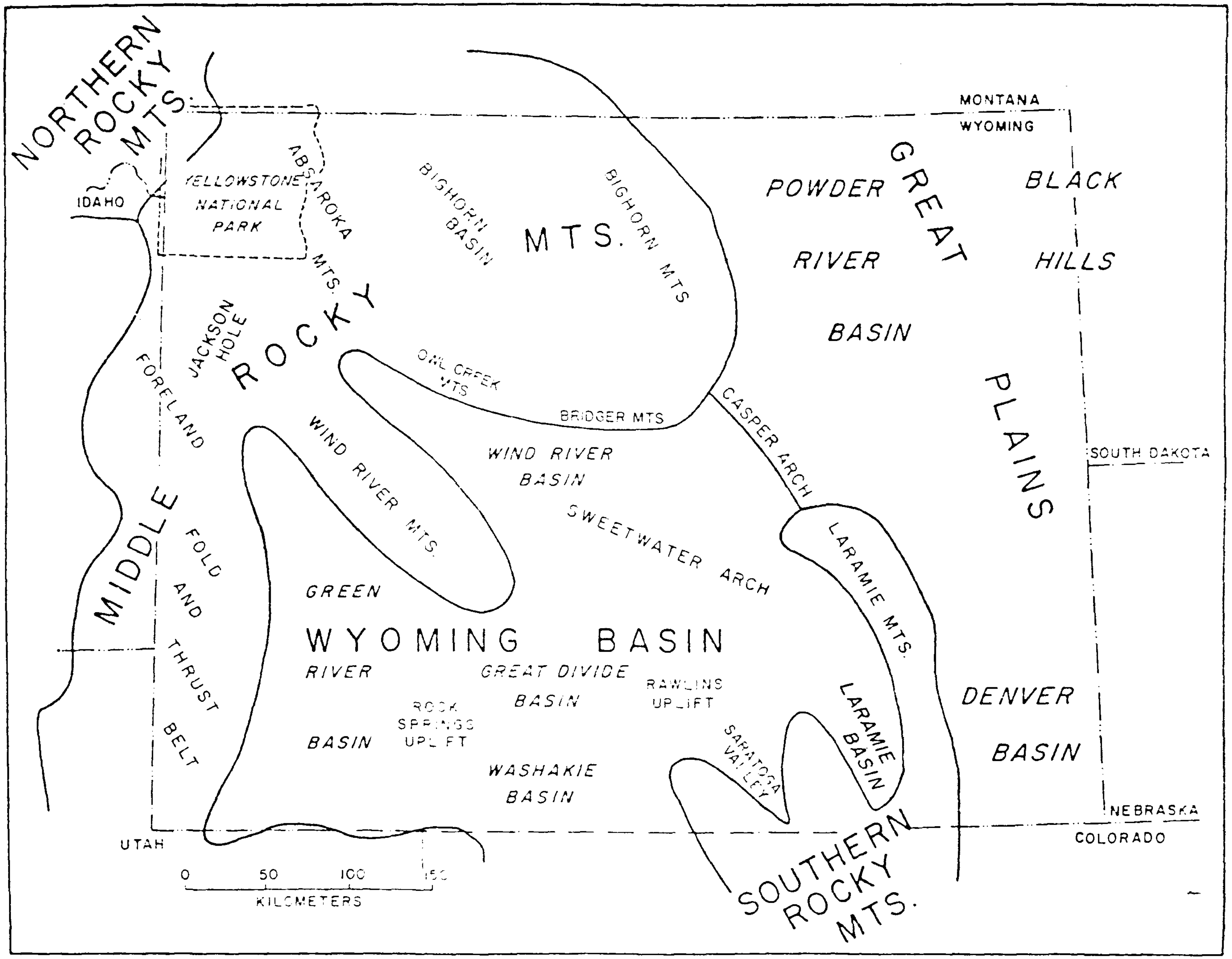

Figure 2. Map of physiographic provinces and major structural elements in Wyoming.

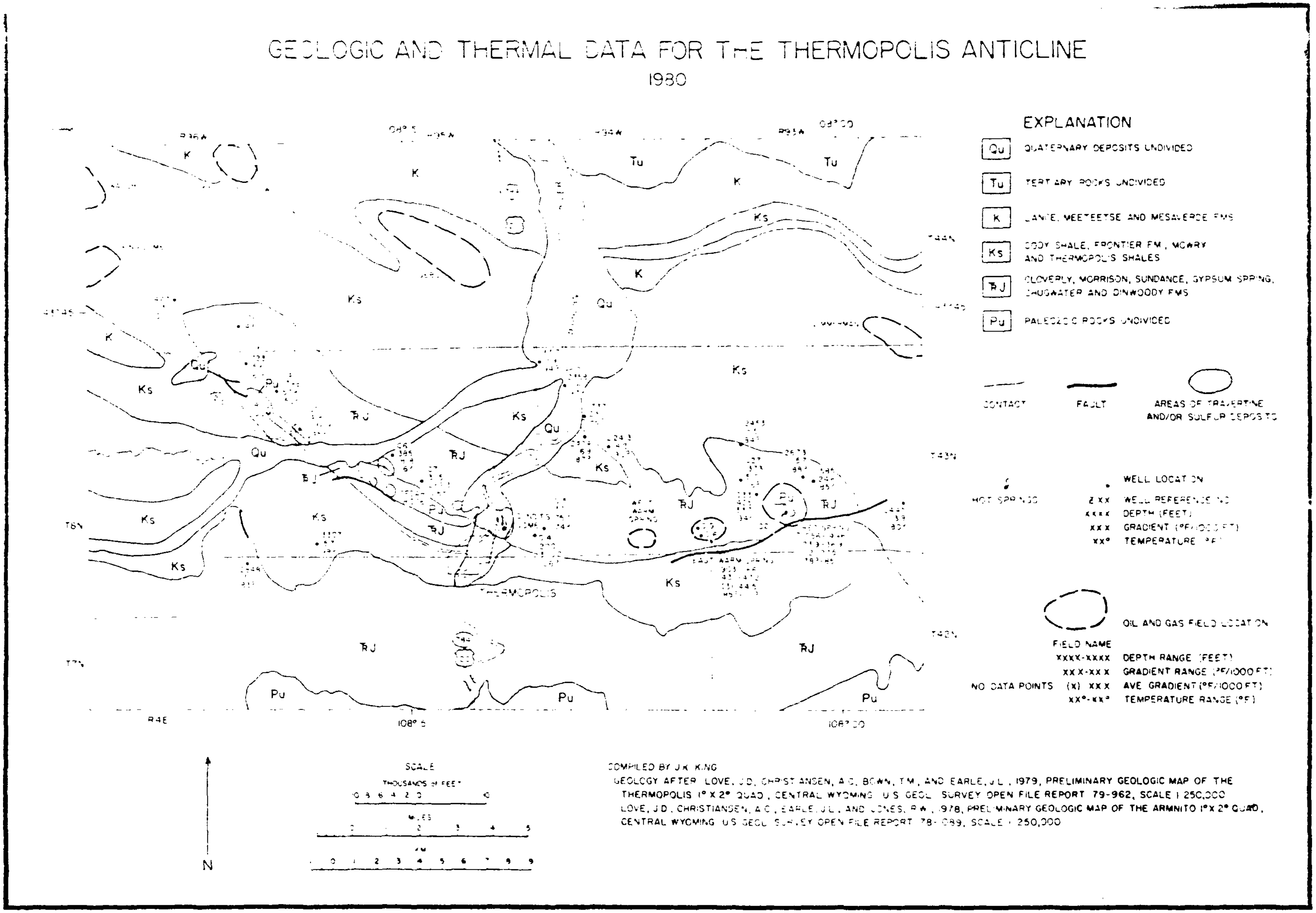

Figure 3. Geologic and thermal data for the Thermopolis anticline area.

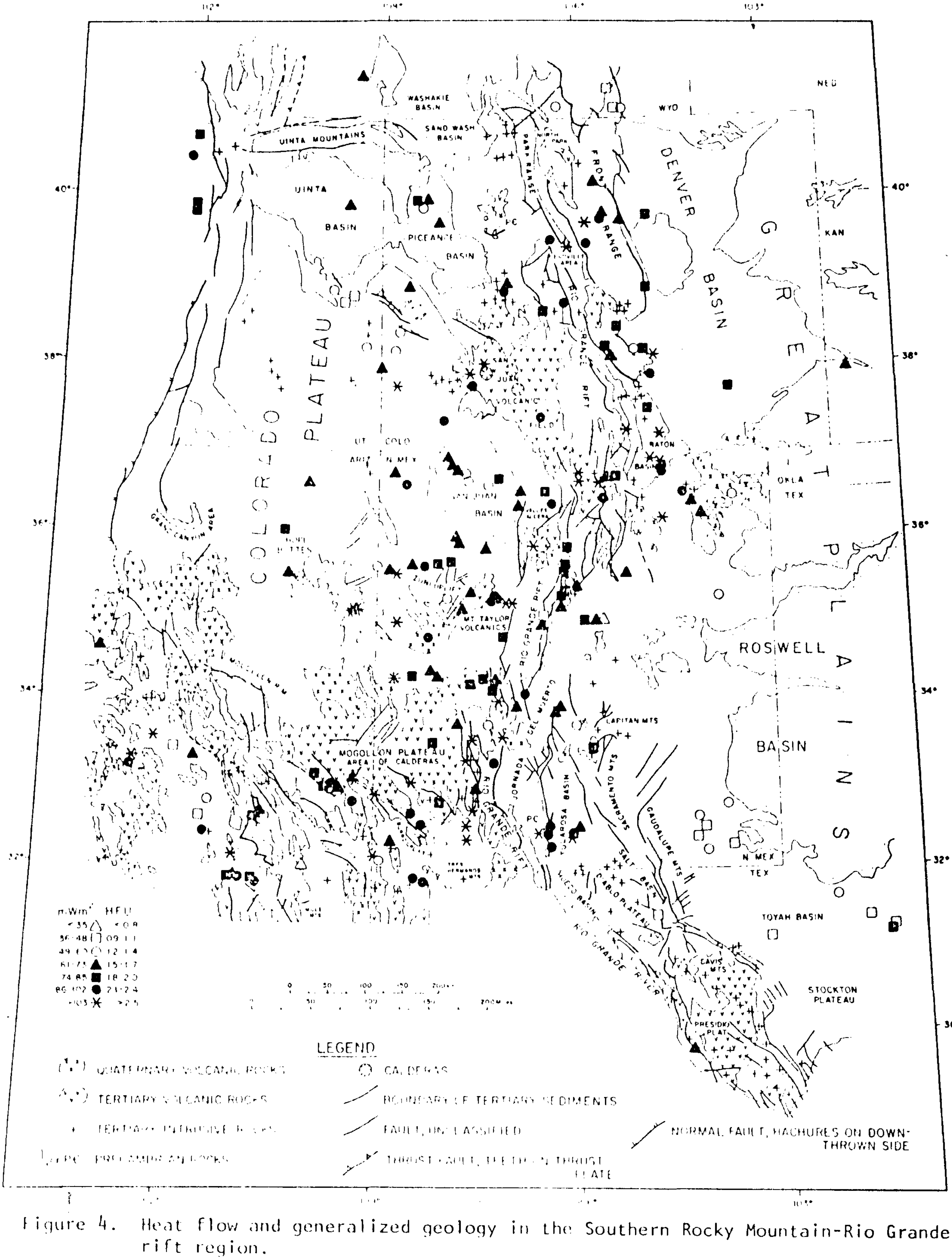

Figure 4. Heat flow and generalized geology in the Southern Rocky Mountain-Rio Grande rift region.

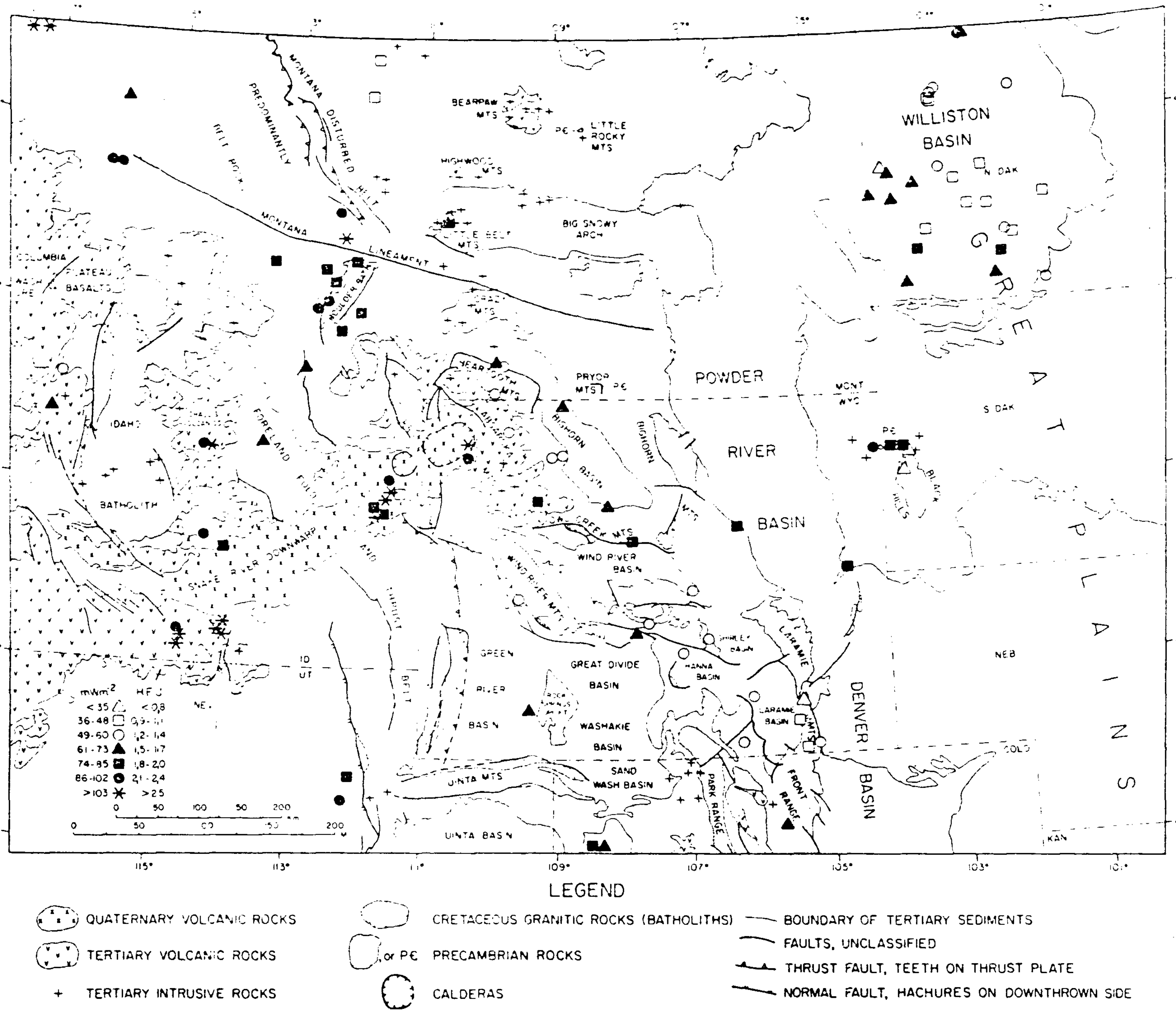

Figure 5. Heat flow and generalized geology in the Northern and Middle Rocky Mountain region.

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GEOTHERMAL ENERGY
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HYDROTHERMAL RESOURCES IN WYOMING: A PRELIMINARY REPORT ON THE UNIVERSITY OF WYOMING'S RESEARCH IN 1979

by

Edward R. Decker, Henry P. Heasler,
and Jon K. King

Department of Geology
University of Wyoming
Laramie, Wyoming 82071

INTRODUCTION

Our first year of research involved detailed studies of indicated low-temperature resource areas, compilations of regional geothermal data, and syntheses of pertinent geology and geophysics. Compilations of geothermal data directly followed bottom hole temperatures in oil wells, and measurements of temperatures in more than 100 drill holes. The regional geology and geophysics were synthesized from published articles. This report is a brief summary of the highlights of our present results.

Figure 1 shows many of the investigated areas. A map of regional physiographic provinces and major structural elements in Wyoming is shown in Figure 2. Throughout the text, temperatures are given in °F or °C and geothermal gradients are given in °F/1000 ft or °C/km. The heat flow unit is abbreviated to HFU, where 1 HFU = 1×10^{-6} cal/cm^2 sec = 41.8 mW/m^2.

AREAS WITH INDICATED LOW-TEMPERATURE RESOURCES

The Thermopolis Area

Temperatures, gradients and regional geology have been compiled for a 1800-1900 mi^2 area that is roughly centered on the Thermopolis hot springs (Figure 1). The results demonstrate that the thermal anomaly occurs all along the central part of the Thermopolis anticline, occupying a 20-mi long by 3-mi wide area that strikes west-northwest between the southwestern part of T. 43 N., R. 93 W. and the southeastern part of T. 44 N., R. 96 W. (Figure 3). Within this zone, calculated gradients are in the range 43-300°F/1000 ft (78-547°C/km) and tabulated bottom hole temperatures range from 90°F (32°C) to 160°F (70°C) at depths less than 2000 ft (∿.6 km). Inasmuch as downward continuation of the lower gradients predicts 60+°C temperatures at depths between 3500 and 4000 ft (1.1-1.2 km), we consider all of the region to be a "viable" low temperature, hydrothermal resource area.

The Red Springs Anticline area in T. 43 N., R. 93 W. may be a "marginal" resource area. Here the calculated gradients are in the range 24-59°F/1000 ft (43-107°C/km) (Figure 3). Consequently, 60°C waters might be encountered at 3900-4500 ft depths (1.2-1.3 km) here.

The narrow boundaries of the Thermopolis-Red Springs anticlines anomaly suggest that "thermal waters" would be at shallow depths. The best examples are the changes from 43-300°F/1000 ft (78-547°C/km) gradients from the Thermopolis anticline to the 11-23°F/1000 ft gradients about 5-6 miles (8-10 km) to the north-northwest (Figure 3). The 10-25°F/1000 ft (18-46°C/km) gradients at five sites 5-10 miles (8-16 km) southwest of the anticline also suggest that shallow sources are responsible for the increased gradient in the middle part of the structure.

A tightly folded syncline is located immediately south of the Thermopolis anticline. We believe that waters from the Owl Creek Mountains are heated at the bottom of this syncline. Subsequent upward movement of these waters along the northern flanks of the syncline could explain the high gradients in the anticline. The thermal waters are most likely to be in the Tensleep and/or Madison Formations--two formations with porosities and permeabilities sufficient to yield the flow rates (∿2800 gpm; Breckenridge and Hinckley, 1978) of the spring system in Hot Springs State Park. Within the central part of the anticline, the "tops" of the Tensleep and Madison range from 200-2800 ft (.06-.85 km) and 800-3450 ft (.24-1.08 km), respectively. It is possible, therefore, that these aquifers could be reached with economical drilling in some parts of the structure.

Referring to "practical" aspects of resource development, one question that must be answered is whether drilling and large scale development would change temperatures and flow rates of the Thermopolis hot springs. Lack of data on porosities and permeabilities of the regional subsurface units also could impede development, as could the data for the springs which suggest that regional thermal waters would contain large amounts of total dissolved solids (2300 ppm; Breckenridge and Hinckley, 1978). Finally, minor structures along the crest of the anticline should be carefully considered during drill site selection; for example, numerous faults cross cut the northwest-southeast trend of the anticline, and a heretofore unmapped fault is evident on air photos of the structure.

The Cody-Horse Center Anticline System

This potential resource area seems to be bounded by the DeMaris hot springs (27-36°C, 1700 gpm) just west of Cody and the Horse Center anticline about 7 miles to the south (Figure 1). The first evidence for a low-temperature resource was provided by the 49-205°C/km gradients calculated using bottom hole temperatures in eleven dry oil wells in the anticline. Recent down hole measurements by Wyoming personnel agree with the oil well data. For example, least-squares gradients and maximum temperatures based on measurements in five shallow wells are in the ranges 96-190°C/km and 38.4-47.5°C, respectively, at subsurface depths in the range 185-500 m.

The Rattlesnake anticline is between Cody and the Horse Center anticline. As seems to be the case elsewhere in the area, the Chugwater Formation in this anticline appears to be an impermeable cap rock that overlies porous, permeable and perhaps water-bearing units in the Tensleep and Madison Formations. From recent detailed geologic mapping, we believe that ∿60°C waters might be encountered at ∿300 m depths in the vicinity of the southeastern flank of this structure. Confirmation of a reservoir at such temperatures and depths with adequate flow rates is a great local interest because the resource could be used in two possible projects--a housing development or an alcohol plant.

The inferred most promising area is presently being examined with a drilling program that started in January of 1980. From measurements in four ∿100 m drill holes, the gradients off the flank of the Rattlesnake anticline are in the range 130 to 200°C/km. Concomitant bottom hole temperatures at these depths are in the range 20 to 29°C. We hope to complete at least one 300+ meter hole in the Madison Formation by the end of the first week in March, 1980. Observed temperature, water geochemistry and flow rate studies for this locality would provide data on the base temperature and other important characteristics of the indicated system.

<u>The Casper-Midwest Area</u>

The town of Midwest is about 40 miles north of Casper (Figure 1). Because of much local interest in utilization of hydrothermal resources in projected housing developments, considerable effort has been spent researching these areas. Present data consist of more than 1000 bottom hole temperature points, from which combined temperature gradient and geologic maps are being prepared.

Most of our data are for areas near Midwest. These results clearly show that the Salt Creek Oil Field is a conspicuous thermal anomaly. Within this 10-12 mi^2 field, bottom hole temperatures between 1000 and 4500 ft (.3-1.4 km) are in the range 120-170°F (49-77°C), and maximum calculated gradients are between 40 and 100°F/1000 ft (72-182°C/km). Additionally, water injection wells that penetrate the Madison Formation produce 160-175°F (71-79°C) waters that flow to the surface at rates exceeding 7,000 gallons/min. There can be little doubt, therefore, that the Salt Creek Field could be used to produce hydrothermal fluids for direct-heat applications in the vicinity of Midwest. The major impedences to resource development could be the relative values of hydrocarbon and geothermal resources, the high concentrations of solids in the nonpotable waters, and the question of whether AMOCO Production Co., Wyoming, or the federal government owns the geothermal resource.

Scant data exist for the Casper region because fewer oil tests have been drilled in the area. The available data do suggest, however, that most of the region within a 10-15 mile radius of the city are not thermally anomalous. However, two areas near the city are being examined in greater detail: (1) the Emmigrant Gap Ridge, where 3 bottom hole temperatures are 90-117°F at depths between 1350 1550 ft; and (2) the airport area, where a 202°F bottom hole temperature was logged in a 2922 ft deep well. The 200°F temperature obviously is of particular interest and much effort is being spent to confirm the measurement, find supporting data, and interpret the local geologic structure.

The Gas Hills Area

Research before 1979 revealed the presence of high gradients (42-100°C/km) at 8 isolated drill holes on the Beaver Rim in the Gas Hills. Recently compiled data consist of 20 bottom hole temperatures and temperature measurements in 31 holes that were drilled during uranium exploration. Maps of heat flow, gradient and regional geologic data are in various stages of compilation.

The present data are consistent with a complex pattern of gradient and flux in the Hills. Briefly, observed gradients range from 20°C/km to 100°C/km and estimated heat flows are in the range 1.2-3.4 HFU. From combined geothermal and geologic data, one hypothesis is that faults control the gradient and heat flow patterns. Thus, any development of geothermal resources is likely to require careful mapping of the local geologic structure to delineate fault zones that could yield waters with potential for direct-heat applications. We hope to conduct more studies in the area because the great interest in subsurface uranium could lead to local settlements and because one deep oil test in the Hills is reported to have encountered high temperature waters in the Madison (J. D. Love, personal communication, 1980).

The Saratoga Valley Thermal System

The 1979 cooperative agreement has allowed us to establish a gradient and heat flow profile that extends from the eastern edge of the Washakie Basin to the Laramie Mountains (Figure 2). Gradients and preliminary heat flow values along this profile are in the ranges 7-30°C/km and .9-1.6 HFU, respectively. Two holes on the profile are near the hot springs in the town of Saratoga (Figure 1). The gradient in the hole about 1 mile west of the springs is 20°C/km, and that in the hole about 1 mile to the east is 30°C/km. Both gradients may be considered "normal," and so these observations suggest that the Saratoga hot springs (∿50°C; Breckenridge and Hinckley, 1978) are not surface manifestations of a subsurface hydrothermal system with large dimensions. The narrow width of the system, in turn, suggests that the springs could be flowing from faults in this part of the Saratoga Valley. This view is supported by geologic evidence for a fault zone near the spring system (Montagne, 1955). Like the Gas Hills, development of geothermal resources in the Saratoga area may require additional research on the correlations between faulting, subsurface temperatures and heat flow in the region.

We may speculate that moderate or higher temperature resource areas could be present at shallow depths in the region between the Saratoga Valley and the southern Rocky Mountains in northern Colorado (Figure 2). From our new data, the heat flow is normal or low (.9-1.6 HFU) in the Saratoga Valley-Sierra Madre Mountains-Medicine Bow Mountains region in Wyoming, whereas the flux is high ($\geq$2.4 HFU) at Hahns Peak and Northgate, Colorado, about 50-60 km to the south. Interpreted in terms of steady or transient heat sources, the width and magnitude of the transition suggest that the excess flux in northern Colorado is partly due to high temperature heat sources at shallow depths in the crust and/or upper mantle. This view, in turn, is consistent with geothermal reservoirs in the transition zone and the high heat flow area immediately to the south.

RESEARCH IN OTHER AREAS

The Big Horn Basin, Excluding the Thermopolis and Cody-Horse Center Systems

Bottom hole temperature data have been compiled and analyzed for ~150 oil wells that are within a triangular area bounded by Worland, Meeteetse and Thermopolis in the southern part of the Big Horn Basin (Figure 2). The widely scattered data points cannot be interpreted in detail, but one general conclusion is that the geothermal gradients increase between Worland and the Absaroka, Wind River and Owl Creek Mountains to the west, southwest, and south, respectively. Confirmation of this regional variation(?) would be important because it suggests that any low-temperature reservoirs are most likely to exist along the flanks of these mountains.

A new heat flow value of 1.78 HFU has been determined for Meadow Creek Basin in the eastern part of the Absaroka Mountains. This flux and Blackwell's (1969) 1.8 HFU value near Kirwin about 20 km to the south suggest that a large part of the Absarokas is a zone of high flux like the western Great Basin. Additional evidence for Basin and Range type flux in these mountains, in turn, would suggest that low-temperature reservoirs could occur in this part of northwestern Wyoming.

Temperatures have been measured in 15 drill holes in the Bridger Mountains (Figure 2). Although some of the observed gradients (5.3-12.8°C/km) are consistent with local hydrologic disturbances in these mountains, the most reliable values of 19.0-22.6°C/km support earlier suggestions that the Lysite-Bridger Mountain area is a zone of above-normal heat flow (see Decker and others, 1980). Like the elevated flux in the Absarokas to the northwest, the above-normal regional heat flow mav imply the presence of hydrothermal reservoirs locally in the Bridger Mountains.

The Wyoming Basin

New temperature-depth data for seven widely separated localities in the Great Divide-Green River Basins area (Figure 2) yield gradients in the range 17-30°C. Estimated heat flows near Eden, Wyoming are 1.6-1.7 HFU, values that agree with Sass and others' (1971) conjecture that this locality is in a zone of normal to intermediate flux. New heat flow values (8) in the Rawlins Uplift-Laramie Basin part of the Wyoming Basin (Figure 2) are low to normal (1.1-1.3 HFU). We, therefore, conclude that there is very little geothermal evidence for shallow reservoirs with direct-heat potential in the eastern Wyoming Basin, although there are very few control points in this province.

The Powder River Basin, Excluding the Casper-Midwest Area

Head and others (1978) have contoured depths and temperatures for the Madison Formation in the Powder River Basin (Figure 2). The temperatures and assumed permeabilities of this unit suggest that it could yield vast quantities of waters adequate for direct-heat applications. It is also the case, however, that the Madison is at great, perhaps uneconomically drilled depths in many parts of the area. Consequently, our studies of the Basin have focused on shallow temperature, gradient and heat flow measurements.

Two reliable heat flow values are now available for the Douglas low-temperature resource (?) area (Figure 1). The values are in the range 2.0-2.2 HFU. These drill holes are in an area where underlying Madison Formation is dipping up to shallower depths from the north, northeast. Perhaps upward circulating waters in the Madison explain the observed above-normal flux. More reliable definition of the suggested resource area will require additional research with shallow drill holes.

Gradients in 5 shallow holes near Torrington are in the range 23-29°C/km. In the Wright area to the north, measurements in 10 holes suggest that the undisturbed regional gradient is between 19 and 29°C/km. The meaning of these data is obscure, but one interpretation is that the eastern part of the Powder River Basin is characterized by a complex pattern of normal to high heat flow and perhaps shallow low-temperature hydrothermal reservoirs in isolated areas. We cannot be more specific without more geothermal data for the Basin.

REFERENCES CITED

Blackwell, D. D., 1969, Heat flow determinations in the northwestern United States, Jour. Geophys. Res., 74, pp. 992-1007.

Breckenridge, R. M. and Hinckley, B. S., 1978, Thermal springs of Wyoming, Wyo. Geol. Survey Bull. 60, 104 pages.

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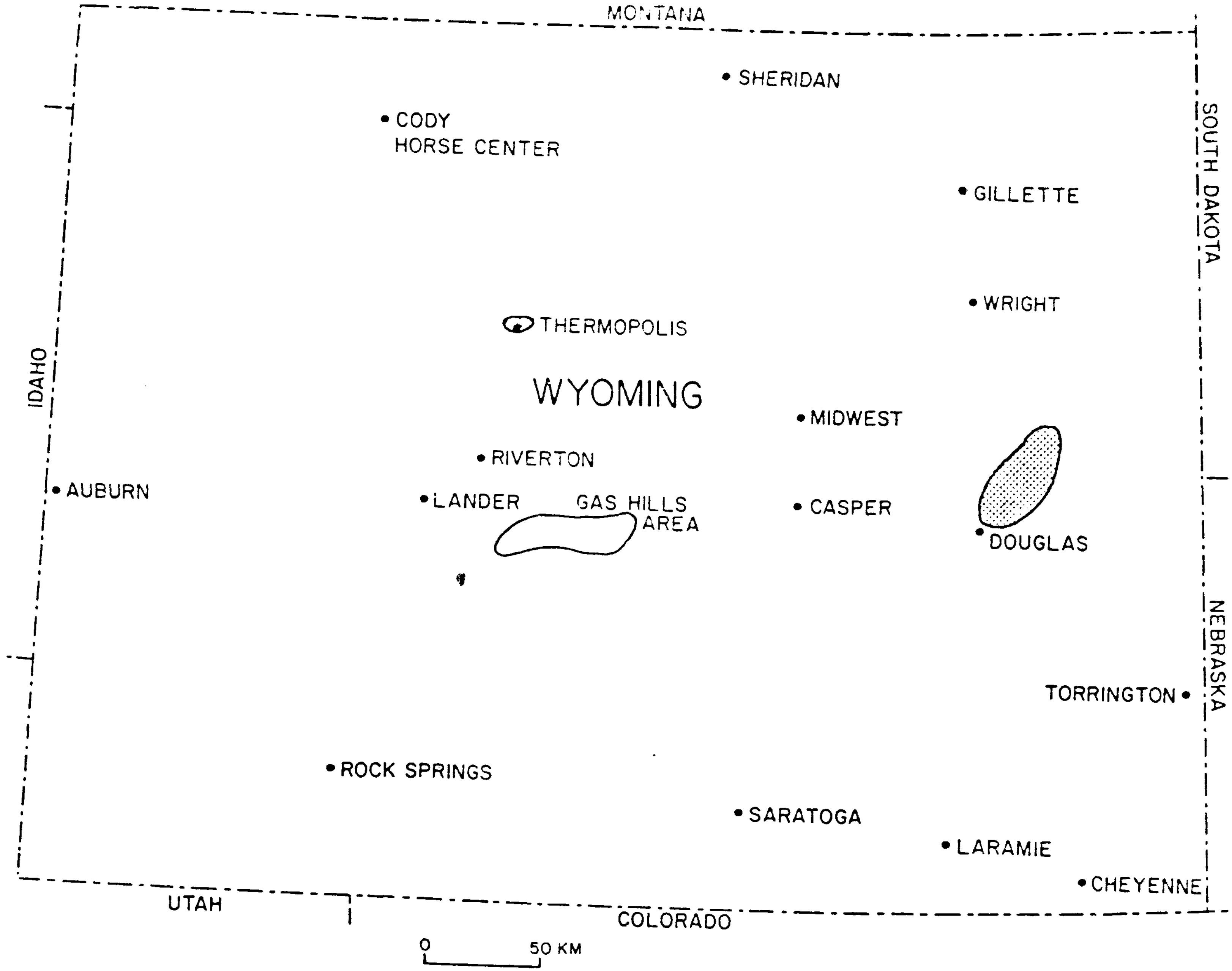


Figure 1. Investigated areas.

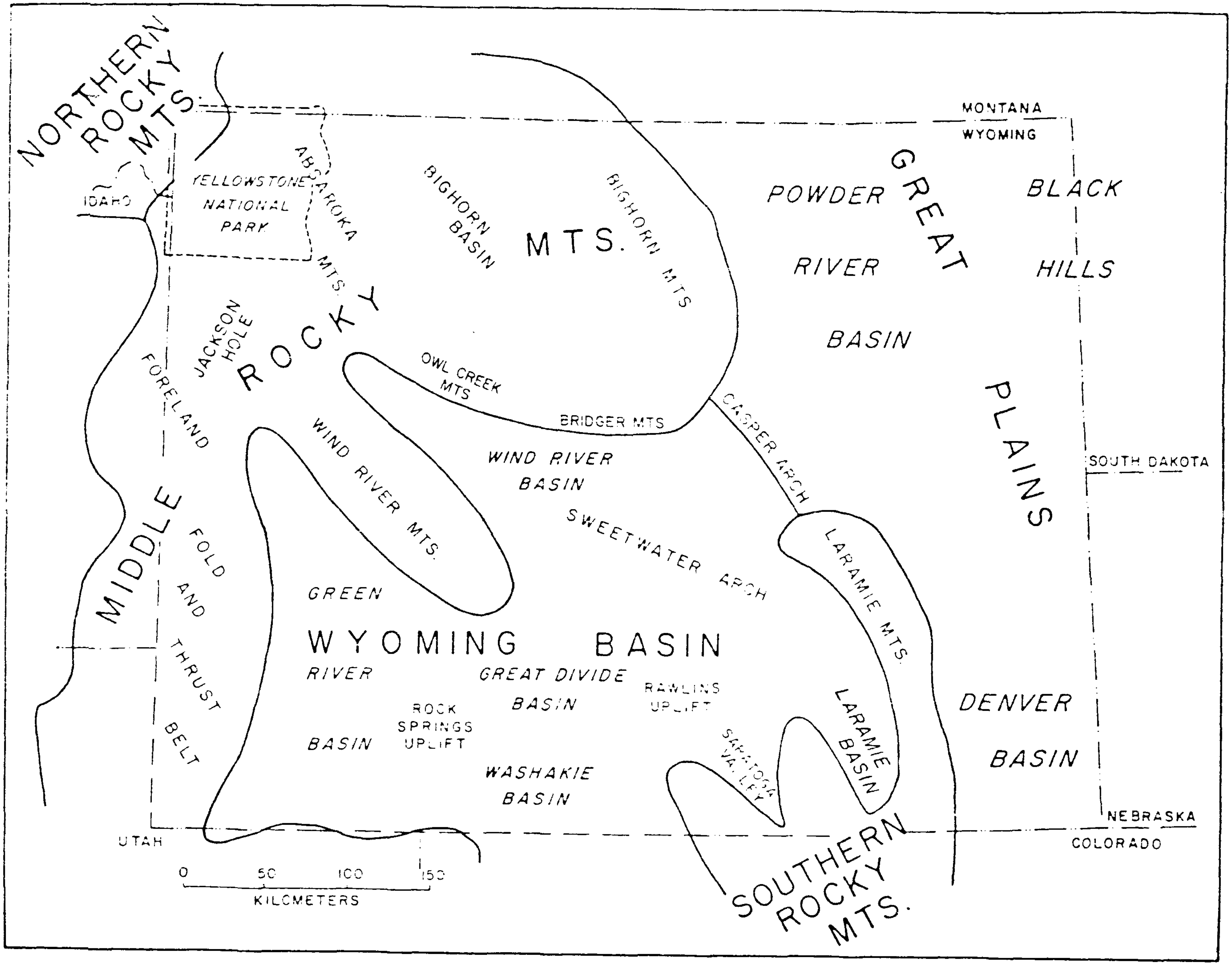


Figure 2. Physiographic provinces and major structural elements in Wyoming.

Hydrothermal Resources in Wyoming - University of Wyoming.

- Good Points.
  - good concept - general evaluation of prospective areas in entire state. - find good areas and bad areas.
  - Good Geologic targets

- Bad Points
  - Apparently no hard data delivered to date and no reports on data.
  - No provisions for reviewing of data
  - No specific proposal.
  - where are these studies in relationship to wilderness areas (existing or proposed) and is it necessary that they be carried out.

- Questions
  - [redacted]
  - What is criteria for spacing or determining the proposed 2,000 feet of drill holes for heat flow studies.

THE UNIVERSITY OF WYOMING
DEPARTMENT OF GEOLOGY
GEOLOGY BUILDING
P. O. BOX 3006
LARAMIE, WYOMING 82071
PH. 307—766-3386

February 11, 1981

Mr. Duncan Foley
Earth Science Lab
University of Utah Research Institute
420 Chipeta Way, Suite 120
Salt Lake City, Utah 84108

Dear Duncan,

Enclosed is a copy of my letter to M. A. Widmayer which constitutes the January technical progress report for the Wyoming Geothermal Resource Assessment Team.

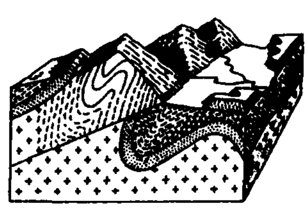
If you have questions or comments, please contact me.

Sincerely,

Henry P. Heasler
Principal Investigator
Hydrothermal Resource Assessment
in Wyoming

HPH/tj

Enclosure



temperatures have been compiled into a set of three maps on the Great Divide and Washakie Basins. These three maps show generalized geology and temperature data sites, structure contours on a potential aquifer (the Cretaceous Mesaverde Formation), and temperature contours on the Mesaverde Formation with areas of high gradient indicated. A report is being prepared to accompany these maps. The study of the Green River Basin has begun with collection of 1200 oil well bottom hole temperatures.

Previously collected temperature information was plotted for the Saratoga area, Gas Hills and Casper-Midwest area. Fifty data sites were plotted for the Saratoga, 166 for the Gas Hills, and 900 for the Casper-Midwest area. Master lists of the data have been compiled and work is continuing on reports for these areas.

During January the principal investigator attended a meeting of the Wyoming State Legislature's Joint Committee on Mines, Minerals, and Industrial Development. Proposed geothermal legislation which will be introduced in this year's legislature resulted from the meeting. Also, the joint resource assessment-commercialization teams meeting held in Seattle was attended. At that meeting a poster session on the Thermopolis hydrothermal system was presented with the Wyoming Commercialization Team.

I hope that this letter is a satisfactory report for work accomplished in January.

Sincerely,

Henry Heasler

Henry P. Heasler
Principal Investigator
Hydrothermal Resource Assessment
in Wyoming

HPH/tj

cc: Robert Gray
Duncan Foley

A PROPOSAL TO THE UNITED STATES DEPARTMENT

OF ENERGY, IDAHO FALLS,

IDAHO

for

"HYDROTHERMAL RESOURCE STUDIES IN WYOMING, JUNE 1, 1980-

MAY 31, 1981"

Amount Requested: $154,500

Investigators:

	Edward R. Decker Professor of Geology 056-32-1937	Date
	Henry P. Heasler Research Associate II 520-62-8409	Date
Department Head	R. S. Houston	Date
University Official	Edward H. Jennings President University of Wyoming	Date

INTRODUCTION

Our original proposal to the U.S. Department of Energy was submitted in the Fall of 1978, with funding being approved in January of 1979. That program is now in the final stages of completion. It was hoped that hydrothermal resource data would be obtained for at least 600 oil wells, five indicated low-temperature reservoirs, and 12-24 new heat flow sites. Additionally, regional gradient and heat flow maps were to be prepared and interpreted. These objectives have been substantially achieved: >1500 bottom hole temperatures for oil wells have been compiled and analyzed; temperature-depth measurements have been made on >100 drill holes; the Thermopolis, Cody-Horse Center Anticline, and Saratoga spring systems have been studied in detail, as have areas in the neighborhood of Casper, Midwest, and the Gas Hills; new heat flow measurements are being completed for some 30 localities; a site specific drilling program near Cody is in progress; and combined heat flow and geologic maps for the Rocky Mountain region have been prepared. A brief summary of the present state of our work is presented below. The principal question discussed here is our proposal for additional work for the coming year (June 1, 1980-May 31, 1981).

Circumstances to be considered are the following (See Figures 1 and 2 for localities):

1. While our analyses of bottom hole temperatures, subsurface gradients and other geothermal data greatly expand the inventory of hydrothermal resource data for Wyoming, the actual investigated area (∿5000 mi^2) is too small to permit reliable assessment of this 95,000-100,000 square mile region. One important justification for additional work, therefore, is that there is a critical need for data in large, unstudied

areas. We plan to improve knowledge of the resource base in these areas in at least four ways: 1) with measurements of temperature in water wells and other accessible drill holes; 2) from compilations and analyses of bottom hole temperatures in oil wells; 3) with analyses of water composition; and 4) with compilations of regional geology and geophysics.

2. Research to date shows that indicated low temperature resource areas must be examined in detail and on an individual basis, if reliable reservoir models are to be obtained. The Thermopolis, Cody-Horse Center anticline, and Salt Creek Oil Field (Midwest) thermal anomalies (Fig. 1), for example, can be explained by hydrologic circulation in the vicinity of anticlinal structures. In contrast, the hot springs and/or high gradients in the neighborhoods of the Saratoga Valley and the Gas Hills (Figs. 1 and 2) appear to be fault controlled and perhaps related to narrow subsurface reservoirs. The controls are not understood in other areas (Auburn, Alcova, Lander, DuBois, etc.), but studies are in progress. This research is expected to extend into the new year of research. Related studies will focus on water quality, regional porosities and permeabilities, and quantification of indicated resources.

3. Although the present distribution of heat flow is incomplete and irregular, it does suggest interesting possibilities as well as directions for further study. Briefly, more heat flow values are needed for the Powder River Basin, the Owl Creek Mountains-Bridger Mountains area, the Absaroka Mountains and the Southern Rockies in extreme southeastern Wyoming (Fig. 2) because there is new evidence for

($>$1.8 HFU ($\pm$ HFU = 1 x 10^{-6} cal/cm^{2}sec = 41.8 m W/m^2)) and thus buried geothermal reservoirs in parts of these regions. The new low to intermediate heat flow values (.9-1.7 HFU) in parts of the Green River, Great Divide and Laramie Basins and the Medicine Bow-Sierra Madre Mountains area (Fig. 2) imply that they are not "viable" geothermal areas. However, like most of Wyoming, the sites are too few and too widely scattered to permit accurate generalizations for these large provinces. The final resolution of these questions may require comprehensive drilling specifically for heat flow measurements, but considerable amounts of new data can be obtained using holes that were drilled for other reasons. Possible research sites are listed in Table 1; others are likely to become available during the coming year.

4. The relatively large increase in drill hole measurements (108 vs. 20-30) has come mainly through intensive cultivation of working relations with mining and other exploration companies. Additionally, the U.S. Geological Survey, the Wyoming Geological Survey, and State of Wyoming personnel have given their complete cooperation. As a result, we have access to locations for numerous water wells in the region. The general public appears to be similarly enthusiastic; for example, it is not unusual for us to receive letters from people describing previously unknown thermal springs or wells. This cooperation and interest has therefore led to an almost continual stream of information on drill holes, etc., and the number is likely to increase in the next year as exploration for water, uranium and other resources continues its upward spiral. There is little doubt, therefore, that much temperature, water quality and other pertinent data can be obtained if the program is handled by qualified personnel. Because necessary equipment and facilities are

already at the University, continued research and exploitation of facilities, equipment and cooperation depends mainly on funds for salaries, field expenses, supplies and equipment repair and replacement and in some cases contract casing, as discussed below.

5. The program now terminating has created a sizeable group of Wyoming personnel with expertise in various aspects of hydrothermal resource evaluation. Interest is likely to remain high: a M.Sc. thesis on heat flow in southern Wyoming and northern Colorado will be completed by June of 1980 (by K. L. Buelow); an experienced M.Sc. candidate in geophysics (Mr. Eric Medlin) from the University of Florida will join our research team in May of 1980; and a "qualified" Ph.D. candidate (Mr. Doug Hanson) wishes to begin geothermal energy research by June of 1980. Considered together, the principal investigators and these students would be a solid group that could accomplish a large amount of resource identification, if new funds are provided.

In view of the above considerations, another year of research on hydrothermal resources in Wyoming is proposed. Primary emphasis would be placed on an assessment of the low and/or moderate temperature resources with direct-heat applications, by compiling and studying temperatures, heat flow, water qualities and other pertinent geothermal, geologic and geophysical data for large areas of the state. However, moderate or high temperature resources also could be defined because there is evidence for high heat flow zones in the regions that would be studied.

PROCEDURES: ACQUISITION AND AVAILABILITY OF DATA

Research would be conducted by five full-time personnel. We propose to divide the state into four quadrants and require that one full-time researcher manage the resource assessment of an entire quadrant. The principal investigators will oversee all aspects of data acquisition and interpretations to insure that the same quality control and procedures are used during research in each quadrant.

Research in the Summer and Fall of 1980 would focus on area by area measurement of temperatures in water wells, exploration holes, or any accessible and reliable underground opening. Concomitant field work would involve the collection of samples of water from flowing or pumpable wells; these samples would be sent to the University of Utah Research Institute (UURI) for chemical analyses. The program in the Winter and Spring of 1980-81 would focus on analyses of data collected in the previous field season, and compile pertinent geologic and geophysical data for each area. Other work in 1980-81 would involve preparation of maps and final reports.

Interpretations and resource assessments would focus on areas in which subsurface temperatures are in the range 30°-$60^{\circ}C$ at depths near 1.0-1.5 km. However, we would also compile gradients, depths, etc., for holes in which $T < 30^{\circ}C$ because these data can yield estimates of the depths to potentially usable low temperature reservoirs. Special attention would be given to areas characterized by high geothermal gradients. Evidence for high gradients and flux in the Gas Hills and Powder River Basin areas was mentioned above; new drilling in both areas should provide a valuable opportunity for more subsurface temperature studies and thus better definition of any resources. Other topics will be investigated; for example, the thermal waters in the Madison Formation in the Big Horn Basin area and the Gas Hills. We cannot be more specific without closer examinations of available data. At present we have access to all of the well logs at the Wyoming Geological Survey and at State offices in Casper. Data for new wells would be examined as records are released and stored in the nearby offices of the Geological Survey of Wyoming.

Water quality data, depths to water, aquifer productivities, regional hydrology and pertinent geology would be compiled for all investigated areas. Water quality must be studied because the environment can be contaminated if certain elements (e.g. Hg, As, S) in some geothermal fluids are not disposed of properly, and because low-temperature heat exchanger systems must be designed according to local water compositions (Wright, 1978). It is equally important to compile specific data or "educated" generalizations on regional aquifer production, hydrology, geologic structure, and proximity of potential resources to communities. It is sufficient to state that a resource is not likely to be developed, if the yield of water is too small, or the market is distant, regardless of the temperature at reasonably shallow depths. Geologic and hydrologic data would be obtained from the literature and records of the U.S. Geological Survey in Cheyenne, Wyoming. Water quality data would be abstracted from the literature, and six previously promised water analyses, and from water analyses provided by UURI.

Regional heat flow and radioactivity studies would be continued throughout the region. We plan to use shallow holes and a limited number of "shut in" oil wells. Thermal conductivities of regional units will be used to determine heat flow in established oil fields, hard rock areas and other regions. Basic heat flow and radioactivity (U, Th, K) data would be collected using well established techniques. To insure acquisition of reliable data in critical areas, selected holes would be cased so that they would remain open for temperature measurements.

DELIVERABLES

All data would be used to update file GEOTHERM of the USGS. Maps for the public and geoscientists would be prepared according to requirements of the Department of Energy, NOA, the USGS, and UURI. All written reports would attempt to quantify reservoirs with direct-heat or other applications.

Short status reports and preliminary results would be submitted to the U. S. DOE on a monthly basis. We expect to furnish the following "hard" deliverables by July, 1981.

1. A compilation of locations, temperatures, depths, gradients, and, if possible, depths to water for the four quadrants of Wyoming. Regional maps of subsurface temperatures and depths would be supplied with the data, as would written reports. Available water quality and aquifer production data would be incorporated into the reports, as would relevant stratigraphy and geologic structure. The maps would show pertinent control points and relevant geology.

2. Regional gradient maps and interpretations thereof would be prepared and delivered. These deliverables would reflect local geology and the thermal properties of local rock units. This would be done because the conductive gradient varies sympathetically with corresponding conductivities of the local rocks. Reports would also summarize available shallow and deep water quality data, aquifer disposition, and aquifer production. We expect to deliver detailed reports and maps for areas that could be prospectively valuable for near term direct-heat or other applications. One of these areas is expected to be the Powder River Basin, where the Madison Formation is known to locally contain thermal waters.

3. The now terminating program will provide reports on the Thermopolis area, the Cody-Horse Center anticline, the Gas Hills area, the Saratoga area, and the Casper-Midwest area. The new program would be arranged so that research on the Saratoga, Casper-Midwest, Auburn and DuBois areas is expanded to include data for regions within a 20-30 mile radius of each suggested resource. This detailed research will be done to better define their lateral extents, and to quantify the magnitude of each reservoir. Other systems would be analyzed in a similar manner as data are located. Reports would directly follow available drill hole data, the geologic and hydrologic literature, and the proximity of resources to population centers.

4. Chemical analyses will be delivered for six heretofore unanalyzed springs or spring systems. These were to be furnished by the now terminating project, but bad weather and the urgency of drilling in the Cody area prevented us from doing such. Water samples and analyses would be accompanied by descriptions of collection sites, local geology and other pertinent geoscience data. From cooperative studies with qualified personnel elsewhere (e.g. the USGS), we expect to deliver preliminary interpretations of the chemical analyses. Following procedures of Breckenridge and Hinckley (1978), these analyses would be done in the laboratory of the Wyoming State Chemist. We also plan to try to collect samples of subsurface waters in areas where gradient data are collected and where existing waters, etc., are flowing or can be pumped. As mentioned above, analysis of these samples will be done by UURI. We believe that 70-75 samples will be sent to UURI for analysis.

5. An updated (1981) regional heat flow map would be delivered, as would detailed maps of gradients and heat flow in prospectively valuable areas. All maps would be interpreted. Both heat flow and available radioactivity data would be used in interpretations. We expect to acquire heat flow data for at least twenty new stations.

One of the tasks of our 1979 program was to contact case about 12,000 feet of drill holes for heat flow studies. This was not possible in many of the suggested areas because of the early onset of winter. It is also true that casing was not needed in many areas because we were able to obtain some 30-35 heat flows, rather than the promised 20. We therefore request permission to carry over $10,000 of 1979 funds so that they can be used to contract case about 5,000 of drill holes (~5) in 1980-81.

PERSONNEL

Dr. Edward R. Decker, Professor of Geology, would be ultimately responsible for every phase of the research. During the academic year, he would devote 50 percent of his time to research and 50 percent to teaching. The summer of 1980 would be entirely devoted to the proposed research.

Mr. Henry P. Heasler would be co-investigator of the project. He would be in immediate charge of most of the library and field research. He would work intimately with Decker on all aspects of the project. Heasler holds an M.Sc. degree in geothermal studies, and is a co-investigator of the 1979 program.

A new research associate would be employed by June 1, 1980. We expect the associate to be K. L. Buelow, an M.Sc. candidate in geophysics (heat flow), at Wyoming. Buelow is very familar with all aspects of the University's procedures for field and laboratory studies of heat flow.

Other personnel would consist of a half-time secretary, three summer field assistants, and two research assistants for the academic year (September, 1980-May 15, 1981). One part-time assistant would also be employed during the academic year.

FACILITIES

Wyoming's heat flow equipment includes portable and truck-mounted temperature cables (1- 2 km lengths), two pick-up trucks, three divided-bar systems for thermal conductivity measurements, a conductivity sample saturation facility, a temperature calibration facility ($-30^{\circ}C$ to $235^{\circ}C$, $\pm$ $.001^{\circ}C$ control), and a gamma ray system (two 5" x 4" NaI(Tl) crystals) for measurements of uranium, thorium and potassium. The temperature calibration facility is traceable to the U.S. National Bureau of Standards. The gamma-ray system and standards are modeled after those used by C. M. Bunker of the U.S. Geological Survey, Denver Federal Center, Denver, Colorado.

The University has XDS Sigma 7 and CDC Cyber computers with multiple stream batch and time-sharing capabilities. Calcomp and Versatec plotters are connected to the computers. The Department of Geology has three time sharing terminals that are connected to the computers. proposed investigators are experienced computer programmers; so digital data and preliminary maps and figures could be readily prepared at the University. We request funding for computer time or other services because the University recently initiated a charge for computing, etc.

The College of Arts and Sciences in the University has well-staffed electronic and machine shops. Both shops have much experience with construction and maintenance of geothermal equipment. The machine shop also expertly prepares conductivity samples. The Geology Department employs an electronics technician.

The Wyoming Geological Survey occupies offices, etc., in a facility that is connected to the building occupied by the Department of Geology. The U.S. Geological Survey maintains offices in the building of the Wyoming Geological Survey. We enjoy good support and relations with these offices and personnel, and with U.S.G.S. and state personnel in Cheyenne.

