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Final Report

Geothermal Modeling of Jackson Hole, Teton County Wyoming

by

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

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INTRODUCTION

This study investigated the possibility of high-temperature-heat sources (greater than 300 °C) in the area of Jackson Hole, northwestern Wyoming (see Figure 1 for study area location). Analytical and finite-difference numerical models describing conductive and convective terrestrial heat transport were utilized in an attempt to define the thermal regime of this area.

This report will first present data which were used as constraints for the analytic and numerical thermal models. These data include a general discussion of geology of the area, thermal spring information, subsurface temperature information, and hydrology of the area.

The modeling techniques are presented next with a discussion of assumptions and data used to constrain the models.

Lastly, results of the models are presented with a discussion of interpretations and implications for the existence of high-temperature heat sources in the Jackson Hole area.

GENERAL GEOLOGY OF JACKSON HOLE

Jackson Hole is a 60 km by 15 to 30 km complexly folded and faulted basin (Love and Reed, 1971; Love et al., 1973). Within the basin are three structurally deep areas in which the Precambrian basement varies from 3 km to 4.5 km below sea level (Love in Behrendt et al., 1968). Sediments contained in Jackson Hole represent all systems except Silurian (see Table I for a generalized stratigraphic column). The Cenozoic sedimentary section is the most complete of any Wyoming basin, due to the basin's subsidence during Cenozoic time.

Surrounding tectonic features include the Teton Mountain Range and the Yellowstone volcanic plateau (refer to Figure 1). The height of the

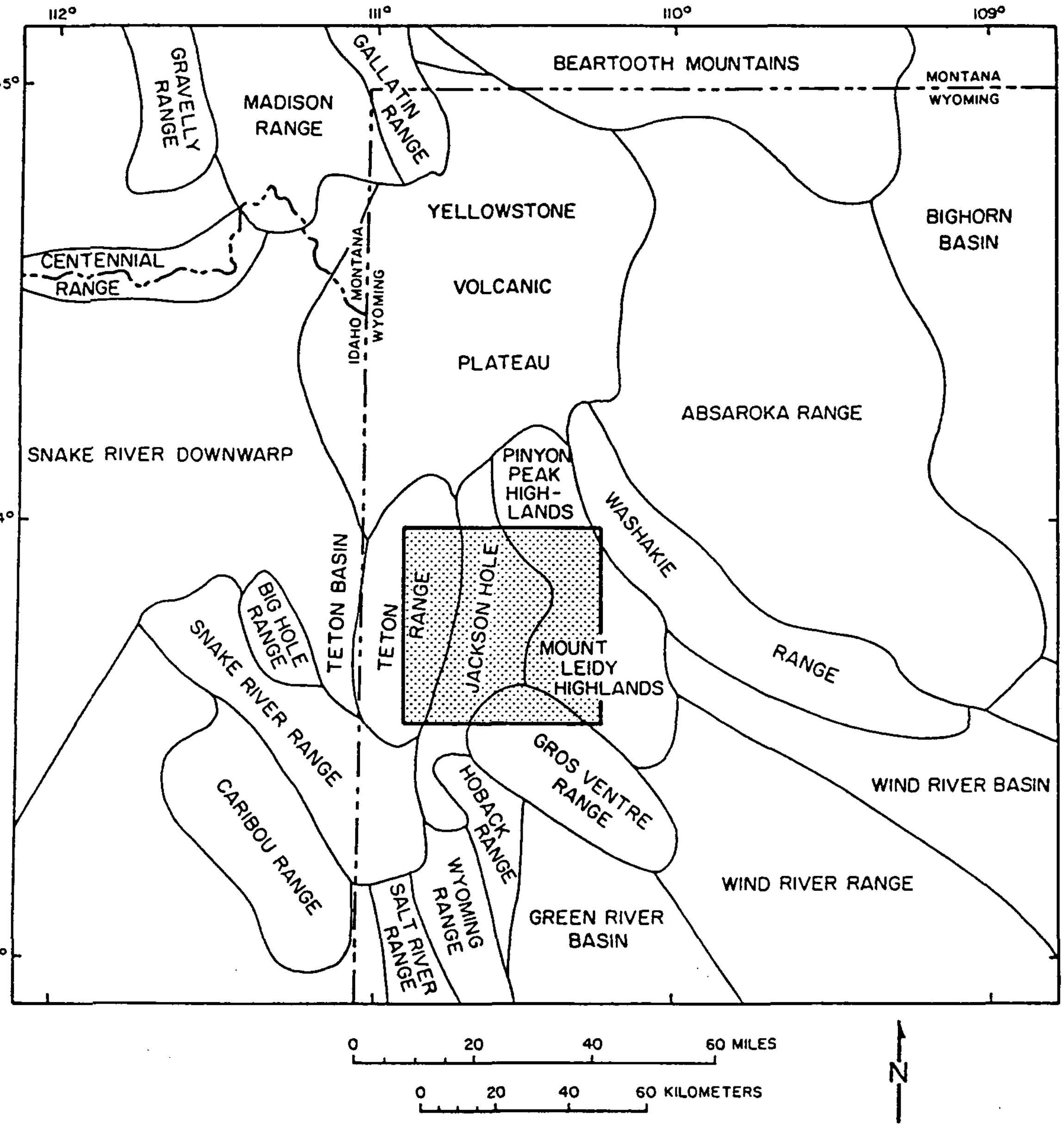


Figure 1. Location of study area (stippled) in relation to Jackson Hole and surrounding tectonic features (modified from Behrendt et al., 1968).

Table I. Generalized stratigraphic column showing thermal conductivities and units used in thermal models.

Era	Period	Description[1]	Modeled Thickness (meters)	Thermal Conductivity[2] (watts/meter Kelvin)	Modeling Unit[3]
Cenozoic	Quaternary	Glacial gravels Stream deposits	0 to 525	3.3	8
Cenozoic	Tertiary	Gray and white clay, limestone, and volcanic ash	0 to 2400	2.5	7
Cenozoic	Tertiary	Gray conglomerate and volcanic ash	300	3.4	6
Mesozoic	Cretaceous	Brown conglomerate	300	3.1	5
Mesozoic	Cretaceous	Gray sandstone and shale	1500 to 3000	1.9	4
Mesozoic	Cretaceous Jurassic Triassic	Red, gray, green and mottled sandstone, shale and limestone	1050	2.3	3
Paleozoic		Gray limestone, gray and green shale, and red-brown sandstone	1200	3.5	2
Precambrian		Gneiss, schist and granite		3.2	1

[1] Description is taken from U.S. Geological Survey's Map of Grand Teton National Park (1968), Love (in Behrendt et al., 1968), and Love et al., (1973).

[2] Thermal conductivity values were assigned using measured data from Heasler (1978). For the Quaternary, Tertiary, and uppermost Cretaceous strata thermal conductivity values were estimated based on lithology.

[3] Refers to cross-section AA′ (Figure 4).

Precambrian in the Teton Range exceeds 4 km above sea level. Love (in Behrendt et al., 1968) interprets the Teton Range as a horst between the two downfaulted blocks of the Teton Basin to the west and Jackson Hole to the east. The north-south trending Teton fault system (Figure 2) separates the Teton Range from Jackson Hole. Behrendt et al. (1968) have interpreted up to 7 km of vertical displacement along the Teton fault system. The Yellowstone volcanic plateau terminates against the northern portion of Jackson Hole.

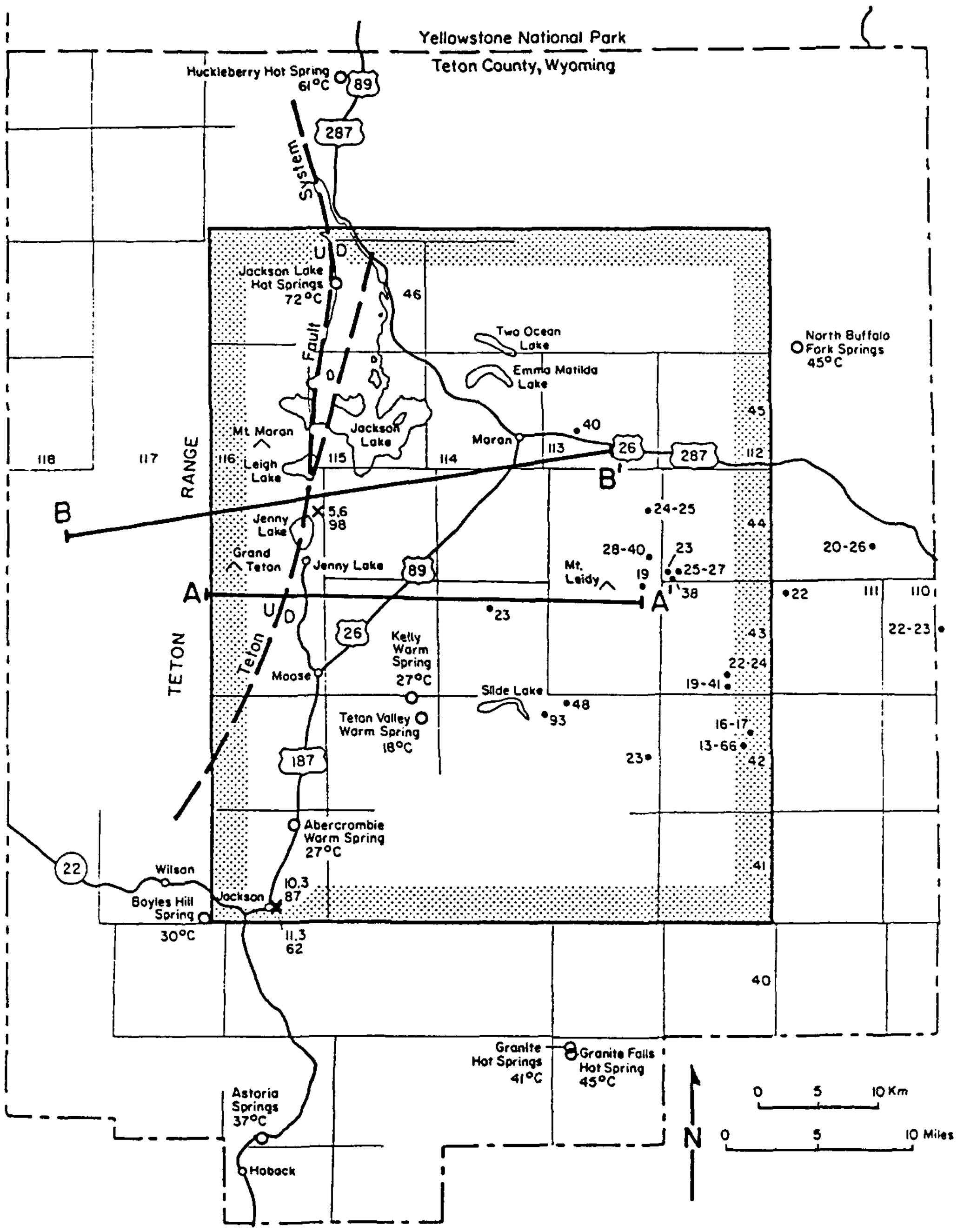
Beginning in the Miocene and continuing through the Pliestocene, there has been extensive volcanism in the Yellowstone region which roughly coincides with the subsidence of Jackson Hole. Contemporaneous with the subsidence of Jackson Hole has been the uplift of the Teton Range. Movement originated in the last 10 my (million years) and is still active (Love in Behrendt et al., 1968). Barnosky (1984) proposes that volcanoes were active in Jackson Hole from the early to middle Miocene (about 24 to 13 my ago). Within 5 km of the southern boundary of Yellowstone National Park are volcanic rocks of the Plateau Rhyolite which ranges in age from 70,000 to 600,000 years old (Christiansen and Blank, 1972).