PRESENT RESULTS

Our first year of research involved detailed studies of indicated low-temperature resource areas, compilations of regional geothermal data, and syntheses of pertinent geology and geophysics. Compilations of geothermal data directly followed >1500 bottom hole temperatures in oil wells, and measurements of temperatures in more than 100 drill holes. The regional geology and geophysics were synthesized from published articles. Present results are summarized below.

The Thermopolis Area. Temperatures, gradients and regional geology have been compiled for a 1800-1900 mi^2 area that is roughly centered on the Thermopolis hot springs (Figure 1). The results demonstrate that the thermal anomaly occurs all along the central part of the Thermopolis anticline, occupying a 20 mi long by 3 mi wide area that strikes west-northwest between the southwestern part of T. 43 N., R. 93 W. and the southeastern part of T. 44 N., R. 96 W. (Fig. 3). Within this zone, calculated gradients range from 43 to 300°F/1000 ft (78-547°C/km) and tabulated bottom hole temperatures are in the range 90°F(32°C)-160°F(70°C) at depths less than 2000 feet ($\sim$.6 km). Because downward continuation of the lower gradients predicts 60$^{+\circ}$C temperatures at depth between 3500 and 4000 feet (1.1-1.2 km), all of the middle part of the structure is considered a viable low temperature resource area.

The Red Springs Anticline area in T. 43 N., R. 93 W. may be a "marginal" resource area. Here the calculated gradients are in the range 24-59°F/1000 ft (43-107°C/km) (Fig. 3). Consequently 60+°C waters might be encountered at 3900-4500 ft depths (1.2-1.3 km) here.

The narrow boundaries of the Thermopolis-Red Springs anticlines anomaly suggest that "thermal waters" would be at shallow depths. The best examples are the changes from 43-300°F/1000 ft (78-547°C/km) gradients from the Thermopolis anticline to the 11-23°F/1000 ft gradients about 5-6 miles (8-10 km) to the north-northwest (Fig. 3). The 10-25°F/1000 ft (18-46°C/km) gradients at five sites 5-10 miles (8-16 km) southwest of the anticline also suggest that shallow sources are responsible for the increased gradient in the middle part of the structure.

A tightly folded syncline is located immediately south of the Thermopolis anticline. We believe that waters from the Owl Creek Mountains are heated at the bottom of this syncline. Subsequent upward movement of these waters along the northern flanks of the syncline could explain the high gradients in the anticline. The thermal waters are mostly likely to be in the Tensleep and/or Madison Formations, two formations with porosities and permeabilities sufficient to yield the flow rates (2800 gpm (Breckenridge and Hinckley, 1978)) of the spring system in Hot Springs State Park. Within the central part of the anticline, the "tops" of the Tensleep and Madison range from 200-2800 ft (0.6-.85 km) and 800-3450 ft (.24-1.08 km), respectively. It is possible, therefore, that these aquifers could be reached with economical drilling in some parts of the structure.

Referring to "practical" aspects of resource development, one question that must be answered is whether drilling and large scale development would change temperatures and flow rates of the Thermopolis hot springs. Lack of data on porosities and permeabilities of the regional subsurface units also could impede development, as could the data for the springs which suggest that regional thermal waters would contain large amounts of total dissolved solids (2300 ppm (Breckenridge and Hinckley, 1978)). Finally, minor structures along the crest of the anticline should be carefully considered during drill site selection; for example, numerous faults cross cut the northwest-southeast trend of the anticline, and a heretofore unmapped fault is evident on air photos of the structure.

The Cody-Horse Center Anticline System. This potential resource area seems to be bounded by the DeMaris hot springs (27-36°C, 1700 gpm) just west of Cody and the Horse Center anticline about 7 miles to the south (Fig. 1). The first evidence for a low-temperature resource was provided by the 49-205°C/km gradients calculated using bottom hole temperatures in eleven dry oil wells in the anticline. Recent down hole measurements by Wyoming personnel agree with the oil well data. For example, least-squares gradients and maximum temperatures based on measurements in five shallow wells are in the ranges 96-190°C/km and 38.4-47.5°C, respectively, at subsurface depths in the range 185-500m.

The Rattlesnake anticline is between Cody and the Horse Center anticline. As seems to be the case elsewhere in the area, the Chugwater Formation in this anticline appears to be an impermeable cap rock that overlies porous, permeable and perhaps water-bearing units in the Tensleep and Madison Formations. From recent detailed geologic mapping, we believe that ~60°C waters might be encountered at ∿300 m depths in the vicinity of the southeastern flank of this structure. Confirmation of a reservoir at such temperatures and depths with adequate flow rates is of great local interest because the resource could be used in two possible projects, a housing development or an alcohol plant.

The inferred most promising area is presently being examined with a drilling program that started in January of 1980. From measurements in four ∿100 m drill holes, the gradients off the flank of the Rattlesnake anticline are in the range 130 to 200°C/km. Concomitant bottom hole temperatures at these depths are in the range 20 to 29°C. We hope to complete at least one 300+ meter hole in the Madison Formation by the end of the third week in March, 1980. Observed temperature, water geochemistry and flow rate studies for this locality would provide data on the base temperature and other important characteristics of the indicated system.

The Casper-Midwest Area. The town of Midwest is about 40 miles north of Casper (Fig. 1). Because of much local interest in utilization of hydrothermal resources in protected housing developments, considerable effort has been spent researching these areas. Present data consist of more than 1000 bottom hole temperature points, from which combined temperature gradient and geologic maps are being prepared.

Most of our data are for areas near Midwest. These results clearly show that the Salt Creek Oil Field is a conspicuous thermal anomaly. Within this 10-12 mi^2 field, bottom hole temperatures between 1000 and 4500 ft (.3-1.4 km) are in the range 120°F-170°F (49-77°C), and maximum calculated gradients are between 40 and 100°F/1000 ft (72-182°C/km). Additionally, water injection wells that penetrate the Madison Formation produce 160-175°F (71-79°C) waters that flow to the surface at rates exceeding 7000 gallons/min. There can be little doubt, therefore, that the Salt Creek Field could be used to produce hydrothermal fluids for direct-heat applications in the vicinity of Midwest. The major impedances to resource development could be the relative values of hydrocarbon and geothermal resources, the high concentrations of solids in the non-potable waters, and the question of whether AMOCO Production Co., Wyoming, or the Federal Government owns the geothermal resource.

Scant data exist for the Casper region because fewer oil tests have been drilled in the area. The available data do suggest, however, that most of the region within a 10-15 mile radius of the city is not thermally anomalous. However, two areas near the city are being examined in greater detail: 1) the Emmigrant Gap Ridge, where 3 bottom hole temperatures are 90-117°F at depths between 1350 and 1550 ft; and 2) the airport area, where a 202°F bottom hole temperature was logged in a 2922 ft. deep well. The 200°F temperature obviously is of particular interest and much effort is being spent to confirm the measurement, find supporting data, and interpret the local geologic structure.

<u>The Gas Hills Area</u>. Research before 1979 revealed the presence of high gradients (42-100°C/km) at 8 isolated drill holes on the Beaver Rim in the Gas Hills (Fig. 1). New data consists of 20 bottom hole temperatures and temperature measurements in 31 holes that were drilled during uranium exploration. Maps of heat flow, gradient and regional geologic data are in various stages of compilation.

The present data are consistent with a complex pattern of gradient and flux in the Hills. Briefly, observed gradients range from 20°C/km to 100°C/km and estimated heat flows are in the range of 1.2-3.4 HFU. From combined geothermal and geologic data, one hypothesis is that faults control the gradient and heat flow patterns. Thus, any development of geothermal resources is likely to require careful mapping of the local geologic structure to delineate fault zones that could yield waters with potential for direct-heat applications. We hope to conduct more studies in the area because the great interest in subsurface uranium could lead to local settlements, and because one deep oil test in the Hills is reported to have encountered high temperature waters in the Madison (J. D. Love, pers. communication, 1980).

The Saratoga Valley Thermal System. The 1979 cooperative agreement has allowed us to establish a gradient and heat flow profile that extends from the eastern edge of the Washakie Basin to the Laramie Mountains (Fig. 2). Gradients and preliminary heat flow values along this profile are in the ranges 7-30°C/km and .9-1.6 HFU, respectively. Two holes on the profile are near the hot springs in the town of Saratoga (Fig. 1). The gradient in the hole about 1 mile west of the springs is 20°C/km, and that in the hole about 1 mile to the east is 30°C/km. Both gradients may be considered "normal," and so these observations suggest that the Saratoga hot springs (∿50°C (Breckenridge and Hinckley, 1978)) are not surface manifestations of a subsurface hydrothermal system with large dimensions. The narrow width of the system, in turn, suggests that the springs could be flowing from faults in this part of the Saratoga Valley. This view is supported by geologic evidence for a fault zone near the spring system (Montagne, 1955). Like the Gas Hills, development of geothermal resources in the Saratoga area may require additional research on the correlations between faulting, subsurface temperatures and heat flow in the region.

We may speculate that moderate or higher temperature resource areas could be present at shallow depths in the region between the Saratoga Valley and the Southern Rocky Mountains in northern Colorado (Fig. 2). From our new data, the heat flow is normal or low (.9-1.6 HFU) in the Saratoga Valley-Sierra Madre Mountains-Medicine Bow Mountains region in Wyoming, whereas the flux is high (>2.4 HFU) at Hahns Peak and Northgate, Colorado about 50-60 km to the south.

Interpreted in terms of steady or transient heat sources, the width and magnitude of the transition suggest that the excess flux in northern Colorado is partly due to high temperature heat sources at shallow depths in the crust and/or upper mantle. This view, in turn, is consistent with geothermal reservoirs in the transition zone and the high heat flow area immediately to the south.

The Big Horn Basin, Excluding the Thermopolis and Cody-Horse Center Systems. Bottom hole temperature data have been compiled and analyzed for ∿150 oil wells that are within a triangular area bounded by Worland, Meeteetse and Thermopolis in the southern part of the Big Horn Basin (Fig. 2). The widely scattered data points cannot be interpreted in detail, but one general conclusion is that the geothermal gradients increase between Worland and the Absaroka, Wind River and Owl Creek Mountains to the west, southwest, and south, respectively. Confirmation of this regional variation(?) would be important because it suggests that any low-temperature reservoirs are most likely to exist along the flanks of these mountains.

A new heat flow value of 1.78 HFU has been determined for Meadow Creek Basin in the eastern part of the Absaroka Mountains. This flux and Blackwell's (1969) 1.8 HFU value near Kirwin about 20 km to the south suggest that a large part of the Absarokas is a zone of high flux like the western Great Basin. Additional evidence for Basin and Range type flux in these mountains, in turn, would suggest that low-temperature reservoirs could occur in this part of northwestern Wyoming.

Temperatures have been measured in 15 drill holes in the Bridger Mountains (Fig. 2). Although some of the observed gradients (5.3-12.8°C/km) are consistent with local hydrologic disturbances in these mountains, the most reliable values of 19.0-22.6°C/km support earlier suggestions that the Lysite-Bridger Mountain area is a zone of above-normal heat flow (see Decker and others, 1980). Like the elevated flux in the Absarokas to the northwest, the above-normal regional heat flow may imply the presence of hydrothermal reservoirs locally in the Bridger Mountains.

The Wyoming Basin. New temperature-depth data for seven widely separated localities in the Great Divide-Green River Basins area (Fig. 2) yield gradients in the range 17-30°C. Estimated heat flows near Eden, Wyoming are 1.6-1.7 HFU, values that agree with Sass and others' (1971) conjecture that this locality is in a zone of normal to intermediate flux. New heat flow values (8) in the Rawlins Uplift-Laramie Basin part of the Wyoming Basin (Fig. 2) are low to normal (1.1-1.3 HFU). We, therefore, conclude that there is very little geothermal evidence for shallow reservoirs with direct-heat potential in the eastern Wyoming Basin, although there are very few control points in this province.

The Powder River Basin, Excluding the Casper-Midwest Area. Head and others (1978) have contoured depths and temperatures for the Madison Formation in the Powder River Basin (Fig. 2). The temperatures and assumed permeabilities of this unit suggest that it could yield vast quantities of waters adequate for direct-heat applications. It is also the case, however, that the Madison is at great, perhaps uneconomically drilled depths in many parts of the area. Consequently, our studies of the Basin have focused on shallow temperature, gradient and heat flow measurements.

Two reliable heat flow values are now available for the Douglas low-temperature resource(?) area (Fig. 1). The values are in the range of 2.0-2.2 HFU. These drill holes are in an area where underlying Madison Formation is dipping up to shallower depths from the north -northeast. Perhaps upward circulating waters in the Madison explain the observed above-normal flux. More reliable definition of the suggested resource area will require additional research with shallow drill holes.

Gradients in 5 shallow holes near Torrington are in the range of 23-29°C/km. In the Wright area to the north, measurements in 10 holes suggest that the undisturbed regional gradient is between 19 and 29°C/km. The meaning of these data are obscure, but one interpretation is that the eastern part of the Powder River Basin is characterized by a complex pattern of normal to high heat flow and perhaps shallow low-temperature hydrothermal reservoirs in isolated areas. We cannot be more specific without more geothermal data for these and other parts of the Basin (Fig. 2).

Maps of Regional Heat Flow and Geology. Figures 4 and 5 are maps of heat flow and generalized geology in Southern Rocky Mountain and Northern Rocky Mountain regions, respectively. The maps were prepared shortly after the beginning of our 1979 program using U.S. DOE funds. They are presently in press in Chapter 13 of a new book entitled "Physical Properties of Rocks and Minerals" that is being published by McGraw Hill and Purdue University. The proposed principal investigators are co-authors of the chapter.

The maps permit rather easy visualization of correlations between flux, faulting and/or bedrock geology. Updated versions of the Wyoming part of the Northern Rocky Mountain region map will be submitted to the U.S. DOE in our final report on research in 1979.

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BUDGET: Funds are requested for the period June 1, 1980 to May 31, 1981, a period that includes the University's entire academic year.

Salaries	From the U.S. DOE	University of Wyoming
Principal Investigator (Decker)		
13 weeks summer, 1980)	9777.00	
10 weeks, acad. yr 1980-81		9192.00
Co-Investigator (Heasler)		
1 mo. (June, 1980)	1346.00	
11 months (July-May, 1980-81)	16291.00	
Research Associate II-		
12 mo. (June, 1980-May, 1981)	15000.00	
Secretary - Half Time	4000.00	
Graduate Assistants		
Summer 1980 3 people x 13 wk x 40 hrs x $5.45/hr.	8502.00	
Acad. yr 80-81 2 people $4500	9000.00	
Part-time Assistant		
40 weeks x 15 hrs x $5.00	3000.00	
	66916.00	9192.00
Fringe (17% x 54916.00)	9336.00	1563.00
	76252.00	10755.00
Travel		
Field expenses, per diem 250 da x $40	10000.00	
Expenses for permanently consigned field trucks (2), 40,000 mi @ .25	10000.00	
Rental of Univ. Wyo. Car Pool vehicle summer, 1980, 10,000 mi @ .25	2500.00	
Travel to US DOE meetings (Salt Lake City, Idaho Falls, Washington, D.C.	2500.00	
Total Travel	25000.00	
Expendable Equipment		
Replacement of Armoured cable (4000' at $2100 and Portable cables (6000' at $1900 Total	4000.00	
Other costs		
Supplies (thermistors, probe parts, standards, water sample containers, computer cards, tapes, etc.)	4500.00	
American Tel and Tel	2000.00	
Publication chartes (drafting, etc.)	3000.00	
Processing of data, etc. 600 mi/$4.00	2400.00	
Machine and Electronics shop time (prepare conductivity samples, construct and repair equipment, etc.) 800 hrs @ $2.50	2000.00	
Chemical analyses (6 @ $100.00	600.00	
Contract Casing (casing and rig time) 6500feet @ $2	13000.00	
Total Other costs	27500.00	
TOTAL DIRECT COSTS	132752.00	10755.00

continued . . .

TOTAL DIRECT COSTS	132752.00	10755.00
INDIRECT COSTS 48.5%)	32454.00	4458.00
	165206.00	15213.00
Less carry-over from 1979	10600.00	
	154606.00	15213.00
NEW AMOUNT REQUESTED FROM U.S. DOE	154500.00	

TABLE I. Areas in which drilling will occur in 1980-81. Localities may be visited and/or cased for subsurface geothermal measurements.

Locality	No. of Holes,	Depth Range
Absaroka Mtns. (Sunlight Basin)	19,	up to 1000'
Beartooth Mtns. (Cooke City)	2-4,	200-400'
Bighorn Mountains	2-4,	200-300'
Central Part Bighorn Basin	6-10,	<700'
Laramie Mtns, Southern (Diamond Exploration)	6-12,	up to 1000'
Sierra Madre-Medicine Bow Mountains	4-6,	up to 1000'
Saratoga Valley	2-4,	up to 1000'
Laramie and Shirley Basins (Rock River to North)	>10,	700-1000'
Rawlins Area	> 3,	1000+ ft.
Ft. Collins, Colo. Area	12+,	500-700'

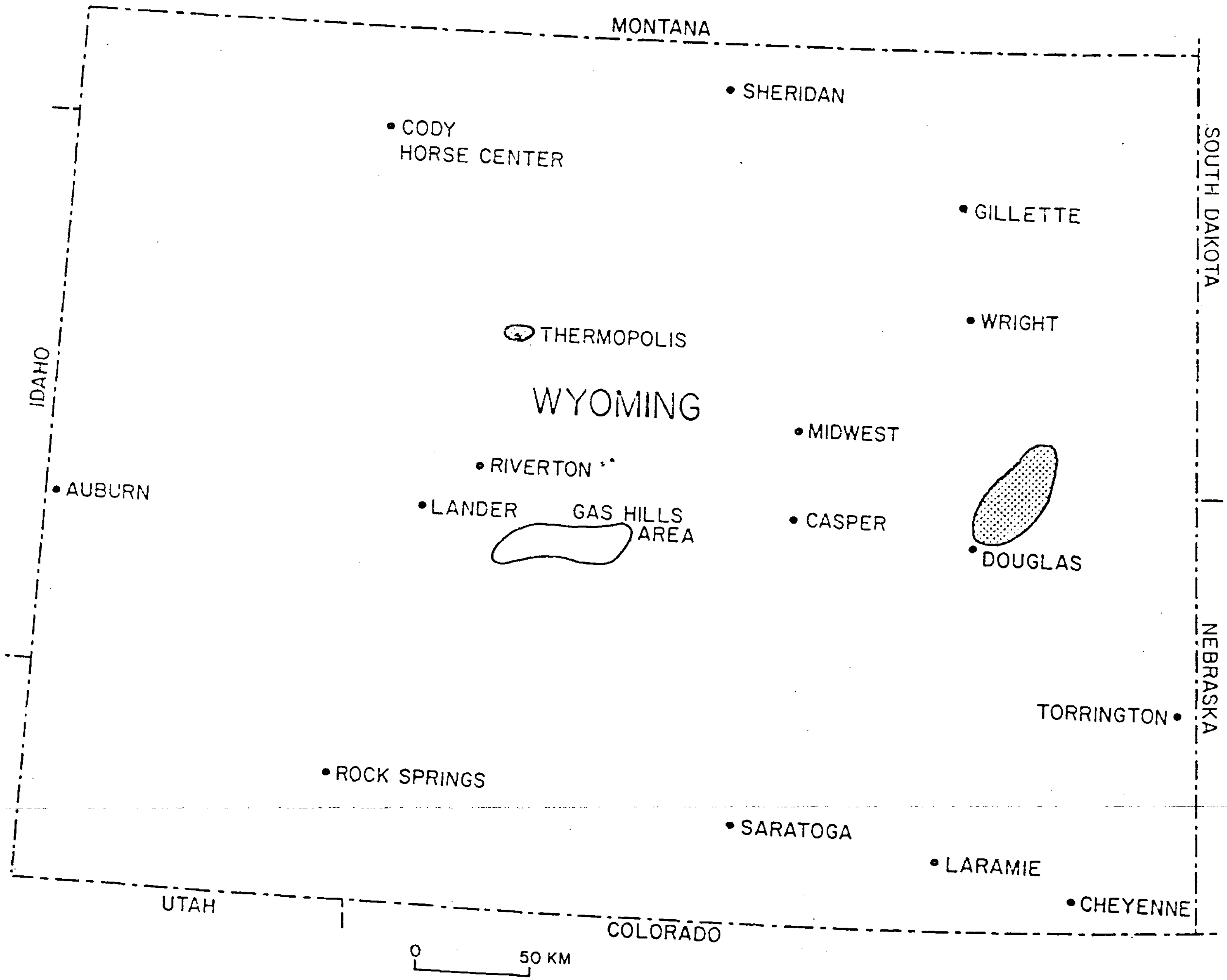


Figure 1. Map showing research localities in Wyoming. Cross-hachured areas may contain low temperature hydrothermal reservoirs.

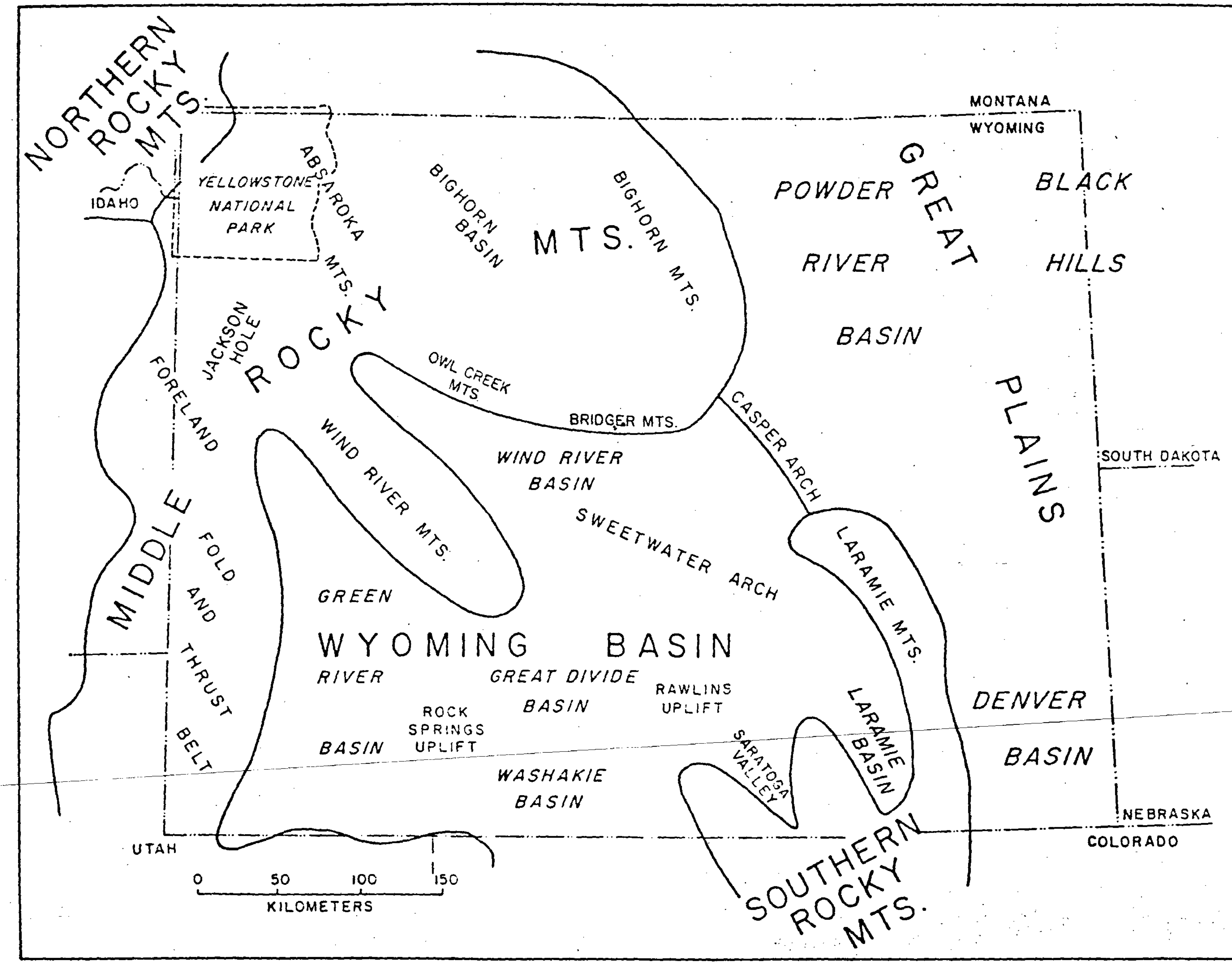


Figure 2. Map of physiographic provinces and major structural elements in Wyoming.

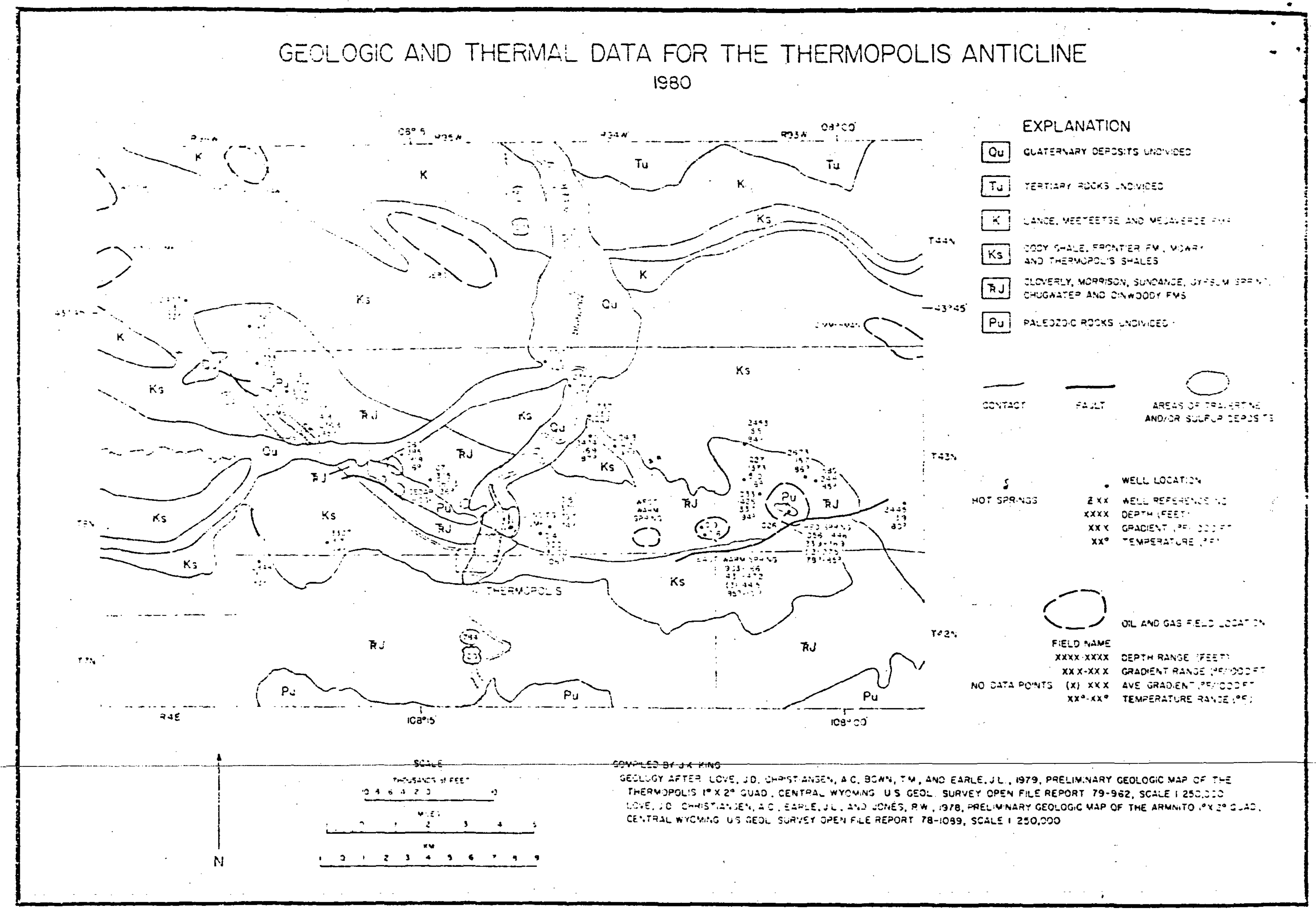


Figure 3. Geologic and thermal data for the Thermopolis anticline area.

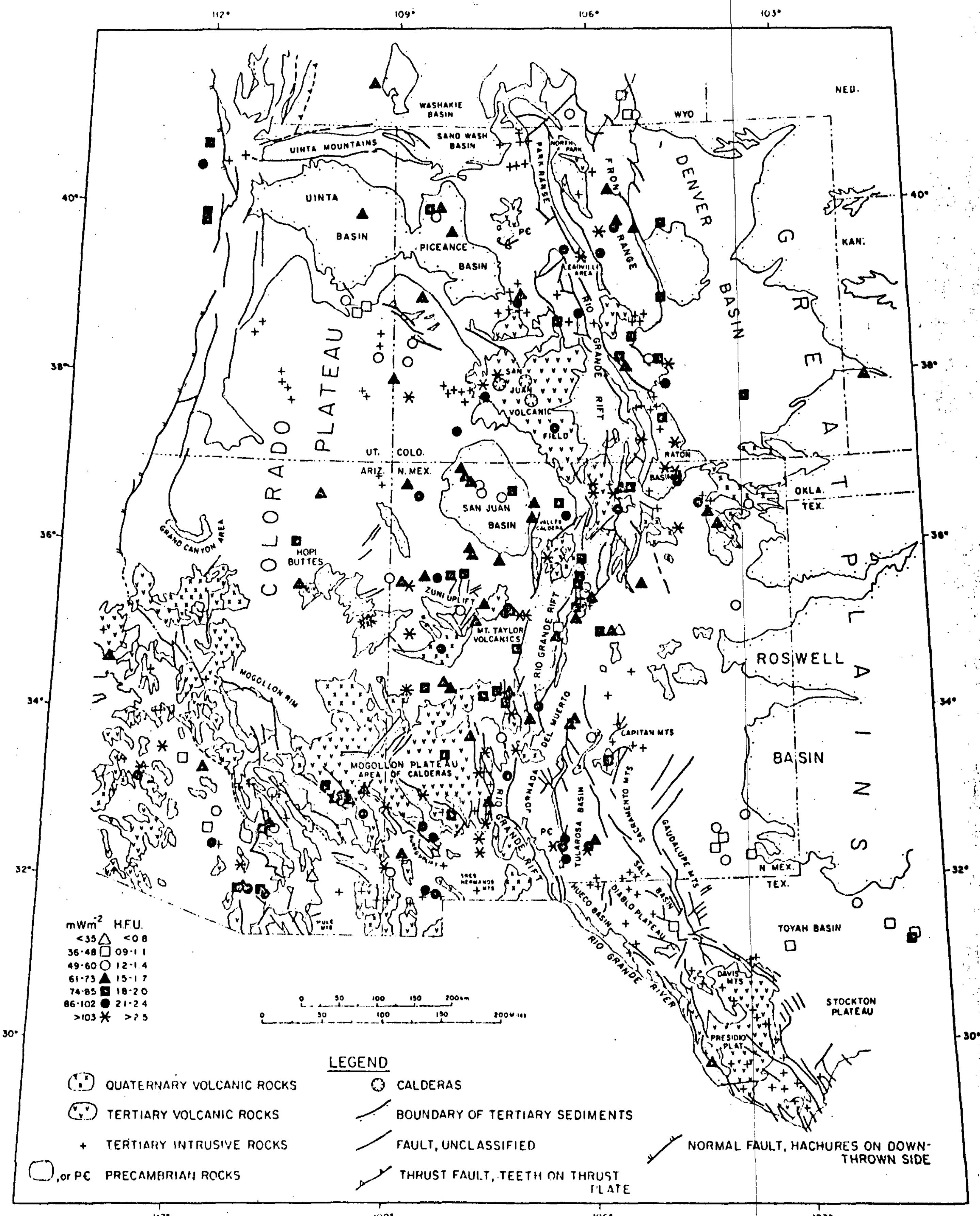


Figure 4. Heat flow and generalized geology in the Southern Rocky Mountain-Rio Grande rift region.

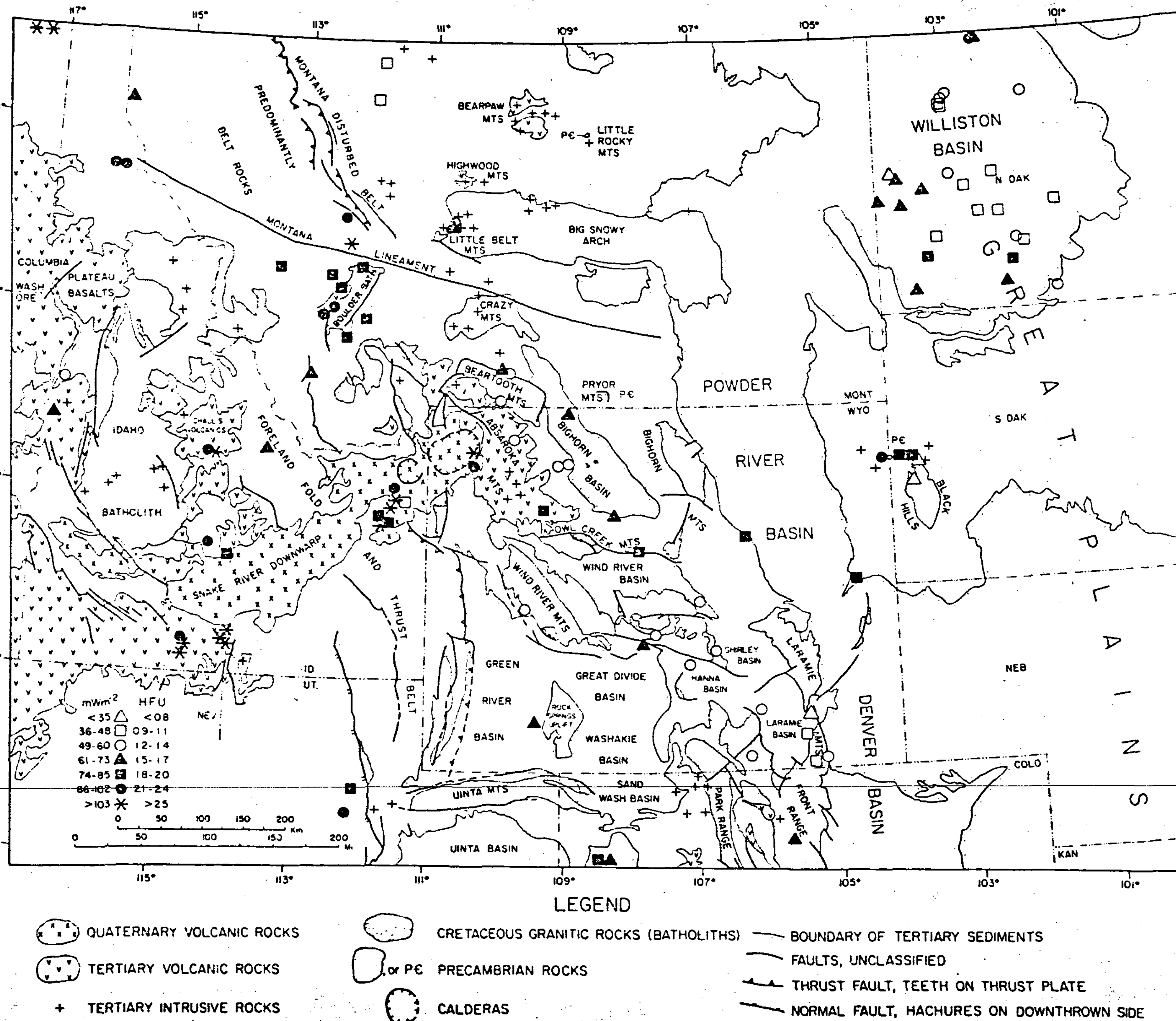


Figure 5. Heat flow and generalized geology in the Northern and Middle Rocky Mountain region.

THE UNIVERSITY OF WYOMING

DEPARTMENT OF GEOLOGY & GEOPHYSICS
GEOLOGY BUILDING
P. O. BOX 3006

LARAMIE, WYOMING 82071

PH. 307-766-3386

February 1, 1982

Ms. Susan M. Prestwich
Department of Energy
Idaho Operations Office
550 Second Street
Idaho Falls, ID 83401

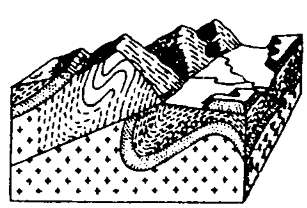
Dear Susan:

This letter and accompanying enclosures constitute the September, October, November and December technical progress reports for work accomplished under contract DE-RC07-79ID 12016. Attempts have been made to complete the technical reports on a monthly basis, however certain projects such as the Wyoming geothermal map and testifying before the U.S. Senate Public Lands and Reserve Water Subcommittee have taken priority. In the future, a more concerted effort will be made to file technical progress reports monthly.

In this time period, two important discussions of Wyoming's geothermal potential occurred. These consisted of testimony by Henry Heasler before the U.S. Senate Public Lands and Reserve Water Subcommittee on the geothermal potential of Wyoming land adjacent to Yellowstone National Park and an article in the December issue of the magazine Western Oil Reporter concerning Wyoming's geothermal potential. A copy of the Western Oil Reporter article is enclosed. A copy of the testimony will be sent when it becomes available in February or March.

Work continued on the thermal reports for the major sedimentary basins in Wyoming. In the Green River Basin all oil well bottom hole temperatures have been compiled and plotted. A rough draft of the gradient contour map has been completed. In the Bighorn Basin the drafting of the structure, geologic, gradient, and temperature maps has been completed. A rough draft of the written report has also been finished. The Washakie-Great Divide Basin report is being reworked to include more data. In the southern Powder River Basin all bottom hole temperature data has been plotted and thermal gradients contoured. In this basin in the areas of the Salt Creek oil field and Old Woman anticline, 500 drill stem tests have been compiled for the Dakota and Tensleep formations. Hydraulic head data was calculated, plotted, and contoured.

A simple thermal model for the Leucite Hills was defined and calculations completed. The model incorporated known geologic information concerning the age and type of intrusions plus data from wells recently logged



by our group. Preliminary results suggest that the present day heat flow anomaly in the area will be .2 micro calories per M^2sec. Such an anomaly is considered to be indistinguishable from the region's background heat flow.

Between October and December hydrologic data from 148 drill stem tests (92 wells) were collected and analyzed for the Cody area. These data were gathered in an effort to define aquifers and aquifer properties of the Lower Mesozoic and Paleozoic rocks. Potentiometric information was calculated from 125 of the drill stem tests. Hydraulic potential data for the Phosphoria and Tensleep Formations were plotted and contoured for 75 wells in an effort to define the flow direction of the low-temperature water. Hydraulic data confirm the theory that water flow in the Cody area is generally southwest to northeast.

During this time period the following wells were thermally logged by our group; ten wells (400 ft deep) east of Rock Springs, two wells (265 and 900 ft deep) east of Evanston, five wells near Big Piney (2200 ft to 4900 ft deep), two wells (4,300 ft deep) near Granger, one well (1460 ft deep) near Little America, two wells at the Winkleman dome oil field, two wells at the Happy Springs oil field, two wells at the Sand Draw oil field, and three wells at the Circle Ridge oil field. Also three wells of over 4,000 ft depth were logged in Nebraska for Will Gosnold of the Nebraska DOE State Coupled Resource Assessment Program.

In addition to helping the Nebraska State Team, other organizations were aided by our group. Two wells owned by Northwest Community College in northern Wyoming were thermally logged to gather temperature data and to define water levels in the wells for the college. A brief report summarizing temperature-depth relationships for the Bearcreek, Wyoming area was sent to Bearcreek Uranium Company. In September, Dr. Dale Ralston of the University of Idaho and the Idaho DOE State Coupled Program briefly visited Laramie to confer with our group about the geothermal potential of the overthrust belt. We have also cooperated with Los Alamos National Labs by sending a copy of our thermistor calibration program.

User assistance also continued for the Town of Thermopolis. We have sent to Coury and Associates (the engineering firm hired to do the $50,000.00 district heating feasibility study) a final draft of our study on the Thermopolis hydrothermal system. Bern Hinckley of our group has discussed with Coury and Associates temperatures, flows, and locations of the low-temperature water. Mr. Hinckley has also attended the district heating advisory board meetings and discussed the known thermal and geologic information. In September we helped the Town of Thermopolis prepare a proposal to the Wyoming Water Development Commission for hydrologic and thermal studies near the town. This proposal was funded in October for $60,000.00. The project will consist of the hydrologic testing of existing wells (to be done by the hydrologic consulting firm of Anderson and Kelly) and the drilling of a hydrologic and thermal test well (to be sited and supervised by the Geology Department at the University of Wyoming). Henry Heasler and Bern Hinckley will be responsible for the Geology Department's portion of the project which should be completed in the summer of 1982.

During this time period, work progressed on the Wyoming Geothermal map to be published by NOAA in Boulder. Most of the definitions, explanations, and squibbs have been written, gray areas defined, and lists of thermal wells and new published heat flow values compiled. A computer list of over 300 temperature gradient wells is still being edited. On September 1, Henry Heasler and Kenn Buelow attended a meeting of the geothermal map committee in Boulder. Also on October 15, George Berry traveled to Laramie to discuss the Wyoming map. All map material will hopefully be sent for review by NOAA and the map committee in January, 1982.

Two new projects were begun in October and November. A shallow hole was drilled 7 miles west of Laramie for the purpose of monitoring surface temperature fluctuations and their effect on thermal gradient calculations from oil well bottom hole temperatures. The hole was drilled to 120 feet by the Wyoming Highway Department for $450.00 (this money will come from our contract casing category). The hole was cased with 2 inch PVC pipe, cemented in place, and filled with antifreeze and water. Thermal logs of the hole will be taken at periodic intervals to gether data on near surface temperature fluctuations. The other project begun in this time period is our attempt to contact the operators of the fifty largest water producing oil fields in Wyoming. Letters have been sent to these operators requesting flow, temperature, and chemical quality data. This is being done in an attempt to quantify and locate areas where thermal waters are being discharged as waste and could consequently be beneficially used.

In September, October, November, and December over 500 thermal conductivity measurements were completed in our lab. Temperature-depth plots and least squares analysis were completed for most of the thermally logged wells.

I hope that this letter and its enclosure constitute a satisfactory report for work accomplished during September, October, November, and December.

Sincerely,

Henry P. Heasler
Principal Investigator
Wyoming Geothermal
Resource Assessment Group

HPH/tj

Geothermal reserves set for commercial test

Wyoming's potentially vast geothermal energy reserves—often encountered by operators drilling for oil and gas—may soon be tested commercially, opening possible new revenue streams for petroleum companies operating in the state.

The town of Thermopolis is making a $50,000 study of the possibility of heating part of the town with hot water from geothermal wells. The study is funded by the U.S. Department of Housing & Urban Development.

"It would be a test well, politically, administratively and scientifically," says Henry Heasler, a University of Wyoming research associate and a leading authority on the state's geothermal potential.

Heasler points out that drillers who strike hot water cannot transfer the well to municipalities for heating uses because of lack of defined legal procedure to do so. The proposed well in Thermopolis could go far toward clarifying geothermal's legal status.

"We'll be eager to see how various governmental agencies involved handle this project. Once policies and procedures are set, we'll be a lot closer to full-scale geothermal development."

Several areas in the state are waiting to be tapped, according to Heasler's paper, "Geothermal Potential and Development in Wyoming," published in the Interstate Oil Compact Commission's Committee Bulletin for June 1981.

"Temperature gradients and regional geology have been studied in a 2,000-sq-mile area centered on Thermopolis," he says. "The results show that a thermal anomaly occurs all along the central part of the 20- by 3-mile Thermopolis anticline" which runs from 43n-93w to 44n-96w. "Within this area, bottomhole temperatures tested in oil wells range from 90°F to 160°F at depths less than 2,000 ft. Since temperatures increase with depth, we consider the entire region to be a viable low-temperature hydrothermal resource area."

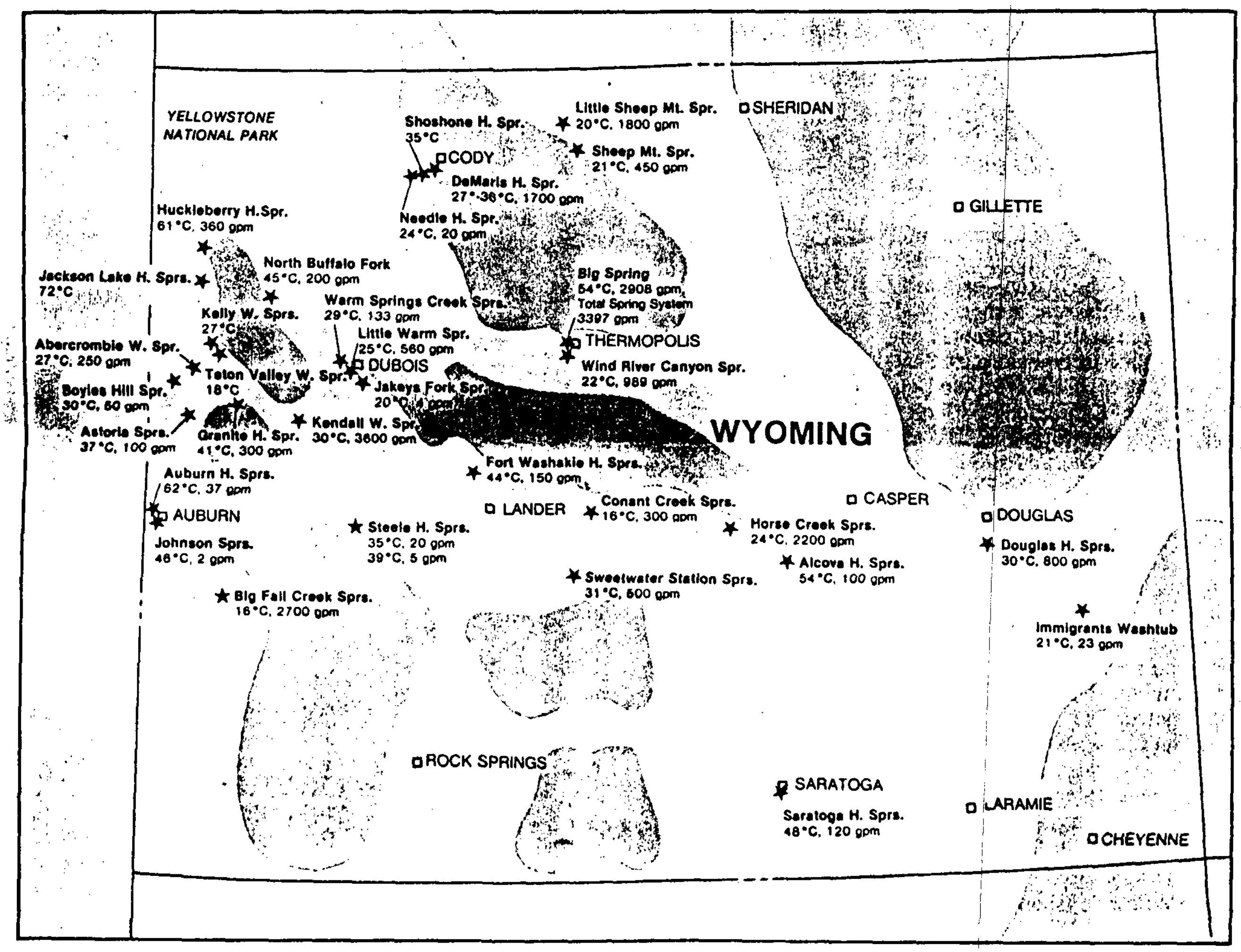
Many researchers believe the anticline's thermal waters are heated at the bottom of a tightly folded syncline abutting it on the south. The waters are thought to flow in the Tensleep and Madison formations, which lie in the anticline at depths between 200 to 3,450 ft.

"It's possible that these aquifers could be reached with economical drilling in some parts of the structure," Heasler notes. However, reliable data are not yet available on the waters' natural pollutants or on the many faults that cross-cut the anticline and could complicate drilling.

Another area of considerable potential has been found along the Horse Center anticline about seven miles south of Cody. Six test wells drilled in 52n-102w by the university's geology department in 1980 showed that waters of 93°F. can be reached at depths of less than 1,000 ft. Highest temperatures in the area near 149°F., and are found between 850 and 1,640 ft. The waters are held in Tensleep sandstone, Madison limestone and Bighorn dolomite, and are probably heated in a syncline to the southwest.

Near Casper, interest is strong in

Wyoming's thermal springs



Hot springs often signal underground reservoirs of geothermal energy.

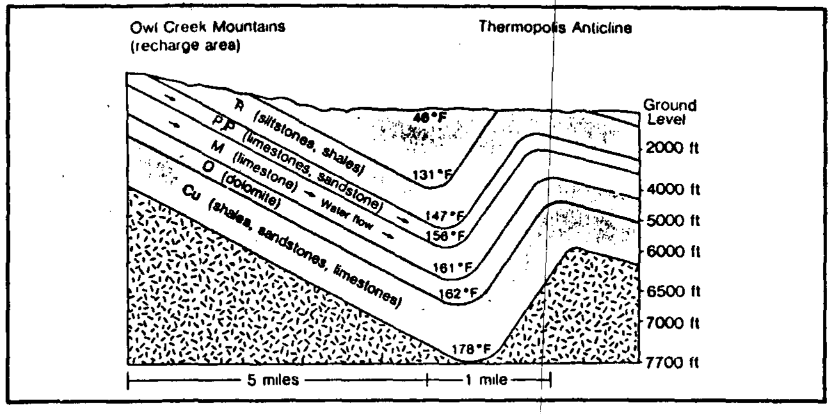
developing geothermal energy for residential heating. Analysis of more than 2,000 bottomhole oilwell temperatures near the town of Midwest show the Salt Creek oilfield to be "a conspicuous thermal anomaly," Heasler says. "Within a 10- to 12-sq-mile area, bottomhole temperatures between 1,000 and 4,500 ft are in the range of 120°F. to 170°F."

Also, water injection wells that have penetrated the Madison formation in the area have struck waters as hot as 175°F. that flow to the surface at rates exceeding 7,000 gal/min.

"There is little doubt that Salt Creek field could be used to produce hydrothermal fluids for direct heating use in the area of Midwest," Heasler states. "The major hindrances to development would be the relative values of hydrocarbon and geothermal resources; the high concentration of solids in the nonpotable waters; and the lingering question of whether Amoco Production Co., the state of Wyoming, or the federal government owns the geothermal resource."

Test results within a 15-mile radius of Casper have been disappointing; no thermal anomalies have been found. Testing continues near Douglas and Torrington, as well as along the so-called Saratoga Valley thermal system, stretching across southcentral Wyoming from the Washakie Basin to the Laramie Mountains. Here, it remains uncertain if natural hot springs flow from a larger geothermal reserve below the surface.

Thermopolis formation cross-section



Owl Creek Mountain springs are heated in a syncline, then circulated to the surface.

The Black Hills of northeastern Wyoming and the Leucite Hills in the southwest also may hold hydrothermal possibilities. Although geothermal data from the area remain sparse, partially molten rock may lie relatively close to the earth's surface in the area, offering high heat to any subsurface waters that may be present.

Waters ranging from 194°F. to 302°F. are known to be present in the deepest parts of most of Wyoming's structural basins, including the Bighorn, Wind River, Washakie, Green River, Powder River and Great Divide. Several water-bearing formations in the basins are folded deeply enough that surrounding rocks heat the water.

Geothermal resources in these zones are too deep to make drilling economical. However, oil and gas wells often reach these depths. Currently, those wells encountering geothermal production are plugged and abandoned because local, state and federal regulations don't permit the easy transfer of geothermal wells to municipalities.

"We're looking to that Thermopolis test to clear up that situation," Heasler says. "It would be extremely useful to everyone concerned if regulations could be streamlined to allow those wells to be used for heating."

Geothermal research and development in the state have concentrated on the shallowest reservoirs—called hydrothermal convective systems—such as those near Thermopolis. The systems heat water at depths between 5,000 and 6,000 ft, where it heats then rises close to the surface through rising strata or a porous fault system. These "low temperature" reserves usually can be drilled inexpensively, and the resulting water can be used directly for heat.

Since 1978, almost $600,000 in Department of Energy funds have been used by the University of Wyoming to continue its geothermal research. Much of the theoretical work has been completed, Heasler says. However, the resources that Heasler and other researchers have identified won't be used until regulatory practices are set.

"Until then, we're just waiting."

REGULATORY TANGLE AWAITS FIRST GEOTHERMAL WELL

Before oil and gas operators can market the geothermal energy reserves they strike in the course of petroleum exploration in Wyoming, a major regulatory barrier will have to be removed.

The state views a geothermal well as a water well. The federal government treats it as a mineral resource, as directed by a recent California court ruling.

Mineral ventures in Wyoming are required to post a reclamation bond to insure any wells drilled will be properly plugged and abandoned and the site reclaimed. Since geothermal wells could flow indefinitely, an operator could be required to leave the bond on deposit "for a very, very long time," according to Henry Heasler, the University of Wyoming's geothermal authority.

"The State Department of Environmental Quality's current method is to review each well on a case-by-case basis, and that makes potential developers a little wary."

In addition, state agencies regulate water wells and mineral operations differently. Should a geothermal well be drilled for commercial use, the conflict between the state and federal classification of the resource would have to be clarified.

"It would be nice," Heasler adds, "if the agencies would write something, even a memo, that would set forth some guidelines: 'a well of less than 2,000-ft depth and of water temperatures less than steam would be treated as a water well, and all others as mineral resources,' or something. So far, they've chosen not to do that."

Some state officials have urged the legislature to change the statute that recognizes geothermal wells as water wells. "Some of them don't want to give geothermal any advantage over oil and gas, so they want it to be classified as a mineral. But the state will never do it."

The Wyoming state constitution claims all the state's waters for Wyoming jurisdiction. The legislature is worried that if it redefined geothermal power as a mineral, the federal government might try to claim jurisdiction over it.

A geothermal test well has been proposed for commercial use by the town of Thermopolis. Should the town decide to proceed with this project, state and federal authorities would be required to confront the issues involved and settle them—in court, if necessary.

"It's going to take additional legislation," Heasler says. "Right now, there are too many unanswered questions."

Oil companies sponsor minority jobs program

The Career Outreach Program sponsored by 25 oil companies operating in Colorado is successfully encouraging gifted minority young women to pursue careers in petroleum technology.

Operating on contributions from individuals, firms and the Colorado State Republican Party, the program has placed about 75 high school students in summer work with six oil companies since the program began in 1978.

In 1980, 15 students were placed, according to program director Bill Grisby. Thirty will be placed this year.

"Most companies start them as 'gofers', but move them into technical work as quickly as possible. The students work as assistants to engineers, geologists and mathematicians, finding out what the work is like and how the oil business operates."

If the students maintain good grades and a commitment to engineering science, the companies agree to employ them as long as work is available.

Minority students with strong, demonstrated aptitude in math and sciences are invited to apply for the program by high school counselors. All screening and hiring is done by the companies offering the jobs.

"We thought the six students we hired were more than just good enough—they were excellent," said John Gable, regional employee relations manager in Amoco's Denver office. "Our evaluation of the program and that of the students was in complete accord. There wasn't a sour note in the group." Amoco hopes to double the number of jobs it offers the program in the coming year.

"It was time to stop talking about private sector initiative and do something about it."

The program began when the problem of providing meaningful part-time work for gifted minority students captured the attention of Denver oil executive Hiram Lewis III of Lewis Energy Corp. and others. Working with other executives and the local Republican organization, they contacted area energy firms, soliciting cash donations and promises of job opportunities. Grisby, a consultant and former social worker, was retained to run the program in 1980.

"The companies knew that the oil business had an undesirable public image among minorities," he said. "They saw this as a chance to heal some wounds and to bring minorities into the industry, as well as a way to encourage talented students."

He added that the state Republican Party became involved, in part, to improve its image among the same minority groups.

The program operated on a 1980 budget of $25,000. For the coming operating year, that figure will double. Oil firms contribute 80% of the budget, with the rest donated by the state Republican Party.

"Most of the budget goes for students' transcripts to companies, evaluation forms the kids and the companies fill out for our records, our quarterly reports to sponsors, and so on," Grisby said. "If someone would give us a copying machine, we could run the program nearly for free."

The Career Outreach Program could handle 100 students effectively, according to Grisby. Should it become that large, his current staff—himself and a part-time secretary—would expand to two full-time people.

"The program was begun also to show that this kind of thing doesn't need to be operated by the government," he noted. "The oil companies decided it was time to stop talking about private sector initiative and do something about it—and they have." ☐

R 3/10

THE UNIVERSITY OF WYOMING
DEPARTMENT OF GEOLOGY AND GEOPHYSICS
P.O. BOX 3006
LARAMIE, WYOMING 82071
(307) 766-3386

March 3, 1982

Dr. Duncan Foley
Earth Science Lab
University of Utah Research Institute
420 Chipeta Way, Suite 120
Salt Lake City, UT 84108

Dear Duncan:

Enclosed is a copy of my letter to S. Prestwich which constitutes the January and February technical progress report for the Wyoming Geothermal Resource Assessment Group.

If you have questions, please contact me.

Sincerely,

Hank

Henry P. Heasler
Principal Investigator
Wyoming Geothermal Resource
Assessment Group

HPH/bc

Enclosure

THE UNIVERSITY OF WYOMING
DEPARTMENT OF GEOLOGY AND GEOPHYSICS
P.O. BOX 3006
LARAMIE, WYOMING 82071
(307) 766-3386

March 3, 1982

Ms. Susan M. Prestwich
Department of Energy
Idaho Operations Office
550 Second Street
Idaho Falls, Idaho 83401

Dear Susan:

This letter constitutes the January and February technical progress reports for work accomplished under contract DE-FC07-79ID12026.

During this time period all information for the Wyoming geothermal map (1:500,00 scale) was submitted to NOAA in Boulder, Colorado and sent out for review. Material sent to NOAA includes data for thermal springs, thermal wells, 401 temperature gradient measurements, published heat flow values, definitions of potential low-temperature geothermal resource areas, explanations of potential use areas, and general explanations of the map and data lists.

Work continued on the geothermal reports for the major basins of Wyoming. Statistical analyses were completed for over 5,000 oil well bottom hole temperatures in an effort to rigorously define anomalous points. Theoretical models were constructed and analyzed to determine the effect of thermal perturbations due to drilling. The plotting of data for the southern Powder River Basin and Green River Basin continued with written reports in various stages of completion for the Bighorn Basin and Washakie - Great Divide Basin.

During this time period we have received an answer from 9 of the 19 letters sent to oil companies requesting information on the temperature and quality of water that is coproduced with oil in their Wyoming fields. One operator, Amoco Oil, has been motivated by out initial letter and consequent discussions to begin checking into the possibility of using 170°F coproduced water at one of its fields to generate electricity for the field through the use of a binary system.

During January and February, four user requests for information were answered. Information was sent to Dr. R. Breckenridge of the Idaho Bureau of Mines and Geology, Mr. C. Rogers, President of Eastern Wyoming College in Torrington, Ms. R. Britton of the Farm Bureau in Wheatland, and Mr. K. Anderson who is a land developer that is based in Cheyenne. On February 17 a 40 minute lecture and slide presentation on Geothermal studies in Wyoming was presented to the Cheyenne Geological Club. This club consists of state employed geologists, USGS geologists, and private geologists. A great deal of interest was expressed in near surface (less than 20 meters) temperature fluctuations.

Two newly constructed wheatstone bridge assemblies were tested on our shallow thermal monitor well near Laramie. The new bridges functioned properly with their results showing that the thermal disturbance in this hole appears to have been transient. Consequently, a heat flow was calculated for this hole and some modeling begun.

In these two months, most of the termal conductivities collected during this contract were completed. 283 samples were run in January and February.

I hope that this letter constitutes a satisfactory technical progress report.

Sincerely,

Henry Heasler

Henry P. Heasler
Principal Investigator
Wyoming Geothermal Resource
Assessment Group

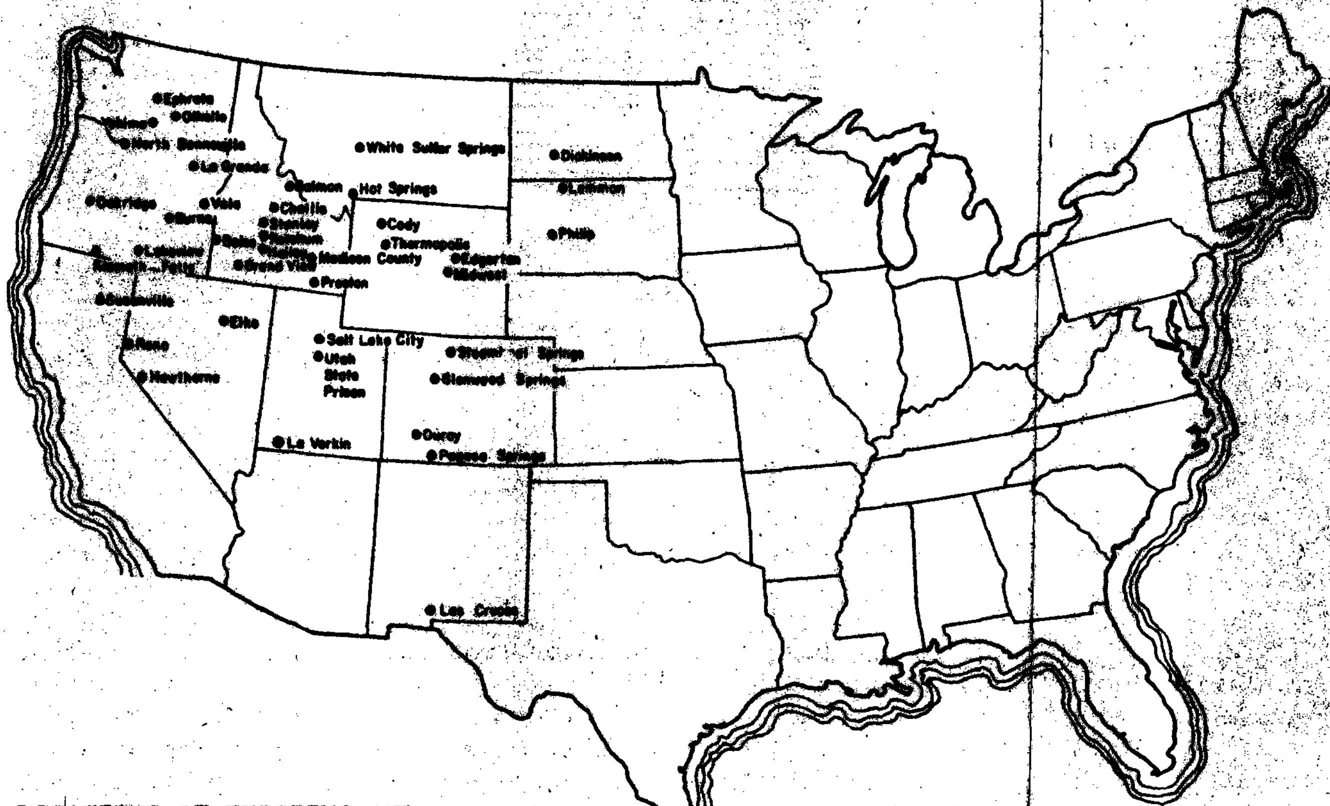
HPH/bc

GEOTHERMAL NEWS

P.O. Box 4096, University Station, Laramie, WY 82071
(307)766-4820

Vol. 3, No. 2 February, 1982

UPDATE ON GEOTHERMAL DISTRICT HEATING SYSTEMS



LOCATIONS OF EXISTING AND PROPOSED DISTRICT HEATING SYSTEMS IN THE WESTERN U.S.

Map Source: Geo-Heat Center Quarterly Bulletin, Vol. 6, No. 3, Oregon Inst. of Tech.

The geothermal district heating systems that are presently in existence are in the communities of Boise, ID; Klamath Falls, OR; Pagosa Springs, CO; Susanville, CA; and Philip, SD. The other communities indicated on the map have systems that are currently under construction, or are actively being considered and/or designed.

The town of Thermopolis is the farthest along in the geothermal district heating system process of the Wyoming communities shown on the map above. The Thermopolis feasibility study and their hydrologic study should both be completed sometime during the spring and summer of 1982.

The Wyoming communities of Cody, Midwest, and Edgerton all show good potential for the development of district heating systems. While these potential geothermal systems are actively being considered by many residents of these three communities, the actual engineering and system design process has not yet begun.

INVENTORY OF GEOTHERMAL WATERS PRODUCED BY OIL COMPANIES IN WYOMING

The Wyoming Geothermal Resource Assessment Group in the University of Wyoming Geology Department is compiling an inventory of geothermal waters produced by oil companies in the state. Hot water is a common by-product as oil and gas are produced from deep sedimentary basins. This hot water can occur in ratios up to 10:1. For example, the Salt Creek Field in the Powder River Basin presently discharges 9900 gallons of water per minute to the surface at temperatures up to 108°F.

The operators of the 50 fields in the state with the largest water production have been contacted and asked to supply data on co-produced water temperature, flows, chemistry, and disposition (surface discharge, waterflood, waste reinjection). While such waters may be located in fairly remote areas, their use for many direct-use heating applications would save considerable expense relative to oil company projects such as: exploration, drilling, and production. This concept of cascading uses would prove financially beneficial to both the hot water developer and the cooperating oil company. Greenhousing and aquacultural projects are just two examples of direct-use heating applications that would be suitable for use with the discharged water in these areas.

--Bern Hinckley, Resource Group

FIRST DRAFT OF WYOMING GEOTHERMAL MAP HAS RECENTLY BEEN COMPLETED

A first draft of a statewide geothermal map has recently been completed by the Wyoming Geothermal Resource Assessment Group at the University of Wyoming. Depicted on this map are hot springs, potential resource areas, flowing thermal wells, heat flow values, and over 300 temperature gradient wells. The temperature gradient well data were collected by the Resource Group through its thermal logging program. Temperature gradient well data includes depth, bottom hole temperature, and measured thermal gradient.

The map will hopefully be reviewed and published within the next three months. Present plans are to have the 1:500,000 scale map distributed by the Wyoming Geological Survey in Laramie, Wyoming.

A final notice of map publication and the date of its availability to the public will be announced in a future issue of the Geothermal News.

--Henry Heasler, Resource Group

MATERIALS AVAILABLE THROUGH THE WGCO

This is just a reminder that the WGCO has a wide variety of printed materials available for distribution to the public. The topics of these materials cover all aspects of geothermal energy development. If you have a question regarding geothermal energy in Wyoming, contact Karen Marcotte at the WGCO address on this newsletter.

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University Station
Laramie, Wyoming 82071

(307) 766-4820

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Duncan Foley, Geologist
Earth Science Laboratory
UURI, 391-A Chipeta Way
Salt Lake City, UT 84108

GEOTHERMAL COMMERCIALIZATION OFFICE

GEOTHERMAL NEWS

P.O. Box 4096, University Station, Laramie, WY 82071
(307)766-4820

Vol. 3, No. 3 March, 1982

DIRECTORY OF WYOMING RENEWABLE ENERGY BUSINESSES TO BE AVAILABLE SOON

The first Directory of Wyoming Renewable Energy Businesses is being compiled by the Wyoming Solar Industries Association (WyoSIA).

The purpose of the Directory is to provide the public with a current guide to businesses in Wyoming that provide services and products for solar, wind, micro-hydro, biomass and geothermal energy.

Businesses will be listed alphabetically and by their particular specialty including architects, engineers, consultants, builders, manufacturers, distributors, dealers, installers, educators, and research and development firms.

"It is WyoSIA's goal that the Directory will provide the consumer with a list of businesses that provide satisfactory services and products related to the renewable energy industry", stated Charles Nation, President of WyoSIA.

The Directory will be ready for distribution in April to consumers and members of the construction industry. The Directory is sponsored by Western SUN (Solar Utilization Network), a program of the western states to increase business activity, sales and consumer satisfaction in solar energy and renewable resources.

WyoSIA is a nonprofit business association formed to promote high business standards and a voice for the solar industry in Wyoming.

For more information about the Directory, contact WyoSIA, 4000 Springs Drive, Rock Springs, WY 82901, or call (307)382-9161.

THERMOPOLIS DISTRICT HEATING UPDATE

After reviewing the results of the Thermopolis citizen preference poll in regard to district heating, the Advisory Work Group has instructed Coury and Associates to complete their feasibility study based on the concept of providing district heating for the entire town, and for the development of the Rose Dome drilling site. The Rose Dome site is located the farthest from town of the three preliminary sites reviewed, but it has the potential for the production of significantly hotter water than the other sites.

Over 30% of the questionnaires that were mailed to town residents have been returned so far. The Advisory Work Group feels that there is sufficient interest in geothermal heating shown by the questionnaire responses to warrant the completion of the study based on heating the entire town. The next Advisory Work Group meeting has been tentatively scheduled for March 18 in Thermopolis.

FINAL THERMOPOLIS REPORT AVAILABLE

The final edition of the Thermopolis Site Specific Development Analysis (SSDA) has been published by the Department of Energy. The Thermopolis SSDA was authored by Patti Burgess-Lyon during her employment with the WGCO in 1981.

The Thermopolis report includes major sections on site description, resource evaluation, potential applications of the resource, heat exchangers and corrosion prevention, and a discussion of the leasing, permitting and financial considerations involved in geothermal development.

The Thermopolis SSDA is available free to the public upon request. Contact this office if you are interested in receiving a copy of this report.

1982 WYOMING ENERGY CONFERENCE HELD IN CASPER ON FEBRUARY 17

An energy conference was held at the Ramada Inn in Casper on February 17, 1982. Senators Alan Simpson and Malcolm Wallop were Co-Chairmen/Moderators. Although advance publicity for the conference billed it as an energy dialogue to help establish pathways that would lead us towards energy independence, only fossil fuel technologies and their related development problems were discussed.

The luncheon keynote address speaker was Dr. Nunzio Palladino, Chairman of the U.S. Nuclear Regulatory Commission. Special guest speaker at the conference was Ted Stevens, Senior Senator from Alaska.

The conference was co-sponsored by the Columbia Institute for Political Research, 11 oil companies, 6 utilities, 6 petroleum service companies, 4 coal companies, 1 synfuel corporation, the Sierra Club and the Wyoming Outdoor Council.

REPORT ON GEOTHERMAL WELL CEMENT HAS BEEN PUBLISHED BY D.O.E.

A report entitled, "Development of Geothermal Well Completion Systems - Final Report" by Erik B. Nelson, is available from the National Technical Information Service, U.S. Department of Commerce, Springfield, VA 22161.

MATERIALS AVAILABLE THROUGH THE WGCO

The following is a list of printed materials available through this office:

- --The Cody Site Specific Development Analysis (xerox of final report)
- --The Thermopolis/East Thermopolis Site Specific Development Analysis
- --Preliminary Data from Six Temperature Gradient Holes near Cody, Wyoming
- --Fremont County Area Development Plan
- --Big Horn Basin Area Development Plan
- --Converse and Natrona Counties Area Development Plan
- --Wyoming Geothermal Institutional Handbook
- --Rules of Thumb for Geothermal Direct Heat Applications
- --Opportunities for Geothermal Energy Use in Wyoming Industries
- --Department of Energy Fact Sheets on: geothermal ethanol plants, resource availability, existing and proposed geothermal electric power plants, direct use demonstration projects, and the Raft River 5-MW pilot plant
- --We also have a variety of printed materials from many different sources on: geothermal greenhouses, aquaculture, heat pumps, space heating, and Rankine cycle generators.
- --Previous issues of the <u>Geothermal News</u> are also available.

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Duncan Foley
Assoc. Geologist
Earth Science Lab.
UURI, 391-A Chipeta Way
Salt Lake City, UT 84108

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DEPARTMENT OF GEOLOGY & GEOPHYSICS
GEOLOGY BUILDING
P. O. BOX 3006
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PH. 307-766-3386

February 1, 1982

Dr. Duncan Foley
Earth Science Lab
University of Utah Research Institute
420 Chipeta Way, Suite 120
Salt Lake City, UT 84108

Dear Duncan:

Enclosed is a copy of my letter to S. Prestwich which constitutes the September, October, November and December technical progress report for the Wyoming Geothermal Resource Assessment Group.

If you have questions, please contact me.

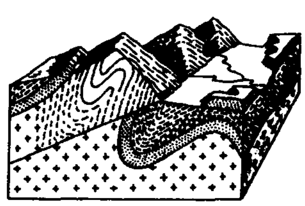
Sincerely,

Hank

Henry P. Heasler
Principal Investigator
Wyoming Geothermal Resource
Assessment Group

HPH/tj

Enclosure



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December 10, 1981

17 Dec 81

Carl - for the list of deliverables

Dr. L. L. Mink
Department of Energy
Idaho Operations Office
550 Second Street
Idaho Falls, Idaho
83401

Dear Roy:

Enclosed are three documents which fulfill two specific tasks of DOE contract number DE-FC07-79ID12026.

The first document is entitled "Heat flow studies in Wyoming, 1979 to 1981" by Decker, Heasler, and Buelow. It fulfills task 13 in modification A006 which states:

> "An updated (1981) regional heat flow map will be delivered, as will detailed maps of gradients and heat flow in prospectively valuable areas. All maps will be accompanied by interpretations. Both heat flow and available radioactivity data will be used in interpretations. Heat flow information will be obtained for approximately 20 new stations".

The second and third documents are entitled "Heat flow, radioactivity, gravity, and geothermal resources in northern Colorado and southern Wyoming" by Decker and Buelow and "Geothermal studies in Wyoming and northern Colorado with a geophysical model of the southern Rocky Mountains near the Colorado-Wyoming Border" by Buelow. The third document is a Master of Science thesis completed by Mr. Buelow under the supervision of Dr. Decker with funds from this contract. These two documents fulfill task four of the original DOE agreement which states:

> "Investigate the northern extension of the Rio Grande Rift through studies of flux, radioactivity and young volcanics for the potential of geothermal resources".

I hope that these documents are an adequate fulfillment of tasks 4 and 13.

Sincerely,

Henry Heasler

Henry P. Heasler
Principal Investigator
Wyoming Geothermal Resource
Assessment Group

cc: Bob Gray
Duncan Foley
Ed Decker

enclosure

HPH:ar

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September 21, 1981

Dr. Duncan Foley
Earth Science Lab
University of Utah Research Institute
420 Chipeta Way, Suite 120
Salt Lake City, UT 84108

Dear Duncan:

Enclosed is a copy of my letter to L. L. Mink which constitutes the June, July, and August technical progress report for the Wyoming Geothermal Resource Assessment Group.

If you have questions, please contact me.

Sincerely,

Hank

Henry P. Heasler
Principal Investigator
Wyoming Geothermal Resource
Assessment Group

HH/dg

Enclosure

THE UNIVERSITY OF WYOMING
DEPARTMENT OF GEOLOGY & GEOPHYSICS
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September 21, 1981

Dr. L. L. Mink
Department of Energy
Idaho Operations Office
550 Second Street
Idaho Falls, ID 83401

Dear Roy:

This letter constitutes the June, July, and August technical progress reports for work accomplished under contract DE-FC07-79ID12026.

Our main effort for the last three months has been the field collection of downhole temperature data. Three field crews have been actively working in the Wind River Basin, Green River Basin, the Thrust Belt, the Bighorn Basin, and the Powder River Basin. Temperatures are measured in holes of opportunity at discrete intervals (usually 10 meter spacing) using thermistor probes and Wheatstone bridge assemblies. A discussion of the work effort follows on a basin by basin level.

In the Green River Basin and Thrust Belt of Wyoming, over 37 wells have been thermally logged. Six of these wells were logged to over 1,800 meters. Companies who are cooperating with our geothermal investigations in this basin include Texaco, Belco Oil, Aquatine, Kemmerer Coal Company, Wexpro, and Champlain Oil. Numerous private well owners and the Bureau of Land Management have also been helpful. A rough draft of the Green River Basin thermal gradient map has been completed and will be further modified through analysis of the new field data.

Our compilation of oil well bottom hole temperatures for the Wind River Basin is almost complete. Thus far, approximately 1,500 data points have been compiled but still need to be plotted and analyzed. Companies which have been contacted in the Wind River Basin include Union 76, Gulf Oil, Phillips Petroleum Company, Monsanto, Kirkwood Oil, Amoco Production Company, Pathfinder Mines, and MCOR Oil. Only seven wells were logged in this basin by the end of August. Also, one well was located near the Alcova Dam that flows 250 gpm of 42°C water but has an obstruction in the casing at 1 meter. There are presently no plans for the use of this well.

In the Powder River Basin four water wells were thermally logged that ranged in depth from 55 meters to 360 meters. These holes were logged as the first step in the analysis of the geothermal potential near Bearcreek, Wyoming, for the Bearcreek Uranium Company. Bearcreek Uranium is presently using shallow groundwater as a source of water in its uranium mill. They are interested in obtaining a deeper source of water that would be warmer and consequently help in their uranium milling process. Also by obtaining deeper waters they hope to stop the depletion of shallow aquifers in the area.

Temperatures and gradients have been calculated for the area near Bearcreek. Thermal conductivity samples have been collected and are in the process of being measured. From these measurements heat flows will be calculated and estimates of temperatures at various aquifer depths will be made. These data and preliminary interpretations will then be given to Bearcreek Uranium Company for their own evaluation in exchange for having permitted our temperature surveys in their wells.

Also in the Powder River Basin an attempt will be made to log coal exploration holes that are being drilled by the U.S. Geological Survey. Negotiations are still in progress to determine rig standby costs and the number of holes we wish to log.

In the Bighorn Basin ten additional wells were thermally logged. This included a 180 meter core hole in the Absaroka Mountains from which samples were obtained for thermal conductivity measurements and one 90 meter water well in which 1 1/4 inch plastic pipe was installed and filled with water. The 90 meter hole will be used as a monitor well to observe near surface temperature variations. This is part of the effort to assess the reliability of oil well bottom hole temperature gradient determinations.

A series of four maps were completed for inclusion in the report on geothermal potential in the Bighorn Basin. These maps, at a scale of 1 to 250,000, include generalized geology, thermal gradient contours, structure contours on the Tensleep Formation, and temperature contours on the Tensleep Formation. The thermal gradient and temperature contour maps resulted from the analysis of over 1,800 oil well bottom hole temperatures and over 30 measured gradient holes.

Our report on the Thermopolis hydrothermal system in the Bighorn Basin has been accepted for publication by the Wyoming Geological Survey. The suggestions of all reviewers have been incorporated into the report. The Wyoming Geological Survey's editor is presently working on the publication.

On August 19, a meeting of the Thermopolis Geothermal District Heating Advisory Group was held. Approximately 2/3 of the committee members were in attendance along with local citizens, media reporters and representatives of DOE, HUD, and the hired engineering firm, Coury and Associates. The University of Wyoming Resource Assessment Group outlined their work to date and presented a general discussion of possible future contributions to the Thermopolis Geothermal District Heating Feasibility Study. More specific discussions of the resource followed the formal meeting, primarily as answers to questions from the engineering firm and DOE sponsored advisors. The feasibility study engineers will be relying almost totally on the University of Wyoming group for all resource assessment input. A general timetable for the cooperative exchange of information was developed and will be implemented.

Other field work accomplished during this time period included the thermal logging of six drill holes near Gunnison, Colorado. All six holes were owned by Amax with the deepest being 700 meters.

Geothermal presentations were made to various groups during June, July, and August. A talk and accompanying paper entitled "A Summary of Geothermal Potential and Development in Wyoming" was presented to the midyear meeting of the Interstate Oil Compact Commission that was held in Casper, Wyoming, on June 28 to 30, 1981. The paper will be included in a publication on the proceedings of the meeting. A copy of the paper is included for your reading.

Another talk was presented to Wyoming high school and elementary teachers at a workshop concerning energy and mining in Wyoming. This workshop was sponsored by the Wyoming Mining Association through the University of Wyoming. An overview of geothermal energy was discussed along with specific references to Wyoming's resource and potential.

A state-wide water well list was compiled in June for use by summer field crews in obtaining holes for thermal logging. The lists were purchased from the Wyoming State Engineers Office and include such things as depth to water, total depth, use, location, and owner. Because of the great number of permitted wells, a depth cutoff of deeper than 200 feet was generally used. The lists were gathered by geologic basin for the entire state excluding the Powder River Basin and the Denver Basin.

Another project initiated during this time period was an inventory of oil field co-produced water. We have become interested in co-produced water because the structure and stratigraphy of Wyoming's sedimentary basins commonly result in deep, hot waters under substantial artesian pressure. While normal or even subnormal gradients preclude economical geothermal drilling in many of these areas, 3,739,848 bbls/day of water is co-produced with petroleum from wells up to 25,000 feet deep.

Co-produced waters are separated from the oil by various physical and chemical processes and are disposed of in three principal ways: (1) surface discharge, (2) waste reinjection, and (3) secondary recovery - water flood injection. The Wyoming Department of Environmental Quality in Cheyenne maintains records for the approximately 400 surface discharge permits in the state. Their files have been examined and correlated to Wyoming Oil and Gas Commission records to determine field and field water production. Individual files for the 15 permits greater than 1 million gallons per day were searched for precise flow, temperature, and chemical data. Waste reinjection records are compiled by the Wyoming Oil and Gas Commission. Disposal well files for the Bighorn Basin have been examined and six-month volume statistics, chemical data, and producing and injected formation information compiled. Individual files for the approximately 4,000 injection wells (both waste disposal and water flood) in the state have not been studied.

Statewide production statistics have been searched to pinpoint the locations of significant water co-production (46 fields produce greater than 10,000 barrels of water per day), and names and addresses for the appropriate operators have been compiled. Amoco Production Company in Powell, Wyoming, was selected for the initial industry contact and has agreed to supply wellhead and separator water temperatures, which are the least available data in the various state files.

Other accomplishments during this time period include the measurement of 482 thermal conductivities for 15 thermal gradient holes. Also, on July 30 through July 2 a representative of Los Alamos National Lab visited our group to learn about thermal conductivity measurements and downhole temperature measurements.

I hope that this letter and its enclosure constitute a satisfactory report for work accomplished during June, July, and August.

Sincerely,

Henry Heasler

Henry P. Heasler
Principal Investigator
Wyoming Geothermal Resource
Assessment Group

HH/dg

Enclosure

cc Robert Gray
Duncan Foley

THE UNIVERSITY OF WYOMING

DEPARTMENT OF GEOLOGY

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LARAMIE, WYOMING 82071

PH. 307—766-3386

June 5, 1981

Mrs. M. A. Widmayer
Department of Energy
Idaho Operations Office
550 Second Street
Idaho Falls, Idaho 83401

Dear Maggie:

This letter constitutes the March, April, and May technical progress reports for work accomplished under contract DE-FC07-79ID12026.

During these months a regional report on the Washakie and Great Divide Basins was written. The report investigates and defines areas of hydrothermal potential in the two Basins (T.12N. - T.27N., R.86W. - R.105W.). To aide in the geothermal evaluation approximately 2,000 oil and gas bottom hole temperatures were gathered, 24 temperature-depth profiles measured by our group were analyzed, and 15 heat flow values were interpreted. These data were then used to construct maps of temperature of the Mesaverde Formation, elevation of the Mesaverde Formation, and the thermal gradient in the Basins. Also shown on the maps are surface geology and the location of data points. Published chemical analyses for oil field waters were gathered and three new analyses for warm artesian wells in the Basins were determined. Other data used in the report consist of published and unpublished reports, maps, and theses. Editing of the report has begun and hopefully the report will be out for DOE review within 1½ months.

During these 3 months the Thermopolis low-temperature hydrothermal system report was completed and sent out for DOE review on May 22. The report is also being reviewed by the Wyoming Geological Survey for possible publication. This report is a comprehensive study of the geothermal potential of the Thermopolis, Wyoming area. Some of the topics addressed are the maximum temperature of the system, extent of the system, depth to the hydrothermal reservoir, hydrology, stratigraphy, and structural geology.

The town of Thermopolis has been awarded $50,000.00 for a HUD district heating feasibility study. As cleared through the DOE contract office in Idaho Falls, our geothermal group is represented on an advisory board for the feasibility study. The first function of the advisory board was to attend a May 19th Thermopolis City Council meeting where four consulting engineering firms (Denver Research Institute, Western Energy Planners, CH2M Hill, Coury and Associates) presented their qualifications for completing the feasibility study. The advisory group then gave their individual recommendations to the city-council. I felt that all four firms are well qualified but that CH2M Hill seems to have more experience and a greater range of expertise available.

During March, April, and May over 2,000 temperature data points were plotted on maps for the Bighorn Basin. Maps thus far compiled include a temperature gradient contour map, structure contour map of the Tensleep Sandstone, and a map showing temperature of water in the Tensleep Sandstone. Also shown on these maps are ground elevation contours, surface geology, and the location of data points. Writing has begun on an interpretative report that will accompany these maps as well as discuss chemistry, hydrology and geology of the Bighorn Basin.

A geologic map showing temperature data points has been compiled for the Saratoga Valley in Wyoming. A brief geologic summary of the area has been written but a more complete interpretation of the thermal data needs to be finished and written.

Most of the temperature data compilation and plotting for the southern Powder River Basin was completed in May. Thus far over 4,000 oil well bottom hole temperatures have been plotted for this area. Oil well drill stem tests have been looked at to determine artesian wells. Research is continuing on the area's hydrology, chemistry, and structural geology.

During the past 3 months work continued on the Thrust Belt of Wyoming. Approximately 54 oil well bottom hole temperatures were gathered and plotted on maps. Also, computer plots were made of the data showing temperature versus depth, thermal gradient versus depth, and thermal gradient versus temperature in an effort to assess the reliability of the data. Our field crews thermally logged 5 water wells in the Star Valley area in the Thrust Belt during April. Also, our field crews have met twice with University of Utah Research Institute personnel in the Star Valley area. This has been to exchange information and cooperate on their geothermal investigations of the Star Valley.

In March, April, and May various presentations were made to different groups. On the evening of March 16th, I made a short presentation to the Cody City Council explaining the geothermal potential of the area. On March 17th a member of the Wyoming Geothermal Commercialization Office and I were questioned for 20 minutes for use by the local Cody radio station. On March 18th two talks were given. Bern Hinckley gave a 20 minute talk to the Powell Rotary Club explaining geothermal energy and generally describing Wyoming's geothermal potential. I gave a presentation at Northwest Community College in Powell that covered in general Wyoming's geothermal potential with emphasis on the Bighorn Basin.

On April 14th the Wyoming Geothermal Commercialization Office sponsored a one day geothermal workshop in Casper. Talks were given by various state officials and geothermal consultants. I presented a one hour talk with an accompanying summary paper entitled "Wyoming Geothermal Resources". This paper and the resultant newspaper publicity are enclosed for your reading.

Four members of our group attended the Resource Assessment Team meeting in Glenwood Springs, Colorado on May 5-6. On May 5th I gave a twenty minute technical presentation on "Conductive Thermal Modeling of Wyoming Geothermal Systems". Thermal assessment techniques used by our group were discussed with emphasis on examples of the site specific studies of the Cody and Thermopolis low-temperature hydrothermal systems. The summary paper which accompanied this talk is included for your reading.

I hope that this letter and its enclosures constitute a satisfactory report for work accomplished during March, April and May.

Sincerely,

Henry P. Heasler

Henry P. Heasler
Principal Investigator
Wyoming Hydrothermal Resource Assessment

HPH/tj

cc: Robert Gray
Duncan Foley
Mike Tucker

CONDUCTIVE THERMAL MODELING OF WYOMING GEOTHERMAL SYSTEMS

by

Henry P. Heasler
Department of Geology and Geophysics
University of Wyoming
Laramie, Wyoming

Introduction

The purpose of this paper is to present a summary of techniques used by the Wyoming Geothermal Resource Assessment Group in defining low-temperature hydrothermal resource areas. Emphasis will be placed on thermal modeling techniques appropriate to Wyoming's geologic setting. Thermal parameters discussed include oil-well bottom hole temperatures, heat flow, thermal conductivity, and measured temperature-depth profiles. Examples of the use of these techniques will be from the regional study of the Bighorn Basin and two site specific studies within the Basin. Funding for this work has been primarily from the U.S. Department of Energy Cooperative Agreement DE-FC07-791D12026.

General Geologic Setting

Wyoming is in the Rocky Mountain and Great Plains physiographic provinces (Fenneman, 1946). This region, often referred to as the Rocky Mountain Foreland, is primarily situated between geosynclines to the west and the stable craton to the east. Much of Wyoming is essentially a group of large intermontane basins separated by major mountain ranges or arches (Figure 1). For most of the region the present distribution of mountains and basins resulted from the Laramide orogeny beginning in the Late Cretaceous (approximately 70 million years ago) and terminating in the middle to late Eocene (approximately 40 million years ago). The tectonic style of Wyoming is characterized by compression, uplift and thrust faulting (Blackstone, 1971; Houston, 1969).

The major mountain uplifts expose rocks of Precambrian age while the basins contain sediments of Paleozoic, Mesozoic and Cenozoic age. Some of the Paleozoic and Mesozoic sediments are porous and permeable forming aquifers that exist over entire basins. The Laramide deformation of these has resulted in a structural relief of many kilometers in the basins. For example, portions of the Bighorn Basin have a structural relief of over 9 kilometers (Prucha et al., 1965). Also, due to the physical properties and deformation of the sediments, a great amount of hydrocarbon exploration has taken place in Wyoming.

There has been volcanic activity in Wyoming in Yellowstone National Park as recent as the Pliestocene (Love et al., 1972), in the Absaroka Mountains in the middle Eocene (Smedes and Prostka, 1972), in the Rattlesnake Hills in central Wyoming in the middle Eocene (Pekarek, 1974) and in the Black Hills in the middle Eocene (Houston, 1963). Preliminary geothermal studies by out group have not identified any geothermal resources near the Eocene age volcanics.

Thermal Techniques

A major portion of the geothermal assessment of Wyoming has been the compilation and depiction of existing bottom hole temperatures from oil and gas wells. The largest problem with using such data is assessing its reliability. The problem of the thermal equilibration of a well after drilling has been discussed by Lachenbruch and Brewer (1959), and the problem of thermal instability of a large diameter drillhole is adressed by Diment (1967). However, with oil and gas well data many of the correction factors for thermal equilibrium and stability are unknown and consequently the bottom hole temperatures cannot be absolutely corrected for various thermal perturbations.

Our attempt at solving this problem has been to define anomalous points within the oil well bottom hole temperature data set. Many parameters must be considered in the definition of anomalous points. First, the data are analyzed only for areas of similar geology. Parameters considered here are the character of aquifers present, lateral extent and continuity of formations, oil and gas producing units, tectonic style, and actual rock types present. By analyzing the data within a similar geologic area we are attempting to eliminate the variability in the data that would be due to differences in crustal heat flow and thermal properties of vastly different rock units.

After the data is gathered for an area, a series of computer plots are made showing temperature versus depth, thermal gradient versus depth, and temperature versus thermal gradient. The effect of average and maximum mud temperatures on the thermal gradient for the region is then plotted with the thermal gradient versus depth data (see Figure 2). From these plots, data with anomalously high thermal gradients can be identified and located on a map. If these data points cluster in an area, we feel confident of the anomaly and study the anomalous areas in greater detail. Also, from the bottom hole temperature data set maps are compiled of the thermal gradient and the major aquifer temperatures.

To further assess the reliability of the oil well bottom hole temperatures considerable effort is expended measuring temperatures in drill holes. Basically, temperatures are measured with a thermistor probe and wheatstone bridge combination at 5 to 10 meter intervals down the wells. Decker (1973) gives a complete discription of equipment used and assesses the errors involved. Least squares gradient computations for linear segments of the temperature versus depth plots and absolute measured temperatures are then compared with the gradients and temperatures from the oil well bottom hole temperature data set. To date what has been found is that the oil well bottom hole temperatures and gradients for holes generally deeper than 750 meters (2500 feet) have always been less than or equal to the measured temperatures and gradients. Above this depth the effect of warm drilling fluids raising the equilibrium temperature must be considered. However, since most of the oil data is below 750 meters (2500 feet), this method of bottom hole temperature analysis generally results in gradient and temperature values less than equilibrium values.

As previously mentioned, a great amount of effort is expended on thermally measuring drill holes. This serves three main purposes. First it is important in the determination of the reliability of the oil and gas temperature data. Second, the resulting temperature-depth profiles show the change of gradient within differing rock units and with depth. Finally, thermally measured holes when combined with rock thermal conductivity can be used to estimate the heat flow for an area. Both of these last two uses of thermally measured holes are critical to the modeling of hydrothermal systems found in the basins of Wyoming.

Most of the hydrothermal systems in Wyoming's basins function in a similar way. Water enters aquifers in the surrounding mountains, flows down the continuous dip slopes to where it becomes heated in a syncline, and is then forced back to the surface or near surface in anticlines. Critical parameters that need to be defined for potential developers of such systems are the maximum temperature of the system, depth to the hydrothermal reservoir, and extent of the reservoir. Conductive thermal modeling is one approach to answering these questions.

The purpose of a conductive thermal model is to calculate the temperature of aquifers in the synclinal portion of these hydrothermal systems. By modeling the temperatures in the aquifers a judgement can be made as to whether the observed thermal anomaly can be explained by the regional heat flow, thermal conductivity of the rocks, depth of the syncline, and water flow direction within the aquifers. If the model fits the thermal anomaly then the critical parameters of maximum temperature, depth to the reservoir, and extent may be predicted with some certainty.

The conductive thermal modeling of an area begins with an understanding of stratigraphy, structural geology, and hydrology. These are parameters which set limits on the thermal conductivity, thermal gradient, and depth to aquifers. Next, a regional heat flow value is determined using published values and new values calculated as a result of our thermal investigations. Since a necessary part of the heat flow determinations is the measurement of rock thermal conductivities, this conductivity data will already exist for use in the thermal model. To model the temperature at a given depth in the syncline one uses the equation:

$$T_a = T_s + [(Q/K_1)\ dx_1 + (Q/K_2 dx_2) + \ldots]$$

where T_a is the sought after temperature in the aquifer, T_s is the mean surface temperature, Q is the regional heat flow, K_1 and dx_1 are the thermal conductivity and thickness of lithologic unit closest the ground surface, K_2 and dx_2 are the thermal conductivity and thickness of the lithologic unit below unit 1, and so on until the aquifer is reached.

Other thermal parameters may also be usefully modeled. For example, the flow of a hot artesian well or spring may be modeled in an attempt to assess how much the temperature is decreased in flowing from the hydrothermal reservoir to the surface (see Truesdell et al., 1977). This is useful in helping to define the maximum temperature of the hydrothermal reservoir. Another useful parameter to model in the syncline-anticline hydrothermal system is the total conductive heat gain and the heat loss of the system. By using the regional heat flow, and the flow and temperature of hot wells and springs a minimum area can be calculated over which the water must flow to attain the needed heat. This calculation will not prove the conductive syncline-anticline thermal model is correct but can help illustrate inconsistencies in the model if the area needed for heat gain is much larger than that available.

Application and Results

The methods discussed have been applied with success to the Bighorn Basin in northwestern Wyoming. Over 1,900 oil well bottom hole temperature points were used in the analysis of anomalously high thermal gradient areas. Gradient-depth data were plotted along with curves representing a gradient resulting from the effect of isothermal drilling mud (Figure 2). This aided in defining areas of anomalously warm fluids (40-70°C (104-158°F)) at shallow depths (150-750 meters (500-2,500 feet)). Based on the data a thermal gradient contour map was compiled and anomalous areas identified near the towns of Cody, Thermopolis, and Greybull (Figure 3). Gradients in these areas were in excess of 90°C/km (50°F/1000 ft).

The Cody and Thermopolis areas were thermally modeled using the described techniques. Heat flow and thermal conductivities were primarily from Decker et al. (1980) and new values determined during the course of this study. Geologic constraints for the modeling resulted from an analysis of existing geologic literature, limited field mapping and an analysis of existing hydrologic data. An important contribution to the thermal model was the actual measurement of temperatures down drill holes in the thermal areas. Twenty four wells were thermally logged near the resource areas. These wells not only resulted in accurate temperature and gradient data but helped define the intermixing of fluids within some aquifers by their isothermal character (Figure 4).

An example of a map presenting geologic and oil well thermal data is shown for the Cody area in Figure 5. The results of thermal studies including a DOE sponsored drilling program in the Cody area defines the area of greatest use to be in T.52N., R.102W., sections 2, 3, 11, and 16. In this area warm waters (34°C (93°F)) can be reached at shallow depths (51 to 300 meters (168 to 1,000 feet)). The maximum temperature of this system may approach 55 to 65°C (131 to 149°F) at depths of 260 to 500 meters (853 to 1640 feet). Warm waters will be found at the shallower depths in the more western portions of this potential use area (see Heasler and Decker, 1980).

Thermal modeling of the Thermopolis low temperature resource area predicts maximum temperatures in the Madison aquifer of 77°C (170°F) northwest of the Thermopolis townsite and 60°C (140°F) in the vicinity of the townsite. Observed temperatures in this area agree well with the model as can be observed from the temperature-depth plot in Figure 4 which has a measured maximum temperature of 71°C (161°F). Depths to the hydrothermal fluid along the Thermopolis anticline vary between 150 to 300 meters (500 to 1000 feet) (see Hinckley et al., 1981).

Conclusion

The use of oil and gas well temperature data and conductive thermal modeling have been shown to be useful techniques in defining low temperature hydrothermal systems in Wyoming. The oil and gas well data are used in locating areas of high thermal gradients by considering the effects of drilling mud temperature, rock thermal conductivities, surface temperature, and drilling duration; and by comparing oil and gas well thermal gradients to gradients computed from measured temperature-depth data. Conductive thermal modeling is accomplished by using regional heat flow data, rock thermal conductivity information, measuring thermal profiles of wells, and applying geologic constraints to the model. Parameters that have been successfully addressed by this method of thermal modeling are the maximum temperature of the hydrothermal systems, extend, and depth to hydrothermal reservoirs.

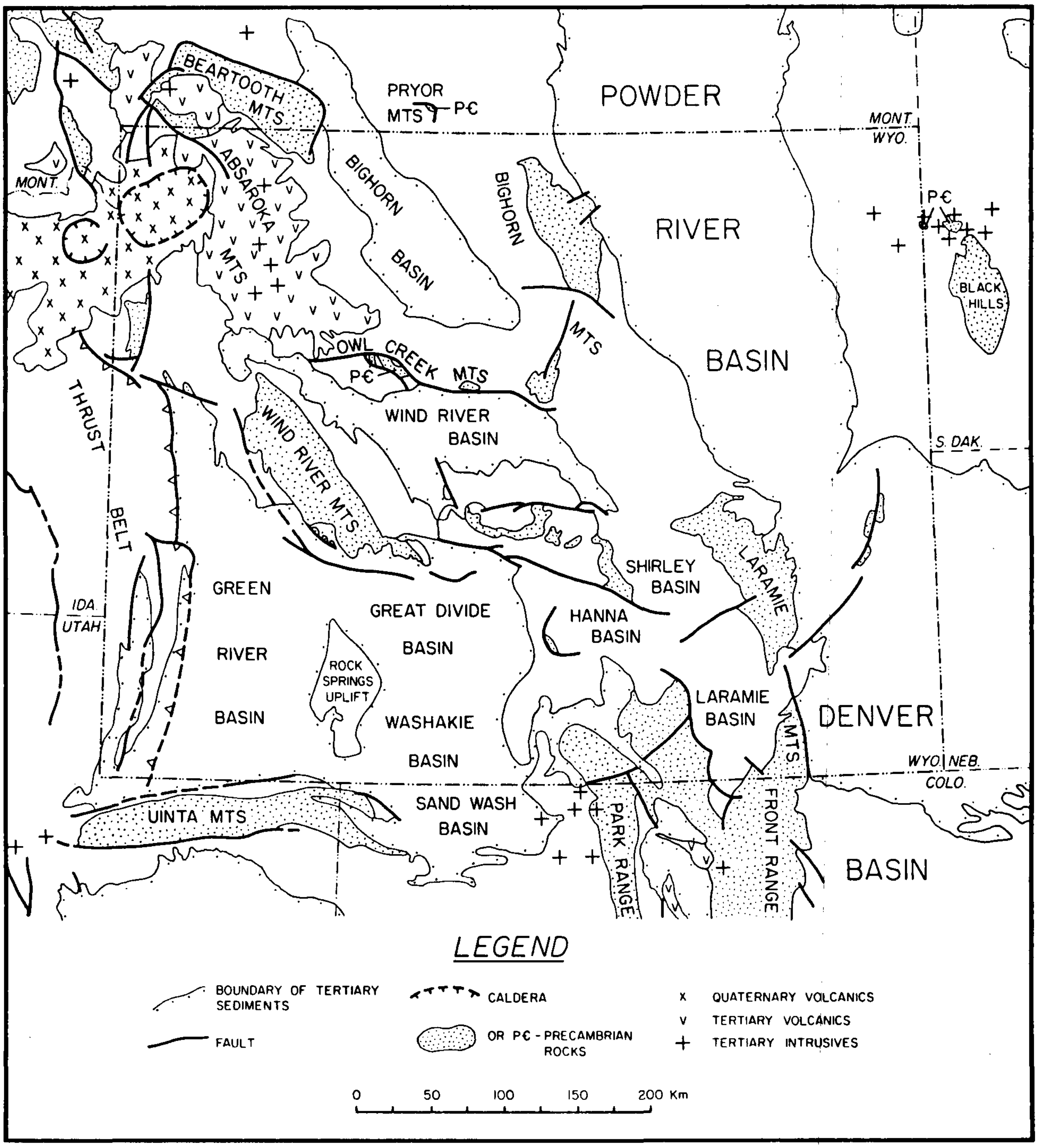
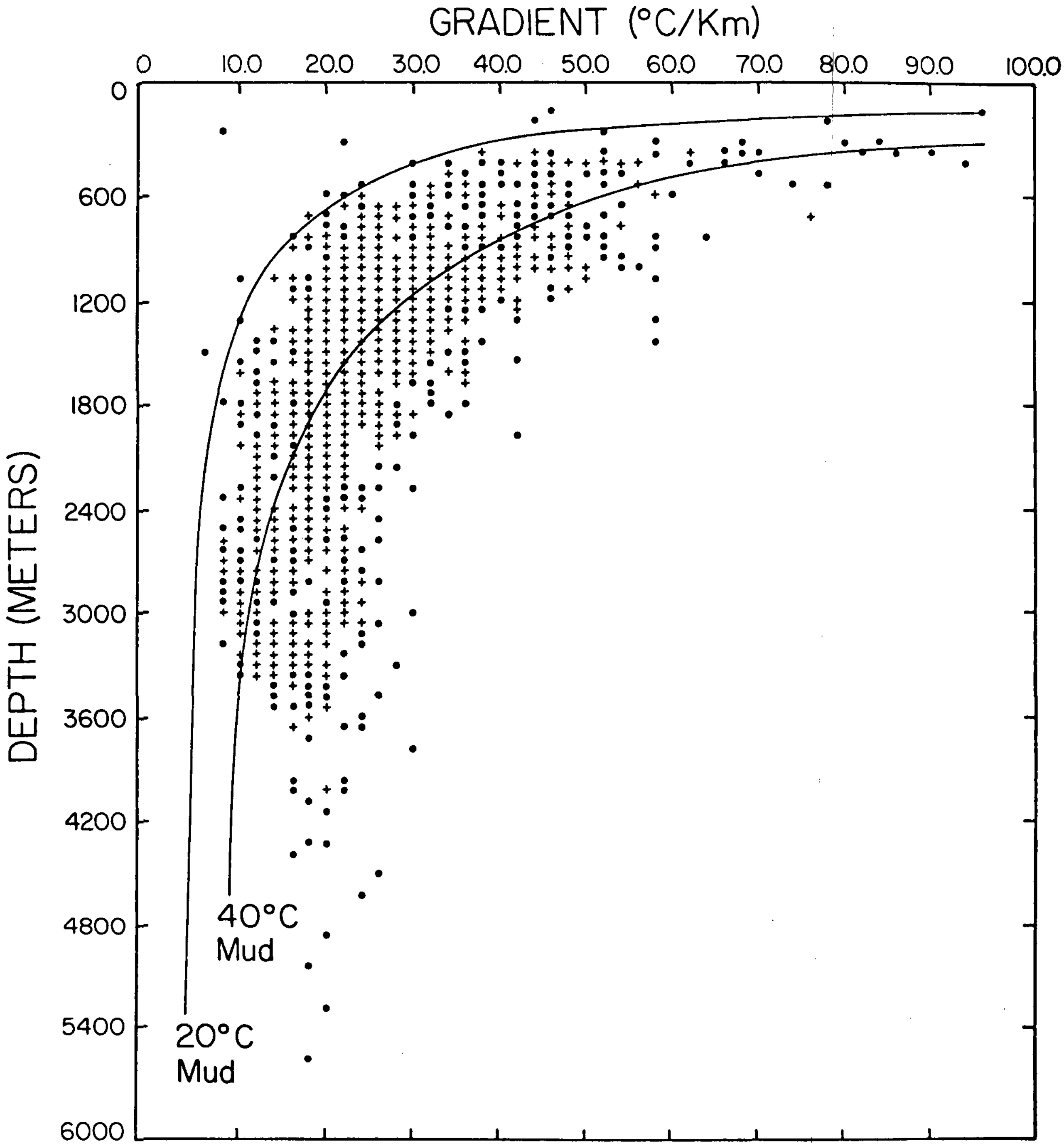


Figure 1. Generalized geology of Wyoming showing major structural basins.



GRADIENT-DEPTH PROFILE FOR THE BIGHORN BASIN

Figure 2. Oil well temperature data from the Bighorn Basin. The solid line represents a gradient assuming an isothermal drilling mud temperature. Pluses (+) represent more than one data point at that depth and gradient.

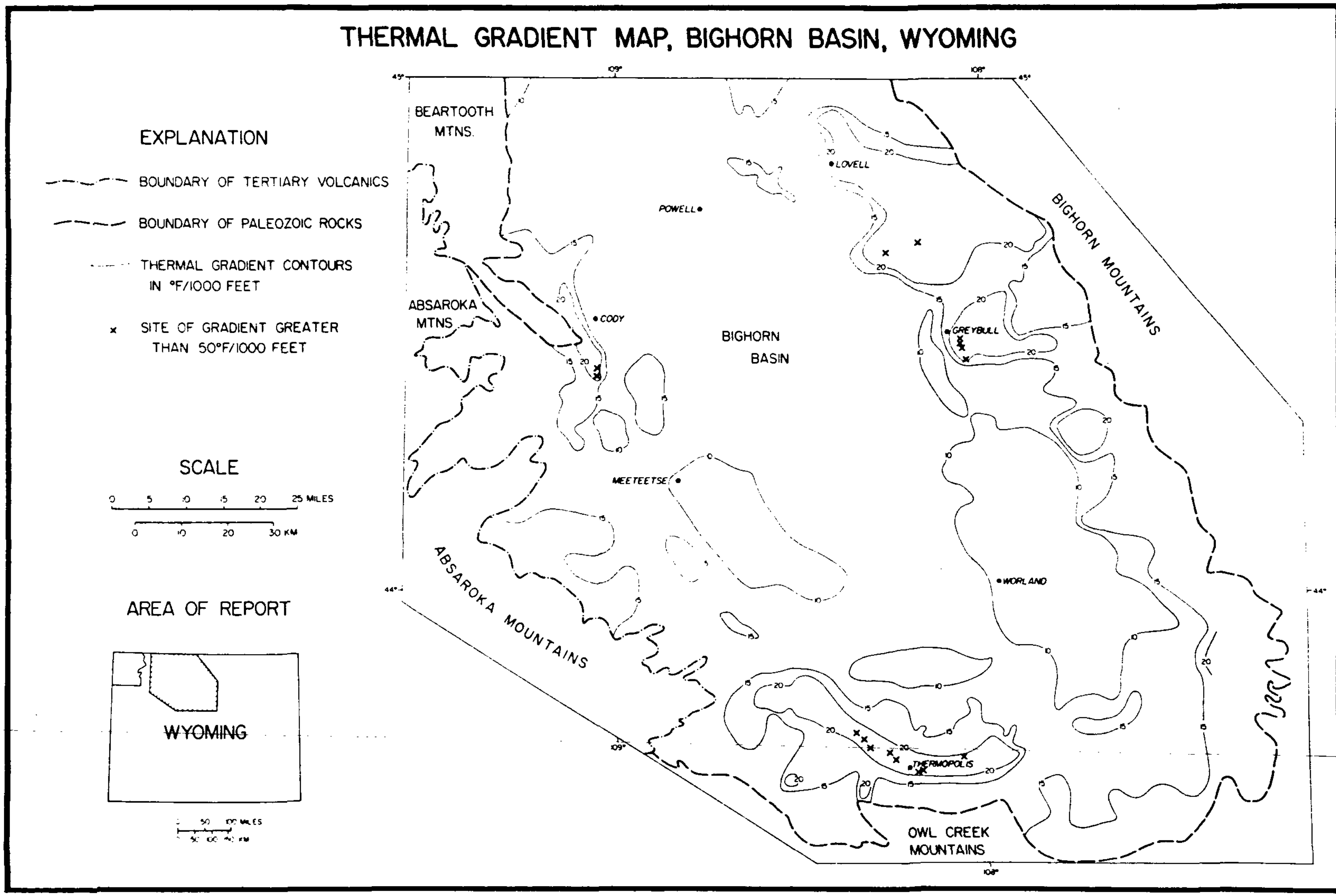


Figure 3. Thermal gradient contour map of the Bighorn Basin. Contours are in °F/1000 feet.