Summaries of the geologic history of Jackson Hole are given in Behrendt et al. (1968), Love and Reed (1971), and Love et al. (1973).

THERMAL SPRINGS

Ten thermal springs are located near the study area with four thermal springs contained within the study area (Figure 2). Chemical and flow data for all ten springs are listed in Table II.

The two highest temperature springs (Huckleberry Hot Springs and Jackson Late Hot Springs) are nearest Yellowstone National Park. Huckleberry Hot Springs includes two groups of vents and seeps flowing 380 L/min (liters per



- ○ Thermal spring showing temperature (Breckenridge and Hinckley, 1978.)
- • Geothermal gradient (°C/Km) calculated from oil well bottom-hole temperatures. See Tables III and IV.
- × Bottom-hole temperature (°C) and depth (meters) from precision thermal measurements. See Figure 3.
- ⊢⊣ Line of cross-sections used in finite-difference thermal models.

Figure 2. Locations of study area (stippled), thermal springs, subsurface temperature data, and cross sections used in finite difference models.

Table II. Thermal spring data for the Jackson Hole area.[1]

Thermal Spring	Temperature (^{o}C)	Flow (L/min)	TDS (Mg/L)	Location (Township/Range/Sec)
Huckleberry	51	1136	688	48/115/20
Jackson Lake	72	5520		46/115/19
North Buffalo Fork	45	757		45/111/32
Kelly	27		284	42/115/2
Teton Valley	18		248	42/115/11
Abercrombie	27	946	192	41/116/2
Boyles Hill	30	189	2480	41/117/36
Granite	41	1136	670	39/113/6
Granite Falls	45	454		39/113/6
Astoria	37	379	1160	39/116/32

[1] All data is from Breckenridge and Hinckley (1978) except for the flow data for Jackson Lake Hot Springs which is from J.D. Love (personal communication, 1986).

minute) of 45 to 61 °C water (Breckenridge and Hinckley, 1978). These springs occur in a large area of siliceous sinter overlying glacial material and Pliestocene rhyolites (Love, 1974). Chemical geothermometry has been interpreted as indicating a subsurface reservoir temperature of 133 °C (Muffler, 1979).

Jackson Lake Hot Springs are located on the western shore of Jackson Lake (Figure 2). Wagner (1964) described a variety of small springs along 275 meters of shoreline with temperatures ranging between 24 to 50 °C. Measurements by J. D. Love indicate a minimum flow of 5520 L/min with the highest temperature being 69 °C (J. D. Love, personal communication, 1986). These springs occur along the north-south trending Teton fault system and the intersection of two smaller converging northwest-southeast trending normal faults (Love and Reed, 1973). Madison Limestone is mapped at the location of the springs (Love and Reed, 1973).

Breckenridge and Hinckley (1978) consider both Teton Valley Warm Springs (18 °C, flow undetermined) and Kelly Warm Springs (27 °C, flow undetermined) to be sourced from the Madison Limestone. They base their assumption on the chemical similarity between these springs and Madison waters and on the geologic structure near the springs. Kelly Warm Springs occur in Quaternary alluvium while nearby Teton Valley Warm Springs are located at the base of a long slope of deeply fractured Madison Limestone (Breckenridge and Hinckley, 1978).

Abercrombie Warm Springs (27 °C, 950 L/min) occur in an area of Holocene loess (Breckenridge and Hinckley; 1978). Paleozoic rocks which have been intruded and covered by Tertiary or Quaternary andesites, are located just south of the springs (Love, 1975). These springs are located along the Warm Springs fault, an east-west normal fault mapped by Love (1975).

SUBSURFACE TEMPERATURE DATA

Bottom-hole temperatures (BHT's) reported with logs from oil and gas wells were analyzed in an attempt to provide subsurface temperature data. Data from Wyoming Geological Survey files for 18 wells are presented on Figure 2 and in Tables III and IV. Figure 2 shows the location and range of calculated geothermal gradients for the 18 wells. Table III statistically summarizes the 34 BHT's and calculated geothermal gradients for the 18 wells. Table IV lists data for the 34 measurements including depth, BHT, location, and calculated gradient.

Geothermal gradients were claculated from BHT data using the formula

$$\text{Gradient} = \frac{(\text{BHT}) - (\text{MAAT})}{\text{Depth}}$$

where MAAT is the mean annual air temperature. For the gradient calculation a mean annual air temperature of 3 ^{o}C was assumed. This is between Becker and Alyea's (1964) reported values of 3.3 ^{o}C for the town of Jackson Hole and 1.2 ^{o}C for Moran.

Difficulties exist with the use of oil well BHT's in geothermal studies. There are problems associated with the thermal effects of drilling and with operator inattention in measuring and reporting BHT's. Also, drilling fluids may transfer heat to the bottom of a drill hole, warming or cooling the rock depending on the drilling fluid temperature and the depth of the hole. The magnitude of the thermal disturbance depends on such factors as the temperature difference between the drilling fluid and the rock, the time between end of fluid circulation and temperature measurement, the type of drilling fluid used, the length of time of fluid circulation, and the degree to which drilling fluids have penetrated the strata.

Table III. Summary of 34 bottom-hole temperature measurements for 18 wells in the Jackson Hole area.

DEPTH - TEMPERATURE ANALYSIS
(meters) (^{o}C)

DEPTH	NO.	HIGH	LOW	MEAN	50%	66%	80%	90%
400.	2.	37.8	22.2	30.0	37.8	37.8	37.8	37.8
1000.	2.	42.2	35.6	38.9	42.2	42.2	42.2	42.2
1200.	2.	46.7	29.4	38.1	46.7	46.7	46.7	46.7
1400.	4.	56.1	23.3	38.6	37.8	37.8	56.1	56.1
1600.	3.	40.0	32.8	36.5	36.7	40.0	40.0	40.0
1800.	1.	73.3	73.3	73.3	73.3	73.3	73.3	73.3
2000.	2.	50.6	27.8	39.2	50.6	50.6	50.6	50.6
2200.	2.	63.3	56.7	60.0	63.3	63.3	63.3	63.3
2400.	4.	65.6	52.2	56.7	56.7	56.7	65.6	65.6
2600.	2.	50.0	45.6	47.8	50.0	50.0	50.0	50.0
2800.	1.	46.7	46.7	46.7	46.7	46.7	46.7	46.7
3000.	2.	81.1	75.6	78.3	81.1	81.1	81.1	81.1
3200.	4.	71.1	53.3	65.1	70.6	70.6	71.1	71.1
3400.	2.	67.8	56.1	61.9	67.8	67.8	67.8	67.8
3800.	1.	72.8	72.8	72.8	72.8	72.8	72.8	72.8

DEPTH - GRADIENT ANALYSIS
(meters) (^{o}C / km)

DEPTH	NO.	HIGH	LOW	MEAN	50%	66%	80%	90%
400.	2.	92.9	66.0	79.5	92.9	92.9	92.9	92.9
1000.	2.	48.1	38.0	43.0	48.1	48.1	48.1	48.1
1200.	2.	40.0	23.4	31.7	40.0	40.0	40.0	40.0
1400.	4.	39.9	16.7	27.1	26.2	26.2	39.9	39.9
1600.	3.	23.4	20.1	22.3	23.3	23.4	23.4	23.4
1800.	1.	41.2	41.2	41.2	41.2	41.2	41.2	41.2
2000.	2.	23.9	13.4	18.6	23.9	23.9	23.9	23.9
2200.	2.	28.9	24.5	26.7	28.9	28.9	28.9	28.9
2400.	4.	27.7	21.0	23.5	23.1	23.1	27.7	27.7
2600.	2.	18.8	16.6	17.7	18.8	18.8	18.8	18.8
2800.	1.	16.8	16.8	16.8	16.8	16.8	16.8	16.8
3000.	2.	26.8	24.3	25.6	26.8	26.8	26.8	26.8
3200.	4.	22.0	16.5	20.1	21.7	21.7	22.0	22.0
3400.	2.	19.6	16.6	18.1	19.6	19.6	19.6	19.6
3800.	1.	19.1	19.1	19.1	19.1	19.1	19.1	19.1

Notes: Depth range is from the indicated value to 200 meters less. Gradients are computed using the formula: ((bottom-hole temperature - mean annual surface temperature) / depth) * 1000. Percentiles identify the data value below which that percentage of the data falls. This is done on a case counting basis, i.e. the actual data values are not considered.