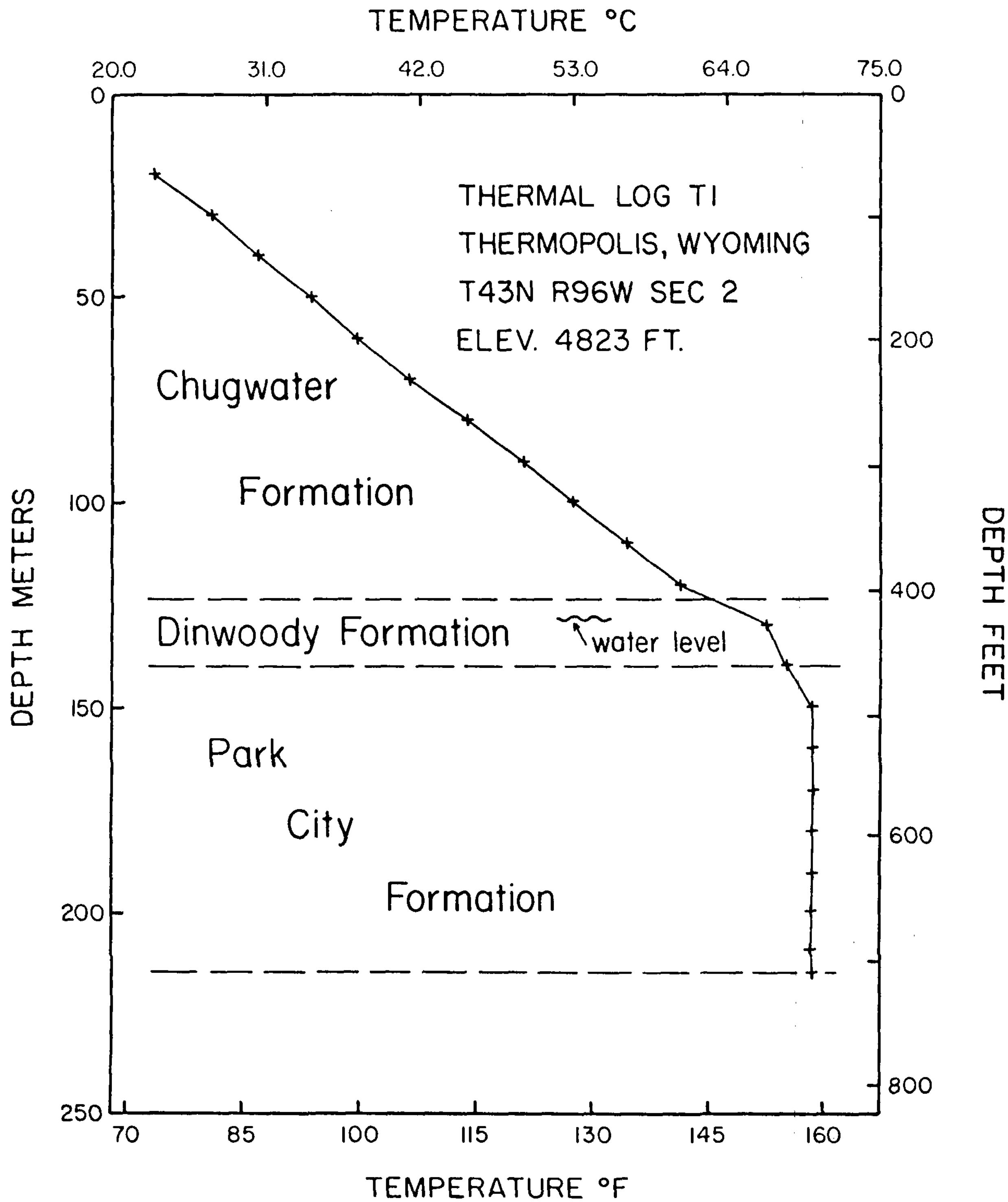


Figure 4. Temperature-depth plot for a well on the Thermopolis anticline showing an isothermal character and implied mixing zone within the Park City Formation.

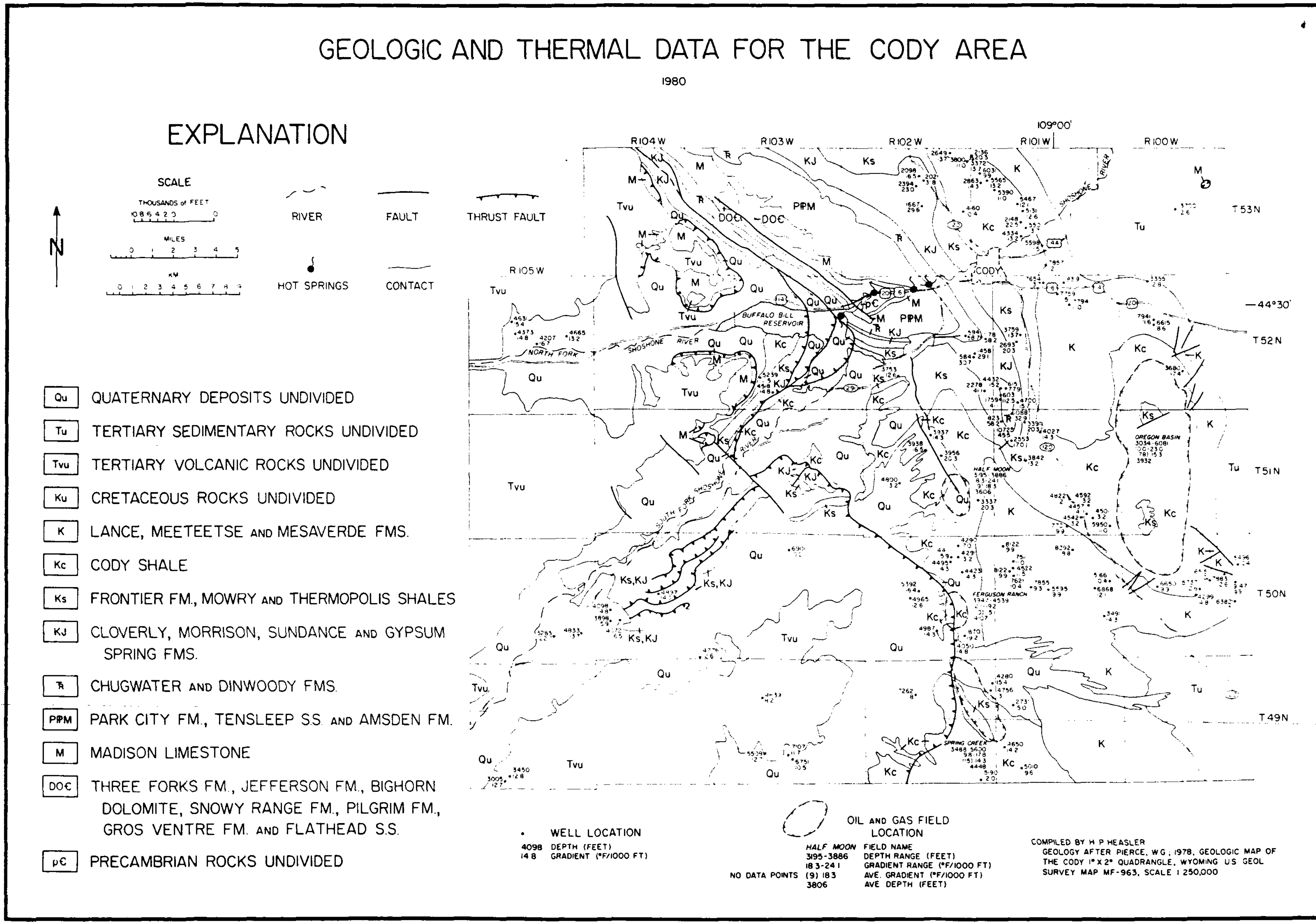


Figure 5. Geologic and thermal data for the Cody area.

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A SUMMARY OF GEOTHERMAL

RESOURCE POTENTIAL IN WYOMING

By

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April 14, 1981

INTRODUCTION

The Department of Geology at the University of Wyoming is conducting heat flow and hydrothermal studies in Wyoming and bordering areas. This research is financially supported by the United States Department of Energy with earlier funding through a grant from the National Science Foundation. Department of Energy funding began in December of 1978 with total funding to date from the D.O.E. amounting to $374,477.00.

Geothermal research by the Department of Geology has focused on detailed studies of indicated low temperature resource areas, compilations of regional geothermal data, and syntheses of pertinent geology and geophysics. Compilations of geothermal data directly followed bottom hole temperatures in oil wells, measurements of temperatures in more than 300 drill holes, and the measurement and computation of over 60 heat flow values. The regional geology and geophysics were synthesized from published articles. This report is a brief summary of the highlights of our present results and is divided into a section on regional geothermal assessment and a section on site specific areas with potential low temperature resources in Wyoming. The regional assessment section is further divided into summaries of heat flow studies and basin studies.

Throughout the text, temperatures are given in ^{o}F or ^{o}C ($^{o}F = 1.8^{o}C + 32$), geothermal gradients are given in $^{o}F/1000$ ft or $^{o}C/km$ ($^{o}F/1000$ ft $= 1.82^{o}C/km$) and depths in feet or meters (foot = .305 meters). The heat flow unit is abbreviated to HFU, where 1 HFU = 1×10^{-6} cal/cm^2 - sec = 41.8 mW/m^2.

REGIONAL GEOTHERMAL CHARACTERIZATION OF WYOMING

Heat Flow Studies

The study of the heat flow in the earth is an important parameter to consider in regional geothermal assessment. When properly used it can help define possible locations of potential resources, their maximum temperatures, and possible extent. Heat flow parameters are also very useful in site specific geothermal studies. Parameters such as the thermal conductivity of rocks and measured thermal gradient values can be used in creating models that help define a specific geothermal system.

Since heat flow is an important factor to consider in regional and site specific geothermal assessment, much time and effort has been spent in the collection of this data. Over 60 new heat flow values have been computed for Wyoming since 1978. A brief preliminary interpretation of this data is presented region by region. (See Figure 2 for regions). Much of this interpretation follows directly from Decker, Heasler and Blackstone, 1980.

The Wyoming Basin

New temperature-depth data for seven widely separated localities in the Great Divide-Green River Basins area (Figure 2) yield gradients in the range 17-30°C/km. Estimated heat flows near Eden, Wyoming are 1.6-1.7 HFU, values that agree with Sass and others' (1971) conjecture that this locality is in a zone of normal to intermediate flux. New heat flow values (8) in the Rawlins Uplift-Laramie Basin part of the Wyoming Basin (Figure 2) are low to normal (1.1-1.3 HFU). The 0.6 HFU intercept of the heat flow-heat production line for these areas provides strong support for low regional flux, as do tectonic stability of the region since the Eocene and low electrical conductivity of the underlying mantle (Decker et al., 1980). We therefore conclude that there is very little geothermal evidence for shallow reservoirs with direct-heat potential in the eastern Wyoming basin.

Middle Rocky Mountains and Western Great Plains in Wyoming

Lachenbruch and Sass (1977) inferred the presence of an east-west trending band of above-normal flux in the Middle Rocky Mountains-Great Plains region in north-central Wyoming. A recent 1.9 HFU determination in the Owl Creek Mountains is consistent with this interpretation (Decker et al., 1980), as are four previously published above-average values in the area (1.6-2.0 HFU) (Blackwell, 1969). The reasons for high flux in this zone are obscure. One speculative hypothesis is that the inferred high heat flow is in part related to young tectonic activity in the region, as may be suggested by Quaternary and Holocene faulting in the Owl Creek Mountains, and Miocene faulting in the Powder River Basin near the northern Laramie Mountains (Decker et al., 1980). But this view is not consistent with other data in Wyoming; for example, late Cenozoic faulting occurred north of the Hanna Basin and the flux in this area is normal (1.3-1.6 HFU). Clearly, more geothermal studies in these parts of the Middle Rocky Mountains and western Great Plains area would be very valuable because they might confirm above-normal regional heat flow and resolve questions related to the kinds of heat sources that exist in the subsurface.

Yellowstone Park - Absaroka Mountain Region

Values in the central and northern part of the Bighorn Basin in north-western Wyoming are $\leq$ 1.6 HFU. Decker et al. (1980) report a 1.3 HFU in the Absaroka Mountains to the west, and Blackwell (1969) obtained a 1.3 HFU flux at the southern edge of the Beartooth Mountains to the north (Figures 2 and 3). The Absaroka-Beartooth Mountains data show that the eastern and northern borders of the Yellowstone caldera high ($\geq$ 2.5 HFU) are very narrow ($\leq$ 40-50 km). The narrow transitions coupled with Quaternary volcanic rocks in the Park area suggest that the unusually high flux (5-10 HFU) in the Yellowstone caldera is caused by near-surface, magmatic heat sources (see Morgan et al., 1977).

The Southern Rocky Mountains

Birch's (1950) analysis of the Adams and Moffat Tunnels showed that the Colorado Front Range was a zone of high flux. Subsequent papers demonstrate that above-normal heat flow ($\geq$ 1.5 HFU) is characteristic of all of the Southern Rocky Mountains in Colorado and New Mexico. This province in Wyoming is not characterized by uniformly high flux, however, because the available values in the Medicine Bow and Laramie Mountains are low to normal (0.6-1.3 HFU). The northern border of the Southern Rocky Mountain high is narrow, on the basis of the lateral distance ($\leq$ 75 km) between very high estimated heat flow ($\geq$ 2.5 HFU) in the North

Park, Colorado area, and the sites in the Medicine Bow Mountains in Wyoming (Decker et al., 1980; Buelow, 1980).

REGIONAL BASIN STUDIES IN WYOMING

The Bighorn Basin

Bottom hole temperature data have been compiled and analyzed for over 2,000 oil wells and 40 measured thermal gradient wells that are within the Bighorn Basin (Figures 2 and 3). A thermal gradient contour map for the Basin shows gradients to be lowest in the central portion of the Basin (10^{o}F/1000 feet (18 ^{o}C/km)) and generally increasing to the margins of the basins (15-20^{o}F/1000 ft (27-36^{o}C/km)). The thermal gradient map also defines three areas of high gradient. These areas are near Cody, Thermopolis, and Greybull and have isolated values of over 50^{o}F/1000 ft (90^{o}C/km). The Cody and Thermopolis areas are further discussed in the section on site specific areas. Additional work is being done on the Greybull area.

A new heat flow value of 1.78 HFU has been determined for Meadow Creek Basin in the eastern part of the Absaroka Mountains. This flux and Blackwell's (1969) 1.8 HFU value near Kirwin about 20 km to the south suggest that a large part of the Absarokas is a zone of high flux like the western Great Basin. Additional evidence for Basin and Range type flux in these mountains, in turn, would suggest that low-temperature reservoirs could occur in this part of northwestern Wyoming.

Temperatures have been measured in 15 drill holes in the Bridger Mountains (Figure 2). Although some of the observed gradients (3-7^{o}F/1000 ft (5.3-12.8^{o}C/km)) are consistent with local hydrologic disturbances in these mountains, the most reliable values of 19.0-22.6^{o}C/km (10-12^{o}F/1000 ft) support earlier suggestions that the Lysite-Bridger Mountain area is a zone of above-normal heat flow (see Decker and others, 1980). Like the elevated flux in the Absarokas to the northwest, the above-normal regional heat flow may imply the presence of hydrothermal reservoirs locally in the Bridger Mountains.

Great Divide and Washakie Basins

For the Great Divide-Washakie Basins over 2,000 oil well bottom hole temperatures were gathered and analyzed along with 20 measured thermal gradient wells. Results of this study indicate a "normal" thermal gradient of 26.4°C/km (14.5°F/1000) with a high gradient of 119°C/km (65°F/1000 ft). The highest reported temperature in the region is 155°C (311°F) at a depth of 6,400 meters (21,000 ft). Areas of greatest potential are considered to be the Lost Soldier oil field area with gradients in the range of 22 to 91°C/km (12° to 50°F/1000 ft) to depths of 300 to 2850 meters (960 to 9364 ft) and the Miller Hill-Hatfield region with gradients in the range of 22° to 78°C/km (12 to 43°F/1000 ft) at depths of 350 to 2600 meters (1154 to 8529 ft).

The Powder River Basin

Head and others (1978) have contoured depths and temperatures for the Madison Formation in the Powder River Basin (Figure 2 and 3 for location). The temperatures and assumed permeabilities of this unit suggest that it could yield vast quantities of waters adequate for direct-heat applications. It is also the case, however, that the Madison is at great, perhaps uneconomically drilled depths in many parts of the area. Consequently, our studies of the Basin have focused on shallow temperature, gradient and heat flow measurements. The results of these shallow measurements are discussed in the following site specific section on the Casper-Midwest-Douglas area.

SITE SPECIFIC AREAS WITH POTENTIAL LOW TEMPERATURE RESOURCES

The Thermopolis Area

Temperatures, gradients and regional geology have been compiled for a 1800-1900 mi^2 area that is roughly centered on the Thermopolis hot springs (Figure 1). The results demonstrate that the thermal anomaly occurs all along the central part of the Thermopolis anticline, occupying a 20-mi long by 3-mi wide area that strikes west-northwest between the southwestern part of T. 43 N., R. 93 W. and the southeastern part of T. 44 N., R. 96 W. Within this zone, calculated gradients are in the range 43-300°F/1000 ft (78-547°C/km) and tabulated bottom hole temperatures range from 90°F (32°C) to 160°F (70°C) at depths less than 2000 ft (∿ .6 km). Inasmuch as downward continuation of the lower gradients predicts 60+°C temperatures at depths between 3500 and 4000 ft (1.1-1.2 km), we consider all of the region to be a "viable" low temperature, hydrothermal resource area.

The Red Springs Anticline area in T. 43 N., R. 93 W. may be a "marginal" resource area. Here the calculated gradients are in the range 24-59°F/1000 ft (43-107°C/km). Consequently, 45°C waters might be encountered at 3900-4500 ft depth (1.2-1.3 km).

A tightly folded syncline is located immediately south of the Thermopolis anticline. We believe that waters from the Owl Creek Mountains are heated at the bottom of this syncline. Subsequent upward movement of these waters along the northern flanks of the syncline could explain the high gradients in the anticline. The thermal waters are most likely to be in the Tensleep and/or Madison Formations--two formations with porosities and permeabilities sufficient to yield the flow rates (∿ 2800 gpm; Breckenridge and Hinckley, 1978) of the spring system in Hot Springs State Park. Within the central part of the anticline, the "tops" of the Tensleep and Madison range from 200-2800 ft (.06-.85 km) and 800-3450 ft (.24-1.08 km), respectively. It is possible, therefore, that these aquifers could be reached with economical drilling in some parts of the structure.

Referring to "practical" aspects of resource development, one question that must be answered is whether drilling and large scale development would change temperatures and flow rates of the Thermopolis hot springs. Lack of data on porosities and permeabilities of the regional subsurface units also could impede development, as could the data for the springs which suggest that regional thermal waters would contain large amounts of total dissolved solids (2300 ppm; Breckenridge and Hinckley, 1978). Finally, minor structures along the crest of the anticline should be carefully considered during drill site selection; for example, numerous faults cross-cut the northwest-southeast trend of the anticline, and a heretofore unmapped fault is evident on air photos of the structure.

The Cody-Horse Center Anticline System

This potential resource area is bounded by the DeMaris hot springs (27-39°C (80-96°F) 1700 gpm) just west of Cody and the Horse Center anticline about 7 miles to the south (Figure 1). The first evidence for a low-temperature resource was provided by the 49-205°C/km (27-112°F/1000 ft) gradients calculated using bottom hole temperatures in eleven dry oil wells in the anticline. Down hole measurements by Wyoming personnel agree with the oil well data. For example, least-squares gradients and maximum temperatures based on measurements in five shallow oil wells are in the ranges 96-190°C/km (52-104°F/1000 ft) and 38.4-47.5°C (101-117°F), respectively, at subsurface depths in the range 185-500 m (607-1640 ft).

Data from six shallow temperature gradient wells drilled by the Department of Geology in early 1980 suggest that the area of greatest potential use is in T. 52 N., R. 102 W., S½ of section 2, and W½ of section 11. In this area warm waters (34°C (93°F)) can be reached at shallow depths (51 to 300 meters (168 to 1,000 feet)). The maximum temperature of this system may approach 55 to 65°C (131 to 149°F) at depths of 260 to 500 meters (853 to 1640 feet). Warm waters will be found at the shallower depths in the more western portions of this potential use area (see Heasler, 1980).

The main aquifers for the Cody-Horse Center hydrothermal system are the Tensleep Sandstone, Madison Limeston, and Bighorn Dolomite. These formations are reported to have good porosities and permeabilities with flows in the Madison Limestone and the Bighorn Dolomite sometimes exceeding 1,000 gallons per minute (Lowry, 1976). However, the water flow of wells drilled into these aquifers may vary greatly between wells due to secondary fracture permeability, secondary silica cementation of the Tensleep Sandstone, and the cavernous nature of the Madison Limestone and Bighorn Dolomite.

The Rattlesnake anticline is between Cody and the Horse Center anticline. As seems to be the case elsewhere in the area, the Chugwater Formation in this anticline appears to be an impermeable cap rock that overlies porous, permeable and perhaps water-bearing units in the Tensleep and Madison Formations. It is believed that waters are heated at depth in a syncline that is to the southwest of the Rattlesnake anticline.

Subsequent upward movement of the water along the northeastern flank of the syncline through the Tensleep and Madison Formations results in the warm temperatures at shallow depths.

The Casper-Midwest-Douglas Area

Because of much local interest in utilization of hydrothermal resources in projected housing development, considerable effort has been spent researching these areas. Present data consist of more than 2,000 bottom hole temperature points, from which combined temperature gradient and geologic maps are being prepared.

Most of our data are for areas near Midwest. These results clearly show that the Salt Creek Oil Field is a conspicuous thermal anomaly. Within this 10-12 mi^2 field, bottom hole temperatures between 1000 and 4500 ft (.3-1.4 km) are in the range 120-170°F (49-77°C), and maximum calculated gradients are between 40 and 100°F/1000 ft (72-182°C/km). Additionally, water injection wells that penetrate the Madison Formation produce 160-175°F (71-79°C) waters that flow to the surface at rates exceeding 7,000 gallons/min. There can be little doubt, therefore, that the Salt Creek Field could be used to produce hydrothermal fluids for direct-heat applications in the vicinity of Midwest. The major impedences to resource development could be the relative values of hydrocarbon and geothermal resources, the high concentrations of solids in the nonpotable waters, and the question of whether AMOCO Production Co., Wyoming, or the federal government owns the geothermal resource.

Scant data exist for the Casper region because fewer oil tests have been drilled in the area. The available data do suggest, however, that most of the region within a 10-15 mile radius of the city is not thermally anomalous. Calculated gradients are generally in the range 14-16°F/1000 ft (25-29°C/km) and temperatures are in the range 100-135°F (38 to 57°C) at depths of 3,500-4,500 feet (1,070-1370 meters).

Two reliable heat flow values are now available for the Douglas low-temperature resource (?) area (Figure 1). The values are in the range 2.0-2.2 HFU. These drill holes are in an area where the underlying Madison Formation is dipping up to shallower depths from the north, northeast. Perhaps upward circulating waters in the Madison explain the observed above-normal flux. More reliable definition of the suggested resource area will require additional research with shallow drill holes.

Gradients in 5 shallow holes near Torrington are in the range 23-29°C/km (13-16°F/1000 ft). In the Wright area to the north, measurements in 10 holes suggest that the undisturbed regional gradient is between 19 and 29°C/km (10-16°F/1000 ft). The meaning of these data is obscure, but one interpretaion is that the eastern part of the Powder River Basin is characterized by a complex pattern of normal to high heat flow and perhaps shallow low-temperature hydrothermal reservoirs in isolated areas. We cannot be more specific without more geothermal data for the Basin.

Research in the Casper-Midwest-Douglas area is continuing in an effort to locate potential resource areas and to better define heat sources and hydrothermal water movement.

The Gas Hills Area

Research before 1979 revealed the presence of high gradients (42-100°C/km) at 8 isolated drill holes on the Beaver Rim in the Gas Hills. Recently compiled data consist of 20 bottom hole temperatures and temperature measurements in 31 holes that were drilled during uranium exploration. Maps of heat flow, gradient and regional geologic data are in various stages of compilation.

The present data are consistent with a complex pattern of gradient and flux in the Hills. Briefly, observed gradients range from 20°C/km to 100°C/km (11-55°F/1000 ft) and estimated heat flows are in the range 1.2-3.4 HFU. From combined geothermal and geologic data, one hypothesis is that faults control the gradient and heat flow patterns. Thus, any development of geothermal resources is likely to require careful mapping of the local geologic structure to delineate fault zones that could yield waters with potential for direct-heat applications. We hope to conduct more studies in the area because the great interest in subsurface uranium could lead to local settlements and because one deep oil test in the Hills is reported to have encountered high temperature waters in the Madison (J. D. Love, personal communication, 1980).

The Saratoga Valley Thermal System

Our DOE cooperative agreement has allowed us to establish a gradient and heat flow profile that extends from the eastern edge of the Washakie Basin to the Laramie Mountains (Figure 2). Gradients and preliminary heat flow values along this profile are in the ranges 7-30^{o}C/km (4-16^{o}F/1000 ft) and .9-1.6 HFU, respectively. Two holes on the profile are near the hot springs in the town of Saratoga (Figure 1). The gradient in the hole about 1 mile west of the springs is 20^{o}C/km (11^{o}F/1000 ft), and that in the hole about 1 mile to the east is 30^{o}C/km (16^{o}F/1000 ft). Both gradients may be considered "normal", and so these observations suggest that the Saratoga hot springs ($\sim$50^{o}C (122^{o}F); Breckenridge and Hinckley, 1978) are not surface manifestations of a subsurface hydrothermal system with large dimensions. The narrow width of the system, in turn, suggests that the springs could be flowing from faults in this part of the Saratoga Valley. This view is supported by geologic evidence for a fault zone near the spring system (Montagne, 1955). Like the Gas Hills, development of geothermal resources in the Saratoga area may require additional research on the correlations between faulting, subsurface temperatures and heat flow in the region.

We may speculate that moderate or higher temperature resource areas could be present at shallow depths in the region between the Saratoga Valley and the southern Rocky Mountains in northern Colorado (Figure 2). From our new data, the heat flow is normal or low (.9-1.6 HFU) in the Saratoga Valley-Sierra Madre Mountains-Medicine Bow Mountains region in Wyoming, whereas the flux is high ($\geq$ 2.4 HFU) at Hahns Peak and Northgate, Colorado, about 50-60 km (31-38 mi) to the south. Interpreted in terms of steady or transient heat sources, the width and magnitude of the transition suggest that the excess flux in northern Colorado is partly due to high temperature heat sources at shallow depths in the crust and/or upper mantle. This view, in turn, is consistent with geothermal reservoirs in the transition zone and the high heat flow area immediately to the south.

CONCLUSION

Additional work is planned for the Wind River Basin, Green River Basin, Laramie Basin, and the Thrust Belt of Wyoming. Studies will also continue in identified resource areas. Public input has been very useful in past studies in supplying information on thermal springs, wells available for logging, and areas of potential resource use. Continued input of this type is strongly encouraged. The Wyoming Geothermal Resource Assessment Group can be contacted at P. O. Box 3006, Department of Geology, University of Wyoming, Laramie, Wyoming 82071 (307-766-4888).

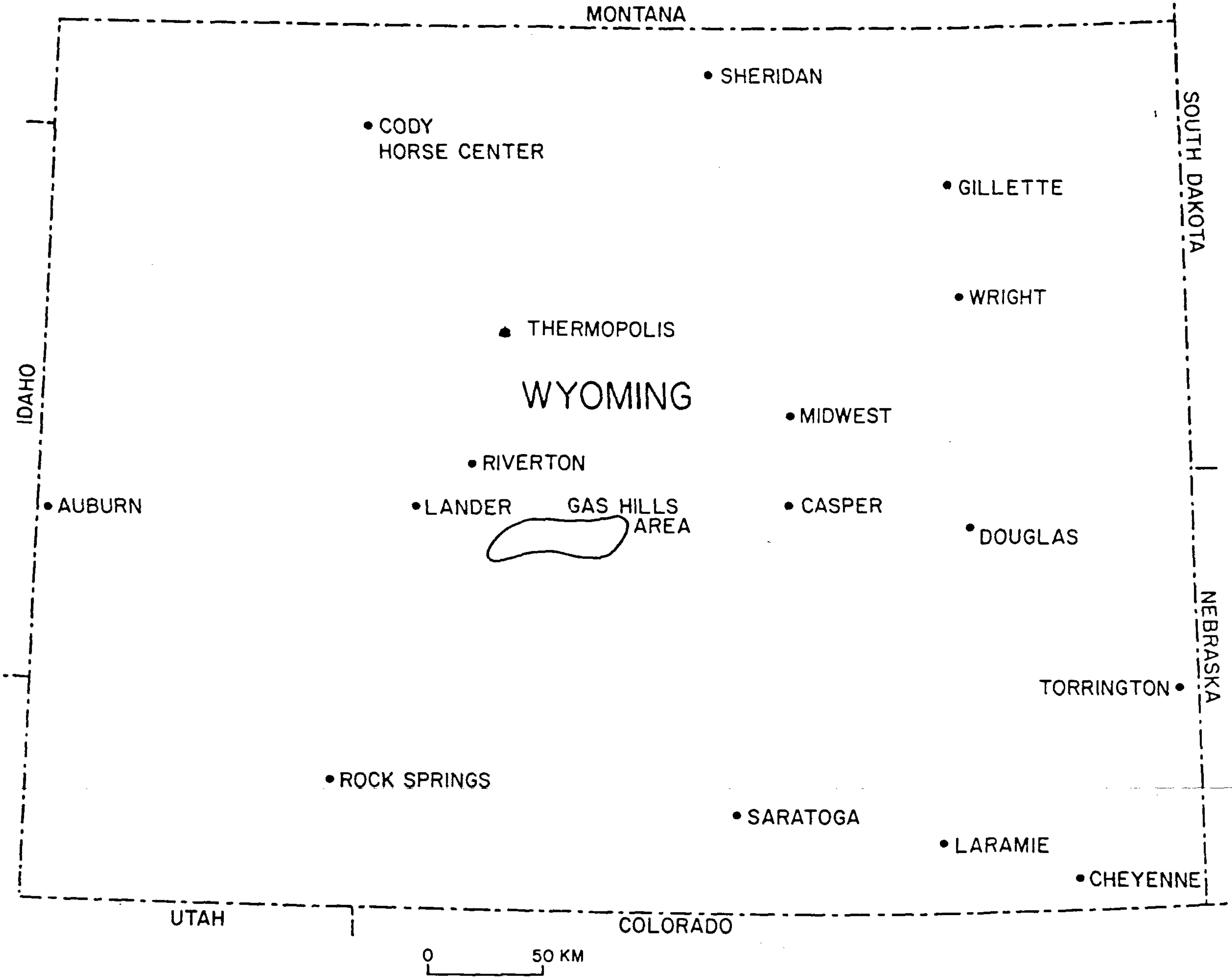

Figure 1. Investigated areas.

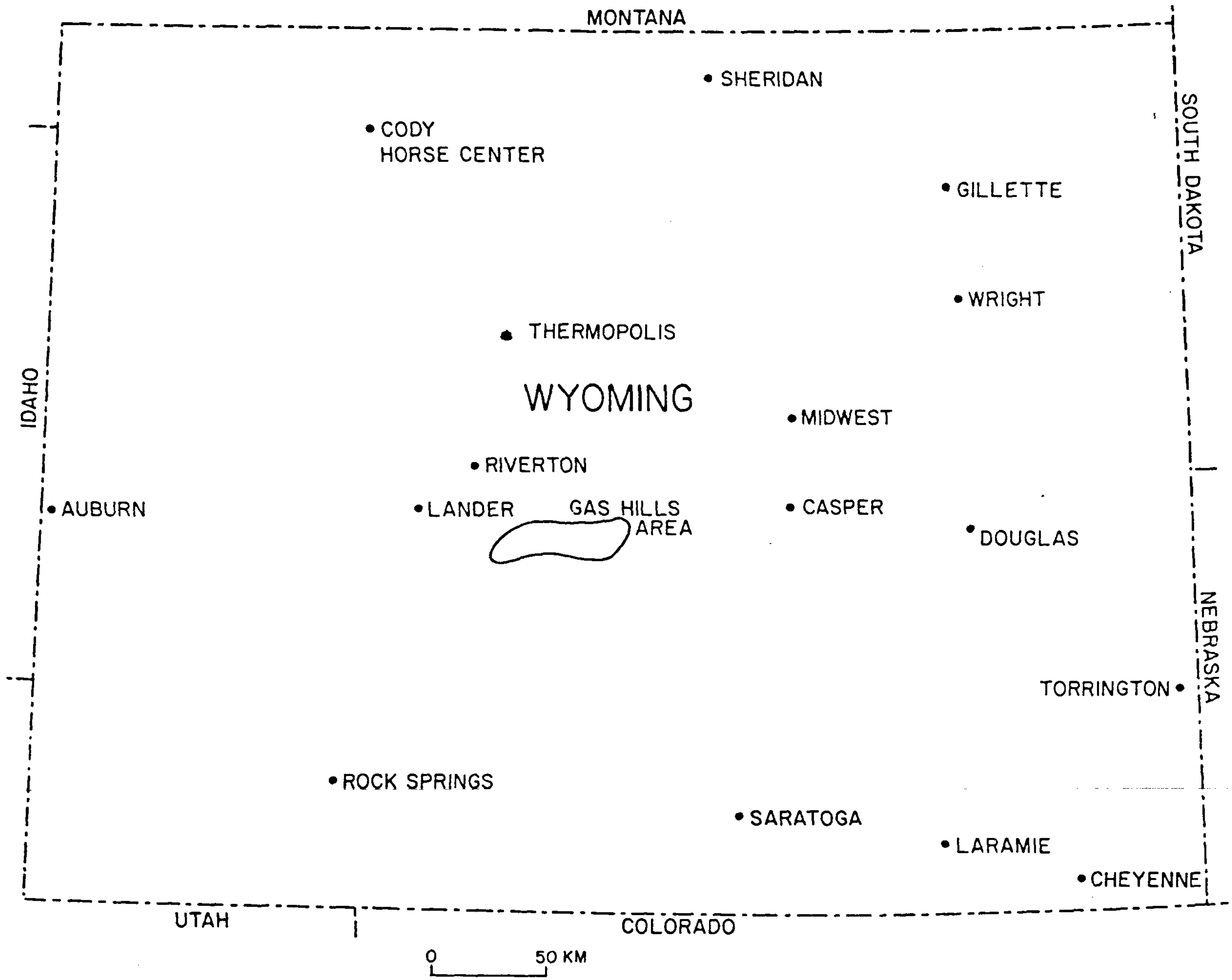

Figure 1. Investigated areas.

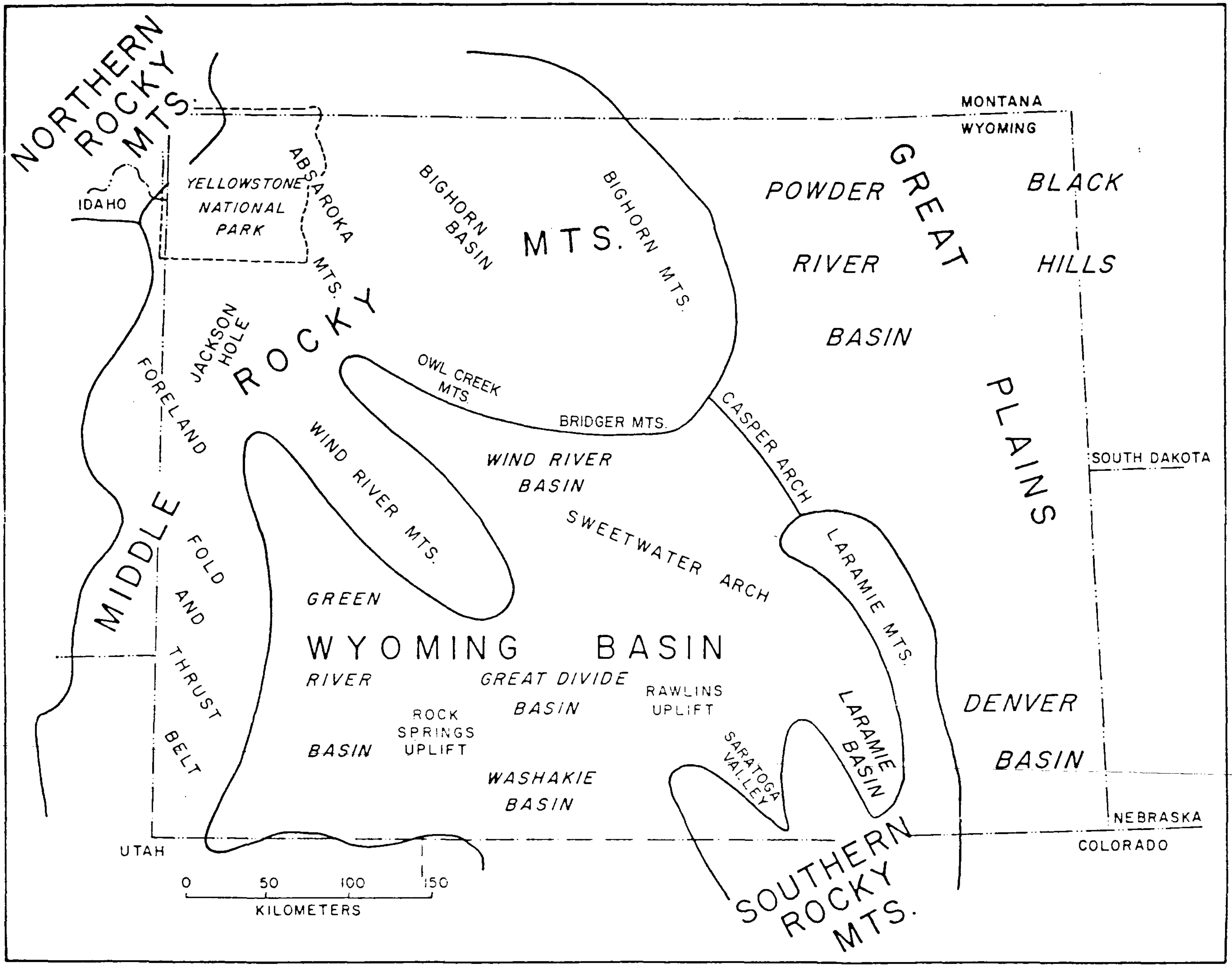

Figure 2. Physiographic provinces and major structural elements in Wyoming.

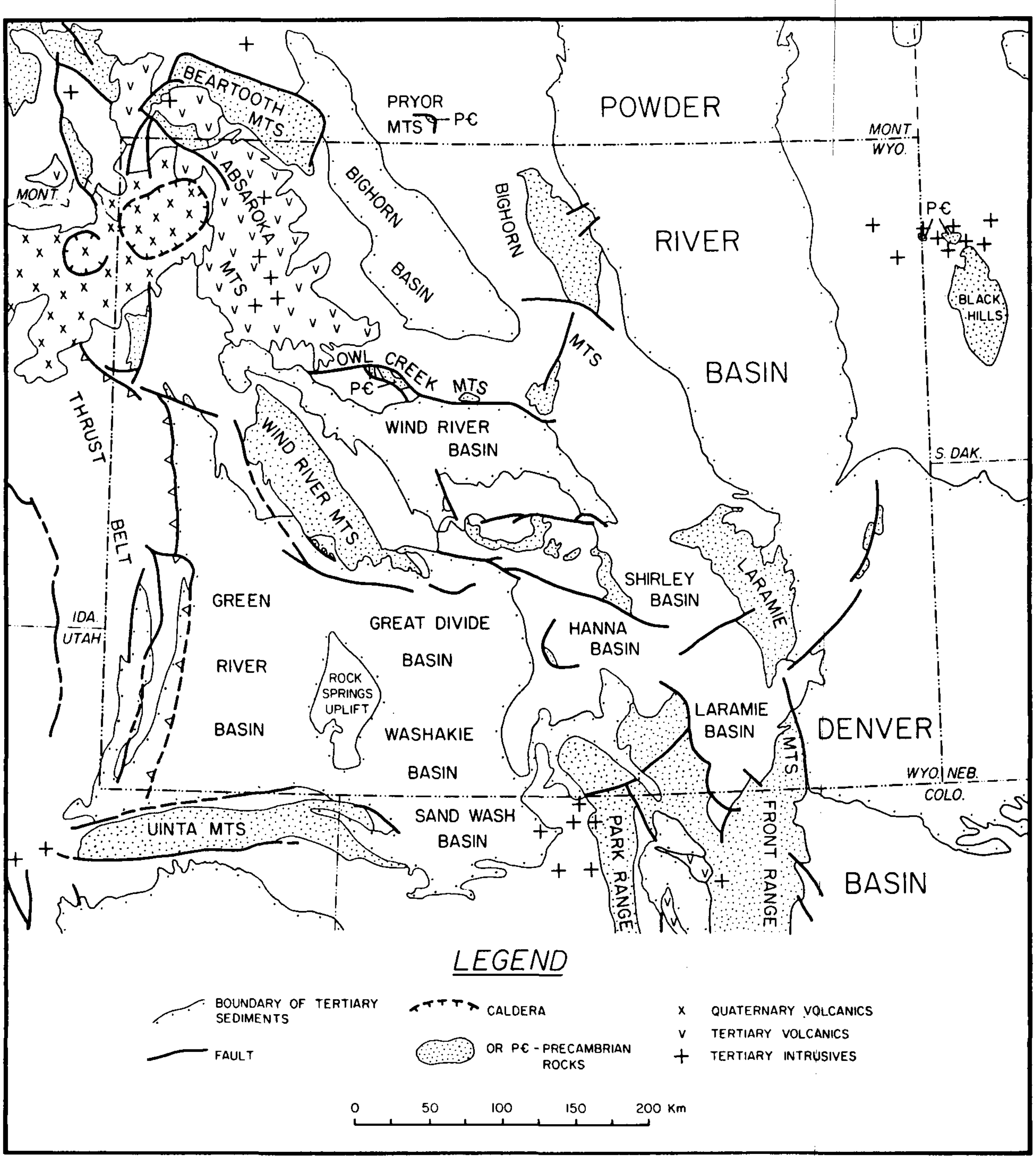

Figure 3. Generalized geology of Wyoming showing major structural features.

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GEOTHERMAL NEWS

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Vol. 2, No. 12 December, 1981

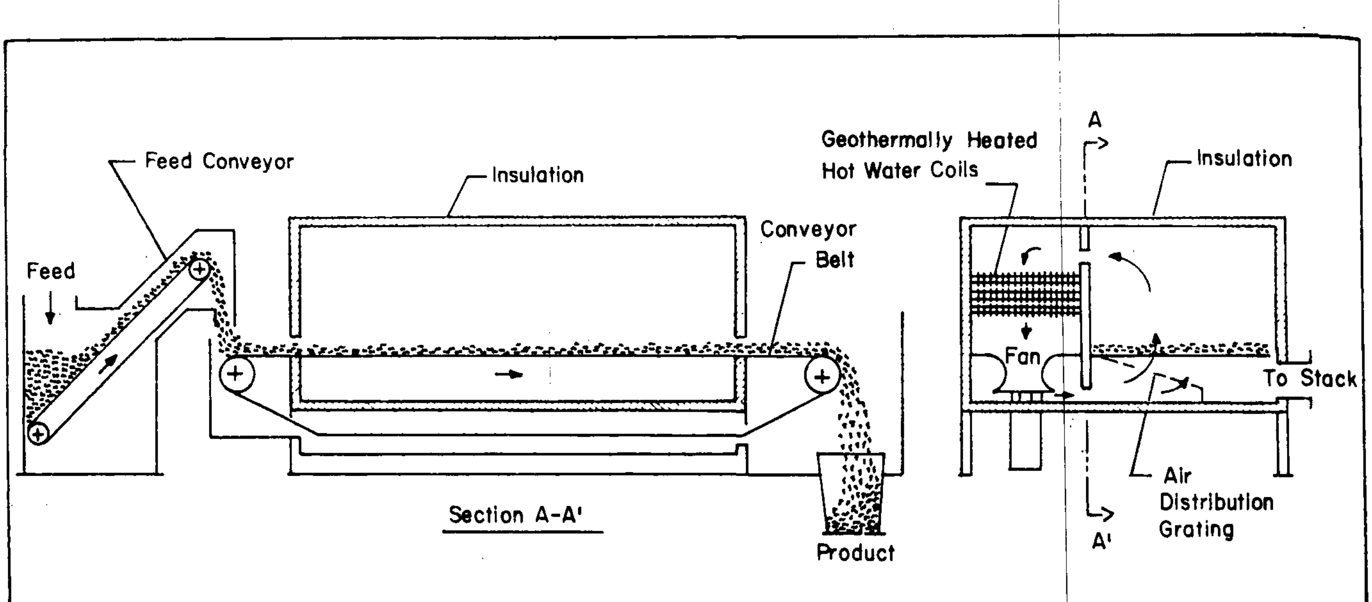
VEGETABLE AND FRUIT DEHYDRATION WITH GEOTHERMAL HEAT

Vegetable and fruit dehydration involves the use of a continuous operation, belt conveyor or batch process using fairly low-temperature hot air from 100-220°F. The heat historically has been generated from steam coils and natural gas, but can be provided by geothermal energy. Typical continuous operation processing plants will handle 10,000 pounds of raw product per hour, reducing the moisture from about 83 percent to 4 percent, depending on the product.

A crop currently being dehydrated with geothermal energy is onions. A similar dehydration process could be applied to fruits and other vegetables. The figure below illustrates a typical conveyor dryer for drying vegetables which is the type presently being used for onions. High-powered blowers and exhaust fans move the air through water coils (which contain either geothermal fluid or water in a secondary loop heated from geothermal energy) and through the beds of onions on the dryer conveyor, to evaporate the necessary tons of water removed from the product each hour. Close air volume and pressure control must be maintained in all parts of this drying stage as the air moves up and down through the bed to obtain product drying uniformity. Automatic temperature controllers control the continuous operation.

At the proper point in the drying process, the onions are automatically transferred to the second stage of drying where, under reduced temperature conditions and deeper bed loadings (about 12 inches), the difficult-to-remove diffused water is slowly withdrawn.

After drying, the onions are passed over a long stainless steel vibrating conveyor that gently carries them to the milling area. In the mill, skin is removed by aspirators from the onion pieces. The onions are then sliced, chopped, ground, granulated and powdered. (Source: Geothermal Resources Council Special Report No.7)



THERMOPOLIS DISTRICT HEATING MEETING

Patti Burgess-Lyon represented the WGCO at a meeting in Thermopolis on December 3, 1981. The purpose of the meeting was to review the progress of the district heating feasibility study that is being conducted by Coury and Associates for the town of Thermopolis. A description of the work completed so far on the feasibility study will be included in the next issue of this newsletter.

GEOTHERMAL ENERGY POTENTIAL OF CODY TO BE PRESENTED AT TWO MEETINGS

Karen Marcotte will represent the WGCO at two meetings in Cody on the geothermal energy potential of the Cody and South Fork region.

The first meeting will be held at the Cody Chamber of Commerce luncheon on December 7, 1981. The meeting will be held at the Cody Convention Center at 12:00 noon in the Cody Club Room.

The second meeting will also be in the Cody Club Room of the Convention Center, and will be held on Tuesday, December 8, at 7:00 p.m. A slide show on geothermal development in the western U.S. will be presented, followed by a discussion of recent geothermal activity in Thermopolis, and the potential for geothermal energy development in the Cody and South Fork area. The public is urged to attend this meeting and find out how an inexpensive, renewable energy resource can be utilized in their community.

MATERIALS AVAILABLE THROUGH THE WGCO

The following is a list of printed materials available through this office:

--The Cody Site Specific Development Analysis (xerox of draft report)
--The Thermopolis/East Thermopolis Site Specific Development Analysis
--Preliminary Data from Six Temperature Gradient Holes near Cody, Wyoming
--Fremont County Area Development Plan
--Big Horn Basin Area Development Plan
--Converse and Natrona Counties Area Development Plan
--Wyoming Geothermal Institutional Handbook
--Rules of Thumb for Geothermal Direct Heat Applications
--Opportunities for Geothermal Energy Use in Wyoming Industries
--Department of Energy Fact Sheets on: geothermal ethanol plants, resource availability, existing and proposed geothermal electric power plants, direct use demonstration projects, and the Raft River 5-MW pilot plant
--We also have a variety of printed materials from many different sources on: geothermal greenhouses, aquaculture, heat pumps and space heating.
--Previous issues of the Geothermal News

WGCO PERSONNEL

Karen Marcotte, Program Director
Patti Burgess-Lyon, Research Associate
Ruth Tebbutt, Senior Secretary

GEOTHERMAL COMMERCIALIZATION OFFICE

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GEOTHERMAL NEWS

P.O. Box 4096, University Station, Laramie, WY 82071
(307)766-4820 Toll-free in Wyoming 1-800-442-8334

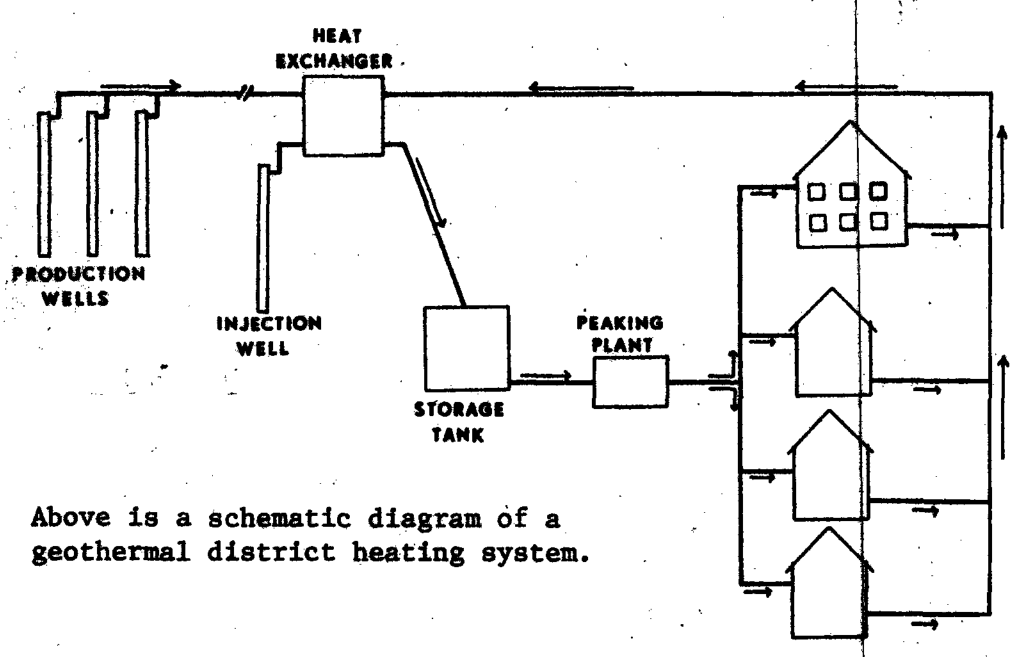
Vol. 2, No. 8 August, 1981

GEOTHERMAL DISTRICT HEATING SYSTEM

A geothermal district heating system is one that uses geothermal waters to heat buildings and residences in a town or a district of that town. In a geothermal heating district the geothermal water is pumped from the production wells to the heat exchanger. In the heat exchanger the geothermal water's heat is transferred to the secondary fluid. Domestic water is commonly used as the secondary fluid. The geothermal water, after heating the secondary fluid in the heat exchanger, is then reinjected into the original aquifer. It must, however, be reinjected at a sufficient distance from the production wells so as to avoid cooling the water in those wells. Thus the geothermal water is not consumed, only its heat is extracted.

The newly warmed secondary fluid passes from the heat exchanger to a storage tank and peaking plant. Here the rate of flow is regulated depending on seasonal demand. For instance, during the cold winter months it may be necessary to run the system at full capacity, whereas the summer load would be much reduced. From the peaking plant the hot secondary fluid travels to the various buildings and residences where its heat is released. After heating the buildings and residences in the district, the cooled secondary fluid is returned to the heat exchanger where it is again warmed by the geothermal water.

The secondary fluid is contained in a closed system. It is not consumed, but continually reused. One of the benefits of using a secondary fluid in a district heating system is that corrosion and scaling due to impurities in the geothermal waters are isolated. This keeps the cost of replacing pipes at a minimum.