Table IV. Oil well bottom-hole temperature data for the Jackson Hole area.[1]

DEPTH (meters)	TEMPERATURE (^oC)	GRADIENT ($^oC/km$)	LOCATION[2] (Township/Range/Section)
291.	22.2	66.0	42/112/14 A
374.	37.8	92.9	42/114/1
815.	42.2	48.1	42/113/6
857.	35.6	38.0	44/112/31
1132.	29.4	23.4	43/114/9
1091.	46.7	40.0	44/113/25 B
1216.	23.3	16.7	42/112/11 C
1305.	37.2	26.2	44/111/25 D
1332.	56.1	39.9	45/113/29
1367.	37.8	25.4	44/113/13 E
1445.	36.7	23.3	42/113/24
1484.	32.8	20.1	44/111/25 D
1582.	40.0	23.4	44/112/31
1707.	73.3	41.2	43/112/34 F
1854.	27.8	13.4	42/112/14 A
1990.	50.6	23.9	43/112/34 G
2088.	63.3	28.9	44/113/25 B
2189.	56.7	24.5	44/112/31 H
2201.	52.2	22.4	43/112/34 G
2258.	65.6	27.7	44/113/25 B
2324.	56.7	23.1	43/110/15 I
2341.	52.2	21.0	43/112/34 G
2494.	50.0	18.8	43/112/34 F
2570.	45.6	16.6	42/112/14 A
2603.	46.7	16.8	42/112/11 C
2914.	81.1	26.8	44/112/31 H
2981.	75.6	24.3	44/113/13 E
3045.	53.3	16.5	42/112/11 C
3075.	70.6	22.0	43/110/15 I
3107.	65.6	20.1	43/112/34 F
3134.	71.1	21.7	43/111/6
3200.	56.1	16.6	42/112/14 A
3313.	67.8	19.6	43/112/34 F
3653.	72.8	19.1	43/113/2

[1] Data gathered from records at the Wyoming Geological Survey, 1986. Thirty-four measurements from 18 wells are listed.

[2] Letters refer to multiple bottom-hole temperature measurements within one well.

It can be generally assumed that such factors as time of year, operator error, time since circulation, and drilling fluid characteristics are random disturbances which average out when considering a large data set. However, circulation of drilling fluids is generally a systematic effect which tends to decrease rock temperature more with increasing depth. With sufficient data at all depths, anomalous gradients may be identified despite the fact that they are depressed in value (for examples see Hinckley and Heasler, 1984; Heasler and Hinckley, 1985; Buelow et al., 1986; and Hinckley and Heasler, 1987).

Given the scarcity of BHT data for the Jackson Hole area, it becomes very difficult to define equilibrium temperatures, geothermal gradients, or thermal anomalies. However, generalities may be discerned from the data as presented in Table III. The calculated gradient falls between 18 to 27 ^{o}C/km for 77 percent of the data. This range of gradient applies roughly over the depth range of 1216 meters to 3653 meters. Such a generalized gradient for the study area is similar to the background gradient for the Bighorn Basin of 29^{o}C/km based on the analysis of 2035 BHT's (Heasler and Hinckley, 1985) and the background gradient for the Wind River Basin of 28 ^{o}C/km on the analysis of 1744 BHT's (Hinckley and Heasler, 1987).

The reliability of using gradient values greater than 27 ^{o}C/km to define thermally anomalous areas cannot be adequately assessed at this time due to the scarcity of BHT data. However, as can be seen from Table IV, most of the gradients greater than 27 ^{o}C/km occur at relatively shallow depths (less than 1100 meters). Similar patterns have been observed in other Wyoming basins and do not necessarily indicate the presence of anomalous heat sources (Hinckley and Heasler, 1984; Heasler and Hinckley, 1985; Buelow et al., 1986; and Hinckley and Heasler, 1987).

One of the most valuable sources of subsurface temperature data results from precision thermal measurements in wells. During September of 1986 precision thermal measurements were made in three wells in the study area using the methodology described by Decker (1973). A calibrated thermistor probe was lowered at discrete intervals and allowed to equilibrate at each level. Temperatures measured in this manner are believed to be precise to 0.005 ^{o}C and accurate to 0.1 ^{o}C (Decker, 1973).

Shown in Figure 3 are the measured temperature-depth profiles for these three wells (locations shown on Figure 2). All three wells are water wells which had been undisturbed for many months. However, all three temperature-depth profiles show effects of convective heat transport (water flow).

The Jenny well is located near Jenny Lake Lodge in Grand Teton National Park (Figure 2) and is drilled into glacial gravels and sands. Temperatures in the Jenny well are substantially lower than in the two wells near the town of Jackson Hole. In this area, the glacial material is an unconfined aquifer recharged by surface waters with generally shallow depth of circulation (Cox, 1976).

The Jackson E1 well is located on the National Elk refuge east of the Jackson Hole hospital. Temperatures in the Jackson E1 well clearly indicate subsurface water flow as shown by the two isothermal segements from 17 to 37 meters and 37 to 58 meters. Water movement from depth is also suggested because the second isothermal segment is near 11.3 ^{o}C. This temperature is greater than could be caused by conductive heat flow or shallow circulation of groundwater.

The Jackson E2 well is located approximately 300 meters west of the Jackson E1 well. Temperatures are cooler than the Jackson E1 well with a more regular change in the geothermal gradient. However, due to the change in gradient down the hole (from 80 ^{o}C/km at 27 meters to 12 ^{o}C/km at 73 meters),

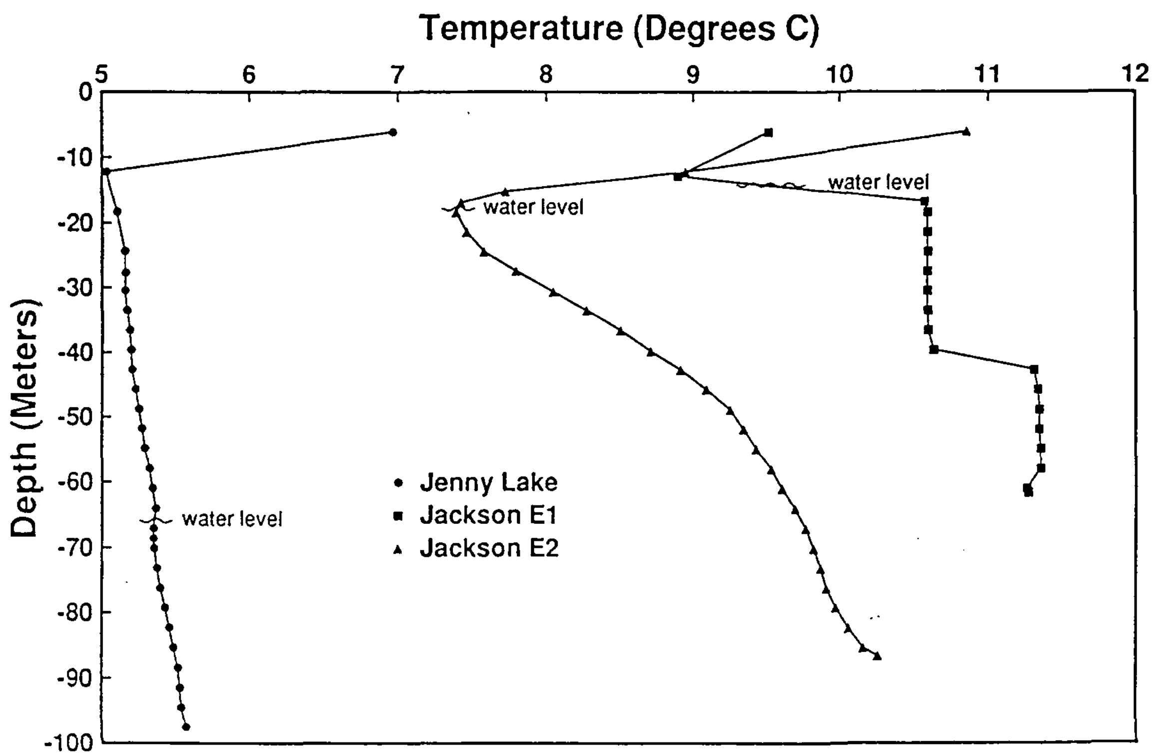


Figure 3. Measured temperature-depth profiles (September, 1986). The Jenny Lake well is located in T44N/R116W, the Jackson E1 and E2 wells are located in T41N/R116W (see Figure 2).

the temperatures in this well are also believed to be disturbed due to water movement.

Although not useful in defining conductive equilibrium temperatures or geothermal gradients, the temperature data from these three wells suggests factors which should be considered. First, data from the Jenny Lake well suggests that water temperatures in the surficial unconfined aquifer will be within a few degrees of the mean annual air temperature. Consequently, the 11.3 ^{o}C temperatures from 43 to 58 meters in the Jackson E1 well indicate that groundwater is transporting heat from a greater depth. This is consisitent with Breckenridge and Hinckley's (1978) interpretation for the origin of Teton Valley Warm Springs, Kelly Warm Springs, and Jackson Lake Hot Springs. Second, the indication of both shallow and deep water movement makes it very difficult to establish a conductive geothermal gradient from shallow well data.

HYDROLOGY

Hydrologic data has primarily been interpreted for alluvium and glacial outwash in Jackson Hole. Cox (1976) has constructed a potentiometric surface map for this unconfined aquifer, mapped approximate thickness of saturated alluvium and glacial outwash, and lists chemical anlayses and specific capacties for selected wells. Cox reports productivity from this aquifer as great as 7600 L/min and a very high transmissivity of .032 m^2/sec. This suggests that the alluvium and glacial outwash will be effective in concealing the deeper thermal structure of the basin because of the great amount of convective heat transport (water flow) which it supports.

Hydrologic data for deeper aquifers are unavailable and consequently are inferred from data collected in other basins. In the Bighorn Basin, major aquifers are the Paleozoic Madison Limestone and Tensleep Sandstone. Artesian flows up to 11400 L/min are reported for the Madison Limestone (Lowry et al., 1976). Minor aquifers may exist stratigraphically higher than these aquifers, but will not be considered in this study because they will generally have poorer aquifer characteristics than the Paleozoic aquifers and will not be as deeply buried and hence will be cooler than the Paleozoic aquifers.

THERMAL MODELING

Two types of thermal models were constructed for Jackson Hole. The first type was used to estimate the temporal thermal effects of known volcanism in the area. The second type was used to estimate the present day thermal regime along cross-sections in Jackson Hole.

Analytic Thermal Models for Intrusions

The temporal thermal effects of volcanism were estimated by considering a rectangular intrusion buried at a depth below a surface held at $0^{o}C$. The rectangular intrusion cools by conduction as described by Carslaw and Jeager (1959). The equation solved was

$$\frac{\partial^2 T}{\partial x^2} + \frac{\partial^2 T}{\partial y^2} + \frac{\partial^2 T}{\partial z^2} = \frac{1}{\kappa}\frac{\partial T}{\partial t}$$

where T represents temperature, t is time, κ is thermal diffusivity, and x, y, and z are spatial coordinates. Input parameters include size of the intrusion, depth of burial, temperature of the intrusion, thermal diffusivity of the strata, and coordinates relative to the intrusion for temperature calculation. The model then calculates the conductive thermal effect of the intrusion at the specified location.

Results of the model are sensitive to the size of the intrusion, initial temperature, and coordinates for temperature calculation. The model assumes uniform thermal properties, an initial temperature distribution of 0 ^{o}C everywhere, a constant surface temperature of 0 ^{o}C, thermal diffusivity of 32 km^2/my, heat transfer by conduction only, and no heat sources or sinks other than the intrusion.

The first application of this model is to the early to middle Miocene volcanism proposed for Jackson Hole by Barnosky (1984). During this time period from approximately 24 to 13 my ago, Barnosky believes that the volcanic vents were located along or near the Teton fault system within 25 km of Pilgrim Mountain perhaps near the northern end of Jackson Lake. Barnosky spearates the volcanism into an andesitic cycle lasting from 24 to 18 my ago and a basaltic cycle at 13 my ago.

In an effort to determine the effect of this volcanism on the present thermal regime on Jackson Hole, parameters which maximize the thermal effect of the volcanism were chosen. Model A as shown in Table V represents an intrusion which is 3 km thick by 30 km long by 12 km wide and is buried 1 km. The coordinate for temperature calculation is centered on the upper surface of the intrusion. The initial temperature of the intrusion was chosen as 1200 ^{o}C. Although such a temperature is unrealistically high for andesitic volcanism, it represents the maximum possible initial temperature. Parameters for Model B (Table V) are identical to Model A except that the intrusion is buried 10 km rather than 1 km.

As can be seen from Table V, the present day temperature increase due to Models A and B would be undetectable. If the intrusion were unrealistically enlarged (6 km thick by 60 km long by 24 km wide) then the present-day thermal effect for a 1 km burial is still undetectable (Model C in Table V). Even for

Table V. Results of cooling intrusion models for Miocene volcanism in Jackson Hole. Models A and B are 3 km thick by 30 km long by 12 km wide and are buried 1 and 10 km, respectively. Models C and D are 6 km thick by 60 km long by 24 km wide and are buried 1 and 10 km, respectively. The coordinate for temperature calculation is centered on the upper surface of the intrusion. An initial intrusion temperature of 1200°C was used. See text for discussion.

Time since Intrusion	Temperature (°C)			
(my)	Model A	Model B	Model C	Model D
0.0	600	600	600	600
0.5	24	171	86	412
1.0	7	87	352	278
1.5	3	53	19	199
2.0	2	34	12	148
2.5	1	24	8	113
3.0	1	17	6	88
3.5	0	13	4	70
4.0	0	10	3	57
4.5	0	8	3	47
5.0	0	6	2	39
5.5	0	5	2	33
6.0	0	4	1	28
6.5	0	4	1	24
7.0	0	3	1	21
7.5	0	3	1	19
8.0	0	2	1	16
5.8	0	2	1	15
9.0	0	2	1	13
9.5	0	2	1	12
10.0	0	1	0	10
10.5	0	1	0	9
11.0	0	1	0	9
11.5	0	1	0	8
12.0	0	1	0	7
12.5	0	1	0	7
13.0	0	1	0	6
13.5	0	1	0	6
14.0	0	1	0	5

the case where the intrusion is buried 10 km (Model D in Table V) the temperature increase for a point centered on the upper face of the intrusion is only 6 ^{o}C.

Models of the thermal effects of Yellowstone volcanism on Jackson Hole are difficult to constrain. First, the size and depth of the intrusive bodies responsible for the volcanism are unknown. Second, the distribution and location of the subsurface intrusive bodies in relation to Jackson Hole are also largely unknown.

As a first approximation, the size of the intrusion responsible for Yellowstone volcanism was chosen to be equal to the size of the Yellowstone caldera (40 km wide by 70 km long (Keefer, 1971; Smith and Braile, 1982)). Smith and Braile (1982) estimated that 6700 km^3 of material has been contained in Quaternary silicic eruptions from the Yellowstone region. This equates to a thickness of 2.4 km over the area of the caldera. An intrusion thickness of 10 km was used as a maximum case. The initial intrusion temperature was modeled as 1200 ^{o}C with the depth of burial being either 3 or 10 km.

Christiansen and Blank (1972) discuss three main volcanic cycles in the Yellowstone region. The oldest cycle considered is associated with the deposition of the Huckleberry Ridge Tuff at 2 my ago. The next cycle is associated with the Lava Creek Tuff deposited at .6 my ago. The final cycle is defined by rocks of the Central Plateau Member (.20 to .07 my ago).

The cross-section lines AA′ and BB′ (Figure 2) are located approximately 50 km from the southern corner of the Yellowstone caldera. Consequently, temperatures were calculated for locations 20 km and 60 km from the southern corner of the intrusion.

Model A of Table VI lists the temperature results for an intrusion that is 10 km thick by 70 km long by 40 km wide and is buried 3 km. The initial

Table VI. Results of cooling intrusion models for thermal effects of Yellowstone volcanism in Jackson Hole. Models A, B, C, and D are 10 km thick by 70 km long by 40 km wide. Models A and B are buried 3 km with the corrdinate for temperature calculation at 8 km depth and 60 and 20 km, respectively, from the corner of the intrusion. Models C and D are buried 10 km with the coordinate for temperature calculation at 15 km depth and 60 and 20 km, respectively, from the corner of the intrusion. An initial intrusion temperature of 1200°C was used. See text for discussion.

Time since Intrusion	Temperature (°C)			
(my)	Model A	Model B	Model C	Model D
0.0	0	0	0	0
0.5	0	0	0	0
1.0	0	1	0	2
1.5	0	3	0	5
2.0	0	5	0	8
2.5	0	6	0	10
3.0	0	6	0	10
3.5	0	6	0	12
4.0	0	6	0	13
4.5	0	6	0	13
5.0	0	6	0	13
5.5	0	5	0	13
6.0	0	5	0	13
6.5	0	5	0	12
7.0	0	5	0	12
7.5	0	4	0	12
8.0	0	4	0	11
8.5	0	4	0	11
9.0	0	4	0	10
9.5	0	4	0	10
10.0	0	3	0	10

temperature of the intrusion is 1200 ^{o}C and temperatures are calculated for a point located 8 km deep and 60 km from the corner of the intrusion. Model B is identical to Model A except the point for temperature calculation is only 20 km away from the edge ofthe intrusion. Model C is identical to Model A except the intrusion is buried 10 km and the depth for temperature calculation is changed to 15 km. Model D is the same as Model C except the point for temperature calculation is only 20 km from the edge of the intrusion.

As can be seen from the results in Tables V and VI, the modeled intrusions have little effect on the present thermal regime of the area studied in Jackson Hole. However, many approximations and assumptions have been used to construct these models. As additional geologic and thermal data become available, the models should be revised to incorporate such data.