Above is a schematic diagram of a geothermal district heating system.

THERMOPOLIS FEASIBILITY GRANT

Thermopolis has recieved the contract from HUD concerning the terms of a feasibility study they are funding. The study concerns the feasibility of installing a geothermal district heating system in Thermopolis. Coury and Associates has been chosen by Thermopolis as the consulting engineering firm that will conduct the study.

According to Renee Magee, Town Administrator/Planner, the first step will be a meeting of the Advisory Board to set up a work program. This will occur when the contract has been signed and returned by HUD.

GCO PERSONNEL

Karen Marcotte, Acting Program Director
Patti Burgess-Lyon, Research Associate
Ruth Tebbutt, Senior Secretary

MATERIALS AVAILABLE THROUGH THE GCO

The following is a list of printed materials available through the GCO:

--Wyoming's Geothermal Resource and Utilization Potential
--The Cody Site Specific Development Analysis (xerox of draft report at this time)
--The Thermopolis/East Thermopolis Site Specific Development Analysis
--Preliminary Data from Six Temperature Gradient Holes near Cody, Wyoming
--Fremont County Area Development Plan
--Big Horn Basin Area Development Plan
--Converse and Natrona Counties Area Development Plan
--Institutional Handbook for the State of Wyoming
--Rules of Thumb for Geothermal Direct Applications
--Geothermal Greenhouse Heating Pamphlet
--Federal Cost Sharing for Exploration of Hydrothermal Reservoirs for Direct Applications
--Geothermal Energy in Wyoming: Site Data Base and Development Status
--Hydrothermal Commercialization Baseline for the State of Wyoming
--All previous issues of Geothermal News

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Wyoming: Additional Work
Wind River Basin
Green River Basin
Laramie Basin
Wyoming Thrust Belt.

→

THE UNIVERSITY OF WYOMING
DEPARTMENT OF GEOLOGY
GEOLOGY BUILDING
P. O. BOX 3006
LARAMIE, WYOMING 82071
PH. 307—766-3386

June 5, 1981

Dr. Duncan Foley
Earth Science Lab
University of Utah Research Institute
420 Chipeta Way, Suite 120
Salt Lake City, Utah 84108

Dear Duncan:

Enclosed is a copy of my letter to M. A. Widmayer which constitutes the March, April, and May technical progress reports for the Wyoming Geothermal Resource Assessment Team.

If you have questions or comments, please contact me.

Sincerely,

Hank

Henry P. Heasler
Principal Investigator
Wyoming Hydrothermal Resource
Assessment

HPH/tj

Enclosures

Casper Star Tribune, April 11, 1981

Hot water from old oil wells could heat homes

By DAVID ANSLEY
Of The Star-Tribune Staff

Hot water from dry wells could heat your home someday.

Wells given up as "dry" by oil companies may nevertheless have tapped hot water thousands of feet down.

If those wells could be used by nearby residents, "that could be the greatest use of low-temperature geothermal (supplies) in the state," says Henry Heasler of the University of Wyoming geology department.

"Low-temperature" geothermal water is less than 190 degrees Fahrenheit and could best be used for direct heating of buildings, he said.

Heasler, part of a team assessing the state's hot water resources for the U.S. Department of Energy, described his work at a Wyoming Geothermal Energy Workshop held Tuesday at Casper College.

Sponsored by the Geothermal Commercialization Office in Laramie, Tuesday's program included discussions of the economics, technology and equipment of geothermal energy use.

THE MOST OBVIOUS sources of naturally-heated water are located near scattered hot springs in Yellowstone Park, the Big Horn Basin, the Saratoga area and the Midwest area, Heasler said.

Near Cody, for example, the assessment team found 140-degree water at depths of only 600 feet, from where it could be removed at reasonable cost.

"It's not economical" to drill new wells into not water trapped several thousand feet underground, he said. "But if the regulations could be streamlined," fruitless oil and gas wells that strike water would be a valuable source.

"It costs more to plug already-dug wells" than use them as hot water supplies, Heasler said.

"I ENCOURAGE PEOPLE to contact us" with the locations of hot springs or wells that have tapped hot water, he said. "We find some hot springs just by talking to people."

Casper

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GEOTHERMAL NEWS

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Vol. 2 No. 10 October, 1981

GEOTHERMAL INSURANCE NOW AVAILABLE

The Insurance Company of North America (INA) has formed a new insurance group providing comprehensive coverage to the energy industry. INA's Energy Insurance Group will be able to serve the insurance needs of renewable energy technologies such as geothermal, solar, and wind, as well as conventional energy risks.

Geothermal insurance eliminates the risk of inadvertent loss to potential investors which makes for a more attractive financial venture.

The Geothermal Resource Program provides insurance against loss arising out of the termination of a project as a result of resource inadequacy or against loss from a project that fails to perform as expected. Coverage is offered through a non-cancellable policy that includes both project construction and an operational period up to seven years.

In direct-use of geothermal energy (such as industrial processes and various agricultural and aquaculture uses) indemnification is based on the insured's loss resulting from an inadequate resource. This may include the actual cost of an alternative fuel system, for example a steam boiler, sufficient to supply the required heat and its alternative fuel. Or, it could cover the costs of redrilling or reworking the geothermal well.

The Geothermal Resource Program is also a strategic financial tool available to expedite development in both direct and indirect uses. It can be a significant factor in attracting capital and financing for these kinds of projects.

For more information on geothermal insurance write: INA Corp., 1600 Arch Street, Philadelphia, PA 19101.

HYDROLOGIC TESTING PROPOSED FOR THERMOPOLIS

The town of Thermopolis has submitted a proposal for some limited hydrological tests to the Wyoming Water Development Commission. During the 1981 special session, the Wyoming legislature approved a measure that would provide for the study and use of underground water for municipal purposes. All proposals submitted under this program must be made by incorporated municipalities in Wyoming. Geothermal applications are included in the list of potential uses of underground water under this program.

The Thermopolis proposal consists of the following two sections:

1. the hydrological testing of existing geothermal wells, in order to define the aquifer parameters in the Thermopolis region, and
2. the drilling and testing of one hydrologic and thermal test well approximately four miles outside of Thermopolis, to a depth of about 500 ft.

The purpose of this proposal is to test the effects, if any, that the operation of wells may have upon each other, or upon the aquifer itself. The data obtained from this study would be very helpful in defining the parameters of the Thermopolis aquifer.

The review of this proposal will take place on October 29 in Cheyenne, Wyoming. Geologists from the Wyoming Resource Assessment Team will assist Thermopolis and other hydrologists on this project if the proposal is accepted.

WIND ENERGY WORKSHOP IN CHEYENNE

A consumer oriented workshop entitled, "Wind Energy for the Rockies" will be held at Holding's Little America in Cheyenne, Wyoming on Saturday, October 31, 1981.

The workshop is being sponsored by the Rocky Mountain Wind Energy Association and Western Sun. It will begin at 8:30 a.m. and close at 6:00 p.m.

Mr. Robert Sherwin, Vice President of Enertech, will be one of the guest speakers. Enertech is the world's leading producer of home-sized wind systems. Mr. Sherwin's presentation will be on "Proper Siting of Wind Systems".

Advance registration is $15.00 for energy council members, and $20.00 for non-members. Registration at the door will be $25.00. For registration materials or additional information, contact Matt at the Rocky Mountain Wind Energy Association, Box 9408, Casper, WY 82609, or call(307)266-2539.

GCO PERSONNEL

Karen Marcotte, Acting Program Director
Patti Burgess-Lyon, Research Associate
Ruth Tebbutt, Senior Secretary

THERMOPOLIS MEETS WITH ELIOT ALLEN

On September 15, 1981 Eliot Allen addressed the Thermopolis town council on alternative methods of funding a geothermal district heating system. Through a Community Assistance grant awarded to Thermopolis, Eliot Allen and Associates will be available to help Thermopolis devise a plan for financing the geothermal district heating system being studied and designed by Coury and Associates. Although it is premature to attempt a financing strategy now, it is hoped that Eliot Allen will be able to provide that assistance at a later stage during the feasibility study.

GEOTHERMAL GREENHOUSE COMPLETED

A commercial geothermal greenhouse has been completed by Tom Berry in Thermopolis, Wyoming. The greenhouse measures 34 feet by 96 feet and uses 126°F water from the Sacajawea well just north of Thermopolis. Mr. Berry is growing tomatoes commercially for sale in the area. Depending on the success of this project, Mr. Berry may expand his operation to include a second geothermal greenhouse.

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GEOTHERMAL NEWS

P.O. Box 4096, University Station, Laramie, WY 82071
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Vol. I, No. 1 May 1980

°F	°C	Uses
266	130	Evaporation in Sugar Refining
248	120	Fresh Water by Distillation
230	110	Refrigeration by Medium Temperatures Drying and Curing of Light Cement Slabs
212	100	Drying of Organic Materials, Vegetables Washing and Drying of Wool
194	90	Drying of Stock Fish Intensive De-Icing
176	80	District Space Heating Greenhouses by Space Heating
158	70	Refrigeration by Low Temperature
140	60	Animal Husbandry Greenhouse by Combined Space and Hotbed Heating
122	50	Residential Space Heating Mushroom Growing Balneological Baths
104	40	Soil Warming
86	30	Swimming Pools Fermentation Warm Water for Year Around Mining in Cold Climates De-Icing
68	20	Hatching of Fish Fish Farming

The Wyoming Geothermal Commercialization Office was established in December 1978 on the campus of the University of Wyoming, and is a project funded jointly by the Department of Energy and the University of Wyoming. The purpose of GCO is to catalog geothermal resources within the state of Wyoming and to assist individuals, businesses, and governmental offices in the evaluation and use of specific geothermal sites.

Geothermal energy is energy that is produced from the heat in the ground. It takes the form of steam in high temperature areas, while it is very hot water in low temperature areas. With the expected shortage of fossil fuels in the future, geothermal energy has become a very important resource in energy-rich Wyoming.

There are three main types of geothermal systems in Wyoming: (1) volcanic systems such as those found in Yellowstone National Park; (2) hydrothermal systems manifesting themselves in hot springs and wells, such as those in the Thermopolis area; and (3) deep sedimentary basins producing unusually hot temperatures at depth, a system which underlies much of Converse and Natrona Counties.

The chart to the left indicates some potential uses of geothermal energy in Wyoming. The upper range of temperatures are not shown, as they are not known to exist in the state outside of Yellowstone National Park. Many resources currently in use in Wyoming are swimming pools and hot baths in the Thermopolis, Saratoga, and Jackson areas; space heating near Lander and Thermopolis; a trout hatchery near Jackson; and bridge de-icing in Sybille Canyon between Laramie and Wheatland.

The Wyoming Geothermal Commercialization Office is currently working on a wide variety of projects. Site specific studies are being done to determine the feasibility of district heating systems for the Midwest/Edgerton and Thermopolis areas. A broader study of the geothermal potentials of the Converse and Natrona County region is nearing completion.

Many individuals around the state are also proposing geothermal resources and development.

- new greenhouse for commercial tomatoes near Thermopolis
- possible aquaculture application near Midwest
- greenhouse for raising Forest Service pine seedlings near Midwest
- existing greenhouse for commercial tomatoes being expanded near Lander
- possible greenhouse or aquaculture application near Powell

GCO Personnel

Program Director. . . . . Rick James

Research Associate. . Karen Marcotte

Graduate Research Assistant . . . . John MacDonald

Research Aide . . . Carole Aspinwall

Work Study Student. . . . Keith Bray

Senior Secretary. . . . .Nancy Nelms

Commercial use of geothermal heat has been in existence in the Midwest/Edgerton area for years in oil field production. The Amoco waterflood system injects hot water into the earth to maximize oil recovery.

GEOTHERMAL NEWS is a quarterly publication of the Wyoming Geothermal Commercialization Office. This and future issues are suitable for filing in a three-ring binder for easy reference.

GEOTHERMAL COMMERCIALIZATION OFFICE

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GEOTHERMAL NEWS

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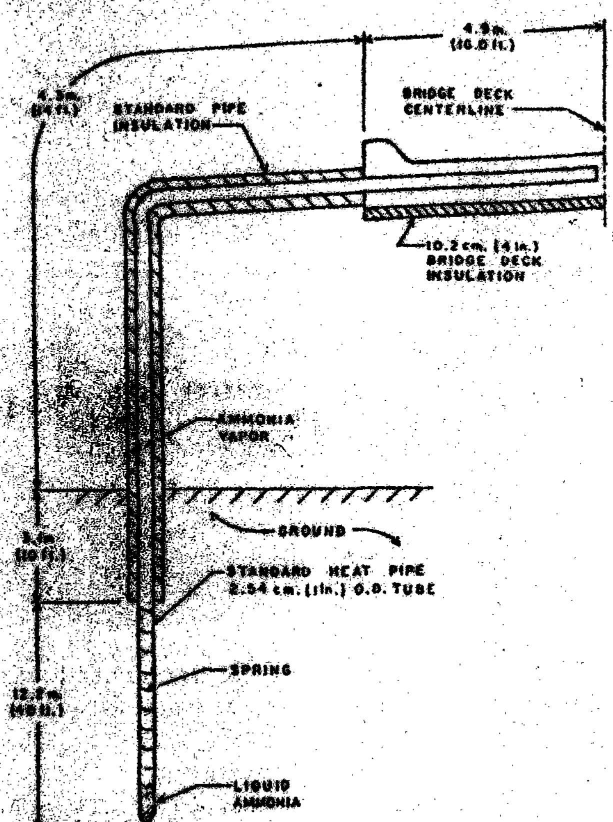
Vol. 1, No. 6 November, [illegible]

GEOTHERMAL HEAT PIPES USED TO DE-ICE BRIDGES

A new system using geothermal heat to de-ice bridges is going to be used in Wyoming. The system designed and developed by Dr. Kynric Pell, Dr. John Nydahl of the University of Wyoming, and the Wyoming State Bridge Engineers Office, is the first of its kind. The project was funded by the Federal Highway Administration and the State of Wyoming.

The purpose of the de-icing system, according to Dr. Pell is to "...increase safety by always keeping the bridge in as good a shape as the highway". Dr. Pell also anticipates that the bridges installed with these units will last longer than conventional bridges because the salt used to de-ice bridges causes deterioration of the rebar. This would be eliminated with the geothermally heated bridge.



A network of 60 pipes is placed under the pavement with the reinforcing steel before the concrete is poured and these are connected with pipes which are placed 100 feet deep in the ground. The 60 pipes are arranged in a manifold system with 15 pipes in each corner [illegible] to a 100 foot depth. The pipes inside the bridge deck are two feet and four feet long. Each pipe is two-inch diameter steel, coated with epoxy and foam insulation wherever they appear outside of the bridge deck.

The heat of the earth, a constant 43°F at a depth of 100 feet, causes the liquid ammonia to vaporize and rise in the heat pipe system to the pavement surface where the heat is released because of the 32°F or lower surface temperature. The inside wall of each evaporator pipe in the ground will be lined with a spring to cause the condensate to spiral down the pipe rather than run down one side in the form of a rivulet. This wets the wall more effectively, allowing for more efficient and uniform vaporization.

The prototype of this bridge was built into a bridge at North Sybille Canyon on Wyoming Highway 34 located between Wheatland and Bosler Jct. [illegible] ten foot section which was geothermally heated was snow covered for 11[illegible] hours. The rest of the bridge was snow covered for 331 hours. The new bridge [illegible] construction on Grand Avenue in [illegible] will be the first completely geothermally heated bridge.

The diagram shown to the left illustrates the conceptual design of [illegible] pipe bridge. The new bridge being installed in Laramie will vary slightly from this standardized design.

The GCO wishes to express their [illegible] to Mr. Keith Bray who authored [illegible] researched the heat pipe article [illegible]

Thermopolis SSDA

The Site Specific Development Analysis for the Thermopolis/East Thermopolis region will be completed by the GCO early in November. This SSDA will include sections of another report entitled, The Thermopolis Hydrothermal System. The hydrothermal report is still in rough draft form, but contains useful information on the Thermopolis system. This report was written under a Department of Energy contract and authored by three geologists at the University of Wyoming. The authors are: J.K. King, H.P. Heasler and E.R. Decker.

The GCO will be scheduling a trip to Thermopolis during November to present information on the geothermal potential of that region. Data gathered by the GCO for this SSDA is public information and can be obtained by attending the presentation in Thermopolis or by writing or calling this office.

GCO Personnel

Program Director...........Rick James
Research Associate.....Karen Marcotte
Graduate Research Asst...Patti Burgess
Senior Secretary...........Mary Weber

The preparation of this newsletter was aided by a grant from the Old West Regional Commission authorized under the Public Investment Program.

Cody Geothermal Report Release

A report entitled, Preliminary Data from Six Temperature Gradient Holes near Cody, Wyoming will be available through the GCO. November 7, 1980 is the tentative release date for this report. This paper was authored by H.P. Heasler and E.R. Decker of the Geology Department at the University of Wyoming. It is a report on data gathered from six temperature gradient holes drilled by the authors during the winter of 1980. This report is public information and a copy may be obtained by writing or calling this office.

Geothermal Consultants File

The GCO has been gathering information on geothermal consultants for the Rocky Mountain Region. This data is intended for use by potential geothermal developers in need of some developmental expertise. Information on areas of expertise, past experience and aspects of geothermal developmental interest has been gathered for individual firms in the form of a questionnaire. If you are interested in obtaining a copy of the consultants file, please write or call the GCO. In addition, if you would like your firm to be included in the consultants file and have not received a questionnaire to date, please contact Karen Marcotte at the GCO address.

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GEOTHERMAL NEWS

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GEOTHERMAL COMMERCIALIZATION OFFICE

Vol. 3, No. 1 January, 1982

PRELIMINARY STUDY PRESENTED TO THERMOPOLIS ADVISORY GROUP ON DECEMBER 3

Coury and Associates presented the preliminary findings for the district heating feasibility study to the Thermopolis advisory work group on December 3, 1981. Three potential well sites have been identified for the district heating system. They are located .35 miles, 4.6 miles, and 9.65 miles from Thermopolis. Expected temperatures are 130°F, 145°F, and 160°F respectively. Two system design options were outlined: heating the entire town, and heating 8 square blocks of the downtown area. These are merely the largest and smallest options. However, something in between might also be considered. There are, of course, different design considerations inherent in various combinations of the system sizes, available temperatures, and well locations. Rough cost estimates for heating the entire town range from $14,000,000 (using 160°F water), to $17,900,000 (using 130°F water). Heating only the downtown area would cost $6,000,000 (with 160°F water) to $3,000,000 (with 130°F water).

The city must now decide what size system they would like to install, and which well site would best meet those needs. City residents are being asked to state their site and size preferences in a citywide poll. Once these decisions have been made, the hydrologic program team will begin the task of accumulating temperature and flow data. Coury and Associates will use the new hydrologic data in their final feasibility study. The final study is scheduled for completion during the spring of 1982.

(For more information on the hydrologic study, see the November, 1981 issue of the Geothermal News*).*

SENATE SUBCOMMITTEE HEARING ON GEOTHERMAL LEASING NEAR NATIONAL PARK AREAS

A U.S. Senate subcommittee hearing on geothermal leasing in areas adjacent to National Parks was held in Casper on December 12, 1981. The purpose of the hearing was to hear testimony in regard to S.1516 and S.669. These two bills are presently being studied by the Subcommittee on Public Lands and Reserved Water.

The hearing was chaired by Senators Wallop (Wyoming), and Melcher (Montana). Most of the discussion concerned geothermal leasing in the Island Park area and subsequent potential effects on the thermal features of Yellowstone. Mr. Henry Heasler, of the Wyoming Geothermal Resource Assessment Group, represented Wyoming at the hearing. Mr. Heasler submitted written testimony and answered questions directed to him by both Senators.

In addition to testimony by Mr. Heasler, statements were accepted into the record by: Senators Wallop and Melcher; Mr. Bill Cunningham, of the Wilderness Society; Dr. Robert Christiansen, of the U.S. Geological Survey at Menlo Park; Dr. Gordon Bloomquist, of the Washington State Energy Office; Ms. Leah Street-Martin, of the Idaho Division of Energy; Mr. Clifton Merritt, of the American Wilderness Alliance; Mr. Bruce Hamilton, of the Sierra Club; Dr. Raymond Herrmann, Director of the National Park Service; and Mr. Townsley, Yellowstone Park Superintendent.

If you would like a copy of S.1516 or S.669, contact this office and a xerox copy will be mailed to you. If you would like a copy of the printed hearing, or if you have any questions in regard to subsequent subcommittee activities, contact:

Public Lands & Reserved Water Subcommittee
3104 Dirksen Senate Office Building
Washington, D.C. 20510

WGCO PERSONNEL AND OUR FUNDING STATUS

As you are undoubtedly aware of by now, there is no funding available from the Department of Energy for geothermal programs such as this one in 1982. The WGCO has received a no-cost extension of our 1981 contract. This means that the office will remain open as long as our previously allocated funds will last.

As a result of the minimal and finite amount of funds remaining to us, the staff of the WGCO has been cut back. Patti Burgess-Lyon, Research Associate, will no longer be working for the GCO effective January 1, 1982. I announce Patti's departure with sincere regret as she has done a great deal towards fulfilling our goal of promoting geothermal energy in Wyoming.

In addition, the WGCO secretarial position will be reduced to a part-time position effective January 11, 1982. I will be the only full-time employee of the WGCO as of January 11. If I am out of my office and my secretary is not in, there will be no answer at our telephone number. This is an unfortunate, yet unavoidable situation. I hope that you will not become discouraged if there is no answer when you call. Please try to call back if there is no answer the first time.

While these cutbacks are certainly disappointing, I wish to stress that I am willing to do as much as possible to maintain our previous high level of assistance to the public. If there is any information that you may need in regard to geothermal energy development in Wyoming, please do not hesitate to contact me.

I will keep the WGCO office operable as long as is financially feasible. If this program has been as successful as I believe it has, the use of geothermal energy in Wyoming will grow to be widespread in the next few years. It is towards that goal that I will continue to direct my efforts throughout the remaining months of this project.

With appreciation to the Wyoming public for their interest and understanding,

Karen Marcotte
Program Director

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UNIVERSITY OF UTAH RESEARCH INSTITUTE

UURI

EARTH SCIENCE LABORATORY
420 CHIPETA WAY, SUITE 120
SALT LAKE CITY, UTAH 84108
TELEPHONE 801-581-5283

20 May, 1983

Mr. Bern Hinckley
Department of Geology
University of Wyoming
Laramie, WY 82071

Dear Bern:

I apologize for being late in getting this report returned to you, but by now you must be getting accustomed to delays in DOE-related projects. Ron Smith at NOAA tells me that you finally have a copy of the second edition of the map; I look forward to your comments.

The best source for information about direct heat applications of geothermal resources is:

Anderson, D. N., J. W. Lund, eds., 1979, Direct Utilization of Geothermal Energy: A Technical Handbook: Geothermal Resources Council Special Report 7

Just about everything anybody ever wanted to know is contained in this source.

I have made several comments on the text of the oil field report. My major problem in reviewing this has been that our writing styles are very different. I have not, however, made suggestions in many places about rephrasing. If you would like me to, let me know and I would be happy to do so.

I have kept a copy with my comments on it, so please call if you have any questions.

Sincerely,

Duncan

Duncan Foley

OIL-FIELD GEOTHERMAL WATERS OF WYOMING

Introduction

Every day, in the oil fields of Wyoming, over 150 million gallons of water are brought to the surface. This water is produced for neither agricultural nor municipal use, but is simply a by-product accompanying the production of oil and gas. The temperature of this water is nearly always greater than 90°F, and ranges as high as 230°F. Most of the water is not reused by the oil and gas industry, but is disposed of either by reinjection or, more commonly, by discharge to the surface. The thermal energy of the water is simply dissipated to the atmosphere and the water either soaks into the ground or finds its way into natural drainages.

Fifty-two of the largest water producing fields in the state (accounting for over 98% of the total oil-field water production) have been inventoried as the basis for this report. Eighty-eight percent of the water produced in these fields is warmer than 100°F; 60% is hotter than 120°F. If the total water production of these 52 fields were cooled to room temperature, approximately 900 megawatts of power would be released. The purpose of this report is to briefly present the location, volume, temperature, and present use status of co-produced oil-field thermal waters. It is hoped that making this information available will focus attention on development of applications for this substantial energy resource which, in spite of ready availability, is virtually unused at present.

Funding for this report was provided under cooperative agreement DE-FI07-79ID12026 between the U.S. Department of Energy and the University of Wyoming, Department of Geology and Geophysics. The oil-field operators contacted were in most cases very helpful and cooperative. Without their gracious assistance this report could not have been completed.

GEOTHERMAL ENERGY IN WYOMING: TEMPERATURES, SOURCES, APPLICATIONS

As the overall limits of traditional energy supplies have become apparent, attention has increasingly focused on ~~so-called~~ "alternative" energy sources such as geothermal. Since geothermal energy derives from the natural heat of the earth, it is dependent neither on past accumulations of organic material nor on the present, sun-powered systems of wind, water, or direct solar energy. Thus, the geothermal resource is uniquely stable, long-lived, and globally distributed.

The quality of this resource varies greatly, however. At the top of the scale are the spectacular hot springs and geysers of Yellowstone National Park and the 900 ~~megawatt geothermal~~ stream electrical generating station at the Geysers, California. At the lower end, including most of the world and all of Wyoming outside Yellowstone, is simply a warming of the earth with depth and an occassional warm spring.

The rate at which the earth warms up with depth (commonly expressed in ^{o}F per 1000 feet of depth) is called the geothermal gradient. Geothermal gradients vary widely across the state of Wyoming as a function of heat flow, rock thermal conductivities, and hydrologic modifications. The nature, distribution, origin, and significance of subsurface temperatures are extensively evaluated in a series of reports by members of the Wyoming Geothermal Resource Assessment Group ~~(Dept. of Geology and Geophysics, U. of Wyo., Laramie, Wyo. 82071) and will not be discussed here.~~ For this report it is sufficient to note that normal geothermal gradients in Wyoming generally fall in the 11-16^{o}F/1000 ft. (°C/km) range. Since most oil and accompanying waters in Wyoming are produced from depths in excess of 5,000 feet (1.6 km?), the high temperatures encountered are not necessarily anamolous, but are the expected result of deep drilling. Temperatures of 100, 200, 300, and even 400^{o}F can be found at sufficient depth in any of the sedimentary basins of the state. In most cases the depth required to

some, including Dan Miller, would argue this point, but I like it

I'd rephrase this, since it is exhaustable at a site, and site specific

usually means TDS, but use of the word may be ok here

I think it's near or over 1000 MWe now

this sentence has a "drill anywhere" flavor. could you be more specific about what you mean?

or °C/km in scientific, state coupled program funded reports (heh?)

reference these reports - don't leave the reader guessing

important, since on p1, 230°F is H_2O Tmax

is this documented in your work from a BHT, or is it an extrapolation? How, if it is true, do the people handle the expected produce high temperatures far exceeds that which can be economically justified by the hot water resource. Thus, the importance of oil fields is that oil and gas production pays well drilling and pumping costs and the produced geothermal waters represent a potentially valuable by-product.

The two critical parameters for geothermal development ~~at the resource temperatures found~~ in Wyoming are the temperature and available quantity of geothermal waters. Since no wells have been drilled specifically to produce hot water in Wyoming, thermal waters presently arrive at the surface via thermal springs, flowing thermal wells, and along with oil and gas in oil and gas wells. ~~In Thermal Springs of Wyoming (Wyoming Geological Survey, 1978),~~ Breckenridge and Hinckley (1978) cite a total flow of approximately 20,000 gallons per minute (gpm) of naturally occuring thermal water (excluding Yellowstone Park) with approximately 4,500 gpm in excess of 100°F. On the Geothermal Map of Wyoming ~~(National Oceanic and Atmospheric Administration, 1982)~~, Heasler et al. (1983) have compiled a partial list of important flowing thermal wells with a total flow of   gpm,   gpm over 100°F. In comparison, the 1981 water production of Wyoming oil fields averaged 110,914 gpm (178,918 acre ft./yr.) (Petroleum Information Corp. ~~Dec.~~ 1981 ~~Production Report~~), with approximately 97,000 gpm in excess of 100°F.

Uses for Wyoming thermal waters are as varied as the temperatures. While it is doubtful the type of dry stream-turbine electrical system used at the Geysers, Califonia will ever be developed in Wyoming, there are technologies for using 180°F and warmer waters to produce electricity through more complex turbine cycles. This represents the high end of potential geothermal energy use in Wyoming and as such is on the margin of economic viability. More widely applicable uses fall generally into the categories of space conditioning and agricultural and industrial processing. Above approximately 170°F geothermal

especially now, where most majors in the electric game consider anything less than 400°F to not be worth their while waters may provide energy to cooling and air conditioning cycles. Geothermal waters may simply replace the boiler-heated water of conventional heating systems down to 130-140°F, and with adaptations, may provide useful direct space heating down to 80-90°F. Through the use of groundwater heat pumps, energy can be economically extracted from waters as cool as 40-50°F. Potential agricultural/industrial applications successfully implemented in many areas of the world include greenhouse heating and agricultural product drying. Success has also been widespread in applying geothermal waters to the raising of fish and other aquatic food sources. Basically, any energy use for which sub-boiling temperatures are adequate may ~~have~~ potential application ~~in the~~ Wyoming geothermal resources. The intention of this report is not to present an exhaustive list of these applications; the above discussion is provided simply to outline the possibilities.

OIL-FIELD THERMAL WATERS: MONITORING, LOCATIONS, VOLUMES, QUALITY, TEMPERATURES, DISPOSITION

There is no systematic monitoring of oil field thermal waters in Wyoming at this time. The Wyoming Oil and Gas Conservation Commission maintains the largest data base on oil and gas activity in the state, including the water production reports from which Petroleum Information Corporation compiles their summaries. The Oil and Gas Commission also maintains cursory records on projects involving the injection of water into oil fields to maintain reservoir pressures. This water may be produced water, surface water, or groundwater developed specifically for this purpose. Where produced waters are discharged to the surface, chemical characteristics and volumes are monitored at irregular intervals by the Water Quality Division of the Wyoming Department of Environmental Quality. ~~The status of water reinjected simply as waste disposal is unclear at present, with both~~ the Oil and Gas Commission and the Department of

Environmental Quality are both ~~becoming~~ involved in the regulation and monitoring of water injected for waste disposal. ~~processes~~. All waters ~~of any sort~~ in the state are also under the jurisdiction – even those in Yellowstone? (this doesn't need to be stated) of the Wyoming State Engineer. Where waters are considered to be beneficially used, as in reinjection for pressure maintenance, water appropriation permits are required. Produced waters, which are not used in this way, are considered by the State Engineer only insofar as they may contribute to the flow of existing natural streams.

No ~~ne of these~~ state agencies ~~is concerned with~~ gathers H2O temp. data on water temperature. (If the temperature of discharged waters ~~was~~ were high enough to be a significant environmental concern, the Department of Environmental Quality is empowered to regulate such discharges.) Therefore, it has been necessary to contact oil-field operators directly for the information of this report. Information on water production, temperature and disposition is that provided by the operators unless otherwise noted. (I have attempted to assemble as much data as possible in Table 1.) [make not first person] The discussion which follows parallels Table 1 on a column by column basis and includes notes on table format and interpretation. [I'm unclear, as following comments will indicate, as to what the focus of this discussion is – applications & interpretation or discussion of source and reliability of the data?]

County/Location/Field. Due to the modest temperature of geothermal waters in Wyoming, most applications need to be near the point of availability, and location is therefore an important constraint. The Salt Creek field in Natrona County, for example, surrounds the town of Midwest and might contribute thermal energy to a wide variety of residential and commercial space heating systems, to industrial and perhaps agricultural processing applications, and to greenhouse and aquaculture projects supplying the readily accessible markets in Midwest and Casper. The Lance Creek field in Niobrara County, in contrast, is in an area of very low population density and is therefore more restricted to application in processes not dependent on community development or local markets.

Is there going to be a map? Or will locations be best referenced, as you have, to T-R-S (maybe cite the geothermal map as having T-R-S on it?)

<u>Operator</u>. In most cases, operations of a single field have been taken over by a single operator. Where this is not the case, the operator (or operators) responsible for the preponderance of the water production are listed, followed by an asterisk.

<u>Water Volume</u>. Oil fields are generally defined on the basis of the geologic conditions creating a more or less continuous oil reservoir. Thus, field sizes will vary greatly as will the number of wells contributing to total production. Since the oil/water production of many wells is commonly collected at oil separation facilities, thermal waters will be concentrated at various locations within each field. The total production figures listed do not reflect in-field distribution; how much water is actually collected at any one point will vary widely depending on specific field characteristics. (All volumes are listed in gallons per minute (gpm). Tabled water production values enclosed by paranthesesare average 1981 values calculated from Petroleum Information Corp. Production Summaries; no reports were received directly from field operators in these cases.)

Since the value of oil field geothermal resources is small relative to the petroleum resources, oil fields will continue to be managed for optimum oil and gas revenues. It is unlikely this will generally lead to optimum geothermal production as well, so geothermal applications will be largely ~~at the mercy of~~ dependant upon petroleum production strategies. The range in water production (based on monthly averages for all operators in the field) has therefore been compiled from the published Production Summaries.

Fields with relatively constant water production are certainly the most attractive candidates for geothermal development; development would have to be carefully coordinated with field operators to establish a secure energy source in any case.

Water table? Not brought up in discussion?

cited above

Move to introduction as this doesn't explain the table

Water Temperature. The temperature of produced water will generally decrease from the formation (bottom-hole temperature) to the point of final disposition. Geothermal applications which follow all oil-water separation processes and in-field water uses will have to depend on somewhat lower temperatures than will applications which can extract heat from produced waters before or during separation processes. It should also be noted that all the thermal energy in produced waters is not un-used by-product. In some fields these waters are used to provide energy to treater facilities, which is of course a geothermal application itself. While the main value of water reinjected to enhance oil recovery derives from the simple pressure of the water, temperature may be of some benefit in terms of altering oil viscosity and mobility. The nature and quantification of such benefit is unclear, but presents a potentially important legal question as to whether this is or is not a use of the geothermal resource.

Water Quality. The quality of oil-field waters is generally quite poor. For space heating applications this may not be a significant problem if scaling and corrosion can be controlled. For agricultural/aquacultural applications, it may be necessary to use heat exchangers to transfer thermal energy to waters of more acceptable chemistry.

Water Disposition. Water produced with oil and gas is disposed of in one of three ways: 1) It may be discharged to the surface to either soak in, evaporate, or run into natural drainages; 2) It may be reinjected into an acceptable formation via waste disposal wells; 3) It may be reinjected into oil-producing strata to improve reservoir drive mechanisms and so to enhance oil recovery.

Water discharged to the surface is clearly the most readily available for geothermal development. Once waters enter a surface drainage they are no longer under the control of the field operator, but are regulated like any other surface water through the Wyoming State Engineer's Office. Heat is recognized as a beneficial use of water in Wyoming and can therefore justify a water appropriation. In many cases discharged oilfield waters are presently used for stock watering and irrigation. Where such uses have appropriated water rights they would take precendence over geothermal applications in the event of a conflict.

Question marks in the "Discharge Water" column of Table 1 indicate the partitioning of produced waters between the 3 options listed above is unclear. A question mark following a value indicates produced water was assumed to be surface discharged because there were no injection projects reported for these fields. Values enclosed by parentheses are taken from the files of the Water Quality Division of the Wyoming Department of Environmental Quality (DEQ). The number of discharge permits has also been extracted from these files. Numbers followed by astericks denote permits which DEQ has noted as covering discharges greater than 1 million gallons per day (700 gallons/minute). Many discharge permits are filed against the contingency of possible discharge. Discharge may rarely occur under these permits, so the number of permits listed for a field is a maximum number of discharge points.

After waters discharged to the surface, the most available waters for geothermal applications are those destined for waste reinjection. (The data of Table 1 on both waste and enhanced recovery injection come from the 1980 Wyoming Oil and Gas Statistics compiled by the Wyoming Oil and Gas Conservation Commission.) These waters are presumably of no value to the oil and gas operations; examination of DEQ files reveals that in many cases waste waters which were previously surface discharged have been converted to reinjection due to tightening discharge water quality standards. Thus, geothermal applications but this expense might hurt geothermal economics

which took over disposal of these waters would actually save the field operator the expense of reinjection. As with the number of surface discharge points, the number of disposal wells reflects the degree of water concentration within the field.

Geothermal applications of waters used in enhanced recovery injection operations would be the most logistically difficult of the three options. Depending on how the field operators view the value of temperature to the recovery processes, however, it may be possible to extract significant heat in "closed loop" processes which return the water for injection. While some portion of injected waters may cycle back through the system as produced water, this does not necessarily decrease their geothermal value. This recycling of cooled waters is an accepted way to usefully extract energy from very large subsurface heat sources. (reference) Unlike the previous disposal options, the number of injection wells in this case represents the dispersal of waters to create the proper injection pattern. The maximum concentrations of thermal waters in these fields will occur at separation facilities.

geothermal application isn't one of the 3 listed options?

which, maybe I'm lost

how did a line on production get in a ¶ on injection?

The reported as form. by oil co. formations involved in enhanced recovery operations are coded as follows: Ams - Amsden, Cam - Cambrian, Cur - Curtis, Dak - Dakota, Emb - Embar, Fox - Fox Hills, Frn - Frontier, Lan - Lance, Leo - Leo, Mad - Madison, Min - Minnelusa, Mor - Morrison, Msv - Mesaverde, Mud - Muddy, Phs - Phosphoria, Shn - Shannon, Sun - Sundance, Sus - Sussex, Ten - Tensleep.

maybe make a footnote on the table?

references
Breckenridge & Hinckley '78
Heasler et al. '83 (map)
PI, 1981
all state reports cited in introduction
Anderson & Lund '79
others cited as needed

COUNTY/ LOCATION (Twp-Rng)	FIELD	OPERATOR	WATER VOLUME			WATER TEMPERATURE		WATER QUALITY	WATER DISPOSITION							
			Water Production (gpm)	1981 Range in Water Production: Low (gpm)	High (gpm)	Bottom-hole (B) or Wellhead (W) Temperature (°F)	Injection (I) or Discharge (D) Temperature (°F)	Total Dissolved Solids (ppm or mg/l)	Discharged Water (gpm)	Number of Discharge Permits	Waste Injected Water (gpm)	Number of Disposal Wells	Water Injected for Enhanced Recovery (gpm)	Number of Active Injection Wells	Source Formation	Formation Injected
Big Horn																
49N-91W	Bonanza	Conoco*	303	290	722	78(W)	50(D)	1224	303	2	---	---	---	---	---	---
55,56N-96,97W	Byron	Marathon	1121	0	1198	120-125(B)	52-60(D) 110-115(I)	3090	168	1	---	---	953	19	Ten	Ten/Emb
55,56N-97,98W	Garland	Marathon*	6397	1132	6952	138-143(B)	78(D) 120-125(I)	3787	3360	3,1*	1222	1	1816	24	Ten	Ten/Phs
		Texaco*	718			---	95(I)	3898	---	2	718	2	---	---	---	---
47N-97,98W	Sage Creek	Sohio*	287	89	366	95(B) 80(W)	60(I)	3330	---	0	---	---	287	2	Ten	Ten
31N-92,93W	Torchlight	Amoco	1750	1408	2859	95	---	---	1750	1*	---	---	---	---	---	---
Campbell																
54N-72W	Gas Draw	Chevron*	671	771	1264	182(B)	150(I)	---	---	0	---	---	671	15	Fox/Lan	Mud
45N-71W	Hilight	Inexco*	2042	1760	2205	230(B)	210(I)	---	---	12	---	---	2042	38	Fox	Mud
48,49N-69W	Raven Creek	Mobil	369	157	390	135(W)	120(I)	---	---	0	---	---	369	13	Fox	Min
56,57N-69W	Rocky Point	Amoco*	(948)	1044	1325	---	115-127(D)	2374	(955)	1*	---	---	---	---	---	---
50N-69,70W	Rozet	Arco*	329	336	418	---	110-155(I)	6,792-31,519	---	0	329	1	---	---	---	---
Carbon																
21N-79W	Big Medicine Bow	Marathon	217	0	3697	152(W)	---	2497	217	1	---	---	---	---	---	---
26N-89,90W	Wertz	Amoco	1458	428	1427	145(B)	135	10,404	77	1	---	---	1458(?)	27	Ten/Mad	Ten
Converse																
32,33,34N-75,76W	South Glenrock	Conoco*	510	590	736	128(W)	100(I)	1333	---	1	---	---	510	53	Mad/Ten	Mud/Dak
Fremont																
33,34N-96W	Beaver Creek	Amoco	715	255	626	230-234(B)	90-140	1975	248	2	---	---	467	6	Mad	Mad
32N-95W	Big Sand Draw	Amoco	3500	2849	5260	220(B)	135-170(D)	2163	3500	3	---	---	---	---	---	---
36,37N-82W	Casper Creek North	Katherman	(244)	0	311	---	---	---	244(?)	1	---	---	---	---	---	---
6,7N-2,3W	Circle Creek	Conoco	636	0	631	74(W)	56	1768	563	2	---	---	73	10	Ams	Ams
28N,92,93W	Crooks Gap	Amoco	758	512	775	150(B)	120(B)	6466	758	1	---	1	---	---	---	---
32N-99W	Dallas	Union	642	0	693	---	61-79	---	642	1	---	---	---	---	---	---
33N-99W 2S-1,2E	Lander	Amoco	379	287	407	96(B)	80(I)	---	---	11	---	---	379	26	Ten	Phs
6N-2W	Maverick Springs	Crown-Central*	(460)	111	1853	---	---	---	460(?)	1	---	---	---	---	---	---
4N-1W	Steamboat Butte	Gulf*	(760)	692	769	---	99-154	---	192	0(?)	---	---	578	7	Ten/Phs	Ten/Phs
2N-1,2W	Winkleman Dome	Amoco*	3159	2437	3134	125-220(B)	100-180	---	207	1	---	---	2952	59	Ten/Phs	Ten/Phs
Hot Springs																
42,43N-91W	Black Mtn.	Texaco	744	53	619	---	90	750	---	1	744	1	---	---	---	---
44N-95W	Gebo	Conoco	510	0	508	120(W)	90(D)	3186	510	1	---	---	---	---	---	---
46N-93W	Grass Creek	Marathon	3305	2721	3584	70-120(B)	65-110(I)	5279	---	6	343	1	2962	99	Msv/Mad	Cur/Frn/Ten
44N-97,98W	Hamilton Dome	Arco	3379	4154	8181	---	143(D)	3565	3379	1,1*	---	---	---	---	---	---
		Petro-Lewis	3183			96-124	103(I), 90(D)	3528	2538	1,1*	---	---	645	21	Ten/Phs	Phs
43N-91,92W	Lake Creek/NW	Getty	(405)	145	410	---	---	---	405(?)	4	---	---	---	---	---	---
47,48N-99,100W	Little Buffalo Basin	Amoco	4181	3376	4322	118-120	---	---	233	11	---	---	3936	110	Emb/Ten	Emb/Ten

COUNTY/ LOCATION (Twp-Rng)	FIELD	OPERATOR	WATER VOLUME			WATER TEMPERATURE		WATER QUALITY	WATER DISPOSITION							
			Water Production (gpm)	1981 Range in Water Production: Low (gpm)	High (gpm)	Bottom-hole (B) or Wellhead (W) Temperature (°F)	Injection (I) or Discharge (D) Temperature (°F)	Total Dissolved Solids (ppm or mg/l)	Discharged Water (gpm)	Number of Discharge Permits	Waste Injected Water (gpm)	Number of Disposal Wells	Water Injected for Enhanced Recovery (gpm)	Number of Active Injection Wells	Source Formation	Formation Injected
Hot Springs (continued)																
44N-96W	Little Sand Draw	Husky	688	349	688	---	123(D)	2840	688	2	---	2	---	---	---	---
Johnson																
41N-78W	Meadow Creek	Conoco	338	0	337	182(W)	160(I)	2348	---	5	---	---	358	30	Mad	Shn/Ten
44N-81,82W	North Fork	Amoco*	513	527	598	170(B)	90(D)	7191	513	1	---	---	---	---	---	---
42N-78,79W	Sussex	Conoco*	475	0	522	174(W)	150(I)	3313	---	3	---	---	475	39	Mad	Sus/Ten
Natrona																
33,34N-83W	Casper Creek South	Union	875	482	2184	---	90	---	875	2	---	---	---	---	---	---
37N-85W	Notches	Terra Resources	1021	1030	1093	115	95(D)	1484	1021	1,1*	---	---	---	---	---	---
39,40N-78,79W	Salt Creek	Amoco*	29983	4044	23240	90-180(B)	85-90	3900	17675	8,8*	---	---	12,309	515	Mad	Frn
		Terra Resources*	2246			188	140(I)	2986	(914)	11,1*	---	---	1246	103	Mad	Frn
38,39N-78W	Teapot East	Union	467	3	12	---	179	---	467	1	---	---	---	---	---	---
36,39N-78W	Teapot Naval	Fenix & Scission*	(300)	274	350	---	---	---	??	9	---	---	??	33	Mad	Frn
Niobrara																
35,36N-65W	Lance Creek	Marathon	1272	481	1919	155(W)	110(D)	3304	1272	6	---	---	---	1	Leo	Mor
		Grace	467			140(W)	50-80(D)	3089	467	2	---	---	---	---	---	---
Park																
57,58N-99,100W	Elk Basin	Amoco	4364	1106	2770	115	---	---	1273	3	---	---	3092	34	Mad/Ten	Mad/Ten
56,57N-99W	Elk Basin South	Conoco	572	0	588	148(W)	140(I)	5131	---	1	---	---	572	6	Ten	Ten
47,48N-103W	Four Bear	Amoco	933	3	2377	130	---	---	---	3	933	6	---	---	---	---
58N-98W	Frannie	Conoco	2158	0	2234	90(W)	84(I)	3200	---	2	---	---	2158	30	Mad	Phs/Ten
51N-102W*	Halfmoon	Husky	601	408	627	---	103(D)	2620	601	1	---	2	---	---	---	---
50,51,52N-100W	Oregon Basin	Marathon	14893	13301	14829	110-120(B)	63-90(D) 100-110(I)	1545	1489	8	---	---	13,403	129	Mad/Emb/Ten	Mad/Emb/Ten
48N-102W	Pitchfork	Husky	944	367	972	---	81(D)	2600	941	1	---	6	---	---	---	---
49N-102W	Spring Creek South	Texaco	2112	1264	2279	---	100	2897	---	0	2112	2	---	---	---	---
56N-98W	Whistle Creek	Texaco	779	758	873	---	95	2602	779	1	---	---	---	---	---	---
Sweetwater																
26N-90W	Lost Soldier	Amoco	3558	2882	3723	159-165(B)	140	7591	438	1	---	---	3121	56	Sun/Cam/Mad	Cam/Ten/Mad
Washakie																
47,48N-90,91W	Cottonwood Creek	Amoco*	292	203	317	110	---	---	58	1	---	---	233	25	Mad/Phs	Phs

* - add explanation to table, even though it is on the text

Plz type on letterhead -

Tnx

D.

20 May, 1983

Mr. Bern Hinckley
Department of Geology
University of Wyoming
Laramie, WY 82071

Dear Bern:

I apologize for being [redacted] late in getting this report returned to you, but by now you must be getting accustomed to delays in DOE-related [redacted] projects. Ron Smith at NOAA tells me that you finally have a copy of the second edition [redacted] of the map; I look for[redacted]ward to your comments.

The best source for information about direct heat applications of geothermal resources is:

Anderson, D.N., J.W. Lund, eds., 1979, Direct Utilization of Geothermal Energy: A Technical Handbook: [redacted] Geothermal Resources Council Special Report 7

Just about everything anybody ever wanted to know is contained in this source.

I have made several comments on the text of the oil field report. My major problem in reviewing this has been that our writing styles are very different. ~~For instance, rather than having the first sentence read as it does, I would rephrase it along the lines of:~~

~~"Over 150 million gallons of water a day are brought to the surface in the oil fields of Wyoming."~~

I have not, however, made suggestions in many places about rephrasing. If you would like me to, let me know and I would be happy to do so.

I have kept a copy with [redacted] my comments on it, so please call if you have any questions.

Sincerely,

Duncan Foley

Duncan Foley - ESL/UURI
420 Chipeta Way
Suite 120
Salt Lake City, Utah
84108

Duncan,

How about sending me a few "everything anybody ever wanted to know about low temperature geothermal applications" references to tack on to this oil-field thermal waters piece. (Any other comments or suggestions you might have would of course be welcome also.) I'm trying to spark some of that down-home entrepreneurial spirit Ronnie keeps telling us will save us all.

Thanks,

- Ben Hinckley

P.S. Hank hasn't heard squat from the NOAA boys in over 2 months and is wondering what the story is on the great geothermal map project. Advice? consolation?

Duncan Foley

OIL FIELD GEOTHERMAL WATERS OF WYOMING

by

Bern S. Hinckley

Work Performed under Cooperative Agreement

No. DE-FC07-79ID12026

for the

U. S. Department of Energy

August 1983

Wyoming Geothermal Resource Assessment Group
Department of Geology and Geophysics
University of Wyoming
Laramie, Wyoming

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Bern S. Hinckley
Wyoming Geothermal Resource Assessment Group
Department of Geology and Geophysics
University of Wyoming
Laramie, Wyoming
August, 1983

Introduction

Over 150 million gallons of water a day are brought to the surface in the oil fields of Wyoming. This water is produced for neither agriculture nor municipal use, but is a by-product accompanying the production of oil and gas. The temperature of this water is nearly always greater than 90° F, and ranges as high as 230° F. Approximately one half of the water is not reused by the oil and gas industry, but is disposed of either by reinjection or, more commonly, by discharge to the surface. The thermal energy of discharged water is simply dissipated, and the water either soaks into the ground or finds its way into natural drainages.

Fifty-two of the largest water producing oil fields in the state (accounting for over 98% of the total oil field water production) were inventoried in 1982 as the basis for this report. Eighty-eight percent of the water produced in these fields is warmer than 100° F; 60% is hotter than 120° F. If the total water production of these 52 fields were cooled to 70° F, approximately 800 megawatts of thermal power would be released.

The purpose of this report is to briefly present the location, volume, temperature, and present use status of co-produced oil field thermal waters. It is hoped that making this information available will focus attention on development of applications for this substantial energy resource which, in spite of ready availability, is virtually unused at present.

Funding for this report was provided under cooperative agreement DE-F107-791D12026 between the U.S. Department of Energy and the University of Wyoming

Department of Geology and Geophysics. The oil field operators contacted were in most cases very helpful and cooperative. Without their gracious assistance this report could not have been completed.

Geothermal Energy In Wyoming: Temperatures, Sources, Applications

As the overall limits of traditional energy supplies have become apparent, attention has increasingly focused on "alternative" energy sources such as geothermal. Since geothermal energy derives from the natural heat of the earth, it is dependent neither on past accumulations of organic material nor on the present, sun-powered systems of wind, water, or direct solar energy. Thus, the geothermal resource in general is uniquely stable, long-lived, and globally distributed.

The quality of this resource varies greatly, however. At the top of the scale are the spectacular hot springs and geysers of Yellowstone National Park and the 1000 megawatt geothermal stream electrical generating station at the Geysers, California. At the lower end, less impressive but much more widespread, is simply a warming of the earth with depth and an occassional warm spring.

The rate at which the earth warms up with depth (commonly expressed in ^{o}F per 1000 feet of depth) is called the geothermal gradient. Geothermal gradients vary widely across the state of Wyoming as a function of heat flow, rock thermal conductivities, and hydrologic modifications. The nature, distribution, origin, and significance of subsurface temperatures are extensively evaluated in a series of reports by members of the Wyoming Geothermal Resource Assessment Group and will not be discussed here. For this report it is sufficient to note that normal geothermal gradients in Wyoming generally fall in the 11-16^{o} F/1000 ft.

range. Since most oil and accompanying waters in Wyoming are produced from depths in excess of 5000 feet, the high temperatures encountered are not necessarily anomalous, but are the expected result of deep drilling. Oil well bottom-hole temperatures of 300° F or higher have been measured in most of the sedimentary basins of the state. The drilling depth required to reach these high temperatures, however, far exceeds that which can be economically justified by the hot water resource. Thus, the importance of oil fields is that oil and gas production pays well drilling and pumping costs and the produced geothermal waters represent a potentially valuable by-product.

Two critical parameters for geothermal development in Wyoming are the temperature and available quantity of geothermal waters. In Wyoming, thermal waters presently arrive at the surface via thermal springs, flowing wells, and along with oil and gas in oil and gas wells. Breckenridge and Hinckley (1978) cite a total flow of approximately 20,000 gallons per minute (gpm) of naturally occurring thermal water (excluding Yellowstone Park) with approximately 4500 gpm in excess of 100° F. Heasler et al. (1983) have compiled a partial list of important flowing thermal wells with a total flow of 20,000 gpm, 18,000 gpm over 100° F. In comparison, the 1981 water production of Wyoming oil fields averaged 110,914 gpm (178,918 acre ft/yr) (Petroleum Information Corp., 1981), with approximately 97,000 gpm in excess of 100° F.

Uses for Wyoming thermal waters are as varied as the temperatures. While it is doubtful the type of dry stream-turbine electrical system used at the Geysers, California, will ever be developed in Wyoming, there are technologies for using 180° F and warmer waters to produce electricity through more complex turbine cycles. This represents the high end of potential geothermal energy use in Wyoming and is of doubtful economic viability at that. More widely applicable uses fall generally into the categories of space conditioning and agricultural and industrial processing. Above approximately 170° F geothermal waters may provide energy to cooling and air conditioning cycles. Geothermal waters may simply replace the boiler-heated water of conventional heating systems down to 130-140° F, and with adaptations, may provide useful direct space heating down to 80-90° F. Through the use of groundwater heat pumps, energy can be economically extracted from waters as cool as 50° F. Agricultural/industrial applications which have been successfully implemented in many areas of the world include greenhouse heating and agricultural product drying. Success has also been widespread in applying geothermal waters to the raising of fish and other aquatic food sources.