Finite-difference Thermal Models for Cross-Sections

Finite-difference thermal models were constructed for two cross-sections through Jackson Hole (see Figure 2). The purpose of the models was to estimate temperatures in the Paleozoic aquifers by solving a two dimensional steady-state heat conduction and convection equation. The equation solved was

$$\frac{\partial K_x \frac{\partial T}{\partial x}}{\partial x} + \frac{\partial K_y \frac{\partial T}{\partial y}}{\partial y} + \rho c \left(V_x \frac{\partial T}{\partial x} + V_y \frac{\partial T}{\partial y} \right) = 0$$

where T represents temperature, K_x and K_y are the thermal conductivity of the fluid-saturated rock in the horizontal and vertical directions, V_x and V_y are the Darcian velocities of the groundwater in the horizontal and vertical directions, ρ is the density of the water, and c is the specific heat of water. This equation was solved using a Gauss-Sidel iterative method similar to that described by Kilty and Chapman (1980).

Input data for the models include the thermal conductivity of strata, the structure (geometry) of the area, approximate mean annual ground temperature, regional heat flow values, Darcian velocity of groundwater and the spacing between node points for temperature calculation. The model uses this data to calculate a temperature at every node point.

The geometry used for cross-section AA′ is shown in Figure 4. This cross-section was taken from the U.S. Geological Survey's map of Grand Teton National Park (1968). The grid spacing used was 150 m vertically between nodes and 250 m horizontally between nodes. This resulted in temperatures being calculated for 9211 node points over a cross-sectional depth of 9 km and a length of 37.5 km.

Thermal conductivities were assigned to the rock units shown in Figure 4 based upon measurements in other Wyoming Basins (Heasler, 1978) and estimates considering rock lithologies (see Table I). The most poorly constrained thermal conductivity was that assigned to the upper Tertiary. To test the sensitivity of the model to the thermal conductivity of this unit, Tertiary thermal conductivity values were changed from 1.8 to 3.4 W/mK (Watts / meter Kelvin). The results of these calculations are shown in Figure 5 for a location where the Paleozoic section is deepest (16 km from the west side of the model shown in Figure 4). The maximum temperatures predicted at the base of the Paleozoic section differs only by 14 ^oC (169 ^oC for a thermal conductivity of 1.8 W/mK verses 155 ^oC for a thermal conductivity of 3.4 W/mK). Using the lithologic description of the Upper Tertiary given by Love (in Behrendt et al., 1968), a estimated thermal conductivity of 2.5 W/mK was used in subsequent models.

No heat flow data exist for Jackson Hole. Nearby heat flow values range from a low of 54 mW/m^2 (milliWatts / $meter^2$) 150 km to the southeast in the

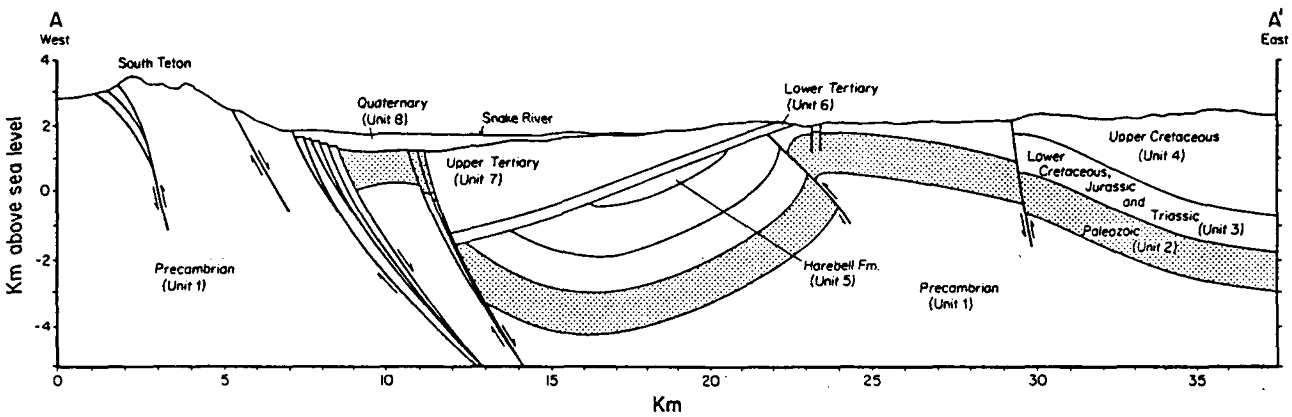


Figure 4. Geologic cross section AA' taken from the U. S. Geological Survey's map of Grand Teton National Park (1968). Unit refers to thermal conductivity values used in the finite difference thermal models (Table I). See text for discussion.

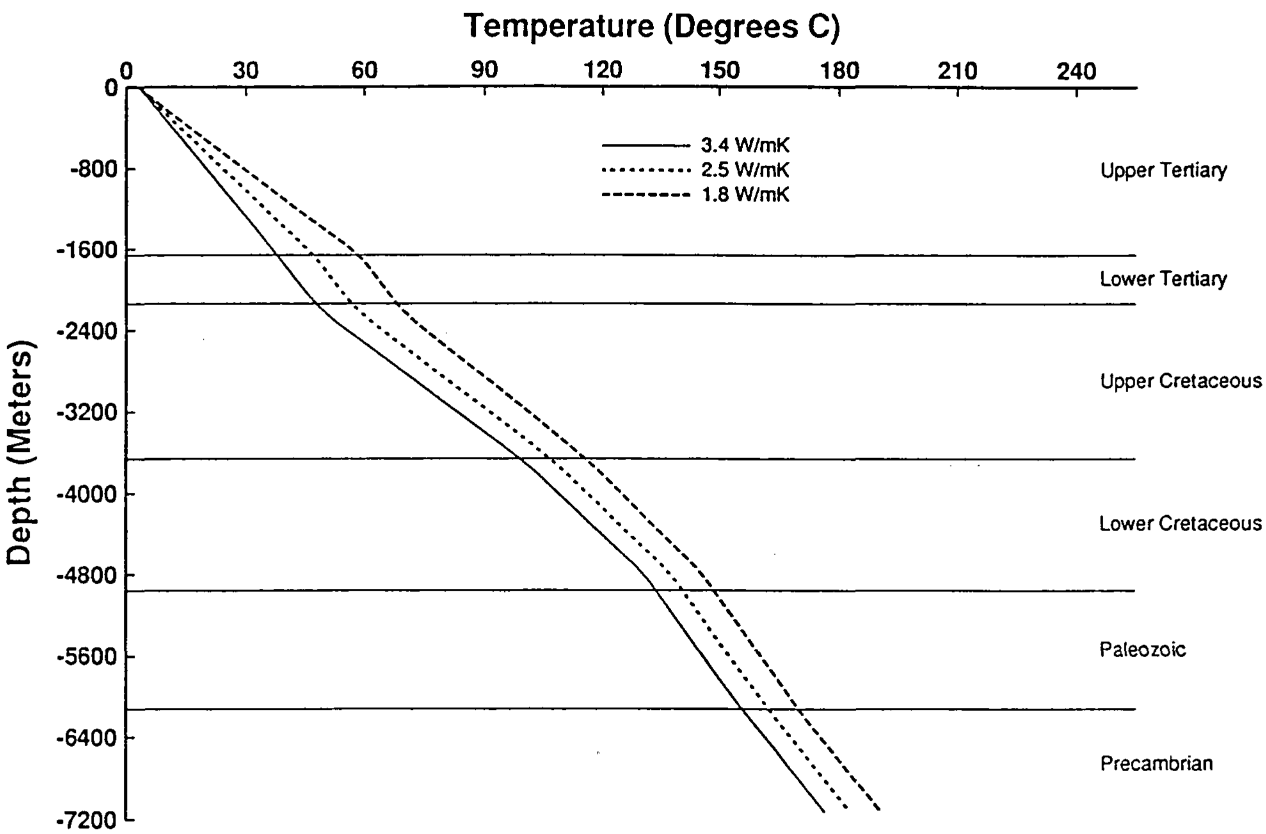


Figure 5. Calculated temperature profiles for three thermal conductivity values for the upper Tertiary. Location for temperature profiles is 16 km from the west boundary of the cross section shown in Figure 4. A heat flow value of 67 mW/m^2 was used in the calculations.

Wind River Range (Sass et al., 1971) to a value of over 100 mW/m^2 as measured in the southeast arm of Yellowstone Lake (Morgan et al., 1977). Heasler et al. (1983) summarize published heat flow data for the area around Jackson Hole and Wyoming. A heat flow value of 67 mW/m^2 has been used to model geothermal systems in the Bighorn Basin (Heasler and Hinckley, 1985) as well as the Wind River Basin (Hinckley and Heasler, 1987). Thus, heat flow values of 50, 67, 75, and 100 mW/m^2 were input into the model for cross-section AA′.

Results of varying the heat flow are shown in Figure 6 for the location where the Paleozoic aquifers are deepest (16 km from the west side of the model shown in Figure 4). The maximum temperatures predicted for the Paleozoic section varies by 100 ^{o}C. However, it is important to note that even for the lowest heat flow value, the Paleozoic section is at a temperature of 108 to 122 ^{o}C. These temperatures are greater than any reported thermal spring temperature in Jackson Hole.