Basically, any energy use for which sub-boiling temperatures are adequate may be a potential application for Wyoming geothermal resources. The intention of this report is not to present an exhaustive list of these applications; the above discussion is provided simply to outline the possibilities. For an excellent treatment of the direct utilization of geothermal energy, including full discussion of the above, see Anderson and Lund (1979).

OIL FIELD THERMAL WATERS: MONITORING, LOCATIONS, VOLUMES, QUALITY TEMPERATURES, DISPOSITION

Monitoring

There is no systematic monitoring of oil field thermal waters in Wyoming at this time. The Wyoming Oil and Gas Conservation Commission maintains the largest data base on oil and gas activity in the state, including the water production reports from which Petroleum Information Corporation compiles their summaries (see References). The Oil and Gas Commission also maintains cursory records (primarily cumulative volumes) on projects involving the injection of water into oil fields to maintain reservoir pressures. This water may be produced water, surface water, or groundwater developed specifically for this purpose.

Where produced waters are discharged to the surface, chemical characteristics and volumes are monitored at irregular intervals by the Water Quality Division of the Wyoming Department of Environmental Quality. Both the Oil and Gas Commission and the Department of Environmental Quality are becoming involved in the regulation and monitoring of water injected simply for disposal. All waters in the state are also under the jurisdiction of the Wyoming State Engineer. Where waters are considered to be beneficially used, as in reinjection for pressure maintenance, water appropriation permits are required. Produced waters which are not used in this way, are considered by the State Engineer only beyond the point at which they may contribute to the flow of existing natural streams.

None of the agencies cited above gathers data on water temperature. (If the temperature of discharged waters were high enough to be a significant environmental concern, the Department of Environmental Quality is empowered to regulate such discharges.) Therefore, it has been necessary to contact oil field operators directly for the information of this report. Information on water production, temperature and disposition is that provided by the operators unless otherwise noted. The essence of this report is assembled in Table 1. The discussion which follows is an explanation and discussion of the Table and proceeds on a column by column basis, including notes on table format and interpretation.

<u>County/Location/Field</u>. Due to the modest temperature of geothermal waters in Wyoming, most applications need to be near the point of availability, and location is therefore an important constraint. The Salt Creek field in Natrona

County, for example, surrounds the town of Midwest and might contribute thermal energy to a wide variety of residential and commercial space heating systems, to industrial and perhaps agricultural processing applications, and to greenhouse and aquaculture projects supplying the readily accessible markets in Midwest and Casper. The Lance Creek field in Niobrara County, in contrast, is in an area of very low population density and is therefore more restricted to application in processes not dependent on community development or local markets.

Operator. In most cases, operations of a single field have been taken over by a single operator. Where this is not the case, the operator (or operators) responsible for the preponderance of the water production are listed, followed by an asterisk.

Water Volume. Oil fields are generally defined on the basis of the geologic conditions creating a more or less continuous oil reservoir. Thus, field sizes will vary greatly as will the number of wells contributing to total production. Since the oil/water production of many wells is commonly collected at oil separation facilities, thermal waters will be concentrated at various locations within each field. The total production figures listed do not reflect in-field distribution; how much water is actually collected at any one point will vary widely depending on specific field characteristics. All volumes are listed in gallons per minute (gpm); 1 gpm = 1.6 acre-ft/yr. Water production values enclosed by parentheses in Table 1 are average 1981 values calculated from Petroleum Information Corp. Production Summaries (see References); no reports were received directly from field operators in these cases.

Since the value of oil field geothermal resources is small relative to the petroleum resources, oil fields will continue to be managed for optimum oil and gas revenues. It is unlikely this will generally lead to optimum geothermal production as well, so geothermal applications will be largely dependent upon petroleum production stategies. The range in water production (based on monthly averages for all operators in the field) has therefore been compiled from the published Production Summaries (see References). Fields with relatively constant water production are certainly the most attractive candidates for geothermal development; development would have to be carefully coordinated with field operators to establish a secure energy source in any case.

Water Temperature. The temperature of produced water will generally decrease from the bottom-hole temperature to the point of final disposition. Geothermal applications which follow oil-water separation processes and in-field water uses will have to depend on somewhat lower temperatures than will applications which can extract heat from produced waters before or during separation processes. It should also be noted that all the thermal energy in produced waters is not an unused by-product. In some fields these waters are used to provide energy to treater facilities, which is of course a geothermal application itself. While the main value of water reinjected to enhance oil recovery derives from the simple pressure of the water, temperature may be of some benefit in terms of altering oil viscosity and mobility.

Water Quality. The chemical quality of oil-field waters is generally quite poor. For space heating applications this may not be a significant problem if scaling and corrosion can be controlled. For agricultural/aquacultural applications, it may be necessary to use heat exchangers to transfer thermal energy to waters of more acceptable chemistry.

Water Disposition. Water produced with oil and gas is disposed of in one of three ways: 1) It may be discharged to the surface to either soak in, evaporate, or run into natural drainages; 2) It may be reinjected into an acceptable formation via waste disposal wells; 3) It may be reinjected into oil-producing strata to improve reservoir drive mechanisms and so to enhance oil recovery.

Water discharged to the surface is clearly the most readily available for geothermal development. Once waters enter a surface drainage they are no longer under the control of the field operator, but are regulated like any other surface water through the Wyoming State Engineer's Office. Heat is recognized as a beneficial use of water in Wyoming and can therefore justify a water appropriation. In many cases discharged oilfield waters are presently used for stock watering and irrigation. Where such uses have appropriated water rights they would take precedence over geothermal applications in the event of a conflict.

Question marks in the "Discharge Water" column of Table 1 indicate the partitioning of produced waters between the 3 options listed above is unclear. A question mark following a value indicates produced water was assumed to be surface discharged because there were no injection projects reported for these fields. Values enclosed by parentheses are taken from the files of the Water Quality Division of the Wyoming Department of Environmental Quality (DEQ). The number of discharge permits has also been extracted from these files. Numbers followed by an asterick denote permits which DEQ has noted as covering discharges greater than 1 million gallons per day (700 gallons/minute). Many discharge permits are filed against the contingency of possible discharge. Discharge may rarely occur under there permits, so the number of permits listed for a field is a maximum number of discharge points.

Second to waters discharged to the surface, the most available waters for geothermal applications are those destined for waste reinjection. These waters are presumably of no value to the oil and gas operations; examination of DEQ files reveals that in many cases waste waters which were previously surface discharged have been converted to reinjection due to tightening discharge water quality standards. Thus, geothermal applications which took over disposal of these waters would actually save the field operator the expense of reinjection. (Geothermal applications will, of course, themselves be subject to the same waste disposal regulations as any other water use.) As with the number of surface discharge points, the number of disposal wells reflects the degree of water concentration within the field. (The number of wells and formation data of Table 1 on both waste and enhanced recovery injection come from the Wyoming Oil and Gas Conservation Commission (1980)).

Of the three water disposition possibilities, waters used in enhanced recovery injection operations would be the most logistically difficult to utilize in geothermal applications. Depending on how the field operators view the value of temperature to the recovery processes, however, it may be possible to extract significant heat in "closed loop" processes which return the water for injection. While some portion of injected waters may cycle back through the system as produced water, this does not necessarily decrease their geothermal value. This recyling of cooled waters is an accepted way to usefully extract energy from very large subsurface heat sources.

Unlike the numbers of discharge permits or waste disposal wells, which represent the concentration of co-produced waters, the number of injection wells represents the dispersal of waters to create the proper injection pattern. The maximum concentrations of thermal waters in these fields will occur at separation facilities.

The "formations" involved in enhanced recovery operations are coded as follows: Ams - Amsden, Cam - Cambrian, Cur - Curtis, Dak - Dakota, Emb - Embar, Fox - Fox HIlls, Frn - Frontier, Lan - Lance, Leo - Leo, Mad - Madison, Min - Minnelusa, Mor - Morrison, Msv - Mesaverde, Mud - Muddy, Phs - Phosphoria, Shn - Shannon, Sun - Sundance, Sus - Sussex, Ten - Tensleep.

COUNTY/ LOCATION (Twp-Rng)	FIELD	OPERATOR	WATER VOLUME: Water Production (gpm)	1981 Range in Water Production: Low (gpm)	High (gpm)	WATER TEMPERATURE: Bottom-hole (B) or Wellhead (W) Temperature (°F)	Injection (I) or Discharge (D) Temperature (°F)	WATER QUALITY: Total Dissolved Solids (ppm or mg/l)	WATER DISPOSITION: Discharged Water (gpm)	Number of Discharge Permits	Waste Injected Water (gpm)	Number of Disposal Wells	Water Injected for Enhanced Recovery (gpm)	Number of Active Injection Wells	Source Formation	Formation Injected
Big Horn																
49N-91W	Bonanza	Conoco*	303	290	722	78(W)	50(D)	1224	303	2	---	---	---	---	---	---
55,56N-96,97W	Byron	Marathon	1121	0	1198	120-125(B)	52-60(D) 110-115(I)	3090	168	1	---	---	953	19	Ten	Ten/Emb
55,56N-97,98W	Garland	Marathon*	6397	1132	6952	138-143(B)	78(D) 120-125(I)	3787	3360	3,1*	1222	1	1816	24	Ten	Ten/Phs
		Texaco*	718			---	95(I)	3898	---	2	718	2	---	---	---	---
47N-97,98W	Sage Creek	Sohio*	287	89	366	95(B) 80(W)	60(I)	3330	---	0	---	---	287	2	Ten	Ten
31N-92,93W	Torchlight	Amoco	1750	1408	2859	95	---	---	1750	1*	---	---	---	---	---	---
Campbell																
54N-72W	Gas Draw	Chevron*	671	771	1264	182(B)	150(I)	---	---	0	---	---	671	15	Fox/Lan	Mud
45N-71W	Hilight	Inexco*	2042	1760	2205	230(B)	210(I)	---	---	12	---	---	2042	38	Fox	Mud
48,49N-69W	Raven Creek	Mobil	369	157	390	135(W)	120(I)	---	---	0	---	---	369	13	Fox	Min
56,57N-69W	Rocky Point	Amoco*	(948)	1044	1325	---	115-127(D)	2374	(955)	1*	---	---	---	---	---	---
50N-69,70W	Rozet	Arco*	329	336	418	---	110-155(I)	6,792-31,519	---	0	329	1	---	---	---	---
Carbon																
21N-79W	Big Medicine Bow	Marathon	217	0	3697	152(W)	---	2497	217	1	---	---	---	---	---	---
26N-89,90W	Wertz	Amoco	1458	428	1427	145(B)	135	10,404	77	1	---	---	1458(?)	27	Ten/Mad	Ten
Converse																
32,33,34N-75,76W	South Glenrock	Conoco*	510	590	736	128(W)	100(I)	1333	---	1	---	---	510	59	Mad/Ten	Mud/Dak
Fremont																
33,34N-96W	Beaver Creek	Amoco	715	255	626	230-234(B)	90-140	1975	248	2	---	---	467	6	Mad	Mad
32N-95W	Big Sand Draw	Amoco	3500	2849	5260	220(B)	135-170(D)	2163	3500	3	---	---	---	---	---	---
36,37N-82W	Casper Creek North	Katherman	(244)	0	311	---	---	---	244(?)	1	---	---	---	---	---	---
6,7N-2,3W	Circle Creek	Conoco	636	0	631	74(W)	56	1768	563	2	---	---	73	10	Ams	Ams
28N,92,93W	Crooks Gap	Amoco	758	512	775	150(B)	120(B)	6466	758	1	---	1	---	---	---	---
32N-99W	Dallas	Union	642	0	693	---	61-79	---	642	1	---	---	---	---	---	---
33N-99W 2S-1,2E	Lander	Amoco	379	287	407	96(B)	80(I)	---	---	11	---	---	379	26	Ten	Phs
6N-2W	Maverick Springs	Crown-Central*	(460)	111	1853	---	---	---	460(?)	1	---	---	---	---	---	---
4N-1W	Steamboat Butte	Gulf*	(760)	692	769	---	99-154	---	192	0(?)	---	---	578	7	Ten/Phs	Ten/Phs
2N-1,2W	Winkleman Dome	Amoco*	3159	2437	3134	125-220(B)	100-180	---	207	1	---	---	2952	59	Ten/Phs	Ten/Phs
Hot Springs																
42,43N-91W	Black Mtn.	Texaco	744	53	619	---	90	750	---	1	744	1	---	---	---	---
44N-95W	Gebo	Conoco	510	0	508	120(W)	90(D)	3186	510	1	---	---	---	---	---	---
46N-98W	Grass Creek	Marathon	3305	2721	3584	70-120(B)	65-110(I)	5279	---	6	343	1	2962	99	Msv/Mad	Cur/Frn/Ten
44N-97,98W	Hamilton Dome	Arco	3379	4154	8181	---	143(D)	3565	3379	1,1*	---	---	---	---	---	---
		Petro-Lewis	3183			96-124	103(I), 90(D)	3528	2538	1,1*	---	---	645	21	Ten/Phs	Phs
43N-91,92W	Lake Creek/NW	Getty	(405)	145	410	---	---	---	405(?)	4	---	---	---	---	---	---
47,48N-99,100W	Little Buffalo Basin	Amoco	4181	3376	4322	118-120	---	---	233	11	---	---	3936	110	Emb/Ten	Emb/Ten

COUNTY/ LOCATION (Twp-Rng)	FIELD	OPERATOR	WATER VOLUME: Water Production (gpm)	WATER VOLUME: 1981 Range in Water Production: Low (gpm)	WATER VOLUME: 1981 Range in Water Production: High (gpm)	WATER TEMPERATURE: Bottom-hole (B) or Wellhead (W) Temperature (°F)	WATER TEMPERATURE: Injection (I) or Discharge (D) Temperature (°F)	WATER QUALITY: Total Dissolved Solids (ppm or mg/l)	WATER DISPOSITION: Discharged Water (gpm)	WATER DISPOSITION: Number of Discharge Permits	WATER DISPOSITION: Waste Injected Water (gpm)	WATER DISPOSITION: Number of Disposal Wells	WATER DISPOSITION: Water Injected for Enhanced Recovery (gpm)	WATER DISPOSITION: Number of Active Injection Wells	WATER DISPOSITION: Source Formation	WATER DISPOSITION: Formation Injected
Hot Springs (continued)																
44N-96W	Little Sand Draw	Husky	688	349	688	---	123(D)	2840	688	2	---	2	---	---	---	---
Johnson																
41N-78W	Meadow Creek	Conoco	338	0	337	182(W)	160(I)	2348	---	5	---	---	358	30	Mad	Shn/Ten
44N-81,82W	North Fork	Amoco*	513	527	598	170(B)	90(D)	7191	513	1	---	---	---	---	---	---
42N-78,79W	Sussex	Conoco*	475	0	522	174(W)	150(I)	3313	---	3	---	---	475	39	Mad	Sus/Ten
Natrona																
33,34N-83W	Casper Creek South	Union	875	482	2184	---	90	---	875	2	---	---	---	---	---	---
37N-85W	Notches	Terra Resources	1021	1030	1093	115	95(D)	1484	1021	1,1*	---	---	---	---	---	---
39,40N-78,79W	Salt Creek	Amoco*	29983	4044	23240	90-180(B)	85-90	3900	17675	8,8*	---	---	12,309	515	Mad	Frn
		Terra Resources*	2246			188	140(I)	2986	(914)	11,1*	---	---	1246	103	Mad	Frn
38,39N-78W	Teapot East	Union	467	3	12	---	179	---	467	1	---	---	---	---	---	---
36,39N-78W	Teapot Naval	Fenix & Scission*	(300)	274	350	---	---	---	??	9	---	---	??	33	Mad	Frn
Niobrara																
35,36N-65W	Lance Creek	Marathon	1272	481	1919	155(W)	110(D)	3304	1272	6	---	---	---	1	Leo	Mor
		Grace	467			140(W)	50-80(D)	3089	467	2	---	---	---	---	---	---
Park																
57,58N-99,100W	Elk Basin	Amoco	4364	1106	2770	115	---	---	1273	3	---	---	3092	34	Mad/Ten	Mad/Ten
56,57N-99W	Elk Basin South	Conoco	572	0	588	148(W)	140(I)	5131	---	1	---	---	572	6	Ten	Ten
47,48N-103W	Four Bear	Amoco	933	3	2377	130	---	---	---	3	933	6	---	---	---	---
58N-98W	Frannie	Conoco	2158	0	2234	90(W)	84(I)	3200	---	2	---	---	2158	30	Mad	Phs/Ten
51N-102W	Halfmoon	Husky	601	408	627	---	103(D)	2620	601	1	---	2	---	---	---	---
50,51,52N-100W	Oregon Basin	Marathon	14893	13301	14829	110-120(B)	63-90(D) 100-110(I)	1545	1489	8	---	---	13,403	129	Mad/Emb/Ten	Mad/Emb/Ten
48N-102W	Pitchfork	Husky	944	367	972	---	81(D)	2600	941	1	---	6	---	---	---	---
49N-102W	Spring Creek South	Texaco	2112	1264	2279	---	100	2897	---	0	2112	2	---	---	---	---
56N-98W	Whistle Creek	Texaco	779	758	873	---	95	2602	779	1	---	---	---	---	---	---
Sweetwater																
26N-90W	Lost Soldier	Amoco	3558	2882	3723	159-165(B)	140	7591	438	1	---	---	3121	56	Sun/Cam/Mad	Cam/Ten/Mad
Washakie																
47,48N-90,91W	Cottonwood Creek	Amoco*	292	203	317	110	---	---	58	1	---	---	233	25	Mad/Phs	Phs

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(Rev 10-77)

U. S. DEPARTMENT OF ENERGY

COOPERATIVE AGREEMENT

PURSUANT TO AUTHORITY OF PL 93-410, PL 93-438, PL 93-473, PL 93-577, and PL 95-91

1.a. Agreement No. DE-FC07-79ID12026

1.b. Modification No.

2. Agreement Period

From: Dec. 11, 1978 To: Sept. 30, 1979

3. Participant Name and Address

University of Wyoming
University Station, Box 3355
Laramie, Wyoming 82071

4. Participant Type

☒ Educational ☒ Nonprofit
☐ State or Local Government ☐ Profit

5. Project Title

Hydrothermal Resources in Wyoming
(State Coop Program)

6. Project Will Be Conducted Per

See Article I

7. Technical Reports Are Required

See Article V

8. Principal Investigator(s) or Program Director(s) Name and Address

Edward R. Decker, Professor of Geology
University of Wyoming
University Station, Box 3355
Laramie, Wyoming 82071

9. DOE Program Officer (Name and Address)

Leland L. Mink, E&T Division
Idaho Operations Office, DOE
550 Second Street, Idaho Falls, ID 83401

Telephone No. 208-526-0638

10. Accounting and Appropriation Data

11. Method of Payment

☐ % At Award, % When Requested, 5% Upon Receipt of Final Report
☐ Letter of Credit ☐ Reimbursement
☒ Other (specify) See Article III

12. Submit Vouchers, if any, to Agreements Officer Unless Otherwise Specified in this Block Director, Contracts Management Division, 550 Second Street Idaho Falls, Idaho 83401

13. Funding Sources

Source	Amount
DOE	$ 99,439.00
Participant:	$ 7,048.00
Total Funding:	$ 106,487.00

14. Remarks:

Wyoming: U. of
Contract
~~10/7/82~~
Mod 010: 2/28/83
completion.

15. Amount Obligated By This Action: $ 99,439.00

16. DOE Issuing Office (Name and Address)

Idaho Operations Office
550 Second Street
Idaho Falls, Idaho 83401

17. DOE Cooperative Agreements Officer

(Signature) (Date)

Name (typed)

Title

Telephone No.

Cooperative Agreement No. DE-FC07-79ID12062

COOPERATIVE AGREEMENT

THIS AGREEMENT, entered into the 29th day of December 1978 (effective as of the 11th day of December 1978), by and between the UNITED STATES OF AMERICA (hereinafter called the "Government"), acting through the DEPARTMENT OF ENERGY (hereinafter called "DOE") with its Idaho Operations Office located at 550 Second Street in Idaho Falls, Idaho 83401, and the UNIVERSITY OF WYOMING (hereinafter called the "Participant") located at Laramie, Wyoming;

WITNESSETH THAT:

WHEREAS, the Government is engaged in the Western States Coupled Direct-Heat Geothermal Program, an integral element of the Rocky Mountain Basin and Range Commercialization Plan; and

WHEREAS, the Participant has proposed to undertake a part of such a program and request that DOE provides certain financial assistance for the accomplishment of such a program; and

WHEREAS, this agreement is authorized by the Department of Energy Organization Act (Public Law 95-91), Sections 7(a)(2) and 8 of Public Law 93-577, and Sections 103(5) and 107(a) of Public Law 93-438;

NOW, THEREFORE, DOE and the Participant agree as follows:

ARTICLE I - STATEMENT OF JOINT OBJECTIVE

The direct application of geothermal and hydrothermal energy at various sites located within Wyoming can be a significant factor in the Government's efforts to achieve energy independence. The research provided for in this Agreement is important to both the Government and the Participant for estimating the potential of geothermal and hydrothermal energy utilization and for fostering its use in Wyoming.

ARTICLE II - DESCRIPTION OF RESPONSIBILITIES

The Participant is responsible to assure that the research is accomplished in a manner consistent with the provisions of this Agreement. The Participant's proposal identified as Phase 1 Research On Hydrothermal Resources In Wyoming, as it may have been amended, is made part of this Agreement by this reference; however, if there is any conflict between the content of the proposal and the content of this Agreement, the content of this Agreement governs. The tasks provided for in the proposal are to be accomplished, and are to result in, a final feasibility assessment report which will include, as a minimum, the following information:

ARTICLE II - DESCRIPTION OF RESPONSIBILITIES (Cont'd)

1. Evaluation of existing thermal spring areas through geologic and hydrologic investigations, chemical sampling and analysis and review of existing thermal information.

2. Measurements of thermal gradients in selected areas through the use of existing wells where possible or through drilling of new thermal gradient holes.

3. Detailed investigations will be conducted in areas of near-term development potential. Two areas which may be investigated based on preliminary data are the Gas Hills and Douglas areas with emphasis near populated centers where direct heat applications could have significant impact.

4. Investigate the northern extension of the Rio Grade Rift through studies of flux, radioactivity and young volcanics for the potential of geothermal resources.

5. Study of existing oil well and other drill hole data to evaluate the geothermal potential of reservoir systems such as the Madison Formation.

ARTICLE III - FINANCIAL SUPPORT OF THE PROJECT

A. The total estimated cost of performing the work under this Agreement is One Hundred Six Thousand Four Hundred Eighty-Seven Dollars ($106,487.00). For performance of work under this Agreement, the agreed share ratio is 93.38% DOE, 6.62% Participant of total allowable costs. The Participant shall be reimbursed by DOE for 93.38 of the costs of the project determined to be allowable in accordance with Article A-I of the General Provisions entitled "Allowable Costs." All other costs that are not determined to be allowable under Article A-I shall constitute the Participant's share for which it will not be reimbursed by DOE. The total cost to DOE is hereby established as Ninety-Nine Thousand Four Hundred Thirty-Nine Dollars ($99,439.00), and this amount is also the maximum amount of the project which is subject to reimbursement by DOE unless such maximum cost is changed in writing by the Contracting Officer.

B. As regards to any increase or decrease in the total estimated cost of this Agreement as a result of any change in the original Statement of Work as may be agreed upon by the parties during the term of this Agreement, the appropriate sharing of the funding, if any, of such increase or decrease shall be shared at the ratio of 93.38% DOE, 6.62% Participant, as agreed upon above.

ARTICLE III - FINANCIAL SUPPORT OF THE PROJECT (Cont'd)

C. The amount of funds obligated under this Agreement by DOE for the period from December 11, 1978 through September 30, 1979 is Ninety-Nine Thousand Four Hundred Thirty-Nine Dollars ($99,439.00).

ARTICLE IV - METHOD AND BASIS OF PAYMENT

A. The Participant shall receive 25% of DOE's share ($24,860.00) at the time this Agreement is executed. The balance becomes payable in periodic installments as requested by the Participant and approved by DOE. Requests for payment shall not be more frequent than monthly, and the request should contain a cost breakdown showing the amount requested, the total amount requested to date, and the total cost of the project to date, including the value of the Participant's cost sharing as provided for in Article III of this Agreement. The total amount paid by DOE will not exceed the amount specified in Article III.

B. Final payment will not be made until the Final Report is received and accepted by DOE. In no event will the final 5% of the amount of obligated funds be paid to the Participant until DOE has received the Final Report and the Final Cost Report described in Article VII.A.1 of this Cooperative Agreement.

ARTICLE V - TERM OF AGREEMENT

Work under this Agreement shall be accomplished during the period from December 11, 1978 through September 30, 1979. The period of this Agreement may be extended as mutually agreed upon by DOE and the Participant.

ARTICLE VI - PROJECT MANAGEMENT

A. In addition to DOE personnel, the Participant agrees to permit non-DOE personnel who are under contract with DOE, and identified from time to time by the Contracting Officer, to assist the DOE representative in performance of his duties and to have necessary access to the Participant's and major subcontractors' records pertaining to the project. DOE correspondence, if any, with subcontractors shall be routed through the Participant.

B.1. DOE's Program Officer on this project and the person who shall be the Participant's contact for all matters pertaining to this Agreement shall be the following-named person or such other person(s) as may be designated by the Contracting Officer:

ARTICLE VI - PROJECT MANAGEMENT (Cont'd)

Leland L. Mink
Energy and Technology Division
Idaho Operations Office, DOE
550 Second Street
Idaho Falls, Idaho 83401
Telephone 208-526-0085

2. The Participant's Project Director for the work under this Agreement will be the following person or such other person(s) as may be mutually acceptable to the parties:

Edward R. Decker
Principal Investigator
Professor of Geology
University of Wyoming
Laramie, Wyoming 82071
Telephone 307-766-3278

C. The term "DOE" means the United States Department of Energy or any duly authorized representative thereof, including the Contracting Officer except for the purpose of deciding an appeal under the article entitled "Disputes."

D. The term "Contracting Officer" means the person executing this Agreement on behalf of DOE, and includes his successors or any duly authorized representative of such person.

ARTICLE VII - PROJECT INFORMATION

A.1. The following reports, as required by DOE Uniform Contractor Reporting System, Volume 1, January 1978, and as indicated on the attached ERDA Form 537, February 1978, shall be submitted to the DOE Program Officer:

Type	Frequency	Number of Copies
Technical Status Report	Monthly	8
Technical Progress Report	Mid-point of work	8
Final Technical Report	Completion of work	8 plus a camera ready copy
Final Cost Report	Completion of work	
Hotline Report	Weekly	
Conference Record	As Required	8

2. The content of the reports will be as follows:

ARTICLE VII - PROJECT INFORMATION (Cont'd)

Project Status Report - A brief two-page letter summarizing the progress of the work.

Hot Line Report - A brief telephone report submitted to DOE every Friday by 12:00 a.m.

Conference Record - A brief description of the contractor's understanding of significant decisions, directions, redirections or required actions resulting from meetings with DOE representatives. It is required for any meeting or conference in which the cost, schedule manpower or scope of work is changed.

Technical Progress Report - Summary of work performed during the first six months. It includes a description of results achieved.

Final Technical Report - A technical accounting of the total work performed on the project.

Final Cost Report - A report showing all costs of the project identified in the same format as the proposal. The report shall show separately the Participant and DOE costs.

B. Quarterly progress meetings will be held which the participant is required to attend. DOE will fund travel expenses for one member of the participants team.

ARTICLE VIII - CHANGES AND MODIFICATIONS

Any changes or modifications to this Agreement or in the scope of work to be performed shall be made by mutual written agreement of the parties. A change may be initiated by either party to this Agreement. The Contracting Officer shall have the authority to determine what constitutes a change.

ARTICLE IX - TERMINATION

A. It is the express intent of DOE and the Participant to fund their respective cost participation for the project.

B. Notwithstanding the foregoing, it is understood that the Participant may at any time upon giving sixty (60) days prior written notice to DOE terminate this Agreement for its convenience for any reason.

C. In the event of termination, it is expected that the parties will cooperate with each other to reasonably phase out cost commitments, including cost liabilities to third parties; provided, however, that the total amount obligated by the Government under this Agreement shall not be exceeded.

ARTICLE IX - TERMINATION (Cont'd)

Moreover, upon any such termination the Participant agrees to promptly, upon DOE's request, transfer to DOE all information resulting from the work performed to the date of the termination notice.

D. In the event of termination, the Government agrees to pay the Participant 93% of all allowable costs for termination, and the Participant shall:

1. Place no further orders or subcontracts for materials, services, or facilities, intended to be invoiced to the Government for its contribution.

2. Cancel all orders and subcontracts to the extent that they relate to the performance of work terminated by the Notice of Termination and intended to be invoiced to the Government for its contribution.

3. Notwithstanding 1. and 2. above, the Participant has the right to proceed with such orders and subcontracts should it decide to continue performance of the work at its expense only.

E. After a termination, the Participant shall submit to the Contracting Officer its termination claim. Such claim shall be submitted promptly but in no event later than one (1) year from the effective date of termination unless one or more extensions in writing are granted by the Contracting Officer. Upon failure of the Participant to submit its termination claim within the time allowed, the Contracting Officer may determine, on the basis of information available to him, the amount, if any, due to the Participant by reason of the termination and shall thereupon pay to the Participant the amount so determined.

F. Costs claimed, agreed to, or determined pursuant to this article must constitute allowable costs as defined in Article A-1 of the Appendix A of this Agreement.

G. Any termination notice rendered by either DOE or the Participant shall be sent by registered mail with return receipt requested.

H. If in the opinion of the Contracting Officer, the Participant fails to substantially perform under this Agreement, and does not cure such failure within a reasonable time, after written notice of such failure by the Contracting Officer, DOE may by written notice to the Participant terminate this Agreement. Such termination notice, signed by the Contracting Officer, shall be effective upon receipt by the Participant. The Government shall not be liable for the incurrence of any obligations under this Agreement from the date of the receipt of such termination notice. Upon

ARTICLE IX - TERMINATION (Cont'd)

any such termination, the Participant agrees to promptly, upon DOE's request, transfer to DOE all information resulting from the work performed to the date of the termination notice.

I. Except with respect to defaults of subcontractors, the Participant shall not be in default by reason of failure to substantially perform under this Agreement if such failure arises out of causes beyond the control and without the fault or negligence of the Participant. Such causes may include, but are not restricted to, acts of God or of the public enemy, acts of the Government in either its sovereign or contractual capacity, fires, floods, epidemics, quarantine restrictions, strikes, freight embargoes, and unusually severe weather, but in every case the failure to perform must be beyond the control and without the fault or negligence of the Participant. If the failure to substantially perform is caused by the failure of a subcontractor to perform or make progress, and if such failure arises out of causes beyond the control of both the Participant and a subcontractor, and without the fault or negligence of either of them, the Participant shall not be deemed to be in default unless the supplies or services to be furnished by the contractor were reasonably obtainable from other sources. Upon request of the Participant, if the Contracting Officer shall determine that failure to perform was occasioned by any one or more of the said causes, this Agreement shall be revised accordingly, subject to the rights of DOE under paragraph B. above.

ARTICLE X - LIABILITY AND INDEMNIFICATION

The Government will not be liable for payment of damages for injuries to any person, or loss of life or personal property, or loss suffered or sustained and arising from the work performed under this Agreement. The Participant agrees to indemnify and save the Government harmless from any and all claims, demands, damages, actions, costs, or charges against the Government arising as the result of the above-mentioned injuries, damages, or loss, except for any such damages or claims arising out of the negligent act of the Government or its employees in the course of their official duties.

ARTICLE XI - USE OF INFORMATION

All data and information generated, derived or obtained from the activities provided for herein, and this Agreement, will be public information.

ARTICLE XII - ADDITIONAL CONTRACT PROVISIONS

Appendix A, attached hereto and made a part hereof, sets forth additional general provisions of this Agreement.

Cooperative Agreement No. DE-FC07-79ID1206

IN WITNESS WHEREOF, the parties hereto have executed this document as of the day and year first above written.

THE UNITED STATES OF AMERICA

BY THE DEPARTMENT OF ENERGY

By J. F. Marmo

J. F. Marmo, Chief, Procurement Branch
Contracts Management Division
Idaho Operations Office
Contracting Officer

Witnesses as to signature of Participant:

Roger Wilmot
(Signature)

Roger Wilmot
Name (typed)

University of Wyoming
(Address)

Terri Burch
(Signature)

Terri Burch
Name (typed)

University of Wyoming
(Address)

UNIVERSITY OF WYOMING

By Elliott G. Hays

Elliott G. Hays
Name (typed)

Title Vice President for Finance
University Station, Box 3355
Laramie, Wyoming 82071
(Business Address)

Cooperative Agreement No. DE-FC07-79ID12062

I, Karleen B. Anderson, certify that I am the Deputy Secretary of the Board of Trustees of the Participant named under this document, that that Elliott G. Hays, who signed this document on behalf of the Participant, was then Vice President for Finance of said Participant; that said document was duly signed for and in behalf of said Participant by authority of its governing body, and is within the scope of its legal powers.

IN WITNESS WHEREOF, I have hereunto affixed my hand and the seal of said corporation this 2nd day of January 1979.

Karleen B. Anderson
Secretary

(CORPORATE SEAL)

APPENDIX A
GENERAL PROVISIONS
COOPERATIVE AGREEMENTS

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APPENDIX A

GENERAL PROVISIONS

COOPERATIVE AGREEMENTS

ARTICLE A-I - ALLOWABLE COST

Costs shall constitute allowable costs as specified in Title 41, Code of Federal Regulations Part 1-15 of the Code of Federal Regulations in effect on the date of this Agreement.

ARTICLE A-II - APPROVAL OF SUBCONTRACTS

All subcontracts and purchase orders in excess of $10,000 shall require the written approval of the Contracting Officer.

ARTICLE A-III - PUBLIC INFORMATION RELEASES

The parties agree that public disclosure or dissemination of new data or information arising out of the feasibility assessment will be coordinated by the parties, it being understood that the intent of both the Participant and DOE is to release all data and information to the greatest practicable extent in order to achieve the objective of obtaining maximum public value from the results of this project. It is understood that the foregoing is not intended to afford either party the right to prevent a public release by the other; however, nothing in this article shall impair the rights of the parties set forth elsewhere in this Agreement, including but not necessarily limited to the article entitled "Patent Rights."

ARTICLE A-IV - AUDIT

A. The Participant shall maintain, and the Contracting Officer or his representative shall have the right to examine books, records, documents, and other evidence and accounting procedures and practices, sufficient to reflect properly all direct and indirect costs of whatever nature claimed to have been incurred and anticipated to be incurred for the performance of this Agreement. Such right of examination shall include inspection at all reasonable times of the Participant's plants, or such parts thereof, as may be engaged in the performance of this Agreement.

B. The materials described above, shall be made available at the office of the Participant, at all reasonable times, for inspection, audit or reproduction, until the expiration of three (3) years from the date of final payment under this Agreement or such lesser time specified in Title 41, Code of Federal Regulations Part 1-20 and for such lesser period, if any, as is required by applicable statute, or by other articles of this Agreement, or by (1) and (2) below:

ARTICLE A-IV - AUDIT (Cont'd)

(1) If this Agreement is completely or partially terminated, the records relating to the work terminated shall be made available for a period of three (3) years from the date of any resulting final settlement.

(2) Records which relate to appeals under the "Disputes" article of this Agreement, or litigation or the settlement of claims arising out of the performance of this Agreement, shall be made available until such appeals, litigation, or claims have been disposed of.

ARTICLE A-V - OFFICIALS NOT TO BENEFIT

No member of or delegate to Congress, or resident commissioner, shall be admitted to any share or part of this Agreement, or to any benefit that may arise therefrom; but this provision shall not be construed to extend to this Agreement if made with a corporation for its general benefit.

ARTICLE A-VI - COVENANT AGAINST CONTINGENT FEES

The Participant warrants that no person or selling agency has been employed or retained to solicit or secure this Agreement upon an agreement or understanding for a commission, percentage brokerage, or contingent fee, excepting bona fide employees or bona fide established commercial or selling agencies maintained by the Participant for the purpose of securing business. For breach or violation of this warranty the Government shall have the right to annual this Agreement without liability or in its discretion to deduct from the Agreement price or consideration, or otherwise recover, the full amount of such commisison, percentage, brokerage, or contingent fee.

ARTICLE A-VII - EXAMINATION OF RECORDS BY COMPTROLLER GENERAL

A. The Participant agrees that the Comptroller General of the United States or any of his duly authorized Government employees shall, until the expiration of three (3) years after final payment under this Agreement, unless DOE authorizes their prior disposition, have access to and the right to examine any directly pertinent books, documents, papers, and records of the Participant involving transactions related to this Agreement.

ARTICLE A-VII - EXAMINATION OF RECORDS BY COMPTROLLER GENERAL (Cont'd)

B. The Participant further agrees to include in all its subcontracts hereunder a provision to the effect that the subcontractor agrees that the Comptroller General of the United States or any of his duly authorized Government employees shall, until the expiration of three (3) years after final payment under the subcontract, or such lesser time specified in either Appendix M of the Armed Services Procurement Regulation or the Federal Procurement Regulations Part 1-20, as appropriate, have access to and the right to examine any directly pertinent books, documents, papers, and records of such subcontractor, involving transactions related to the subcontract. The term "subcontract" as used in this article excludes (1) purchase orders not exceeding $10,000 and (2) subcontracts or purchase orders for public utility services at rates established for uniform applicability to the general public.

C. The periods of access and examination described in A. and B., above, for records which relate to (1) appeals under the "Disputes" article of this Agreement, (2) litigation or the settlement of claims arising out of the performance of this Agreement, or (3) costs and expenses of this Agreement as to which exception has been taken by the Comptroller General or any of his duly authorized representatives, shall continue until such appeals, litigation, claims or exceptions have been disposed of.

ARTICLE A-VIII - ASSIGNMENT OF CLAIMS

Pursuant to the provisions of the Assignment of Claims Act of 1940, as amended (31 U.S.C. 203, 41 U.S.C. 15), claims for moneys due or to become due the Participant from the Government under this Agreement may be assigned to a bank, trust company, or other financing institution, including any Federal lending agency, and may thereafter be further assigned and reassigned to any such institution. Any such assignment or reassignment shall cover all amounts payable under this Agreement and not already paid, and shall not be made to more than one party, except that any such assignment or reassignment may be made to one party as agent or trustee for two or more parties participating in such financing. Unless otherwise provided in this Agreement, payments to assignee of any moneys due or to become due under this Agreement shall not, to the extent provided in said Act, as amended, be subject to reduction or setoff.

ARTICLE A-IX - PERMITS

Except as otherwise directed by the Contracting Officer, the Participant shall procure all necessary permits or licenses and abide by all applicable laws, regulations, and ordinances of the United States and of the State, territory, and political subdivision in which the work under this Agreement is performed.

ARTICLE A-X - DISPUTES

A. Except as otherwise provided in this Agreement, any dispute concerning a question of fact arising under this Agreement shall be decided by the Contracting Officer, who shall reduce his decision to writing and mail or otherwise furnish a copy thereof to the Participant. The decision of the Contracting Officer shall be final and conclusive unless within thirty (30) days from the date of receipt of such copy, the Participant mails or otherwise furnishes to the Contracting Officer a written appeal addressed to DOE. The decision of DOE or its duly authorized representative for the determination of such appeals shall be final and conclusive unless determined by a court of competent jurisdiction to have been fraudulent, or capricious, or arbitrary, or so grossly erroneous as necessarily to imply bad faith, or not supported by substantial evidence. In connection with any appeal proceeding under this article, the Participant shall be afforded an opportunity to be heard and to offer evidence in support of its appeal. Pending final decision of a dispute hereunder, the Participant shall proceed diligently with the performance of this Agreement and in accordance with the Contracting Officer's decision.

B. This "Disputes" article does not preclude consideration of law questions in connection with decisions provided for in paragraph A, above: Provided, That nothing in this Agreement shall be construed as making final the decision of any administrative official, representative, or board on a question of law.

ARTICLE A-XI - PAYMENT OF INTEREST ON PARTICIPANT'S CLAIMS

A. If an appeal is filed by the Participant from a final decision of the Contracting Officer under the "Disputes" article of this Agreement, denying a claim arising under the Agreement, simple interest on the amount of the claim finally determined owed by the Government shall be payable to the Participant. Such interest shall be at the rate determined by the Secretary of the Treasury pursuant to Public Law 92-41, 85 Stat. 97, from the date the Participant furnishes to the Contracting Officer its written appeal under the "Disputes" article of this Agreement, to the date of (1) a

ARTICLE A-XI - PAYMENT OF INTEREST ON PARTICIPANT'S CLAIMS (Cont'd)

final judgment by a court of competent jurisdiction, or (2) mailing to the Participant of a supplemental agreement for execution either confirming completed negotiations between the parties or carrying out a decision of a board of contract appeals.

B. Notwithstnding A., above, (1) interest shall be applied only from the date payment was due, if such date is later than the filing of appeal, and (2) interest shall not be paid for any period of time that the Contracting Officer determines the Participant has unduly delayed in pursuing its remedies before a board of contract appeals or a court of competent jurisdiction.

ARTICLE A-XII - SEX DISCRIMINATION PROHIBITED

No person shall on the ground of sex be excluded from participation in, be denied a license under, be denied the benefits of, or be subjected under any program or activity carried on or receiving Federal assistance under any title of this Act (P. L. 93-438).

ARTICLE A-XIII - CIVIL RIGHTS

The Participant agrees that no person in the United States shall, on the ground of race, color, or national origin, be excluded from participation in, be denied the benefits of, or be subject to discrimination under any program or activity for which the Participant receives Federal financial assistance from DOE.

ARTICLE A-XIV - DISCRIMINATION AGAINST HANDICAPPED PROHIBITED

The Participant agrees that no otherwise qualified handicapped individual in the United States [as defined in Section 7(6) of the Act], shall, solely by reason of his handicap, be excluded from the participation in, be denied the benefits of, or be subjected to discrimination under any program or activity receiving Federal financial assistance.

ARTICLE A-XV - SMALL AND MINORITY BUSINESS PARTICIPATION

It is the policy of DOE to ensure that small and minority businesses have a reasonable opportunity to participate in the projects which it supports. In accordance with this policy, the Participant will make a reasonable effort to ensure fair consideration and utilization of small and minority businesses in purchases and subcontracts awarded by the Participant under this Agreement.

ARTICLE A-XVI - PREFERENCE FOR U. S. FLAG AIR CARRIERS

A. It is the policy of the United States that all Federal agencies and Government contractors and subcontractors utilize U. S. flag air carriers for international air transportation of personnel and cargo.

B. The Participant agrees to utilize U. S. flag air carriers to the maximum extent practicable in connection with the performance of this Agreement in the transportation by air of any personnel and cargo between the United States and a foreign country, or between foreign countries.

C. The terms used in this article have the following meanings:

(1) "International air transportation" means transportation by air of personnel and cargo from the United States to a foreign country, between two or more foreign countries, and between a foreign country and the United States.

(2) "U. S. flag air carrier" means one of a class of air carriers holding a certificate of public convenience and necessity issued by the Civil Aeronautics Board, approved by the President, authorizing operations between the United States and/or its territories and one or more foreign countries.

(3) The term "United States" incudes the fifty States, Commonwealth of Puerto Rico, possessions of the United States and the District of Columbia.

(4) "Practicable" includes (i) satisfactory servicing of agency programs, and (ii) timely deliveries at fair and reasonable prices.

D. The Participant shall include the substance of this article, including this paragraph D. in each subcontract or purchase order hereunder which may involve air transportation between the United States and a foreign country, or between foreign countries.

ARTICLE A-XVII - CLEAN AIR AND WATER

A. The Participant agrees as follows:

(1) To comply with all the requirements of section 114 of the Clean Air Act, as amended (42 U.S.C. 1857, et seq., as amended by P. L. 91-604) and section 308 of the Federal Water Pollution Control Act (33 U.S.C. 1251, et seq., as amended by P. L. 92-500), respectively, relating to inspection, monitoring, entry, reports and information, as

ARTICLE A-XVII - CLEAN AIR AND WATER (Cont'd)

well as other requirements specified in section 114 and section 308 of the Air Act and the Water Act, respectively, and all regulations and guidelines issued thereunder before the award of this Agreement.

(2) That no portion of the work required by this Agreement will be performed in a facility listed on the Environmental Protection Agency List of Violating Facilities on the date when this Agreement was awarded unless and until the EPA eliminates the name of such facility or facilities from such listing.

(3) To use its best efforts to comply with clean air standards and clean water standards at the facility in which the Agreement is being performed.

(4) To insert the substance of the provisions of this article into any nonexempt contract, including this subparagraph A.(4).

B. The terms used in this article have the following meanings:

(1) The term "Air Act" means the Clean Air Act, as amended (42,U.S.C. 1857, et seq., as amended by P. L. 91-604).

(2) The term "Water Act" means Federal Water Pollution Control Act, as amended (33 U.S.C. 1251 et seq., as amended by P. L. 92-500).

(3) The term "clean air standards" means any enforceable rules, regulations, guidelines, standards, limitations, orders, controls, prohibitions, or other requirements which are contained in, issued under, or otherwise adopted pursuant to the Air Act or Executive Order 11738, an applicable implementation plan as described in section 110(d) of the Clean Air Act [42 U.S.C. 1857c-5(d)], an approved implementation procedure or plan under section 111(c) or section 111(d), respectively, of the Air Act (42 U.S.C. 1157(c)-6(c) or (d), or an approved implementation procedure under section 112(d) of the Air Act [42 U.S.C. 1857c-7(d)].

(4) The term "clean water standards" means any enforceable limitation, control, condition, prohibition, standard, or other requirement which is promulgated pursuant to the Water Act or contained in a permit issued to a discharger by the Environmental Protection Agency or by a State under an approved program, as authorized by section 402 of the Water Act (33 U.S.C. 1342), or

ARTICLE A-XVII - CLEAN AIR AND WATER (Cont'd)

by local government to ensure compliance with pretreatment regulations as required by section 307 of the Water Act (33 U.S.C. 1317).

(5) The term "compliance" means compliance with clean air or water standards. Compliance shall also mean compliance with a schedule or plan ordered or approved by a court of competent jurisdiction, the Environmental Protection Agency or an air or water pollution control agency in accordance with the requirements of the Air Act or Water Act and regulations issued pursuant thereto.

(6) The term "facility" means any building, plant, installation, structure, mine, vessel, or other floating craft, location, or site of operations, owned, leased, or supervised by a contractor or subcontractor, to be utilized in the performance of a contract or subcontract. Where a location or site of operations contains or includes more than one building, plant, installation, or structure, the entire location or site shall be deemed to be a facility except where the Director, Office of Federal Activities, Environmental Protection Agency, determines that independent facilities are collocated in one geographical area.

ARTICLE A-XVIII - RIGHTS IN TECHNICAL DATA

A. Definitions

(1) "Technical Data" means recorded information regardless of form or characteristic, of a scientific or technical nature. It may, for example, document research, experimental, developmental, or demonstration, or engineering work, or be usable or used to define a design or process, or to procure, produce, support, maintain, or operate materiel. The data may be graphic or pictorial delineations in media such as drawings or photographs, text in specifications or related performance or design type documents or computer software (including computer programs, computer software data bases, and computer software documentation). Examples of technical data include research and engineering data, engineering drawings and associated lists, specifications, standards, process sheets, manuals, technical reports, catalog item identification, and related information. Technical data as used herein does not include financial reports, cost analyses, and other information incidental to contract administration.

ARTICLE A-XVIII - RIGHTS IN TECHNICAL DATA (Cont'd)

(2) "Proprietary Data" means technical data which embody trade secrets developed at private expense, such as design procedures or techniques, chemical composition of materials, or manufacturing methods, processes, or treatments, including minor modifications thereof, provided that such data:

(i) Are not generally known or available from other sources without obligation concerning their confidentiality.

(ii) Have not been made available by the owner to others without obligation concerning its confidentiality, and

(iii) Are not already available to the Government without obligation concerning their confidentiality.

(3) "Contract Data" means technical data first produced in the performance of the Agreement, technical data which are specified to be delivered in the Agreement, technical data that may be called for under the "Additional Technical Data Requirements" article of the Agreement, if any, or technical data actually delivered in connection with the Agreement.

(4) "Unlimited Rights" means rights to use, duplicate, or disclose technical data, in whole or in part, in any manner and for any purpose whatsoever, and to permit others to do so.

B. Allocation of Rights

(1) The Government shall have:

(i) Unlimited rights in contract data except as otherwise provided below with respect to proprietary data.

(ii) The right to remove, cancel, correct or ignore any marking not authorized by the terms of this Agreement on any technical data furnished hereunder, if in response to a written inquiry by DOE concerning the propriety of the markings, the Participant fails to respond thereto within 60 days or fails to substantiate the propriety of the markings. In either case DOE will notify the Participant of the action taken.

ARTICLE A-XVIII - RIGHTS IN TECHNICAL DATA (Cont'd)

(iii) No rights under this Agreement in any technical data which are not contract data.

(2) The Participant shall have:

(i) The right to withhold proprietary data in accordance with the provisions of this article.

(ii) The right to use for its private purposes, subject to patent, security or other provisions of this Agreement, contract data it first produces in the performance of this Agreement provided the data requirements of this Agreement have been met as of the date of the private use of such data. The Participant agrees that to the extent it receives or is given access to proprietary data or other technical, business or financial data in the form of recorded information from DOE or a DOE contractor or subcontractor, the Participant shall treat such data in accordance with any restrictive legend contained thereon, unless use is specifically authorized by prior written approval of the Contracting Officer.

(3) Nothing contained in this "Rights in Technical Data" article shall imply a license to the Government under any patent or be construed as affecting the scope of any licenses or other rights otherwise granted to the Government under any patent.

C. Copyrighted Material

(1) The Participant shall not, without prior written authorization of the Contracting Officer, establish a claim to statutory copyright in any contract data first produced in the performance of the Agreement. To the extent such authorization is granted, the Government reserves for itself and others acting on its behalf a royalty-free, non-exclusive, irrevocable, world-wide license for Governmental purposes to publish, distribute, translate, duplicate, exhibit and perform any such data copyrighted by the Participant.

(2) The Participant agrees not to include in the technical data delivered under the Agreement any material copyrighted by the Participant and not to knowingly include any material copyrighted by others without first granting or obtaining at

ARTICLE A-XVIII - RIGHTS IN TECHNICAL DATA (Cont'd)

no cost a license therein for the benefit of the Government of the same scope as set forth in paragraph C.(1) above. If such royalty-free license is unavailable and the Participant nevertheless determines that such copyrighted material must be included in the technical data to be delivered, rather than merely incorporated therein by reference, the Participant shall request the written authorization of the Contracting Officer to include such copyrighted material in the technical data without a license.

D. Subcontracting. It is the responsibility of the Participant to obtain from its subcontractors technical data and rights therein, on behalf of the Govenment, necessary to fulfill the Participant's obligations to the Government with respect to such data. In the event of refusal by a subcontractor to accept an article affording the Government such rights, the Participant shall:

(1) Promptly submit written notice to the Contracting Officer setting forth reasons for the subcontractor refusal and other pertinent information which may expedite disposition of the matter; and

(2) Not proceed with the subcontract without the written authorization of the Contracting Officer.

E. Withholding of Proprietary Data. Notwithstanding the inclusion of the "Additional Technical Data Requirements" article in this Agreement or any provision of this Agreement specifying the delivery of technical data, the Participant may withhold proprietary data from delivery, provided that the Participant furnishes in lieu of any such proprietary data, so withheld technical data disclosing the source, size, configuration, mating and attachment characteristics, functional characteristics and performance requirements ("Form, Fit and Function" data, e.g., specification control drawings, catalog sheets, envelope drawings, etc.) or a general description of such proprietary data where "Form Fit and Function" data are not applicable. The Government shall acquire no rights to any proprietary data so withheld except that such data shall be subject to the "Inspection Rights" provisions of paragraph F., and if included, the "Limited Rights in Proprietary Data" provisions of paragraph G. and the "Contractor Licensing" provisions of paragraph H.

F. Inspection Rights. Except as may be otherwise specified in this Agreement for specific items of proprietary data which are not subject to this paragraph, the Contracting Officer's representatives, at all reasonable times up to three (3) years after final payment under this Agreement,

ARTICLE A-XVIII - RIGHTS IN TECHNICAL DATA (Cont'd)

may inspect at the Participant's facility any proprietary data withheld under paragraph E. and not furnished under paragraph G. for the purposes of verifying that such data properly fell within the withholding provision of paragraph E., or for evaluating work performance.

ARTICLE A-XIX - REPORTING OF ROYALTIES

If this contract is in an amount which exceeds $10,000 and if any royalty payments are directly involved in the contract or are reflected in the contract price to the Government, the Contractor agrees to report in writing to the Patent Counsel (with notification by Patent Counsel to the Contracting Officer) during the performance of this contract and prior to its completion or final settlement the amount of any royalties or other payments paid or to be paid by it directly to others in connection with the performance of this contract together with the names and addresses of licensors to whom such payments are made and either the patent numbers involved or such other information as will permit identification of the patents or other basis on which the royalties are to be paid. The approval of DOE of any individual payments or royalties shall not stop the Government at any time from contesting the enforceability, validity or scope of, or title to, any patent under which a royalty or payments are made.

ARTICLE XX - PATENT RIGHTS

A. Definitions

(1) "Subject Invention" means any invention or discovery of the Participant conceived or first actually reduced to practice in the course of or under this Agreement, and includes any art, method process, machine, manufacture, design, or composition of matter, or any new and useful improvement thereof, or any variety of plants, whether patented or unpatented under the Patent Laws of the United States of America or any foreign country.

(2) "Contract" means any contract, grant, agreement, understanding or other arrangement, which includes research, development, or demonstration work, and includes any assignment or substitution of parties.

(3) "States and domestic municipal governments" means the States of the United States, the District of Columbia, Puerto Rico, the Virgin Islands, American Samoa, Guam, the Trust Territory of the Pacific Islands, and any political subdivision and agencies thereof.

ARTICLE A-XX - PATENT RIGHTS (Cont'd)

(4) "Government agency" includes an executive department, independent commission, board, office, agency, administration, authority, Government corporation, or other Government establishment of the Executive Branch of the Government of the United States of America.