Modeled results for the four cases of varying heat flow are shown as temperature cross-sections in Figures 7A through 7D. The effects of thermal refraction due to variations in thermal conductivity and structural geometry are shown in these figures. Also shown are the steady-state conductive temperatures associated with the Paleozoic aquifers. Note that in all four cases of varying heat flow, the Paleozoic section in the deepest portion of Jackson Hole is substantially warmer than the highest reported thermal spring temperature (72 ^{o}C for Jackson Lake Hot Springs)

Given the modeled results as shown in Figure 7, BHT analyses as listed in Tables III and IV, and familiarity with geothermal studies in nearby basins (Heasler and Hinckley, 1985; Hinckley and Heasler, 1987), a heat flow value of 67 mW/m^2 is chosen as being the most reasonable value. It will be important in further studies to more precisely determine heat flow values for the

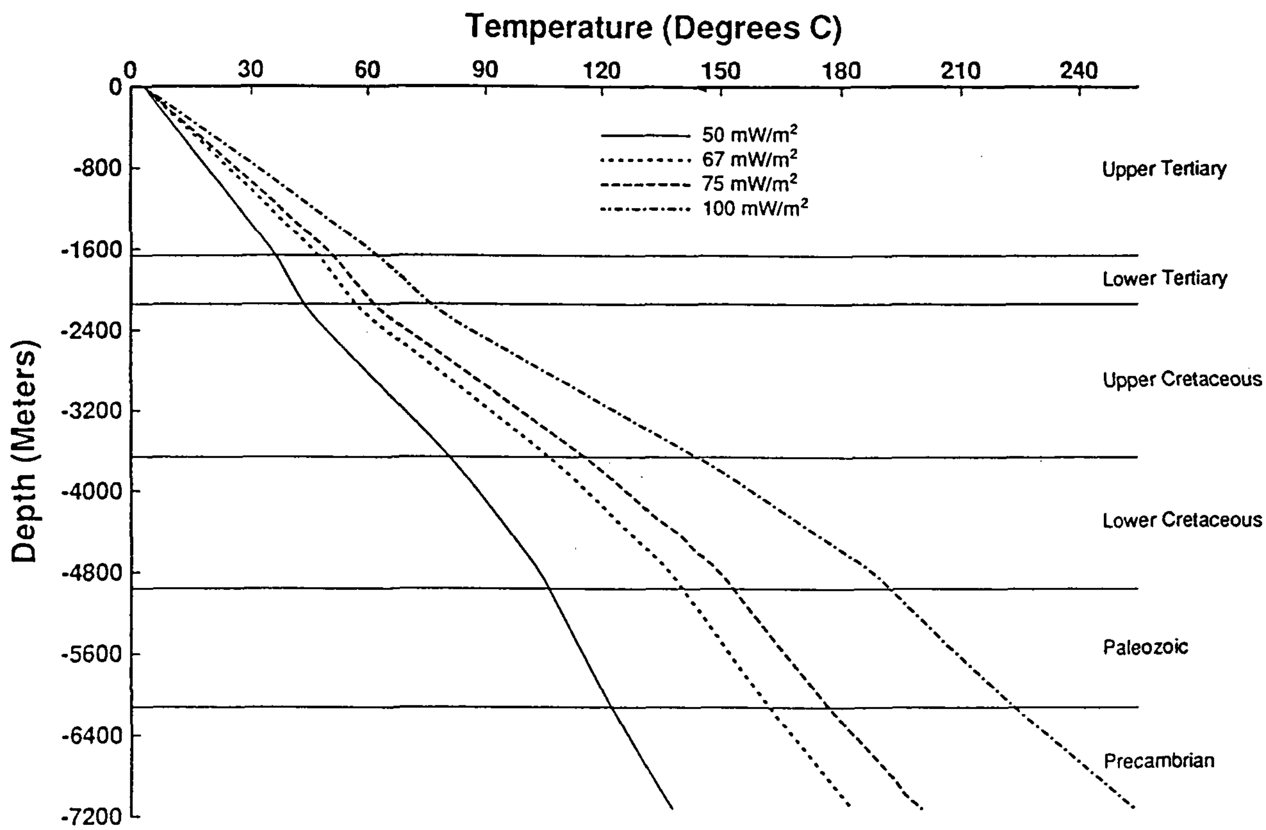


Figure 6. Calculated temperature profiles for four heat flow values. Location for the temperature profiles is 16 km from the west boundary of the cross section shown in Figure 4. Thermal conductivities used for the calculations are listed in Table I.

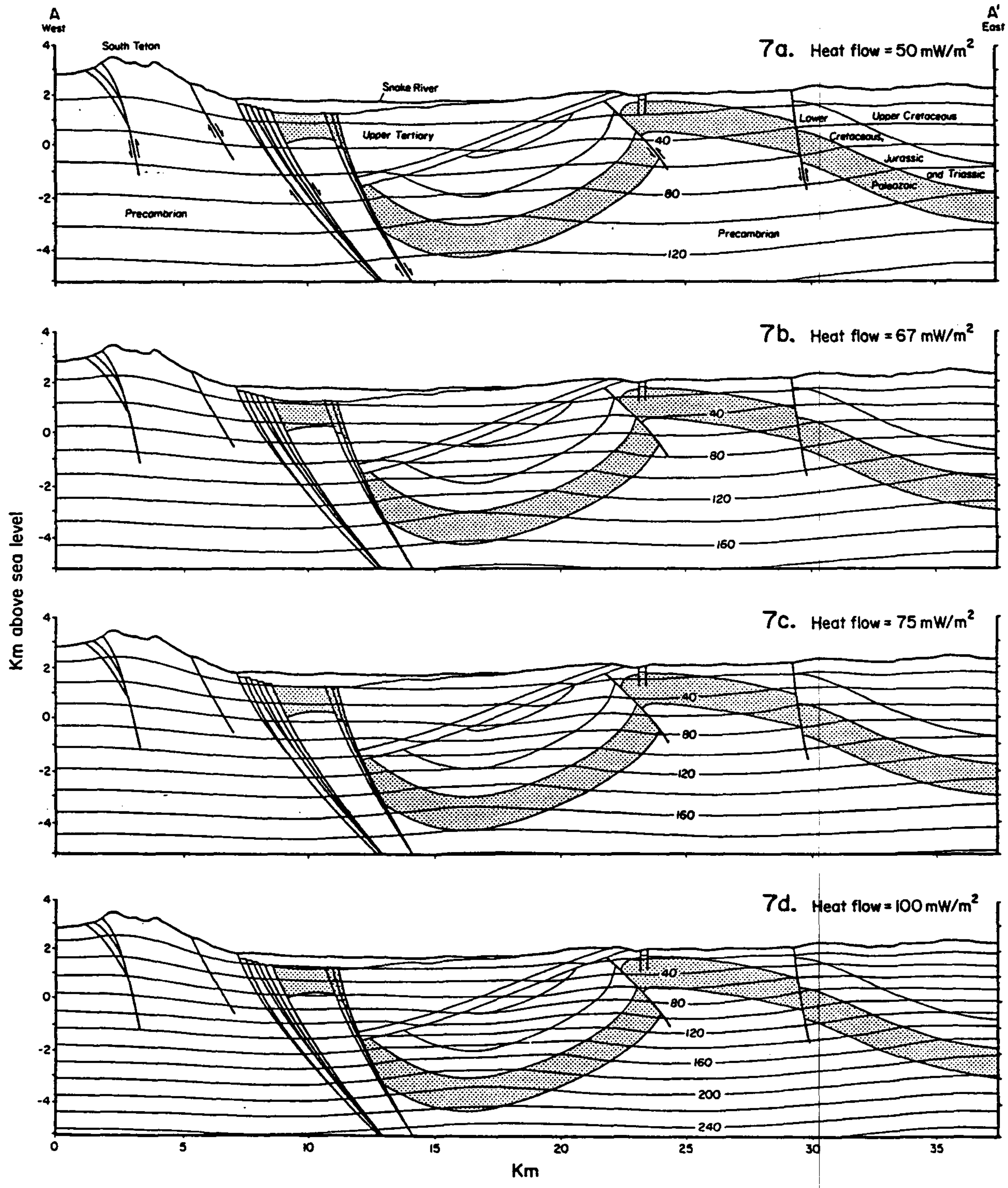


Figure 7. Calculated temperatures for cross section AA' (Figures 2 and 4) for four heat flow values. Thermal conductivities used are listed in Table I. See text for discussion.

Jackson Hole area.

In order to estimate the steady-state, two-dimensional thermal effects of forced convective heat transport using the method of Kilty and Chapman (1980), the mass flux (Darcian flow) of the water contained within the Paleozoic section must be estimated. As discussed in the section on hydrology, hydrologic data for aquifers in Jackson Hole are sparse. Consequently, at this time only very general constraints can be placed on the Darcian flow.

Darcey's law was used to estimate reasonable values for the Darcian velocity. In one form of Darcey's law

$$v = \frac{-T}{b} \frac{dh}{dl}$$

where v is Darcian velocity (also termed specific discharge), T is transmissivity, dh/dl is hydraulic gradient, and b is saturated aquifer thickness.

For the northeastern Bighorn Basin, Huntoon (1985) lists Madison Limestone transmissivities of 2.7×10^{-6} to 6.9×10^{-4} m^2/sec. Heasler (1982) shows hydraulic gradients for the northwestern Bighorn Basin of 2.3 to 31.6 m/km. If an aquifer thickness of 1 km is assumed, then Darcian velocities calculated using these parameters range from 6.4×10^{-12} to 2.2×10^{-8} m/sec.

The Darcian velocity could approach zero m/sec as a lowest limit. For such a case, the thermal regime would be purely conductive as modeled in Figures 7A through 7D and Figure 8A. An reasonable upper limit to the Darcian velocity is more difficult to define. Huntoon (1985) believes that the high transmissivity values reported for the Madison Limestone are only applicable to basin margins. He believes that in the deeper centers of basins, hydraulic transmissivities are much less than those reported for basin margins.

Consequently, the Darcian velocity estimate of 2.2×10^{-8} m/sec which was calculated using a high transmissivity value of 6.9×10^{-4} m^2/sec and a large hydraulic gradient of 31.6 m/km is perhaps orders of magnitude too great. Lacking additional constraints, a Darcian velocity of 10^{-9} m/sec was used as a maximum value.