(5) "To the point of practical application" means to manufacture in the case of a composition or product, to practice in the case of a process, or to operate in the case of a machine and under such conditions as to establish that the invention is being worked and that its benefits are reasonably accessible to the public.

(6) "Patent Counsel" means the DOE Patent Counsel assisting the procuring activity.

B. Allocation of Principal Rights

(1) Assignment to the Government. The Participant agrees to assign to the Government the entire right, title, and interest throughout the world in and to each Subject Invention except to the extent that rights are retained by the Participant under paragraphs B.(2) and C. of this article.

(2) Greater Rights Determinations. The Participant or the employee-inventor with authorization of the Participant may request greater rights than the nonexclusive license and the foreign patent rights provided in paragraph C. of this article on identified inventions, in accordance with 41 CFR 9-9.109-6. Such requests must be submitted to Patent Counsel (with notification by Patent Counsel to the Contracting Officer) at the time of the first disclosure pursuant to paragraph E.(2) of this article, or not later than 9 months after conception or first actual reduction to practice, whichever occurs first, or such longer period as may be authorized by Patent Counsel (with notification by Patent Counsel (with notification by Patent Counsel to the Contracting Officer) for good cause shown in writing by the Participant.

C. Minimum Rights to the Participant

(1) Participant License. The Participant reserves a revocable, nonexclusive, paid-up license in each patent application filed in any country on a Subject Invention and any resulting patent in which the Government acquires title. The license shall extend to the Participant's domestic subsidiaries and affiliates, if any,

ARTICLE A-XX - PATENT RIGHTS (Cont'd)

within the corporate structure of which the Participant is a part and shall include the right to grant sublicenses of the same scope to the extent the Participant was legally obligated to do so at the time the Agreement was awarded. The license shall be transferable only with approval of DOE except when transferred to the successor of that part of the Participant's business to which the invention pertains.

(2) Revocation Limitations. The Participant's nonexeclusive license retained pursuant to subparagraph C.(1) of this article and sublicenses granted thereunder may be revoked or modified by DOE, either in whole or in part, only to the extent necessary to achieve expeditious practical application of the Subject Invention under DOE's published licensing regulations (10 CFR 781), and only to the extent an exclusive license is actually granted. This license shall not be revoked in that field of use and/or the geographical areas in which the Participant, or its sublicensee, has brought the invention to the point of practical application and continues to make the benefits of the invention reasonably accessible to the public, or is expected to do so within a reasonable time.

(3) Revocation Procedures. Before modification or revocation of the license or sublicense, pursuant to subparagraph C.(2) of this article, DOE shall furnish the Participant a written notice of its intention to modify or revoke the license and any sublicense thereunder, and the Participant shall be allowed 30 days, or such longer period as may be authorized by the Patent Counsel (with notification by Patent Counsel to the Contracting Officer) for good cause shown in writing by the Participant, after such notice to show cause why the license or any sublicense should not be modified or revoked. The Participant shall have the right to appeal in accordance with 10 CFR 781, any decision concerning the modification or revocation of its license or any sublicense.

(4) Foreign Patent Rights. Upon written request to Patent Counsel (with notification by Patent Counsel to the Contracting Officer), in accordance with subparagraph E.(2)(i) of this article, and subject to DOE security regulations and requirements, there shall be reserved to the Participant, or the employee-inventor with authorization of the Participant, the patent rights to a Subject Invention in any foreign country where the Government has elected not to secure such rights provided:

ARTICLE A-XX - PATENT RIGHTS (Cont'd)

(i) The recipient of such rights, when specifically requested by DOE and three years after issuance of a foreign patent disclosing said Subject Invention, shall furnish DOE a report setting forth:

(a) The commercial use that is being made, or is intended to be made, of said invention, and

(b) The steps taken to bring the invention to the point of practical application or to make the invention available for licensing.

(ii) The Government shall retain at least an irrevocable, nonexclusive, paid-up license to make, use, and sell the invention throughout the world by or on behalf of the Government (including any Government agency) and States and domestic municipal governments, unless the Administrator or his designee determines that it would not be in the public interest to acquire the license for the States and domestic municipal governments.

(iii) Subject to the rights granted in C.(1), (2), and (3) of this article, the Secretary of DOE or his designee shall have the right to terminate the foreign patent rights granted in this subparagraph C.(4) in whole or in part unless the recipient of such rights demonstrates to the satisfaction of the Secretary of DOE or his designee that effective steps necessary to accomplish substantial utilization of the invention have been taken or within a reasonable time will be taken.

(iv) Subject to the rights granted in C.(1), (2), and (3) of this article, the Secretary of DOE or his designee shall have the right, commencing four years after foreign patent rights are accorded under this subparagraph C.(4), to acquire the granting of a nonexclusive or partially exclusive license to a responsible applicant or applicants, upon terms reasonable under the circumstances and in appropriate circumstances to terminate said foreign patent rights in whole or in part, following a hearing upon notice thereof to the public, upon a petition by an interested person justifying such hearing:

(a) If the Secretary of DOE or his designee determines, upon review of such material as he deems relevant, and after the recipient of such rights, or other interested person, has had the

ARTICLE A-XX - PATENT RIGHTS (Cont'd)

opportunity to provide such relevant and material information as the Secretary of DOE or his designee may require that such foreign patent rights have tended substantially to lessen competition or to result in undue market concentration in any section of the United States in any line of commerce to which the technology relates; or

(b) Unless the recipient of such rights demonstrates to the satisfaction of the Secretary of DOE or his designee at such hearing that the recipient has taken effective steps or within a reasonable time thereafter is expected to take such steps, necessary to accomplish substantial utilization of the invention.

D. Filing of Patent Applications

(1) With respect to each Subject Invention in which the Participant or the inventor requests foreign patent rights in accordance with subparagraph C.(4) of this article, a request may also be made for the right to file and prosecute the U. S. application on behalf of the U. S. Government. If such request is granted the Participant or inventor shall file a domestic patent application on the invention within six (6) months after the request for foreign patent rights is granted, or such longer period of time as may be approved by the Patent Counsel for good cause shown in writing by the requester. With respect to the invention the requester shall promptly notify the Patent Counsel (with notification by Patent Counsel to the Contracting Officer) of any decision not to file an application.

(2) For each Subject Invention on which a domestic patent application is filed by the Participant or inventor the Participant or inventor shall:

(i) Within two (2) months after the filing or within two (2) months after submission of the invention disclosure if the patent application previously has been filed, deliver to the Patent Counsel a copy of the application as filed including the filing date and serial number:

(ii) Within six (6) months after filing the application or within six (6) months after submitting the invention disclosure if the application has been filed previously, deliver

ARTICLE A-XX - PATENT RIGHTS (Cont'd)

to the Patent Counsel a duly executed and approved Assignment to the Government, on a form specified by the Government;

(iii) Provide the Patent Counsel with the original patent grant promptly after a patent is issued on the application; and

(iv) Not less than 30 days before the expiration of the response period for any action required by the Patent and Trademark Office, notify the Patent Counsel of any decision not to continue prosecution of the application.

(3) With respect to each Subject Invention in which the Participant or inventor has requested foreign patent rights, the Participant or inventor shall file a patent application on the invention in each foreign country in which such request is granted in accordance with applicable statutes and regulations and within one of the following periods:

(i) Eight months from the date of filing a corresponding United States application, or if such an application is not filed, six months from the date the request was granted;

(ii) Six months from the date a license is granted by the Commissioner of Patents and Trademarks to file the foreign patent application where such filing has been prohibited by security reasons; or

(iii) Such longer periods as may be approved by the Patent Counsel for good cause shown in writing by the Participant or inventor.

(4) Subject to the license specified in subparagraphs C.(1), (2) and (3) of this article, the Participant or inventor agrees to convey to the Government upon request the entire right, title, and interest in any foreign country in which the Participant or inventor fails to have a patent application filed in accordance with subparagraph D.(3) of this article, or decides not to continue prosecution or to pay any maintenance fees covering the invention. To avoid forfeiture of the patent application or patent the Participant or inventor shall not less than 60 days before the expiration period for any action required by any Patent Office notify the Patent Counsel of such failure or decision and deliver to the Patent Counsel the executed instruments necessary for the conveyance specified in this paragraph.

ARTICLE A-XX - PATENT RIGHTS (Cont'd)

E. Invention Identification, Disclosures and Reports.

(1) The Participant shall establish and maintain active and effective procedures to ensure that Subject Inventions are promptly identified and timely disclosed. These procedures shall include the maintenance of laboratory notebooks or equivalent records and any other records that are reasonably necessary to document the conception and/or the first actual reduction to practice of Subject Inventions, and records which show that the procedures for identifying and disclosing the inventions are followed. Upon request, the Participant shall furnish the Contracting Officer a description of these procedures so that he may evaluate and determine their effectiveness.

(2) The Participant shall furnish the Patent Counsel (with notification by Patent Counsel to the Contractor Officer) on a DOE-approved form:

(i) A written report containing full and complete technical information concerning each subject Invention within six (6) months after conception or first actual reduction to practice whichever occurs first in the course of or under this Agreement, but in any event prior to any on sale, public use or public disclosure of such invention known to the Participant. The report shall identify the Agreement and inventor and shall be sufficiently complete in technical detail and appropriately illustrated by sketch or diagram to convey to one skilled in the art to which the invention pertains a clear understanding of the nature, purpose, operation, and to the extent known, the physical, chemical, biological, or electrical characteristics of the invention. The report should also include any request for foreign patent rights under subparagraph C.(4) of this article and any request to file a domestic patent application under D.(1) of this article. However, such requests shall be made within the period set forth in subparagraph B.(2) of this article. When an invention is reported under this subparagraph E.(2)(i), it shall be presumed to have been made in the manner specified in Section 9(a)(1) and (2) of 42 U.S.C. 5908 unless the Participant contends it was not so made in accordance with subparagraph G.(2)(ii) of this article.

ARTICLE A-XX - PATENT RIGHTS (Cont'd)

(ii) Upon request, but not more than annually, interim reports on an DOE-approved form listing Subject Inventions and subcontracts awarded containing a Patent Rights article for that period and certifying that:

(a) The Participant's procedures for identifying and disclosing Subject Inventions as required by this paragraph E. have been followed throughout the reporting period;

(b) All subject inventions have been disclosed or that there are no such inventions; and

(c) All subcontracts containing a Patent Rights article have been reported or that no such subcontracts have been awarded.

(iii) A final report on an DOE-approved form within three (3) months after completion of the Agreement work listing all Subject Inventions and all subcontracts awarded containing a Patent Rights article and certifying that:

(a) All Subject Inventions have been disclosed or that there were no such inventions; and

(b) All subcontracts containing a Patent Rights article have been reported or that no such subcontracts have been awarded.

(3) The Participant shall obtain patent agreements to effectuate the provisions of this article from all persons in its employ who perform any part of the work under this Agreement except nontechnical personnel, such as clerical employees and manual laborers.

(4) The Participant agrees that the Government may duplicate and disclose Subject Invention disclosures and all other reports and papers furnished or required to be furnished pursuant to this article. If the Participant is to file a foreign patent application on a Subject Invention, the Government agrees, upon written request, to use its best efforts to withhold publication of such invention disclosures until the expiration of the time period specified in subparagraph D.(1) of this article, but in no event shall the Government or its employees be liable for any publication thereof.

ARTICLE A-XX - PATENT RIGHTS (Cont'd)

F. Publication. It is recognized that during the course of the work under this Agreement the Participant or its employees may from time to time desire to release or publish information regarding scientific or technical developments conceived or first actually reduced to practice in the course of or under this Agreement. In order that public disclosure of such information will not adversely affect the patent interests of DOE or the Participant, patent approval for release or publication shall be secured from Patent Counsel prior to any such release or publication.

G. Forfeiture of Rights in Unreported Subject Inventions.

(1) The Participant shall forfeit to the Government, at the request of the Secretary of DOE or his designee, all rights in any Subject Invention which the Participant fails to report to Patent Counsel (with notification by Patent Counsel to the Contracting Officer) within 6 months after the time the Participant:

(i) Files or causes to be filed a United States or foreign patent application thereon; or

(ii) Submits the final report required by subparagraph E.(2)(iii) of this article whichever is later.

(2) However, the Participant shall not forfeit rights in a Subject Invention if, within the time specified in (1)(i) or (1)(ii) of this paragraph G., the Participant:

(i) Prepared a written decision based upon a review of the record that the invention was neither conceived nor first actually reduced to practice in the course of or under the Agreement and delivers the same to Patent Counsel (with notification by Patent Counsel to the Contracting Officer); or

(ii) Contending that the invention is not a Subject Invention the Participant nevertheless discloses the invention and all facts pertinent to this contention to the Patent Counsel (with notification by Patent Counsel to the Contracting Officer); or

(iii) Establishes that the failure to disclose did not result from the Particopant's fault or negligence.

ARTICLE A-XX - PATENT RIGHTS (Cont'd)

(3) Pending written assignment of the patent applications and patents on a Subject Invention determined by the Secretary of DOE or his designee to be forfeited (such determination to be a final decision under the "Disputes" article of this Agreement), the Participant shall be deemed to hold the invention and the patent applications and patents pertaining thereto in trust for the Government. The forfeiture provision of this paragraph G. shall be in addition to and shall not supersede other rights and remedies which the Government may have with respect to Subject Inventions.

H. Examination of Records Relating to Inventions.

(1) The Contracting Officer or his authorized representative, until the expiration of three (3) years after final payment under this Agreement, shall have the right to examine any books (including laboratory notebooks) records, documents, and other supporting data of the Participant which the Contracting Officer or his authorized representative, reasonably deem pertinent to the discovery or identification of Subject Inventions or to determine compliance with the requirements of this article.

(2) The Contracting Officer or his authorized representative shall have the right to examine all books (including laboratory notebooks) records and documents of the Participant relating to the conception on first actual reduction to practice of inventions in the same field of technology as the work under this Agreement to determine whether any such inventions are Subject Inventions. If the Participant refuses or fails to:

(i) Establish the procedures of paragraph E.(1) of this article; or

(ii) Maintain and follow such procedures; or

(iii) Correct or eliminate any material deficiency in the procedures within thirty (30) days after the Contracting Officer notifies the Participant of such a deficiency.

I. Withholding of Payment (Not Applicable to Subcontracts)

(1) Any time before final payment of the amount of this Agreement the Contracting Officer may, if he deems such action warranted, withhold payment until a reserve not exceeding $50,000 or 5 percent of the amount of this Agreement, whichever is less, shall have been set aside if in his opinion, the Participant fails to:

ARTICLE A-XX - PATENT RIGHTS (Cont'd)

(i) Establish, maintain and follow effective procedures for identifying and disclosing subject inventions pursuant to subparagraph E.(1) of this article; or

(ii) Disclose any Subject Invention pursuant to paragraph E.(2)(i) of this article; or

(iii) Deliver the interim reports pursuant to subparagraph E.(2)(ii) of this article; or

(iv) Provide the information regarding subcontracts pursuant to subparagraph J.(5) of this article; or

(v) Convey to the Government in a DOE-approved form the title and/or rights of the Government in each subject invention as required by this article.

The reserve or balance shall be withheld until the Contracting Officer has determined that the Participant has rectified whatever deficiencies exist and has delivered all reports, disclosures and other information required by the article.

(2) Final payment under this Agreement shall not be made by the Contracting Officer before the Participant delivers to Patent Counsel all disclosures of Subject Inventions and other information required by E.(2)(i) of this article, the final report required by E.(2)(iii) of this article, and Patent Counsel has issued a patent clearance certification to the Contracting Officer.

(3) The Contracting Officer may, in his discretion, decrease or increase the sums withheld up to the maximum authorized above. If the Participant is a nonprofit organization, the maximum amount that may be withheld under this paragraph shall not exceed $50,000 or one percent (1%) of the amount of this Agreement, whichever is less. No amount shall be withheld under this paragraph while the amount specified by this paragraph is being withheld under other provisions of the Agreement. The withholding of any amount or subsequent payment thereof shall not be construed as a waiver of any rights accruing to the Government under this Agreement.

ARTICLE A-XX - PATENT RIGHTS (Cont'd)

J. Subcontracts.

(1) For the purpose of this paragraph the term "Participant" means the party awarding a subcontract and the term "subcontractor" means the party being awarded a subcontract regardless of tier.

(2) Unless otherwise authorized or directed by the Contracting Officer, the Participant shall include the Patent Rights article of 41 CFR 9-9.107-5(a) or 41 CFR 9-9.107-6 as appropriate, modified to identify the parties in any subcontract hereunder having as a purpose the conduct of research, development, or demonstration work. In the event of refusal by a subcontractor to accept this article, or if in the opinion of the Participant this article is inconsistent with DOE's patent policies, the Participant:

(i) Shall promptly submit written notice to the Contracting Officer setting forth reasons for the subcontractor's refusal and other pertinent information which may expedite disposition of the matter; and

(ii) Shall not proceed with the subcontract without the written authorization of the Contracting Officer.

(3) Except as may be otherwise provided in this article, the Participant shall not, in any subcontract or by using a subcontract as consideration therefor, acquire any rights in its subcontractor's Subject Invention for the Participant's own use (as distinguished from such rights as may be required solely to fulfill the Participant's Agreement obligations to the Government in the performance of this Agreement).

(4) All invention disclosures, reports, instruments, and other information required to be furnished by the subcontractor to DOE, under the provisions of a Patent Rights article in any subcontract hereunder may, in the discretion of the Contracting Officer, be furnished to the Participant for transmission to DOE.

(5) The Participant shall promptly notify the Contracting Officer in writing upon the award of any subcontract containing a Patent Rights article by identifying the subcontractor, the work to be performed under the subcontract, and the dates of award and estimated completion. Upon the request of the Contracting Officer the Participant shall furnish him a copy of the subcontract.

ARTICLE A-XX - PATENT RIGHTS (Cont'd)

(6) The Participant shall identify all Subject Inventions of the subcontractor of which it acquires knowledge in the performance of this Agreement and shall notify the Patent Counsel (with notification by Patent Counsel to the Contracting Officer) promptly upon the identification of the inventions.

(7) It is understood that the Government is a third party beneficiary of any subcontract article granting rights to the Government in subject inventions, and the Participant hereby assigns to the Government all rights that the Participant would have to enforce the subcontractor's obligations for the benefit of the Government with respect to Subject Inventions. The Participant shall not be obligated to enforce the agreements of any subcontractor hereunder relating to the obligations of the subcontractor to the Government regarding Subject Inventions.

K. Background Patents.

(1) "Background Patent" means a domestic patent covering an invention or discovery which is not a Subject Invention and which is owned or controlled by the Participant at any time through the completion of this Agreement:

(i) Which the Participant but not the Government, has the right to license to others without obligation to pay royalties thereon, and

(ii) Infringement of which cannot reasonably be avoided upon the practice of any specific process, method, machine, manufacture or composition of matter (including relatively minor modifications thereof) which is a subject of the research, development, or demonstration work performed under this Agreement.

(2) The Participant agrees to and does hereby grant to the Government a royalty-free, nonexclusive, license under any Background Patent for purposes of practicing a subject of this Agreement by or for the Government in research, development and demonstration work only.

(3) The Participant also agrees that upon written application by DOE, it will grant to responsible parties for purposes of practicing a subject of this Agreement, nonexclusive licenses under any

ARTICLE A-XX - PATENT RIGHTS (Cont'd)

Background Patent on terms that are reasonable under the circumstances. If however, the Participant believes that exclusive or partially exclusive rights are necessary to achieve expeditious commercial development or utilization, then a request may be made to DOE for DOE approval of such licensing by the Participant.

(4) Notwithstanding the foregoing subparagraph K.(3), the Participant shall not be obligated to license any Background Patent if the Participant demonstrates to the satisfaction of the Secretary of DOE or or his designee that:

(i) A competitive alternative to the subject matter covered by said Background Patent is commercially available or readily introducible from one or more other sources; or

(ii) The Participant or its licensees are supplying the subject matter covered by said Background Patent in sufficient quantity and at reasonable prices to satisfy market needs, or have taken effective steps or within a reasonable time are expected to take effective steps to so supply the subject matter.

L. Atomic Energy.

(1) No claim for pecuniary award or compensation under the provisions of the Atomic Energy Act of 1954, as amended, shall be asserted by the Participant or its employees with respect to any invention or discovery made or conceived in the course of or under this Agreement.

(2) Except as otherwise authorized in writing by the Contracting Officer, the Participant will obtain patent agreements to effectuate the provisions of subparagraph L.(1) of this article from all persons who perform any part of the work under this Agreement, except nontechnical personnel, such as clerical employees and manual laborers.

M. Limitation of Rights. Nothing contained in this Patent Rights article shall be deemed to give the Government any rights with respect to any invention other than a subject invention except as set forth in the Patent Rights article of this Agreement with respect to Background Patents and the Facilities License.

ARTICLE A-XXI - NOTICE AND ASSISTANCE REGARDING PATENT AND COPYRIGHT INFRINGEMENT

(The provisions of this article shall be applicable only if the amount of this Agreement exceeds $10,000.)

A. The Participant shall report to the Contracting Officer, promptly and in reasonable written detail, each notice or claim of patent or copyright infringement based on the performance of this Agreement of which the Participant has knowledge.

B. In the event of any claim or suit against the Government on account of any alleged patent or copyright infringement arising out of the performance of this Agreement or out of the use of any supplies furnished or work or services performed hereunder, the Participant shall furnish to the Government when requested by the Contracting Officer, all evidence and information in possession of the Participant pertaining to such suit or claim. Such evidence and information shall be furnished at the expense of the Government except where the Participant has agreed to indemnify the Government.

C. This article shall be included in all subcontracts.

DOE Form CR-537
(1-78)

U. S. DEPARTMENT OF ENERGY

REPORTING REQUIREMENTS CHECKLIST

(See Instructions on Reverse)

FORM APPROVED
OMB NO. 38R-0190

1. IDENTIFICATION	2. OBLIGATION INSTRUMENT:
Hydrothermal Resources In Wyoming (State Coop Program)	Cooperative Agreement

3. REPORTING REQUIREMENTS

A. PROJECT MANAGEMENT	No	Frequency
1. ☐ Management Plan		
2. ☐ Milestone Schedule & Status Report		
3. ☐ Cost Plan		
4. ☐ Manpower Plan		
5. ☒ Contract Management Summary Report	5	M
6. ☐ Project Status Report		
7. ☐ Cost Management Report		
8. ☐ Manpower Management Report		
9. ☒ Conference Record	5	M
10. ☒ Hot Line Report		Z

B. TECHNICAL INFORMATION REPORTING	No	Frequency
1. ☐ Notice of Energy RD&D Project (SSIE)		
2. ☒ Technical Progress Report	10	S
3. ☐ Topical Report		
4. ☒ Final Technical Report	10	F
C. PMS/MINI-PMS		
1. Cost Performance Report		
☐ Format 1 WBS		
☐ Format 2 Functional		
☐ Format 3 Baseline		
☐ Format 5 Problem Analysis		
2. ☐ Cost/Schedule Status Report		
3. ☐ Management Control System Description		
4. ☐ Summary System Description		
5. ☐ WBS Dictionary		

FREQUENCY CODES:
A – As Required
C – Contract Change
F – Final (End of Contract)
M – Monthly
O – One Time (Soon After Contract Award)
Q – Quarterly
S – Semi-Annually
X – Mandatory for Delivery with Proposals/Bid
Y – Yearly or Upon Contract Renewal

4. SPECIAL INSTRUCTIONS

Freq. Code	Definition	Due Date at DOE/DGE
A	As Required	5 days after the event that initiates the report.
C	Contract Change	15 days after receipt of contract modification.
F	Final	45 days prior to the end (completion date) of the contract, submit in draft. Allow 30 days for DOE/DGE comment, then submit in final format.
M	Monthly	Mail not later than the 20th calendar day after the end of the calendar month.
O	One Time	15 days after contract award.
S	Semi-Annually	Mail (draft format) not later than 10 working days after the end of each six months period measured from the contract start date. Allow 15 days for DOE/DGE comment and then submit in final form.
X	Mandatory	With delivery of Proposals/Bid.
Y	Yearly	Within 30 days after the end of each government fiscal year or upon contract renewal.
Q	Quarterly	Within 20 calendar days after end of calendar quarter.

5. ATTACHED HEREWITH:

☐ Report Distribution List ☐
☐ WBS/Reporting Category ☐

6. PREPARED BY (Signature and date):	7. REVIEWED BY (Signature and date):
Arthur G. Dixon, Jr. 12/28/78	[illegible]

file M. 2.10

DOE FORM PR-799A (TEST)
10 AUGUST 1978

U. S. DEPARTMENT OF ENERGY

PROCUREMENT/FINANCIAL ASSISTANCE REQUEST-AUTHORIZATION

1. TO Contract Negotiation Branch - ID
2. FROM INITIATING OFFICE Energy and Technology Division
   Office of Geothermal Energy

3. INITIAL: [ ] UPDATE: [ ] 4. PROCUREMENT: [ ] FINANCIAL ASSISTANCE: [ ]
5. PR NUMBER: ____ 6. PR CORRECTION LETTER: _ 7. RELATED PR NUMBER: ____

ACTION IDENTIFICATION

8. TITLE: Hydrothermal Resources in Wyoming
   ~~(Wyoming State Co-op Project)~~

9. UNSOLICITED PROPOSAL NO: ____ 10. PROJECT NO: ____ 11. CFDA NO: ____
12. PRODUCT OR SERVICE:* AG3X 13. SUPPORT SERVICES: YES [ ] NO [X] 14. CONSULTANT AWARD: YES [ ] NO [X]
15. CONTROLLED DELIVERABLE:* A6Y 16. REPORT/DRAWING REQ: YES [X] NO [ ] IF YES, ATTACH DETAILS.
17. CLASSIFICATION OF MATERIALS/WORK: U U—UNCLASSIFIED C—CONFIDENTIAL S—SECRET T—TOP SECRET
18. GOVERNMENT PROPERTY: N F—FURNISHED P—PURCHASED N—NOT INVOLVED IF CODE F OR P, ATTACH DETAILS.

AWARD PLANNING

19. AWARD AS ORDER UNDER BIN: ____ IF CODE T, ATTACH DETAILS.
20. DESIRED AWARD DATE: 06 01 79 (MONTH DAY YEAR) 21. KIND OF AWARD ACTION:* 1P 22. TYPE OF AWARD:* X
23. IF MULTI-YEAR AWARD, INDICATE NUMBER OF YEARS: _ 24. TYPE SOLICITATION INSTRUMENT:* __
25. EXTENT OF COMPETITION:* __ IF COMPETITIVE, ATTACH TECHNICAL EVALUATION PLAN. IF NON-COMPETITIVE, ATTACH JUSTIFICATION. REF: DOE-PR 9-3.805.51 or 9-4.909(f).
26. SOURCE SELECTION PROCEDURE: _ 1—A-E 2—SEB 3—OTHER 4—NONE
27. FOR A-E, SHOW ESTIMATED CONSTRUCTION COST IN DOLLARS: ____

AWARDEE

IF COMPETITIVE, HAS LIST OF SOURCES BEEN ATTACHED? YES [ ] NO [ ] IF NON-COMPETITIVE, COMPLETE 28-31.

28. NAME: University of Wyoming 29. ADDRESS: P.O. Box 3006, Laramie, WY
30. DIVISION: Dept. of Geology
31. GOCO/LAB: _ A—GOCO/LAB B—GOCO/NON-LAB C—NON-GOCO/LAB D—NOT APPLICABLE

FINANCIAL

AWARD VALUE — DOLLAR AMOUNT

32. GOV'T SHARE $16,501.00
33. TOTAL $16,501.00
34. CONSIDERATION IN KIND, LOAN, OR LOAN GUARANTEE DATA REPORTED ON PR—799C: [ ]
35. PROJECT PERIOD: FROM 12 11 78 (MONTH DAY YEAR) THRU 09 31 79 (MONTH DAY YEAR)

CURRENT FY FUNDS COMMITTED

36. B&R NUMBER	37. FUND CLASS	38. DOLLAR AMOUNT
AE10-02-020	-	$16,501.00
____	-	____
____	-	____

39. FROM PR—799B (PART A) ____
40. TOTAL THIS PR $16,501.00
41. FUNDING PERIOD: FROM 12 11 78 (MONTH DAY YEAR) THRU 09 31 79 (MONTH DAY YEAR)
42. APPROPRIATION SYMBOL: 89X0210.91
43. ALLOTMENT SYMBOL: ID-90-91
44. OBJECT CLASS: ____

PROJECT MANAGER

45. NAME: Leland L. Mink
46. SIGNATURE: *Leland L. Mink*
47. DATE: __ __ __ (MONTH DAY YEAR) 48. OFFICE CODE: ____
49. FTS TELEPHONE NUMBER: 583-0638

PROGRAM OFFICIAL

50. NAME: R. E. Wood
51. SIGNATURE: *R E Wood*
52. DATE: __ __ __ (MONTH DAY YEAR)

CERTIFYING OFFICIAL

53. NAME: E. S. Smith

I HEREBY CERTIFY THAT THE FUNDS CITED IN ITEM 40 ARE AVAILABLE.

54. SIGNATURE: ____
55. DATE: __ __ __ (MONTH DAY YEAR)

* SEE BACK OF FORM FOR CODES

THE UNIVERSITY OF WYOMING
DEPARTMENT OF GEOLOGY
GEOLOGY BUILDING
P. O. BOX 3006
LARAMIE, WYOMING 82071
PH. 307—766-3386

May 14, 1979

L. L. Mink
E and T Division
Idaho Operations Office
Department of Energy
550 Second Street
Idaho Falls, Idaho 83401

Dear Mr. Mink:

At the request of Dr. Brophy, we wish to increase this summer's program for our investigations of Hydrothermal Resources in Wyoming. This would require more funding for salaries, field expenses, etc., with our ultimate tasks remaining as they exist in Cooperative Agreement DE-FC07-79ID12026.

The required monies for salaries, per diem, and so on are itemized on the enclosed budget sheet. All additional personnel could start by late May, 1979. Consequently, it is desirable that the University receive notice of funding as quickly as possible, if the addition is approved.

We hope the additional funding is approved. It would allow us to greatly expand our information on Wyoming's hydrothermal resource base.

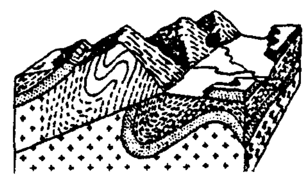
Thank you.

Sincerely,

Edward R. Decker
Professor of Geology
Principal Investigator

Henry P. Heasler
Research Associate
Co-Principal Investigator

ERD/eh



REQUESTED ADDITIONAL FUNDING FOR AGREEMENT NUMBER DE-FC07-791 D12026

HYDROTHERMAL RESOURCES IN WYOMING

E. R. Decker,
Department of Geology
University of Wyoming
Laramie, Wyoming 82071

(307-766-3278)

Principal Investigator	E. R. Decker 056-32-1937	5/14/7 Date
Co-Principal Investigator:	Henry P. Heasler 520-62-8409	5/14/7 Date
Department Head	R. S. Houston	5/14/7 Date
University Official	Hugh B. McFadden President University of Wyoming	5-14-79 Date

REQUESTED ADDITIONAL FUNDING FOR AGREEMENT NUMBER DE-FC07-791 D12026,

HYDROTHERMAL RESOURCES IN WYOMING

Budget Explanation	DOE	UW
I. Salaries		
A. Principal Investigator 3 da.		402.84
B. Summer '79 (3 people)		
3 x 60 da. x 8 hr. x $4.25/hr	6120.00	
Total Salaries	6120.00	402.84
Fringe (15%)	918.00	60.43
	7038.00	463.27
II. Field Expenses		
100 days @ $35/da.	3500.00	
Mileage - field vehicles		
15,000 x .15/mi	2250.00	
Total Field expenses	5750.00	
III. Other Costs (freight, communication	500.00	
	13288.00	463.27
IV. Indirect Costs		
52.5% x 6120	3213.00	
52.5% x 402.84		211.49
	16501.00	674.76

Grand Total requested: $16,501.00

Rounded to $16,500.00

STANDARD FORM 30, JULY 1966
GENERAL SERVICES ADMINISTRATION
FED. PROC. REG. (41 CFR) 1-16.101

AMENDMENT OF SOLICITATION/MODIFICATION OF CONTRACT

PAGE 1 OF 1

1. AMENDMENT/MODIFICATION NO.	2. EFFECTIVE DATE	3. REQUISITION/PURCHASE REQUEST NO.	4. PROJECT NO. (If applicable)
A001	6/13/79	07-79ID12626.501	

5. ISSUED BY — CODE
U. S. Department of Energy
Idaho Operations Office
550 Second Street
Idaho Falls, Idaho 83401

6. ADMINISTERED BY (If other than block 5) — CODE

7. CONTRACTOR NAME AND ADDRESS (Street, city, county, state, and ZIP Code) — CODE — FACILITY CODE
University of Wyoming
University Station Box 3355
Laramie, Wyoming 82071

8.
☐ AMENDMENT OF SOLICITATION NO. ____
DATED ____ (See block 9)
☒ MODIFICATION OF CONTRACT/ORDER NO. FC07-79ID12026
DATED 12/29/78 (See block 11)

9. THIS BLOCK APPLIES ONLY TO AMENDMENTS OF SOLICITATIONS
☐ The above numbered solicitation is amended as set forth in block 12. The hour and date specified for receipt of Offers ☐ is extended, ☐ is not extended.
Offerors must acknowledge receipt of this amendment prior to the hour and date specified in the solicitation, or as amended, by one of the following methods:
(a) By signing and returning ____ copies of this amendment; (b) By acknowledging receipt of this amendment on each copy of the offer submitted; or (c) By separate letter or telegram which includes a reference to the solicitation and amendment numbers. FAILURE OF YOUR ACKNOWLEDGMENT TO BE RECEIVED AT THE ISSUING OFFICE PRIOR TO THE HOUR AND DATE SPECIFIED MAY RESULT IN REJECTION OF YOUR OFFER. If, by virtue of this amendment you desire to change an offer already submitted, such change may be made by telegram or letter, provided such telegram or letter makes reference to the solicitation and this amendment, and is received prior to the opening hour and date specified.

10. ACCOUNTING AND APPROPRIATION DATA (If required)

11. THIS BLOCK APPLIES ONLY TO MODIFICATIONS OF CONTRACTS/ORDERS
(a) ☐ This Change Order is issued pursuant to ____
The Changes set forth in block 12 are made to the above numbered contract/order.
(b) ☐ The above numbered contract/order is modified to reflect the administrative changes (such as changes in paying office, appropriation data, etc.) set forth in block 12.
(c) ☒ This Supplemental Agreement is entered into pursuant to authority of Public Law 95-91
It modifies the above numbered contract as set forth in block 12.

12. DESCRIPTION OF AMENDMENT/MODIFICATION

1. Item o is added to Article II, Description of Responsibilities, to read as follows:
   o. The contractor shall perform assessment and investigations in the Gas Hills, the Red Desert of East Central Wyoming, and the Powder River Basin of North Central Wyoming.

2. The total estimated cost under Article III, Financial Support of the Project, Paragraph A, is increased from $106,487.00 to $123,663.00 and the DOE share is increased by $16,039.00 from $99,439.00 to $115,478.00.

3. The amount of funds obligated under Paragraph C of Article III, Financial Support of the Project, is increased from $99,439.00 to $115,478.00.

Except as provided herein, all terms and conditions of the document referenced in block 8, as heretofore changed, remain unchanged and in full force and effect.

13. ☐ CONTRACTOR/OFFEROR IS NOT REQUIRED TO SIGN THIS DOCUMENT ☒ CONTRACTOR/OFFEROR IS REQUIRED TO SIGN THIS DOCUMENT AND RETURN 2 COPIES TO ISSUING OFFICE

14. NAME OF CONTRACTOR/OFFEROR
BY Elliott G. Hays (Signature of person authorized to sign)

17. UNITED STATES OF AMERICA
BY [signature] (Signature of Contracting Officer)

15. NAME AND TITLE OF SIGNER (Type or print)	16. DATE SIGNED	18. NAME OF CONTRACTING OFFICER (Type or print)	19. DATE SIGNED
Elliott G. Hays Vice President for Finance	7/2/79	R. E. Simonds, Director Contracts Management Division	JUN 27 1979

30-101-31

U.S. GOVERNMENT PRINTING OFFICE

file M. 2.10

STANDARD FORM 30, JULY 1966
GENERAL SERVICES ADMINISTRATION
FED. PROC. REG. (41 CFR) 1-16.101

AMENDMENT OF SOLICITATION/MODIFICATION OF CONTRACT

PAGE 1 OF 2

1. AMENDMENT/MODIFICATION NO.	2. EFFECTIVE DATE	3. REQUISITION/PURCHASE REQUEST NO.	4. PROJECT NO. (If applicable)
A002	8/1/79		

5. ISSUED BY CODE
U. S. Department of Energy
Idaho Operations Office
550 Second Street
Idaho Falls, Idaho 83401

6. ADMINISTERED BY (If other than block 5) CODE

7. CONTRACTOR NAME AND ADDRESS (Street, city, county, state, and ZIP Code) CODE FACILITY CODE

University of Wyoming
University Station Box 3355
Laramie, Wyoming 82071
Attn: Edward R. Decker,
Professor of Geology

8.
☐ AMENDMENT OF SOLICITATION NO. ______
DATED ______ (See block 9)
☒ MODIFICATION OF CONTRACT/ORDER NO. DE-FC07-79ID12026
DATED 12/29/78 (See block 11)

9. THIS BLOCK APPLIES ONLY TO AMENDMENTS OF SOLICITATIONS

☐ The above numbered solicitation is amended as set forth in block 12. The hour and date specified for receipt of Offers ☐ is extended, ☐ is not extended.

Offerors must acknowledge receipt of this amendment prior to the hour and date specified in the solicitation, or as amended, by one of the following methods:

(a) By signing and returning ______ copies of this amendment; (b) By acknowledging receipt of this amendment on each copy of the offer submitted; or (c) By separate letter or telegram which includes a reference to the solicitation and amendment numbers. FAILURE OF YOUR ACKNOWLEDGMENT TO BE RECEIVED AT THE ISSUING OFFICE PRIOR TO THE HOUR AND DATE SPECIFIED MAY RESULT IN REJECTION OF YOUR OFFER. If, by virtue of this amendment you desire to change an offer already submitted, such change may be made by telegram or letter, provided such telegram or letter makes reference to the solicitation and this amendment, and is received prior to the opening hour and date specified.

10. ACCOUNTING AND APPROPRIATION DATA (If required)

11. THIS BLOCK APPLIES ONLY TO MODIFICATIONS OF CONTRACTS/ORDERS

(a) ☐ This Change Order is issued pursuant to ______
The Changes set forth in block 12 are made to the above numbered contract/order.

(b) ☐ The above numbered contract/order is modified to reflect the administrative changes (such as changes in paying office, appropriation data, etc.) set forth in block 12.

(c) ☒ This Supplemental Agreement is entered into pursuant to authority of Public Law 95-91 and other applicable laws.
It modifies the above numbered contract as set forth in block 12.

12. DESCRIPTION OF AMENDMENT/MODIFICATION

1. Item 7 is added to Article II, Description of Responsibility to read:

   7. Site-specific studies will be conducted in the following areas: the Cody-Horse Center Region, Thermopolis, Gillette, Saratoga, the Wyoming border area north of Northgate Colorado, and the Leucite Hills area in the Rock Springs Uplift. Studies will expand on current contracted work and will include temperature, gradient, and heat flow measurements.

2. The total estimated cost under Article III, Financial Support of the Project, Paragraph A is increased from $123,663.00 to $160,792.00 and the DOE share is increased by $34,671.00 from $115,478.00 to $150,149.00. Total cost of cooperative agreement and share totals are delineated as follows:

CONTINUED.......

Except as provided herein, all terms and conditions of the document referenced in block 8, as heretofore changed, remain unchanged and in full force and effect.

13. ☐ CONTRACTOR/OFFEROR IS NOT REQUIRED TO SIGN THIS DOCUMENT ☒ CONTRACTOR/OFFEROR IS REQUIRED TO SIGN THIS DOCUMENT AND RETURN 2 COPIES TO ISSUING OFFICE

14. NAME OF CONTRACTOR/OFFEROR		17. UNITED STATES OF AMERICA	
BY Elliott G Hays (Signature of person authorized to sign)		BY [signature] (Signature of Contracting Officer)	
15. NAME AND TITLE OF SIGNER (Type or print)	16. DATE SIGNED	18. NAME OF CONTRACTING OFFICER (Type or print)	19. DATE SIGNED
Elliott G. Hays Vice President for Finance	8/1/79	J. P. Anderson, Chief Contract Administration Branch	JUL 25 1979

30-101-01

	U. of Wy. Share	DOE Share	Extension
Original Contract	$7,048.00	$99,439.00	$106,487.00
Increase Modification A001	1,137.00	16,039.00	17,176.00
Increase Modification A002	2,458.00	34,671.00	37,129.00
Totals:	$10,643.00	$150,149.00	$160,792.00
Percent:	6.62%	93.38%	100%

3. The amount of funds obligated by DOE under paragraph C. of Article III, Financial Support of Project, is increased from $115,478.00 to $150,149.00.

file M. 2.10

STANDARD FORM 30, JULY 1966
GENERAL SERVICES ADMINISTRATION
FED. PROC. REG. (41 CFR) 1-16.101

AMENDMENT OF SOLICITATION/MODIFICATION OF CONTRACT

PAGE 1 OF 1

1. AMENDMENT/MODIFICATION NO.	2. EFFECTIVE DATE	3. REQUISITION/PURCHASE REQUEST NO.	4. PROJECT NO. (If applicable)
M003	8/13/79		

5. ISSUED BY CODE

U. S. Department of Energy
Idaho Operations Office
550 Second Street
Idaho Falls, Idaho 83401

6. ADMINISTERED BY (If other than block 5) CODE

7. CONTRACTOR NAME AND ADDRESS (Street, city, county, state, and ZIP Code) CODE FACILITY CODE

University of Wyoming
University Station, Box 3355
Laramie, Wyoming 82071

Attn: Edward R. Decker, Professor of Geology

8. ☐ AMENDMENT OF SOLICITATION NO. ________

DATED ________ (See block 9)

☒ MODIFICATION OF CONTRACT/ORDER NO. DE-FC07-79DI012026

DATED 12/29/78 (See block 11)

9. THIS BLOCK APPLIES ONLY TO AMENDMENTS OF SOLICITATIONS

☐ The above numbered solicitation is amended as set forth in block 12. The hour and date specified for receipt of Offers ☐ is extended, ☐ is not extended.

Offerors must acknowledge receipt of this amendment prior to the hour and date specified in the solicitation, or as amended, by one of the following methods:

(a) By signing and returning ____ copies of this amendment; (b) By acknowledging receipt of this amendment on each copy of the offer submitted; or (c) By separate letter or telegram which includes a reference to the solicitation and amendment numbers. FAILURE OF YOUR ACKOWLEDGMENT TO BE RECEIVED AT THE ISSUING OFFICE PRIOR TO THE HOUR AND DATE SPECIFIED MAY RESULT IN REJECTION OF YOUR OFFER. If, by virtue of this amendment you desire to change an offer already submitted, such change may be made by telegram or letter, provided such telegram or letter makes reference to the solicitation and this amendment, and is received prior to the opening hour and date specified.

10. ACCOUNTING AND APPROPRIATION DATA (If required)

11. THIS BLOCK APPLIES ONLY TO MODIFICATIONS OF CONTRACTS/ORDERS

(a) ☐ This Change Order is issued pursuant to ________
The Changes set forth in block 12 are made to the above numbered contract/order.

(b) ☐ The above numbered contract/order is modified to reflect the administrative changes (such as changes in paying office, appropriation data, etc.) set forth in block 12.

(c) ☒ This Supplemental Agreement is entered into pursuant to authority of Public Law 95-91 and other applicable laws.
It modifies the above numbered contract as set forth in block 12.

12. DESCRIPTION OF AMENDMENT/MODIFICATION

As requested in your letter dated July 25, 1979, the period of performance is hereby extended from September 30, 1979 to January 31, 1980.

Except as provided herein, all terms and conditions of the document referenced in block 8, as heretofore changed, remain unchanged and in full force and effect.

13. ☒ CONTRACTOR/OFFEROR IS NOT REQUIRED TO SIGN THIS DOCUMENT ☐ CONTRACTOR/OFFEROR IS REQUIRED TO SIGN THIS DOCUMENT AND RETURN ____ COPIES TO ISSUING OFFICE

14. NAME OF CONTRACTOR/OFFEROR

BY ________ (Signature of person authorized to sign)

17. UNITED STATES OF AMERICA

BY [signature] (Signature of Contracting Officer)

15. NAME AND TITLE OF SIGNER (Type or print)	16. DATE SIGNED	18. NAME OF CONTRACTING OFFICER (Type or print)	19. DATE SIGNED
		J. P. Anderson	8/9/79

30-101-01

☆ U.S. GOVERNMENT PRINTING OFFICE

STANDARD FORM 30, JULY 1966
GENERAL SERVICES ADMINISTRATION
FED. PROC. REG. (41 CFR) 1-16.101

AMENDMENT OF SOLICITATION/MODIFICATION OF CONTRACT

1. AMENDMENT/MODIFICATION NO. A004
2. EFFECTIVE DATE
3. REQUISITION/PURCHASE REQUEST NO.
4. PROJECT NO. (If applicable)

5. ISSUED BY CODE
U. S. Department of Energy
Idaho Operations Office
550 Second Street
Idaho Falls, Idaho 83401

6. ADMINISTERED BY (If other than block 5) CODE

7. CONTRACTOR NAME AND ADDRESS (Street, city, county, state, and ZIP Code) CODE FACILITY CODE
University of Wyoming
University Station, Box 3355
Laramie, Wyoming 82071

Attn: Edward R. Decker
Professor of Geology

8. ☐ AMENDMENT OF SOLICITATION NO. ________
DATED ________ (See block 9)
☒ MODIFICATION OF CONTRACT/ORDER NO. DE-FC07-79ID12026
DATED 12-29-78 (See block 11)

9. THIS BLOCK APPLIES ONLY TO AMENDMENTS OF SOLICITATIONS
☐ The above numbered solicitation is amended as set forth in block 12. The hour and date specified for receipt of Offers ☐ is extended, ☐ is not extended.
Offerors must acknowledge receipt of this amendment prior to the hour and date specified in the solicitation, or as amended, by one of the following methods:
(a) By signing and returning ____ copies of this amendment; (b) By acknowledging receipt of this amendment on each copy of the offer submitted; or (c) By separate letter or telegram which includes a reference to the solicitation and amendment numbers. FAILURE OF YOUR ACKNOWLEDGMENT TO BE RECEIVED AT THE ISSUING OFFICE PRIOR TO THE HOUR AND DATE SPECIFIED MAY RESULT IN REJECTION OF YOUR OFFER. If, by virtue of this amendment you desire to change an offer already submitted, such change may be made by telegram or letter, provided such telegram or letter makes reference to the solicitation and this amendment, and is received prior to the opening hour and date specified.

10. ACCOUNTING AND APPROPRIATION DATA (If required)

11. THIS BLOCK APPLIES ONLY TO MODIFICATIONS OF CONTRACTS/ORDERS
(a) ☐ This Change Order is issued pursuant to ________
The Changes set forth in block 12 are made to the above numbered contract/order.
(b) ☐ The above numbered contract/order is modified to reflect the administrative changes (such as changes in paying office, appropriation data, etc.) set forth in block 12.
(c) ☒ This Supplemental Agreement is entered into pursuant to authority of Public Law 95-91 and other applicable laws.
It modifies the above numbered contract as set forth in block 12.

12. DESCRIPTION OF AMENDMENT/MODIFICATION

1. Item 8 is added to Article II - Description of Responsibilities to read:

   8. Conduct a drilling program in the Cody, Wyoming area as described in Participant's proposal dated October 23, 1979, which is hereby made a part of this Modification No. A004. Six geothermal gradiant holes will be drilled and cased, four of which will be 100± meters deep, two of which will be 305± meters deep. Bottom hole temperatures, thermal gradiants, and heat flow calculations will be measured for each hole. The Participant's representative for this drilling work will be responsible for generating daily drilling reports and lithology logs for all holes drilled. DOE will receive copies of all data, heat flow values, and final interpretations of the results of this drilling program as part of the reporting requirements of Article VII - Project Information.

--continued

Except as provided herein, all terms and conditions of the document referenced in block 8, as heretofore changed, remain unchanged and in full force and effect.

13. ☐ CONTRACTOR/OFFEROR IS NOT REQUIRED TO SIGN THIS DOCUMENT ☐ CONTRACTOR/OFFEROR IS REQUIRED TO SIGN THIS DOCUMENT AND RETURN 3 COPIES TO ISSUING OFFICE

14. NAME OF CONTRACTOR/OFFEROR
BY [signature] (Signature of person authorized to sign)

17. UNITED STATES OF AMERICA
BY [signature] (Signature of Contracting Officer)

15. NAME AND TITLE OF SIGNER (Type or print)
Elliott G. Hays
Vice President for Finance

16. DATE SIGNED 12/27/79

18. NAME OF CONTRACTING OFFICER (Type or print)
J. P. Anderson, Chief
Contract Administration Branch

19. DATE SIGNED 1/2/80

12. Description of Amendment/Modification (cont'd)

2. The total estimated cost under Article III, Financial Support of the Project, Paragraph A, is increased from $160,792.00 to $235,570.00 and the DOE share is increased by $69,828.00 from $150,149.00 to $219,977.00. The total cost of this agreement and share totals are delineated as follows:

	Univ. of Wyoming Share	DOE Share	Extension
Original Contract	$ 7,048.00	$ 99,439.00	$106,487.00
Increase Mod. A001	1,137.00	16,039.00	17,176.00
Increase Mod. A002	2,458.00	34,671.00	37,129.00
Increase Mod. A003	-0-	-0-	-0-
Increase Mod. A004	4,950.00	69,828.00	74,778.00
Totals:	$15,593.00	$219,977.00	$235,570.00
Percents:	6.62%	93.38%	100%

3. The amount of funds obligated by DOE under Article III, Financial Support of the Project, Paragraph C, is increased from $150,149.00 to $219,977.00.

4. The period of performance under Article V, Term of Agreement is extended from January 31, 1980, to April 1, 1980.

STANDARD FORM 30, JULY 1966
GENERAL SERVICES ADMINISTRATION
FED. PROC. REG. (41 CFR) 1-16.101

AMENDMENT OF SOLICITATION/MODIFICATION OF CONTRACT

PAGE 1 OF 1

1. AMENDMENT/MODIFICATION NO. M005
2. EFFECTIVE DATE 4/1/80
3. REQUISITION/PURCHASE REQUEST
4. PROJECT NO. (If applicable)

5. ISSUED BY — CODE

U. S. Department of Energy
Idaho Operations Office
550 Second Street
Idaho Falls, Idaho 83401

6. ADMINISTERED BY (If other than block 5) — CODE

7. CONTRACTOR NAME AND ADDRESS (Street, city, county, state, and ZIP Code) — CODE — FACILITY CODE

University of Wyoming
University Station, Box 3355
Laramie, Wyoming 82071

Attn: Edward R. Decker
Professor of Geology

8.
☐ AMENDMENT OF SOLICITATION NO. ____
DATED ____ (See block 9)
☒ MODIFICATION OF CONTRACT/ORDER NO. DE-FC07-79ID12026
DATED 12/29/78 (See block 11)

9. THIS BLOCK APPLIES ONLY TO AMENDMENTS OF SOLICITATIONS

☐ The above numbered solicitation is amended as set forth in block 12. The hour and date specified for receipt of Offers ☐ is extended, ☐ is not extended.

Offerors must acknowledge receipt of this amendment prior to the hour and date specified in the solicitation, or as amended, by one of the following methods:

(a) By signing and returning ____ copies of this amendment; (b) By acknowledging receipt of this amendment on each copy of the offer submitted; or (c) By separate letter or telegram which includes a reference to the solicitation and amendment numbers. FAILURE OF YOUR ACKNOWLEDGMENT TO BE RECEIVED AT THE ISSUING OFFICE PRIOR TO THE HOUR AND DATE SPECIFIED MAY RESULT IN REJECTION OF YOUR OFFER. If, by virtue of this amendment you desire to change an offer already submitted, such change may be made by telegram or letter, provided such telegram or letter makes reference to the solicitation and this amendment, and is received prior to the opening hour and date specified.

10. ACCOUNTING AND APPROPRIATION DATA (If required)

11. THIS BLOCK APPLIES ONLY TO MODIFICATIONS OF CONTRACTS/ORDERS

(a) ☐ This Change Order is issued pursuant to ____
The Changes set forth in block 12 are made to the above numbered contract/order.

(b) ☐ The above numbered contract/order is modified to reflect the administrative changes (such as changes in paying office, appropriation data, etc.) set forth in block 12.

(c) ☒ This Supplemental Agreement is entered into pursuant to authority of Mutual Agreement of the parties
It modifies the above numbered contract as set forth in block 12.

12. DESCRIPTION OF AMENDMENT/MODIFICATION

As requested by the participant's letter dated February 21, 1980, the period of performance is hereby extended from April 1, 1980 to June 1, 1980 with no increase in either the total estimated cost of $235,570.00 or the DOE share of $219,977.00.

Except as provided herein, all terms and conditions of the document referenced in block 8, as heretofore changed, remain unchanged and in full force and effect.