Data from cross-section BB′ (Figure 2) were used to estimate the combined effects of heat conduction and convection. Figure 8 (taken from Figure 7 in Behrendt et al., 1968) shows the structural geometry used in the model. Temperatures were calculated every 500 m horizontally and 200 m vertically for 3914 node points over a cross-sectional depth of 7.4 km and a length of 51 km. Because Behrendt et al. (1968, their Figure 7) separate the geologic units differently than shown in Figures 4 and 7, the thermal conductivity values used to model Figure 8 were chosen to roughly correspond to those listed in Table I. A single heat flow value of 67 mW/m^2 is used.

Figure 8A shows the results of modeling cross-section BB′ when there is no water flow (a Darcian velocity of zero). Note that the maximum temperature of the Paleozoic section is similar to that shown in Figure 7B.

Figure 8B shows the temperature disturbance caused by the maximum Darcian velocity (10^{-9} m/sec). The Paleozoic section still attains temperatures of near 100°C even with this large volume of water flow.

The temperature structure shown along the fault system in Figure 8A is highly speculative. This is for two main reasons. First, hydrologic properties of the fault (transmissivity, saturated thickness, hydraulic gradient) are unknown. Second, the nature of heat transfer near the surface is ill-defined. Whether the heated water travels to the surface and cools by Newton's law or whether the heated water flows into the surficial Quaternary aquifers and cools by mixing and conduction will significantly effect the

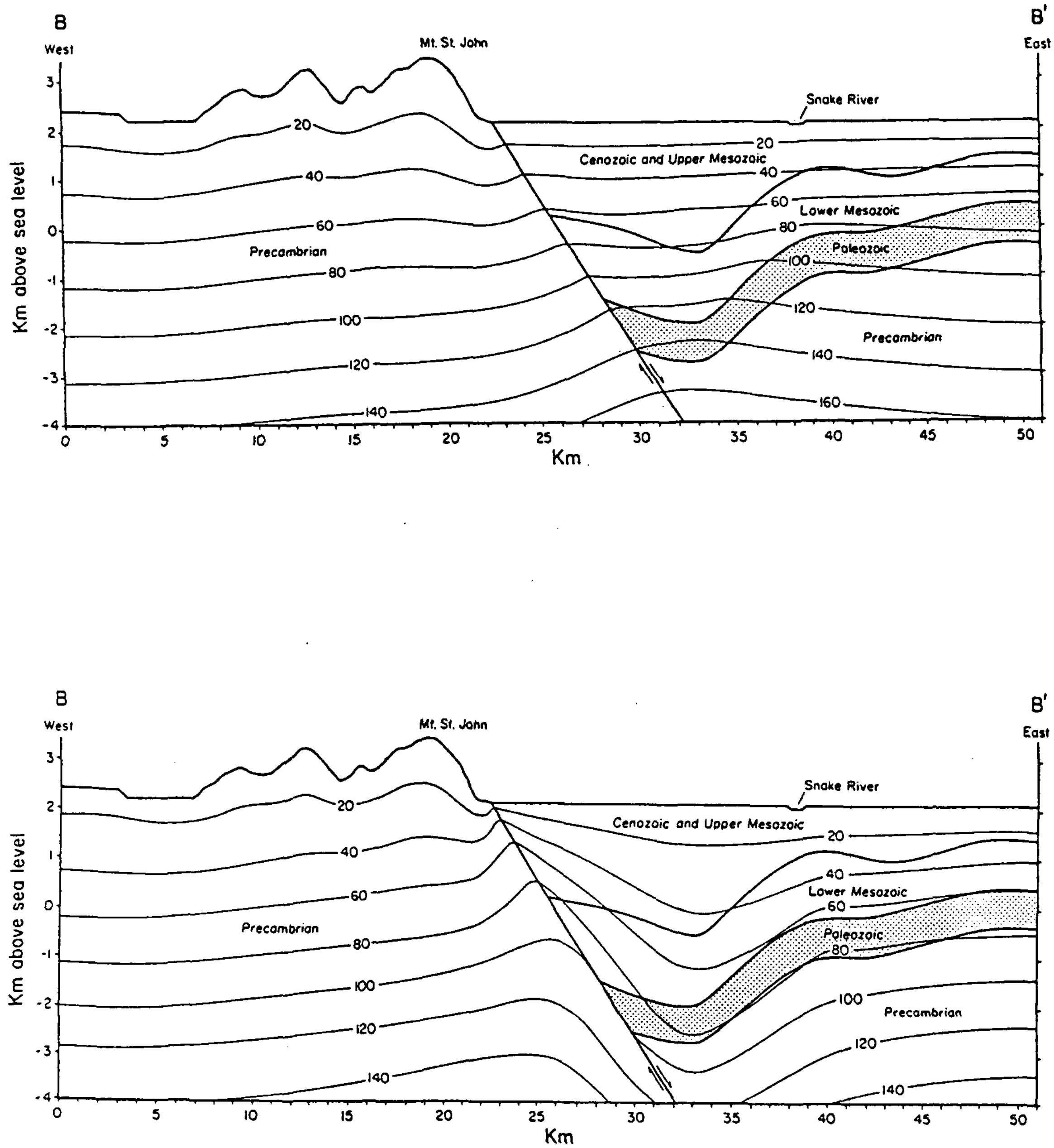


Figure 8. Calculated temperatures along cross section BB' (Figure 2). Geology taken from Figure 7 in Behrendt et al. (1968). In Figure 8A (upper cross section) there is no water flow. Figure 8B (lower cross section) includes the effect of water flow in the Paleozoic section and up the Teton fault. See text for discussion.

modeled temperature structure along the fault.

CONCLUSION

The results of the thermal models for cross-sections AA′ and BB′ indicate that the temperatures of the deepest Paleozoic section in Jackson Hole are greater than observed hot springs temperatures. Since Jackson Lake Hot Springs, Teton Valley Warm Springs, Kelly Warm Springs, and perhaps Abercrombie Warm Springs may all be sourced from Paleozoic aquifers (Breckenridge and Hinckley, 1978), the heating mechanism for the thermal spring waters appears to be deep circulation of groundwater. Such a heating mechanism is similar to other geothermal systems in Wyoming associated with thermal springs (Hinckley et al., 1982; Heasler, 1982).

Maximum temperatures of water contained in the Paleozoic aquifers are poorly defined. This is due to uncertainty in the heat flow (Figures 7A to 7D), thermal conductivities (Figure 5), and Darcian velocity of the Paleozoic groundwater (Figures 8A and 8B). Modeled Paleozoic temperatures range from over 220 ^{o}C (Figure 7D) to 100 ^{o}C (Figure 8B).

Other important unknown factors include hydrologic data for both the Paleozoic aquifers and the Teton fault system. The validity of the proposed mechanism of groundwater heating (deep circulation) is linked directly to the water-bearing properties of the deeply buried Paleozoic section and the nature of water flow up the Teton fault system.

Given the assumptions delineated in this report, the observed thermal spring temperatures, and the numerical model results, the possibility of high temperature heat sources in the Jackson Hole study area is unlikely. The possibility for high temperature heat sources greatly increases nearer Yellowstone National Park due to recent igneous activity.

Additional study is warranted in Jackson Hole for more concise definition of the thermal and tectonic evolution of the area. Much needed data should be collected on the heat flow of the region, thermal conductivities of strata, rock temperatures, geochemistry, and hydrology. The collection of such additional data will greatly reduce the uncertainties associated with modeling maximum temperatures of the geothermal regime.

ACKNOWLEDGMENTS

I greatly appreciate the cooperation of the National Park Service (Roger Haney and Curt Mossestad) and the Town of Jackson Hole (Mel Webb, Bob McLaurin, and Mike Yokel) for helping me locate and measure the three wells described in this report. J. Good helped with my understanding of the surface aquifers in Jackson Hole. Dr. J.D. Love is thanked for use of his unpublished data on Jackson Lake Hot Springs and his willingness to discuss geologic constraints for the thermal models. This research was funded by the U.S. Department of Energy, Division of Geothermal Energy, Contract Number DE-FG07-85ID12607.

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Rec 5/4/87
HPR

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

April, 30, 1987

Dr. Howard P. Ross
Earth Science Laboratory
University of Utah Research Institute
391 Chipeta Way
Suite C
Salt Lake City, UT 84108

Dear Howard:

Enclosed is one copy of the final report for Contract Number DE-FG07-85ID12607. Eleven copies plus one camera ready copy have been sent to DOE in Idaho Falls. The final Financial Status Report was mailed to DOE on April 23, 1987.

I wish to thank you for your timely review of the draft final report for this project. The quality of the final report was improved by incorporating your suggestions.

If you have additional questions or comments on the project, please contact me.

Sincerely,

Henry P. Heasler

Henry P. Heasler
Temporary Assistant Professor

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

Rec 4/13/87 HPR

April, 7, 1987

Dr. Howard P. Ross
Earth Science Laboratory
University of Utah Research Institute
391 Chipeta Way
Suite C
Salt Lake City, UT 84108

Dear Howard:

Enclosed is a draft of the final report for Contract Number DE-FG07-85ID12607.

Some of the figures for the report are presently being redrafted. Consequently, in order to send the report to you I have included rough diagrams of some figures. The remaining figures will be mailed to you as they are completed.

I hope this is acceptable.