13. ☒ CONTRACTOR/OFFEROR IS NOT REQUIRED TO SIGN THIS DOCUMENT ☐ CONTRACTOR/OFFEROR IS REQUIRED TO SIGN THIS DOCUMENT AND RETURN ____ COPIES TO ISSUING OFFICE

14. NAME OF CONTRACTOR/OFFEROR
BY ____ (Signature of person authorized to sign)

17. UNITED STATES OF AMERICA
BY ____ (Signature of Contracting Officer)

15. NAME AND TITLE OF SIGNER (Type or print)

16. DATE SIGNED

18. NAME OF CONTRACTING OFFICER (Type or print)
J. P. Anderson, Chief
Contract Administration Branch

19. DATE SIGNED 3/4/80

0-101-01

U.S. GOVERNMENT PRINTING OFFICE

STANDARD FORM 30, JULY 1966
GENERAL SERVICES ADMINISTRATION
FED. PROC. REG. (41 CFR) 1-16.101

AMENDMENT OF SOLICITATION/MODIFICATION OF CONTRACT

1. AMENDMENT/MODIFICATION NO. A006
2. EFFECTIVE DATE 6/1/80
3. REQUISITION/PURCHASE REQUEST NO.
4. PROJECT NO. (If applicable)

5. ISSUED BY CODE

U.S. Department of Energy
Idaho Operations Office
550 Second Street
Idaho Falls, Idaho 83401

6. ADMINISTERED BY (If other than block 5) CODE

7. CONTRACTOR NAME AND ADDRESS CODE FACILITY CODE

(Street, city, county, state, and ZIP Code)

University of Wyoming
University Station, Box 3355
Laramie, Wyoming 82071

Attn: E. R. Decker
Professor of Geology

8. ☐ AMENDMENT OF SOLICITATION NO. ______, DATED ______ (See block 9)

☒ MODIFICATION OF CONTRACT/ORDER NO. DE-FC07-79ID12026

DATED 12/29/78 (See block 11)

9. THIS BLOCK APPLIES ONLY TO AMENDMENTS OF SOLICITATIONS

☐ The above numbered solicitation is amended as set forth in block 12. The hour and date specified for receipt of Offers ☐ is extended, ☐ is not extended.

Offerors must acknowledge receipt of this amendment prior to the hour and date specified in the solicitation, or as amended, by one of the following methods:

(a) By signing and returning ______ copies of this amendment; (b) By acknowledging receipt of this amendment on each copy of the offer submitted; or (c) By separate letter or telegram which includes a reference to the solicitation and amendment numbers. FAILURE OF YOUR ACKNOWLEDGEMENT TO BE RECEIVED AT THE ISSUING OFFICE PRIOR TO THE HOUR AND DATE SPECIFIED MAY RESULT IN REJECTION OF YOUR OFFER. If, by virtue of this amendment you desire to change an offer already submitted, such change may be made by telegram or letter, provided such telegram or letter makes reference to the solicitation and this amendment, and is received prior to the opening hour and date specified.

10. ACCOUNTING AND APPROPRIATION DATA (If required)

11. THIS BLOCK APPLIES ONLY TO MODIFICATIONS OF CONTRACTS/ORDERS

(a) ☐ This Change Order is issued pursuant to ______
The Changes set forth in block 12 are made to the above numbered contract/order.

(b) ☐ The above numbered contract/order is modified to reflect the administrative changes (such as changes in paying office, appropriation data, etc.) set forth in block 12.

(c) ☒ This Supplemental Agreement is entered into pursuant to authority of Public Law 95-91 et al.
It modifies the above numbered contract as set forth in block 12.

12. DESCRIPTION OF AMENDMENT/MODIFICATION

1. Article II - DESCRIPTION OF RESPONSIBILITIES, is revised to add the following items:

9. A compilation of locations, temperatures, depths, gradients, and, if possible, depths to water for all thermal wells and springs in Wyoming. Regional maps of subsurface temperatures and depths will be supplied with the data, as would written reports. Available water quality and aquifer production data will be incorporated into the reports, as will relevant stratigraphy and geologic structure. The maps will show pertinent control points and relevant geology.

10. Regional thermal gradient maps and interpretations thereof will be prepared and delivered. These deliverables will reflect local geology and the thermal properties of local rock units. Reports will summarize available shallow and deep water quality data, aquifer disposition, and aquifer production. Detailed reports and maps will be prepared for areas that could be prospectively valuable for near-term direct-heat or other applications.

--continued

Except as provided herein, all terms and conditions of the document referenced in block 8, as heretofore changed, remain unchanged and in full force and effect.

13. ☐ CONTRACTOR/OFFEROR IS NOT REQUIRED TO SIGN THIS DOCUMENT ☒ CONTRACTOR/OFFEROR IS REQUIRED TO SIGN THIS DOCUMENT AND RETURN 3 COPIES TO ISSUING OFFICE

14. NAME OF CONTRACTOR/OFFEROR
BY Elliott G. Hays
(Signature of person authorized to sign)

17. UNITED STATES OF AMERICA
BY Nell W. Fraser
(Signature of Contracting Officer)

15. NAME AND TITLE OF SIGNER (Type or print)
Elliott G. Hays
Vice President for Finance

16. DATE SIGNED 6/2/80

18. NAME OF CONTRACTING OFFICER (Type or print)
Nell W. Fraser, Acting Chief
R&D Contracts Branch

19. DATE SIGNED JUN 6 1980

1. ARTICLE II (Cont'd)

   11. Research will be conducted in the Saratoga, Casper-Midwest, Auburn and DuBois areas to include data for regions within a 20-30 mile radius of each suggested resource. This detailed research will be done to better define their lateral extents, and to quantify the magnitude of each reservoir. Other systems will be analyzed in a similar manner as data are located. Reports will include available drill hole data, the geologic and hydrologic literature, and the proximity of resources to population centers.

   12. Chemical analyses will be delivered for six heretofore unanalyzed springs or spring systems. Water samples and analyses will be accompanied by descriptions of collection sites, local geology and other pertinent geoscience data. Preliminary interpretations of the chemical analyses from cooperative studies with qualified personnel elsewhere (e.g., the USGS) will be made available. Collection of 70-75 samples of subsurface waters in areas where gradient data are collected and where existing waters, etc., are flowing or can be pumped will be done. Analysis of these samples will be done by UURI.

   13. An updated (1981) regional heat flow map will be delivered, as will detailed maps of gradients and heat flow in prospectively valuable areas. All maps will be accompanied by interpretations. Both heat flow and available radioactivity data will be used in interpretations. Heat flow information will be obtained for approximately 20 new stations.

   Reporting will be performed in accordance with Article VII - <u>PROJECT INFORMATION</u>. All pertinent information will be provided to the USGS GEOTHERM file.

2. Article III - <u>FINANCIAL SUPPORT OF THE PROJECT</u>, Paragraph A, is revised to read as follows:

   "A. The total estimated cost of performing the work under this Agreement is Four Hundred Five Thousand Two Hundred Eighty-Three Dollars ($405,283.00). For performance of work under this Agreement, the agreed share ratio is 92.4% to DOE, 7.6% Participant, of total allowable costs. The Participant shall be

2. Article III (Cont'd)

reimbursed by DOE for 92.4% of the costs of the project determined to be allowable in accordance with Article A-I of the General Provisions entitled 'Allowable Costs.' All other costs that are not determined to be allowable under Article A-I shall constitute the Participant's share for which it will not be reimbursed by DOE. The total cost to DOE is hereby established as Three Hundred Seventy-Four Thousand Four Hundred Seventy-Seven Dollars ($374,477.00), and this amount is also the maximum amount of the project which is subject to reimbursement by DOE unless such maximum cost is changed in writing by the Contracting Officer."

The total cost of this Agreement and share totals are summarized below:

	U of WY Share	DOE Share	Est. Cost
Original Contract	$ 7,048.00	$ 99,439.00	$106,487.00
Increase Mod. A001	1,137.00	16,039.00	17,176.00
Increase Mod. A002	2,458.00	34,671.00	37,129.00
Increase Mod. A003	-0-	-0-	-0-
Increase Mod. A004	4,950.00	69,828.00	74,778.00
Increase Mod. M005	-0-	-0-	-0-
Increase Mod. A006	15,213.00	154,500.00	169,713.00
TOTALS	$30,806.00	$374,477.00	$405,283.00
PERCENTS	7.6%	92.4%	100%

3. The amount of funds obligated by DOE under Article III - FINANCIAL SUPPORT OF THE PROJECT, Paragraph C, is increased from $219,977.00 to $374,477.00

4. The period of performance under Article V - TERM OF AGREEMENT, is extended from June 1, 1980, to May 31, 1981.

5. Article VI - PROJECT MANAGEMENT, is revised to add:

H. P. Heasler
Co-Principal Investigator
University of Wyoming
Laramie, Wyoming 82071

6. Article VI - PROJECT MANAGEMENT, is also revised to change the DOE Program Officer to:

M. A. Widmayer
Idaho Operations Office, DOE
550 Second Street
Idaho Falls, Idaho 83401

STANDARD FORM 30, JULY 1966
GENERAL SERVICES ADMINISTRATION
FED. PROC. REG. (41 CFR) 1-16.101

AMENDMENT OF SOLICITATION/MODIFICATION OF CONTRACT

PAGE 1 OF 1

1. AMENDMENT/MODIFICATION NO.	2. EFFECTIVE DATE	3. REQUISITION/PURCHASE REQUEST NO.	4. PROJECT NO. (If applicable)
M007		07-81ID12026.501	

5. ISSUED BY CODE

U. S. Department of Energy
Idaho Operations Office
550 Second Street
Idaho Falls, Idaho 83401

6. ADMINISTERED BY (If other than block 5) CODE

7. CONTRACTOR NAME AND ADDRESS CODE FACILITY CODE

(Street, city, county, state, and ZIP Code)

University of Wyoming
University Station, Box 3355
Laramie, Wyoming 82071
Attn: H. P. Heasler
Department of Geology

8.
☐ AMENDMENT OF SOLICITATION NO. ______
DATED ______ (See block 9)
☒ MODIFICATION OF CONTRACT/ORDER NO. DE-FC07-79ID12026
DATED 12-29-78 (See block 11)

9. THIS BLOCK APPLIES ONLY TO AMENDMENTS OF SOLICITATIONS

☐ The above numbered solicitation is amended as set forth in block 12. The hour and date specified for receipt of Offers ☐ is extended, ☐ is not extended.

Offerors must acknowledge receipt of this amendment prior to the hour and date specified in the solicitation, or as amended, by one of the following methods:

(a) By signing and returning ____ copies of this amendment; (b) By acknowledging receipt of this amendment on each copy of the offer submitted; or (c) By separate letter or telegram which includes a reference to the solicitation and amendment numbers. FAILURE OF YOUR ACKNOWLEDGEMENT TO BE RECEIVED AT THE ISSUING OFFICE PRIOR TO THE HOUR AND DATE SPECIFIED MAY RESULT IN REJECTION OF YOUR OFFER. If, by virtue of this amendment you desire to change an offer already submitted, such change may be made by telegram or letter, provided such telegram or letter makes reference to the solicitation and this amendment, and is received prior to the opening hour and date specified.

10. ACCOUNTING AND APPROPRIATION DATA (If required)

11. THIS BLOCK APPLIES ONLY TO MODIFICATIONS OF CONTRACTS/ORDERS

(a) ☐ This Change Order is issued pursuant to ______
The Changes set forth in block 12 are made to the above numbered contract/order.

(b) ☐ The above numbered contract/order is modified to reflect the administrative changes (such as changes in paying office, appropriation data, etc.) set forth in block 12.

(c) ☒ This Supplemental Agreement is entered into pursuant to authority of mutual agreement of the Parties.
It modifies the above numbered contract as set forth in block 12.

12. DESCRIPTION OF AMENDMENT/MODIFICATION

In accordance with Participant's letter dated September 5, 1980,
Article VI - PROJECT MANAGEMENT is hereby revised to change the Participant's Project Director from E. R. Decker to:

H. P. Heasler
Principal Investigator
Department of Geology
University of Wyoming
Laramie, Wyoming 82071

There will no longer be a Co-Principal Investigator on the Project.

Except as provided herein, all terms and conditions of the document referenced in block 8, as heretofore changed, remain unchanged and in full force and effect.

13. ☒ CONTRACTOR/OFFEROR IS NOT REQUIRED TO SIGN THIS DOCUMENT ☐ CONTRACTOR/OFFEROR IS REQUIRED TO SIGN THIS DOCUMENT AND RETURN ____ COPIES TO ISSUING OFFICE

NAME OF CONTRACTOR/OFFEROR
(Signature of person authorized to sign)

17. UNITED STATES OF AMERICA
BY Nell W Fraser
(Signature of Contracting Officer)

15. TITLE OF SIGNER (Type or print)	16. DATE SIGNED	18. NAME OF CONTRACTING OFFICER (Type or print)	19. DATE SIGNED
		Nell W. Fraser	10/24/80

☆U.S.GPO:1979-0-281-187/5001

STANDARD FORM 30, JULY 1966
GENERAL SERVICES ADMINISTRATION
FPD. PROC. REG. (41 CFR) 1-16.101

AMENDMENT OF SOLICITATION/MODIFICATION OF CONTRACT

1. AMENDMENT/MODIFICATION NO. M007
2. EFFECTIVE DATE
3. REQUISITION/PURCHASE REQUEST NO. 07-81ID12026.501
4. PROJECT NO. (If applicable)

5. ISSUED BY CODE
U. S. Department of Energy
Idaho Operations Office
550 Second Street
Idaho Falls, Idaho 83401

6. ADMINISTERED BY (If other than block 5) CODE

M.2.10

7. CONTRACTOR NAME AND ADDRESS CODE FACILITY CODE
(Street, city, county, state, and ZIP Code)
University of Wyoming
University Station, Box 3355
Laramie, Wyoming 82071
Attn: H. P. Heasler
Department of Geology

8.
☐ AMENDMENT OF SOLICITATION NO.
DATED (See block 9)
☒ MODIFICATION OF CONTRACT/ORDER NO. DE-FC07-79ID12026
DATED 12-29-78 (See block 11)

9. THIS BLOCK APPLIES ONLY TO AMENDMENTS OF SOLICITATIONS
☐ The above numbered solicitation is amended as set forth in block 12. The hour and date specified for receipt of Offers ☐ is extended, ☐ is not extended.
Offerors must acknowledge receipt of this amendment prior to the hour and date specified in the solicitation, or as amended, by one of the following methods:
(a) By signing and returning ____ copies of this amendment; (b) By acknowledging receipt of this amendment on each copy of the offer submitted; or (c) By separate letter or telegram which includes a reference to the solicitation and amendment numbers. FAILURE OF YOUR ACKNOWLEDGEMENT TO BE RECEIVED AT THE ISSUING OFFICE PRIOR TO THE HOUR AND DATE SPECIFIED MAY RESULT IN REJECTION OF YOUR OFFER. If, by virtue of this amendment you desire to change an offer already submitted, such change may be made by telegram or letter, provided such telegram or letter makes reference to the solicitation and this amendment, and is received prior to the opening hour and date specified.

10. ACCOUNTING AND APPROPRIATION DATA (If required)

11. THIS BLOCK APPLIES ONLY TO MODIFICATIONS OF CONTRACTS/ORDERS
(a) ☐ This Change Order is issued pursuant to ____
The Changes set forth in block 12 are made to the above numbered contract/order.
(b) ☐ The above numbered contract/order is modified to reflect the administrative changes (such as changes in paying office, appropriation data, etc.) set forth in block 12.
(c) ☒ This Supplemental Agreement is entered into pursuant to authority of mutual agreement of the Parties.
It modifies the above numbered contract as set forth in block 12.

12. DESCRIPTION OF AMENDMENT/MODIFICATION

In accordance with Participant's letter dated September 5, 1980,
Article VI - PROJECT MANAGEMENT is hereby revised to change the Participant's Project Director from E. R. Decker to:

H. P. Heasler
Principal Investigator
Department of Geology
University of Wyoming
Laramie, Wyoming 82071

There will no longer be a Co-Principal Investigator on the Project.

Except as provided herein, all terms and conditions of the document referenced in block 8, as heretofore changed, remain unchanged and in full force and effect.

13. ☒ CONTRACTOR/OFFEROR IS NOT REQUIRED TO SIGN THIS DOCUMENT ☐ CONTRACTOR/OFFEROR IS REQUIRED TO SIGN THIS DOCUMENT AND RETURN ____ COPIES TO ISSUING OFFICE

14. NAME OF CONTRACTOR/OFFEROR
BY ____ (Signature of person authorized to sign)

17. UNITED STATES OF AMERICA
BY Nell W. Fraser (Signature of Contracting Officer)

15. NAME AND TITLE OF SIGNER (Type or print)
16. DATE SIGNED
18. NAME OF CONTRACTING OFFICER (Type or print) Nell W. Fraser
19. DATE SIGNED 10/24/80

☆U.S.GPO:1979-0-281-187/5001

STANDARD FORM 30, JULY 1966
GENERAL SERVICES ADMINISTRATION
FED. PROC. REG. (41 CFR) 1-16.101

AMENDMENT OF SOLICITATION/MODIFICATION OF CONTRACT

1. AMENDMENT/MODIFICATION NO.	2. EFFECTIVE DATE	3. REQUISITION/PURCHASE REQUEST NO.	4. PROJECT NO. (If applicable)
A006	6/1/80		

5. ISSUED BY CODE
U.S. Department of Energy
Idaho Operations Office
550 Second Street
Idaho Falls, Idaho 83401

6. ADMINISTERED BY (If other than block 5) CODE

File M.2.10

7. CONTRACTOR CODE FACILITY CODE
NAME AND ADDRESS
(Street, city, county, state, and ZIP Code)
University of Wyoming
University Station, Box 3355
Laramie, Wyoming 82071
Attn: E. R. Decker
Professor of Geology

8.
☐ AMENDMENT OF SOLICITATION NO. ____________
DATED ____________ (See block 9)
☒ MODIFICATION OF CONTRACT/ORDER NO. DE-FC07-79ID12026
DATED 12/29/78 (See block 11)

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(a) By signing and returning ____ copies of this amendment; (b) By acknowledging receipt of this amendment on each copy of the offer submitted; or (c) By separate letter or telegram which includes a reference to the solicitation and amendment numbers. FAILURE OF YOUR ACKNOWLEDGEMENT TO BE RECEIVED AT THE ISSUING OFFICE PRIOR TO THE HOUR AND DATE SPECIFIED MAY RESULT IN REJECTION OF YOUR OFFER. If, by virtue of this amendment you desire to change an offer already submitted, such change may be made by telegram or letter, provided such telegram or letter makes reference to the solicitation and this amendment, and is received prior to the opening hour and date specified.

10. ACCOUNTING AND APPROPRIATION DATA (If required)

11. THIS BLOCK APPLIES ONLY TO MODIFICATIONS OF CONTRACTS/ORDERS

(a) ☐ This Change Order is issued pursuant to ____________
The Changes set forth in block 12 are made to the above numbered contract/order.

(b) ☐ The above numbered contract/order is modified to reflect the administrative changes (such as changes in paying office, appropriation data, etc.) set forth in block 12.

(c) ☒ This Supplemental Agreement is entered into pursuant to authority of Public Law 95-91 et al.
It modifies the above numbered contract as set forth in block 12.

12. DESCRIPTION OF AMENDMENT/MODIFICATION

1. Article II - DESCRIPTION OF RESPONSIBILITIES, is revised to add the following items:

   9. A compilation of locations, temperatures, depths, gradients, and, if possible, depths to water for all thermal wells and springs in Wyoming. Regional maps of subsurface temperatures and depths will be supplied with the data, as would written reports. Available water quality and aquifer production data will be incorporated into the reports, as will relevant stratigraphy and geologic structure. The maps will show pertinent control points and relevant geology.

   10. Regional thermal gradient maps and interpretations thereof will be prepared and delivered. These deliverables will reflect local geology and the thermal properties of local rock units. Reports will summarize available shallow and deep water quality data, aquifer disposition, and aquifer production. Detailed reports and maps will be prepared for areas that could be prospectively valuable for near-term direct-heat or other applications.

--continued

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14. NAME OF CONTRACTOR/OFFEROR	17. UNITED STATES OF AMERICA
BY Elliott G Hays (Signature of person authorized to sign)	BY Nell W Fraser (Signature of Contracting Officer)

15. NAME AND TITLE OF SIGNER (Type or print)	16. DATE SIGNED	18. NAME OF CONTRACTING OFFICER (Type or print)	19. DATE SIGNED
Elliott G. Hays Vice President for Finance	6/2/80	Nell W. Fraser, Acting Chief R&D Contracts Branch	JUN 6 1980

1. ARTICLE II (Cont'd)

11. Research will be conducted in the Saratoga, Casper-Midwest, Auburn and DuBois areas to include data for regions within a 20-30 mile radius of each suggested resource. This detailed research will be done to better define their lateral extents, and to quantify the magnitude of each reservoir. Other systems will be analyzed in a similar manner as data are located. Reports will include available drill hole data, the geologic and hydrologic literature, and the proximity of resources to population centers.

12. Chemical analyses will be delivered for six heretofore unanalyzed springs or spring systems. Water samples and analyses will be accompanied by descriptions of collection sites, local geology and other pertinent geoscience data. Preliminary interpretations of the chemical analyses from cooperative studies with qualified personnel elsewhere (e.g., the USGS) will be made available. Collection of 70-75 samples of subsurface waters in areas where gradient data are collected and where existing waters, etc., are flowing or can be pumped will be done. Analysis of these samples will be done by UURI.

13. An updated (1981) regional heat flow map will be delivered, as will detailed maps of gradients and heat flow in prospectively valuable areas. All maps will be accompanied by interpretations. Both heat flow and available radioactivity data will be used in interpretations. Heat flow information will be obtained for approximately 20 new stations.

Reporting will be performed in accordance with Article VII - PROJECT INFORMATION. All pertinent information will be provided to the USGS GEOTHERM file.

2. Article III - FINANCIAL SUPPORT OF THE PROJECT, Paragraph A, is revised to read as follows:

"A. The total estimated cost of performing the work under this Agreement is Four Hundred Five Thousand Two Hundred Eighty-Three Dollars ($405,283.00). For performance of work under this Agreement, the agreed share ratio is 92.4% to DOE, 7.6% Participant, of total allowable costs. The Participant shall be

2. Article III (Cont'd)

reimbursed by DOE for 92.4% of the costs of the project determined to be allowable in accordance with Article A-I of the General Provisions entitled 'Allowable Costs.' All other costs that are not determined to be allowable under Article A-I shall constitute the Participant's share for which it will not be reimbursed by DOE. The total cost to DOE is hereby established as Three Hundred Seventy-Four Thousand Four Hundred Seventy-Seven Dollars ($374,477.00), and this amount is also the maximum amount of the project which is subject to reimbursement by DOE unless such maximum cost is changed in writing by the Contracting Officer."

The total cost of this Agreement and share totals are summarized below:

	U of WY Share	DOE Share	Est. Cost
Original Contract	$ 7,048.00	$ 99,439.00	$106,487.00
Increase Mod. A001	1,137.00	16,039.00	17,176.00
Increase Mod. A002	2,458.00	34,671.00	37,129.00
Increase Mod. A003	-0-	-0-	-0-
Increase Mod. A004	4,950.00	69,828.00	74,778.00
Increase Mod. M005	-0-	-0-	-0-
Increase Mod. A006	15,213.00	154,500.00	169,713.00
TOTALS	$30,806.00	$374,477.00	$405,283.00
PERCENTS	7.6%	92.4%	100%

3. The amount of funds obligated by DOE under Article III - <u>FINANCIAL SUPPORT OF THE PROJECT</u>, Paragraph C, is increased from $219,977.00 to $374,477.00

4. The period of performance under Article V - <u>TERM OF AGREEMENT</u>, is extended from June 1, 1980, to May 31, 1981.

5. Article VI - <u>PROJECT MANAGEMENT</u>, is revised to add:

H. P. Heasler
Co-Principal Investigator
University of Wyoming
Laramie, Wyoming 82071

6. Article VI - PROJECT MANAGEMENT, is also revised to change the DOE Program Officer to:

M. A. Widmayer
Idaho Operations Office, DOE
550 Second Street
Idaho Falls, Idaho 83401

STANDARD FORM 30, JULY 1966
GENERAL SERVICES ADMINISTRATION
FED. PROC. REG. (41 CFR) 1-16.101

AMENDMENT OF SOLICITATION/MODIFICATION OF CONTRACT

1. AMENDMENT/MODIFICATION NO.	2. EFFECTIVE DATE	3. REQUISITION/PURCHASE REQUEST NO.	4. PROJECT NO. (If applicable)
A008	Blk 19	07-81-ID12026.502	

5. ISSUED BY CODE

U. S. Department of Energy
Idaho Operations Office
550 Second Street
Idaho Falls, Idaho 83401

6. ADMINISTERED BY (If other than block 5) CODE

7. CONTRACTOR NAME AND ADDRESS CODE FACILITY CODE
(Street, city, county, state, and ZIP Code)

University of Wyoming
University Station, Box 3355
Laramie, Wyoming 82071

8. ☐ AMENDMENT OF SOLICITATION NO. ______
DATED ______ (See block 9)
☒ MODIFICATION OF CONTRACT/ORDER NO. DE-FC07-79ID12026
DATED 12-29-78 (See block 11)

9. THIS BLOCK APPLIES ONLY TO AMENDMENTS OF SOLICITATIONS

☐ The above numbered solicitation is amended as set forth in block 12. The hour and date specified for receipt of Offers ☐ is extended, ☐ is not extended.

Offerors must acknowledge receipt of this amendment prior to the hour and date specified in the solicitation, or as amended, by one of the following methods:

(a) By signing and returning ______ copies of this amendment; (b) By acknowledging receipt of this amendment on each copy of the offer submitted; or (c) By separate letter or telegram which includes a reference to the solicitation and amendment numbers. FAILURE OF YOUR ACKNOWLEDGEMENT TO BE RECEIVED AT THE ISSUING OFFICE PRIOR TO THE HOUR AND DATE SPECIFIED MAY RESULT IN REJECTION OF YOUR OFFER. If, by virtue of this amendment you desire to change an offer already submitted, such change may be made by telegram or letter, provided such telegram or letter makes reference to the solicitation and this amendment, and is received prior to the opening hour and date specified.

10. ACCOUNTING AND APPROPRIATION DATA (If required)

89X0224.91	ID-14-91	250	AM 15-10	$211,342.00
			CapEq 35 AMIS	3,165.00
				$214,507.00 Increase

11. THIS BLOCK APPLIES ONLY TO MODIFICATIONS OF CONTRACTS/ORDERS

(a) ☐ This Change Order is issued pursuant to ______
The Changes set forth in block 12 are made to the above numbered contract/order.

(b) ☐ The above numbered contract/order is modified to reflect the administrative changes (such as changes in paying office, appropriation data, etc.) set forth in block 12.

(c) ☒ This Supplemental Agreement is entered into pursuant to authority of Public Law 95-91
It modifies the above numbered contract as set forth in block 12.

12. DESCRIPTION OF AMENDMENT/MODIFICATION

1. Article II - DESCRIPTION OF RESPONSIBILITIES, is revised to add the following items:

   TASK 1 - Regional Surveys
   - See Attached Statement of Work
   TASK 7 - Reports

2. Article III - FINANCIAL SUPPORT OF THE PROJECT, Paragraph A, is revised to read as follows:

   "A. The total estimated cost of performing the work under this Agreement is Six Hundred Thirty-Six Thousand One Hundred Eighty-Three Dollars ($636,183). For performance of work under this Agreement, the agreed share ratio is 92.4% to DOE, 7.6% Participant, of total allowable costs. The Participant shall be reimbursed by DOE for 92.4% of the costs of the project determined to be allowable in accordance with Article A-I of the General Provisions entitled "Allowable Costs." All other costs that are not determined to be allowable under Article A-I

Except as provided herein, all terms and conditions of the document referenced in block 8, as heretofore changed, remain unchanged and in full force and effect.

CONTINUED....

13. ☐ CONTRACTOR/OFFEROR IS NOT REQUIRED TO SIGN THIS DOCUMENT ☒ CONTRACTOR/OFFEROR IS REQUIRED TO SIGN THIS DOCUMENT AND RETURN 3 COPIES TO ISSUING OFFICE

14. NAME OF CONTRACTOR/OFFEROR	17. UNITED STATES OF AMERICA
BY Keith K. Raitt (Signature of person authorized to sign)	BY William C. Drake (Signature of Contracting Officer)

15. NAME AND TITLE OF SIGNER (Type or print)	16. DATE SIGNED	18. NAME OF CONTRACTING OFFICER (Type or print)	19. DATE SIGNED
Keith K. Raitt Associate V.P. for Finance	6/1/81	William C. Drake	6/10/81

☆U.S.GPO:1980-0-311-153/5520

shall constitute the Participant's share for which it will not be reimbursed by DOE. The total cost to DOE is hereby established as Five Hundred Eighty-Eight Thousand Nine Hundred, Eighty-Four Dollars ($588,984), and this amount is also the maximum amount of the project which is subject to reimbursement by DOE unless such maximum cost is changed in writing by the Contracting Officer."

The total cost of the Agreement and share totals are summarized below:

	U of WY Share	DOE Share	Est. Cost
Original Contract	$ 7,048.00	$ 99,439.00	$106,487.00
Increase Mod. A001	1,137.00	16,039.00	17,176.00
Increase Mod. A002	2,458.00	34,671.00	37,129.00
Increase Mod. A003	-0-	-0-	-0-
Increase Mod. A004	4,950.00	69,828.00	74,778.00
Increase Mod. A005	-0-	-0-	-0-
Increase Mod. A006	15,213.00	154,500.00	169,713.00
Increase Mod. A007	-0-	-0-	-0-
Increase Mod. A008	16,393.00	214,507.00	230,900.00
TOTALS	$47,199.00	$588,984.00	$636,183.00
PERCENTS	7.6%	92.4%	100%

3. Article XIII - TITLE TO PROPERTY AND SITE RESTORATION is hereby incorporated into the Agreement as follows:

A. The Government will own and maintain title to all items of materials, supplies, and all tangible property purchased in full or in part with Government funds provided under this Agreement. The Government will determine disposition of such property at completion of the work under this Agreement or upon termination by either party and agrees that those costs incurred by the Participant in final disposition will be allowable costs.

B. The Participant agrees that the Government shall not be subject to any obligation to restore or rehabilitate any of the premises, facilities or equipment owned and/or leased by the Participant which are altered, improved or otherwise affected by this Agreement.

4. The amount of funds obligated by DOE under Article III - FINANCIAL SUPPORT OF THE PROJECT, Paragraph C, is increased from $374,477.00 to $588,984.00.

5. The period of performance under Article V - TERM OF AGREEMENT, is extended from May 31, 1981 to May 31, 1982.

STATEMENT OF WORK

TASK 1 - REGIONAL SURVEYS

Regional gradient maps and interpretations thereof will be prepared and delivered. These deliverables would reflect local geology and thermal properties of local rock units. Reports would also summarize available shallow and deep water quality data, aquifer disposition, and aquifer production. Areas that will be studied include the Wind River Basin, Green River Basin, Laramie Basin, and the Wyoming portion of the Thrust Belt. Regional maps of subsurface temperatures and depths will be supplied with the data, as will written reports. Available water quality and aquifer production data will be incorporated into the reports, as will relevant stratigraphy and geologic structure. The maps will show pertinent control points and relevant geology.

TASK 2 - THERMAL GRADIENT STUDIES

A compilation of locations, temperatures, depths, and thermal gradients for all holes measured during work on this contract will be prepared. A report will be prepared discussing the relation of mean annual air surface temperature to the temperature in shallow portions of drill holes in Wyoming. Included in the report will be a discussion of the effect of the difference in these temperatures upon the calculated thermal gradient when using oil well bottom hole temperatures.

TASK 3 - HEAT FLOW STUDIES

A compilation will be prepared of all heat flow data collected during work on this contract. This will include 24 heat flow values from 1979 to 80, 38 from 1980 to 81, and an additional 25 for 1981 to 82. Information included in the compilation will be locations, depths, gradients, thermal conductivities, and heat flow values.

TASK 4 - GEOCHEMISTRY

The Department of Geology will analyze a total of 120 water samples in an effort to better detail the geochemistry of waters in previously studied and new areas. Of the 120 samples, 70 will be in fulfillment of the 1980-81 project's scope of work plus an additional 50 samples will be analyzed. Duplicate samples will be taken at 5 to 10 localities and sent to the University of Utah Research Institute as quality check. Samples will be analyzed for major cation (Ca, Mg, Na, K), anions (CO_3, HCO_3, SO_4, Cl, NO_3), trace elements (As, Cu, Fe, Mn, Zn, Ba, Cd, Cr, Pb, Se, Ag, Hg, Ni), and other important parameters such as specific conductance, total dissolved solids, pH, flouride, sulfide, silica, and boron.

TASK 5 - USER ASSISTANCE

The Wyoming Resource Team will provide technical assistance to requestors for geothermal resource information, be given on a time-available basis, and will be coordinated with the Wyoming

Energy Office and the Wyoming Commercialization Team.

TASK 6 - STATE RESOURCE MAP

A map, scale 1:500,000, will be produced for the state depicting the geothermal resource potential for the state. The map will be produced by NOAA under the guidance of the Wyoming resource team. All data will be used to update the GEOTHERM data file.

TASK 7 - REPORTS

Monthly, topical, and final reports will be produced and distributed according to the guidelines established in DOE Form CR-537 (Appendix A). The final report will be a complete compilation and interpretation of tasks performed for this contract. All data, maps, and topical reports will be made part of the final product.

DOE Form CR-537
(1-78)

U. S. DEPARTMENT OF ENERGY

REPORTING REQUIREMENTS CHECKLIST

(See Instructions on Reverse)

Appendix A
DE-FC07-79ID12026
A008

FORM APPROVED
OMB NO. 38R-0190

1. IDENTIFICATION University of Wyoming	2. OBLIGATION INSTRUMENT:

3. REPORTING REQUIREMENTS

A. PROJECT MANAGEMENT	Frequency	B. TECHNICAL INFORMATION REPORTING	Frequency
1. ☐ Management Plan		1. ☐ Notice of Energy RD&D Project (SSIE)	
2. ☐ Milestone Schedule & Status Report		2. ☒ Technical Progress Report	M
3. ☐ Cost Plan		3. ☒ Topical Report	Y
4. ☐ Manpower Plan		4. ☒ Final Technical Report	Y
5. ☒ Contract Management Summary Report	M	C. PMS/MINI-PMS	
6. ☒ Project Status Report	M	1. Cost Performance Report	
7. ☒ Cost Management Report	M	☐ Format 1 WBS	
8. ☐ Manpower Management Report		☐ Format 2 Functional	
9. ☐ Conference Record		☐ Format 3 Baseline	
10. ☐ Hot Line Report		☐ Format 5 Problem Analysis	
		2. ☐ Cost/Schedule Status Report	
		3. ☐ Management Control System Description	
		4. ☐ Summary System Description	
		5. ☐ WBS Dictionary	

FREQUENCY CODES:
A — As Required
C — Contract Change
F — Final (End of Contract)
M — Monthly
O — One Time (Soon After Contract Award)
Q — Quarterly
S — Semi-Annually
X — Mandatory for Delivery with Proposals/Bid
Y — Yearly or Upon Contract Renewal

4. SPECIAL INSTRUCTIONS

A.5., A.6., and A.7. - Copies are due within fifteen days after end of the calendar month.

B.2. - Copies are due within fifteen days after end of the calendar month.

B.3. - Submit 2 copies in draft forty-five days prior to completion of the yearly term. After DOE approval is received, submit copies as required on attached "Report Distribution List."

B.4. - Submit 2 copies in draft forty-five days prior to completion date of contract term. After DOE approval is received, submit eleven copies including one camera-ready copy.

5. ATTACHED HEREWITH:

☐ Report Distribution List ☐
☐ WBS/Reporting Category ☐

6. PREPARED BY (Signature and date):	7. REVIEWED BY (Signature and date):

ID F-129 (Rev. 08-79)
Ref. DOE 13302
(use with DOE CR-537)

U.S. DEPARTMENT OF ENERGY
IDAHO OPERATIONS OFFICE

REPORT DISTRIBUTION LIST

Contract No.

DE-FC07-79ID12026

Number of Report Copies

Addressees	Management Plan	Milestone Schedule & Status Report	Cost Plan	Manpower Plan	Contract Management Summary Report	Project Status Report	Cost Management Report	Manpower Management Report	Conference Record	Hot Line Report	Notice of Energy RD&D Project (SSIE)	Technical Progress Report	Topical Report	Final Technical Report	Cost Performance Report	Cost/Schedule Status Report	Management Control System Description	Summary System Description	WBS Dictionary
Elizabeth Hyster U. S. Department of Energy Idaho Operations Office 550 Second Street Idaho Falls, Idaho 83401					1	1													
M. A. Widmayer, Program Manager Resource Definition Branch U. S. Department of Energy Idaho Operations Office 550 Second Street Idaho Falls, Idaho 83401					1	1						2	2	12					
Bob Gray U. S. Department of Energy Division of Geothermal Energy MS 3344 Federal Building 12th and Penn., N.W. Washington, D.C. 20461					2	2						2	2						
Duncan Foley UURI 420 Chipeta Way Suite 120 Salt Lake City, UT 84108					1	1						1	1						

Special Instructions

UNIVERSITY OF UTAH RESEARCH INSTITUTE

UURI

EARTH SCIENCE LABORATORY
420 CHIPETA WAY, SUITE 120
SALT LAKE CITY, UTAH 84108
TELEPHONE 801-581-5283

April 14, 1982

Dr. Henry P. Heasler
Department of Geology
University of Wyoming
Laramie, WY 82071

Re: Completion Date and Deliverables: DOE Contract DE-FC07-79ET27034

Dear Hank:

I wish to personally thank you for attending the Roundup Conference and your valuable contribution to the success of this meeting. I'm sorry we didn't get a chance to review your contract with you during the meeting . . . we just plain ran out of time. With respect to your conference paper and bibliography, please make every effort to get these to me, camera ready, by April 30th. My goal is to have the proceedings edited and published by July 1, 1982.

During the course of the conference, contract reviews were conducted by Susan Prestwich and the state teams, with special emphasis on the status of various deliverables as stipulated in each contract. To assist in this review, I prepared summaries of each contract, listing modifications, tasks, deliverables (where such were specifically delineated) and contract completion dates. When I could find copies of reports, etc. in E.S.L. files, I indicated this on the summaries. I made no attempt to ascertain if monthly and quarterly reports had been issued as required by most contracts.

You will find enclosed a copy of the summary I prepared for your contract with notations of some deliverables that have been received and are on file at ESL. Please review this summary and let us know of any errors or omissions. Also, please indicate when you expect to finish each task and publish reports corresponding to the tasks or specific deliverables. This work is necessary so that DOE-Idaho can accurately close out each contract and assure adherence to contract requirements. If any tasks, time extensions or deliverables have been changed by verbal or letter agreements, not covered in formal modifications, it will be important for you to provide details of such changes to Susan Prestwich or me as soon as possible.

I note in your contract a termination date of May 31, 1982. If all work and deliverables will not have been completed by that date, it will be advisable for you to formally request a time extension by contacting Ms. Prestwich.

Please do not hesitate to call me on (801) 581-5414 if you have any questions.

Best regards,

Carl A. Ruscetta
Technical Program Coordinator

encl.

cc. S. Prestwich
Idaho Falls, ID.

DOE FORM PR-799A (TEST)
30 AUGUST 1978

Mod DE-FC07-79ID 12026
WYOMING
NCTE 10/7/82

U. S. DEPARTMENT OF ENERGY

PROCUREMENT/FINANCIAL ASSISTANCE REQUEST-AUTHORIZATION

1. TO OMP

2. FROM INITIATING OFFICE EET Geothermal

3. INITIAL: [X] UPDATE: [ ] 4. PROCUREMENT: [ ] FINANCIAL ASSISTANCE: [ ]

5. PR NUMBER: ______ 6. PR CORRECTION LETTER: _ 7. RELATED PR NUMBER: ______

ACTION IDENTIFICATION

8. TITLE: Wyoming Geothermal Resource Assessment Modification to DE-FC07-79ID12026 for No Cost Time Extension

9. UNSOLICITED PROPOSAL NO: ______ 10. PROJECT NO: ______ 11. CFDA NO: ______

12. PRODUCT OR SERVICE:* ____ 13. SUPPORT SERVICES: YES [ ] NO [ ] 14. CONSULTANT AWARD: YES [ ] NO [ ]

15. CONTROLLED DELIVERABLE:* ___ 16. REPORT/DRAWING REQ: YES [ ] NO [ ] IF YES, ATTACH DETAILS.

17. CLASSIFICATION OF MATERIALS/WORK: _ U – UNCLASSIFIED C CONFIDENTIAL S SECRET T – TOP SECRET

18. GOVERNMENT PROPERTY: _ F – FURNISHED P – PURCHASED N – NOT INVOLVED IF CODE F OR P, ATTACH DETAILS.

AWARD PLANNING

19. AWARD AS ORDER UNDER BIN: ______ IF CODE T, ATTACH DETAILS.

20. DESIRED AWARD DATE: __ __ __ (MONTH DAY YEAR) 21. KIND OF AWARD ACTION:* 1Q 22. TYPE OF AWARD:* T

23. IF MULTI-YEAR AWARD, INDICATE NUMBER OF YEARS: _ 24. TYPE SOLICITATION INSTRUMENT: * __

25. EXTENT OF COMPETITION:* __ IF COMPETITIVE, ATTACH TECHNICAL EVALUATION PLAN. IF NON-COMPETITIVE, ATTACH JUSTIFICATION. REF: DOE-PR 9-3.805.51 or 9-4.909(f).

26. SOURCE SELECTION PROCEDURE: _ 1 – A-E 2 – SEB 3 – OTHER 4 – NONE

27. FOR A-E, SHOW ESTIMATED CONSTRUCTION COST IN DOLLARS: ______

AWARDEE

IF COMPETITIVE, HAS LIST OF SOURCES BEEN ATTACHED? YES [ ] NO [ ] IF NON-COMPETITIVE, COMPLETE 28 - 31

28. NAME: University of Wyoming 29. ADDRESS: Dept Geol & Geoph Box 3006 Laramie Wyo 82071

30. DIVISION: Henry Heasler

31. GOCO/LAB: _ A – GOCO/LAB B – GOCO/NON-LAB C – NON-GOCO/LAB D – NOT APPLICABLE

FINANCIAL

AWARD VALUE

	DOLLAR AMOUNT
32. GOV'T SHARE	-0-
33. TOTAL	______

34. CONSIDERATION IN KIND, LOAN, OR LOAN GUARANTEE DATA REPORTED ON PR 799C: [ ]

35. PROJECT PERIOD: FROM 5 31 82 (MONTH DAY YEAR) THRU 10 7 82 (MONTH DAY YEAR)

CURRENT FY FUNDS COMMITTED

36. B&R NUMBER	37. FUND CLASS	38. DOLLAR AMOUNT
______	_	______
______	_	______
______	_	______

39. FROM PR 799B (PART A) ______

40. TOTAL THIS PR -0-

41. FUNDING PERIOD: FROM __ __ __ (MONTH DAY YEAR) THRU __ __ __ (MONTH DAY YEAR)

42. APPROPRIATION SYMBOL: ______

43. ALLOTMENT SYMBOL: ______

44. OBJECT CLASS: ____

PROJECT MANAGER

45. NAME: S. M. Prestwich

46. SIGNATURE: SM Prestwich

47. DATE: 5 5 82 (MONTH DAY YEAR) 48. OFFICE CODE: ______

49. FTS TELEPHONE NUMBER: ______

PROGRAM OFFICIAL

50. NAME: R E Wood

51. SIGNATURE: W. Hnith for R.E. Wood

52. DATE: 5 6 82 (MONTH DAY YEAR)

CERTIFYING OFFICIAL

53. NAME: F S Smith

I HEREBY CERTIFY THAT THE FUNDS CITED IN ITEM 40 ARE AVAILABLE.

54. SIGNATURE: ______

55. DATE: __ __ __ (MONTH DAY YEAR)

* SEE BACK OF FORM FOR CODES

THE UNIVERSITY OF WYOMING
DEPARTMENT OF GEOLOGY AND GEOPHYSICS
P.O. BOX 3006
LARAMIE, WYOMING 82071
(307) 766-3386

April 26, 1982

Susan M. Prestwich
Department of Energy
Idaho Operations Office
550 Second Street
Idaho Falls, Idaho 83401

Dear Susan:

This letter is a request for a no cost extension from May 31, 1982 to October 7, 1982 for cooperative agreement number DE-F107-79ID12026.

I am expecting $7,000 to $11,000 to be unexpended at the May 31, 1982 termination date of the contract. The requested no cost extension would be used for the completion of contractual reports. The money would be primarily used for my salary and duplicating costs.

If you have questions, please contact me.

Sincerely,

Henry P. Heasler

Henry P. Heasler
Principal Investigator
Wyoming Geothermal Resource
Assessment Group

HPH/tj

Recorded 8/23. AR

DOE FORM PR-799A (TEST)
30 AUGUST 1978

U. S. DEPARTMENT OF ENERGY

PROCUREMENT/FINANCIAL ASSISTANCE REQUEST-AUTHORIZATION

1. TO CMD

2. FROM INITIATING OFFICE E&T Geothermal

3. INITIAL: [X] UPDATE: [ ] 4. PROCUREMENT: [ ] FINANCIAL ASSISTANCE: [ ]

5. PR NUMBER: ________ 6. PR CORRECTION LETTER: _ 7. RELATED PR NUMBER: ________

ACTION IDENTIFICATION

8. TITLE: Wyoming State Resource Assessment Modification to DE-FA07-79ID12026 for No Cost Time Extension

9. UNSOLICITED PROPOSAL NO: ________ 10. PROJECT NO: ________ 11. CFDA NO: ____

12. PRODUCT OR SERVICE:* ____ 13. SUPPORT SERVICES: YES [ ] NO [ ] 14. CONSULTANT AWARD: YES [ ] NO [ ]

15. CONTROLLED DELIVERABLE:* ___ 16. REPORT/DRAWING REQ: YES [ ] NO [ ] IF YES, ATTACH DETAILS.

17. CLASSIFICATION OF MATERIALS/WORK: _ U — UNCLASSIFIED C — CONFIDENTIAL S — SECRET T — TOP SECRET

18. GOVERNMENT PROPERTY: _ F — FURNISHED P — PURCHASED N — NOT INVOLVED IF CODE F OR P, ATTACH DETAILS.

AWARD PLANNING

19. AWARD AS ORDER UNDER BIN: ________

20. DESIRED AWARD DATE: 10 01 82 (MONTH DAY YEAR) 21. KIND OF AWARD ACTION:* LQ 22. TYPE OF AWARD:* T IF CODE T, ATTACH DETAILS.

23. IF MULTI-YEAR AWARD, INDICATE NUMBER OF YEARS: _ 24. TYPE SOLICITATION INSTRUMENT: * __

25. EXTENT OF COMPETITION:* __ IF COMPETITIVE, ATTACH TECHNICAL EVALUATION PLAN. IF NON-COMPETITIVE, ATTACH JUSTIFICATION. REF: DOE-PR 9-3.805.51 or 9-4.909(f).

26. SOURCE SELECTION PROCEDURE: _ 1 — A-E 2 — SEB 3 — OTHER 4 — NONE

27. FOR A-E, SHOW ESTIMATED CONSTRUCTION COST IN DOLLARS: ________

AWARDEE

IF COMPETITIVE, HAS LIST OF SOURCES BEEN ATTACHED? YES [ ] NO [ ] IF NON-COMPETITIVE, COMPLETE 28--31.

28. NAME: University of Wyoming 29. ADDRESS: Box 3006 Laramie, Wy 82071

30. DIVISION: Dept of Geology & Geophysics PI Henery Hesler

31. GOCO/LAB: _ A — GOCO/LAB B — GOCO/NON-LAB C — NON-GOCO/LAB D — NOT APPLICABLE

FINANCIAL

AWARD VALUE — DOLLAR AMOUNT

32. GOV'T SHARE -0-

33. TOTAL ________

34. CONSIDERATION IN KIND, LOAN, OR LOAN GUARANTEE DATA REPORTED ON PR-799C: [ ]

35. PROJECT PERIOD: FROM 10 07 82 (MONTH DAY YEAR) THRU 2 28 83 (MONTH DAY YEAR)

CURRENT FY FUNDS COMMITTED

36. B&R NUMBER	37. FUND CLASS	38. DOLLAR AMOUNT
________	-	-0-
________	-	________
________	-	________

39. FROM PR-799B (PART A) ________

40. TOTAL THIS PR -0-

41. FUNDING PERIOD: FROM __ __ __ (MONTH DAY YEAR) THRU __ __ __ (MONTH DAY YEAR)

42. APPROPRIATION SYMBOL: ________

43. ALLOTMENT SYMBOL: ________

44. OBJECT CLASS: ____

PROJECT MANAGER

45. NAME: S M Prestwich

46. SIGNATURE: SM Prestwich

47. DATE: 8 12 82 (MONTH DAY YEAR) 48. OFFICE CODE: ________

49. FTS TELEPHONE NUMBER: ________

PROGRAM OFFICIAL

50. NAME: R E Wood

51. SIGNATURE: E E Gilmore for R E Wood

52. DATE: 8-12-82 (MONTH DAY YEAR)

CERTIFYING OFFICIAL

53. NAME: F. S. Smith

I HEREBY CERTIFY THAT THE FUNDS CITED IN ITEM 40 ARE AVAILABLE.

54. SIGNATURE: ________

55. DATE: __ __ __ (MONTH DAY YEAR)

* SEE BACK OF FORM FOR CODES

RECEIVED
AUG 11 1982
ADVANCED TECHNOLOGY
[illegible]

THE UNIVERSITY OF WYOMING
DEPARTMENT OF GEOLOGY AND GEOPHYSICS
P.O. BOX 3006
LARAMIE, WYOMING 82071
(307) 766-3386

August 9, 1982

Susan M. Prestwich
Department of Energy
Idaho Operations Office
550 Second Street
Idaho Falls, Idaho 83401

Dear Susan:

This letter is a request for a no cost extension from October 7, 1982 to February 28, 1983 for cooperative agreement number DE-F107-79ID12026.

I am requesting this extension to allow continued editing and final compilation of contractual reports. This task is taking more time than originally anticipated due to our involvement this summer in a State funded geothermal drilling project.

If you have questions, please contact me.

Sincerely,

Henry Heasler

Henry P. Heasler,
Principal Investigator
Wyoming Geothermal Resource
Assessment Group.

HPH/bw

M 2.10
Posted X

NOTICE OF FINANCIAL ASSISTANCE AWARD

(See Instructions on Reverse)

Under the authority of Public Law 96-294

subject to legislation, regulations and policies applicable to *(cite legislative program title)*: National Geothermal Resource Assessment Program

1. PROJECT TITLE: Hydrothermal Resources in Wyoming

2. INSTRUMENT TYPE: ☐ GRANT ☒ COOPERATIVE AGREEMENT

3. RECIPIENT *(Name, address, zip code, area code and telephone no.)*
University of Wyoming
University Station - P.O. Box 3006
Laramie, WY 82071

4. INSTRUMENT NO.: DE-FC07-79ID12026

5. AMENDMENT NO.: M010

6. BUDGET PERIOD: FROM: 12/11/78 THRU: 2/28/83

7. PROJECT PERIOD: FROM: 12/11/78 THRU: 2/28/83

8. RECIPIENT PROJECT DIRECTOR *(Name and telephone No.)*: H.P. Heasler

9. RECIPIENT BUSINESS OFFICER *(Name and telephone No.)*

10. TYPE OF AWARD: ☐ NEW ☐ CONTINUATION ☐ RENEWAL ☐ REVISION ☒ SUPPLEMENT

11. DOE PROJECT OFFICER *(Name, address, zip code, telephone No.)*
S. M. Prestwich 208/526-1147
Idaho Operations Office
550 Second St., Idaho Falls, ID 83401

12. ADMINISTERED FOR DOE BY *(Name, address, zip code, telephone No.)*
E. M. Hyster 208/526-1229
U. S. Department of Energy
Idaho Operations Office
550 Second Street
Idaho Falls, Idaho 83401

13. RECIPIENT TYPE: ☐ STATE GOV'T ☐ INDIAN TRIBAL GOV'T ☐ HOSPITAL ☐ FOR PROFIT ORGANIZATION ☐ C ☐ P ☐ SP ☐ INDIVIDUAL ☐ LOCAL GOV'T ☒ INSTITUTION OF HIGHER EDUCATION ☐ OTHER NONPROFIT ORGANIZATION ☐ OTHER *(Specify)*

14. ACCOUNTING AND APPROPRIATIONS DATA

a. Appropriation Symbol	b. B & R Number	c. FT/AFP/OC	d. CFA Number
N/A	N/A		

15. EMPLOYER I.D. NUMBER/SSN

16. BUDGET AND FUNDING INFORMATION

a. CURRENT BUDGET PERIOD INFORMATION

(1) DOE Funds Obligated This Action	$ -0-
(2) DOE Funds Authorized for Carry Over	$ -0-
(3) DOE Funds Previously Obligated in this Budget Period	$ 588,984
(4) DOE Share of Total Approved Budget	$ 588,984
(5) Recipient Share of Total Approved Budget	$ 47,199
(6) Total Approved Budget	$ 636,183

b. CUMULATIVE DOE OBLIGATIONS

(1) This Budget Period *[Total of lines a.(1) and a.(3)]*	$ 588,984
(2) Prior Budget Periods	$ -0-
(3) Project Period to Date *[Total of lines b. (1) and b. (2)]*	$ 588,984

17. TOTAL ESTIMATED COST OF PROJECT $ 636,183

(This is the current estimated cost of the project. It is not a promise to award nor an authorization to expend funds in this amount.)

18. AWARD/AGREEMENT TERMS AND CONDITIONS

This award/agreement consists of this form plus the following:

a. Special terms and conditions (if grant) or schedule, general provisions, special provisions (if cooperative agreement)

b. Applicable program regulations *(specify)* ______ *(Date)* ______

c. DOE Assistance Regulations, 10 CFR Part 600, as amended, Subparts A and ☐ B (Grants) or ☒ C (Cooperative Agreements).

d. Application/proposal dated 8/9/82, ☒ as submitted ☐ with changes as negotiated

19. REMARKS

This modification extends the budget and project period from 10/7/82 to 2/28/83 with no change in the estimated cost or financial support of the project.

20. EVIDENCE OF RECIPIENT ACCEPTANCE

Durward Long 9-5-82
(Signature of Authorized Recipient Official) *(Date)*
Durward Long
(Name)
Acting Vice President for Finance
(Title)

21. AWARDED BY

William C. Drake 8/30/82
(Signature) *(Date)*
William C. Drake
(Name)
Contracting Officer
(Title)