Sincerely,

Henry Heasler

Henry P. Heasler
Temporary Assistant Professor

WYOMING $

Voucher	1 $	2 Σ $	3 $ avail	4 $ left	5 billed thru	6 comments	7	8 updated	9	
1	1000	1000	17,595	16,595	10-31-85			11-14-85		
2ND #1 ~~2~~								$9,000 request on hold -		
2 ~~3~~	6000	7000		10,595	2-28-86	revised #2,	start 11-01-85	revised ESL 2-26-86		
3 ~~4~~	1000	8000		9,595	4-30-86					
4 ~~5~~	2000	10000		7,595	5-31-86					
5 ~~6~~	3000	13000		4,595	6-30-86			@ID June 23 '86		
6 ~~7~~	2000	15,000		2,595				@ID Oct. 6 '86		
7 ~~8~~	1000.	16,000		1,595			ok 10/28/86	@ID Oct. 28 '86; Hold until	remainder report rec.	
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8 ~~10~~	1,595.	17,595		0	10-16-87 FINAL		ok	[illegible] 9/13/87.		✓
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d. Application/proposal dated 1/9/87, XX as submitted ☐ with changes as negotiated

19. REMARKS

This document is a no-cost time extension to allow Participant to complete project reports. Only costs for report completion will be allowed from 1/31/87 to 4/30/87.

20. EVIDENCE OF RECIPIENT ACCEPTANCE

(Signature of Authorized Recipient Official) (Date)

(Name)

(Title)

21. AWARDED BY

William C. Drake 1/29/87

(Signature) (Date)

William C. Drake

(Name)

Contracting Officer

(Title)

Rec 01/12/87

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

January 9, 1987

Mr. R. A. King, CMD
U. S. Department of Energy
Idaho Operations Office
785 DOE Place
Idaho Falls, ID 83402

Dear Mr. King:

I am requesting a no-cost extension for Project DE-FC07-85ID12607 through April 30, 1987. During the last month I have been ill and consequently unable to finish the final report. An April completion date will allow DOE a full 45 day review period for the final report.

Thank you for your consideration in this matter.

Sincerely,

Henry P. Heasler

Henry P. Heasler

cc Howard Ross, Peggy Brookshier

(See Instructions on Reverse)

Under the authority of Public Law 93-410 and subject to legislation, regulations and policies applicable to (cite legislative program title): Geothermal RD&D Act of 1977

1. PROJECT TITLE Geothermal Studies in the Jackson Hole Area, Wyoming	2. INSTRUMENT TYPE [X] GRANT [ ] COOPERATIVE AGREEMENT
3. RECIPIENT (Name, address, zip code, area code and telephone no.) University of Wyoming Department of Geology & Geophysics Laramie, Wyoming 82071	4. INSTRUMENT NO. DE-FG07-85ID12607 5. AMENDMENT NO. M001 6. BUDGET PERIOD FROM 9/30/86 THRU 12/31/86 7. PROJECT PERIOD FROM 7/30/85 THRU 12/31/86
8. RECIPIENT PROJECT DIRECTOR (Name and telephone No.) Henry P. Heasler (307) 766-3386	10. TYPE OF AWARD [ ] NEW [ ] CONTINUATION [ ] RENEWAL [X] REVISION [ ] SUPPLEMENT
9. RECIPIENT BUSINESS OFFICER (Name and telephone No.)	12. ADMINISTERED FOR DOE BY (Name, address, zip code, telephone No.) Ronald A. King (208) 526-0790 U. S. DOE Idaho Operations Office 785 DOE Place Idaho Falls, ID 83402
11. DOE PROJECT OFFICER (Name, address, zip code, telephone No.) Peggy Brookshier (208) 526-1403 U. S. DOE Idaho Operations Office 785 DOE Place, Idaho Falls, ID 83402	

13. RECIPIENT TYPE

[ ] STATE GOV'T [ ] INDIAN TRIBAL GOV'T [ ] HOSPITAL [ ] FOR PROFIT ORGANIZATION [ ] INDIVIDUAL

[ ] LOCAL GOV'T [X] INSTITUTION OF HIGHER EDUCATION [ ] OTHER NONPROFIT ORGANIZATION [ ] C [ ] P [ ] SP [ ] OTHER (Specify)

14. ACCOUNTING AND APPROPRIATIONS DATA

a. Appropriation Symbol	b. B & R Number	c. FT/AFP/OC	d. CFA Number	15. EMPLOYER I.D. NUMBER/SSN
N/A				

16. BUDGET AND FUNDING INFORMATION

a. CURRENT BUDGET PERIOD INFORMATION		b. CUMULATIVE DOE OBLIGATIONS	
(1) DOE Funds Obligated This Action	$ -0-	(1) This Budget Period (Total of lines a.(1) and a.(3))	$ 17,595
(2) DOE Funds Authorized for Carry Over	$ 4,595	(2) Prior Budget Periods	$ -0-
(3) DOE Funds Previously Obligated in this Budget Period	$ 17,595	(3) Project Period to Date (Total of lines b. (1) and b. (2))	$ 17,595
(4) DOE Share of Total Approved Budget	$ 17,595		
(5) Recipient Share of Total Approved Budget	$ -0-		
(6) Total Approved Budget	$ 17,595		

17. TOTAL ESTIMATED COST OF PROJECT $

(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) N/A (Date)

c. DOE Assistance Regulations, 10 CFR Part 600, as amended, Subparts A and [ ] B (Grants) or [ ] C (Cooperative Agreements)

d. Application/proposal dated 8/13/86, [X] as submitted [ ] with changes as negotiated

19. REMARKS

This modification revises the budget and project period with no increase in the budget or obligated funds. Revision as attached.

20. EVIDENCE OF RECIPIENT ACCEPTANCE	21. AWARDED BY
(Signature of Authorized Recipient Official) (Date)	William C. Drake 8/22/86 (Signature) (Date)
(Name)	William C. Drake (Name)
(Title)	Contracting Officer (Title)

1. SPECIAL TERMS AND CONDITIONS FOR RESEARCH GRANTS,

   Paragraph 4. Project Completion Date, is revised to read as follows:

   > The project completion date is December 31, 1986, which includes an additional 90 days for completion of the final report. All research effort must be completed by September 30, 1986. Only costs associated with preparation of the final report will be allowed during the 90 days from September 30, through December 31, 1986.

FEDERAL ASSISTANCE BUDGET INFORMATION FORM

FORM EIA 459C
(10/80)

FORM APPROVED
OMB No 1900-0127

1. Program/Project Identification No. DE-FG07-85ID12607	2. Program/Project Title Geothermal Studies in the Jackson Hole Area, WY.
3. Name and Address University of Wyoming Department of Geology and Geophysics, Larmie, WY 82071	4. Program/Project Start Date 9/30/86 5. Completion Date 12/31/86

SECTION A - BUDGET SUMMARY

Grant Program, Function or Activity (a)	Federal Catalog No (b)	Estimated Unobligated Funds		Carryover ~~XXXXXXXXXX~~ FY86/87		
		Federal (c)	Non-Federal (d)	Federal (e)	Non-Federal (f)	Total (g)
1 12607		$	$	$	$	$ 4,595
2						
3						
4						
5 TOTALS		$	$	$	$	$ 4,595

SECTION B - BUDGET CATEGORIES

6 Object Class Categories	Carryover - Grant Program, Function or Activity				Total (5)
	(1) FY86/87	(2)	(3)	(4)	
a Personnel (includes F.B)	$ 3,404	$	$	$	$3,404
b Fringe Benefits					
c Travel	115				115
d Equipment					
e Supplies					
f Contractual					
g Construction					
h. Other	127				127
i. Total Direct Charges					
j Indirect Charges	949				949
k TOTALS	$4,595	$	$	$	$4,595
7 Program Income	$	$	$	$	$

DOE F 4600.1
(7-81)

U.S. DEPARTMENT OF ENERGY

NOTICE OF FINANCIAL ASSISTANCE AWARD

(See Instructions on Reverse)

Duncan Foley

Under the authority of Public Law 93-410 and subject to legislation, regulations and policies applicable to *(cite legislative program title)*:
Geothermal RD&D Act of 1977

1. PROJECT TITLE
Geothermal Studies in the Jackson Hole Area Wyoming

2. INSTRUMENT TYPE
☒ GRANT ☐ COOPERATIVE AGREEMENT

3. RECIPIENT *(Name, address, zip code, area code and telephone no.)*
University of Wyoming
Department of Geology & Geophysics
Laramie, WY 82071

4. INSTRUMENT NO. DE-FG07-85ID12607

5. AMENDMENT NO. 0

6. BUDGET PERIOD FROM: 7/30/85 THRU: 9/30/86

7. PROJECT PERIOD FROM: 9/30/85 THRU: 9/30/86

8. RECIPIENT PROJECT DIRECTOR *(Name and telephone No.)*
Henry P. Heasler (307) 766-3386

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.)*
Peggy A. M. Brookshier (208) 526-1403
785 DOE Place
Idaho Operations Office, Idaho Falls, ID 83402

12. ADMINISTERED FOR DOE BY *(Name, address, zip code, telephone No.)*
Ronald A. King (208) 526-0790
Idaho Operations Office
785 DOE Place
Idaho Falls, ID 83402

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
89X0224-91	AM1510000	ID-54-91/250	

15. EMPLOYER I.D. NUMBER/SSN

16. BUDGET AND FUNDING INFORMATION

a. CURRENT BUDGET PERIOD INFORMATION	
(1) DOE Funds Obligated This Action	$ 17,595
(2) DOE Funds Authorized for Carry Over	$ -
(3) DOE Funds Previously Obligated in this Budget Period	$ -
(4) DOE Share of Total Approved Budget	$ 17,595
(5) Recipient Share of Total Approved Budget	$ -
(6) Total Approved Budget	$ 17,595

b. CUMULATIVE DOE OBLIGATIONS	
(1) This Budget Period *[Total of lines a.(1) and a.(3)]*	$ 17,595
(2) Prior Budget Periods	$ -0-
(3) Project Period to Date *[Total of lines b. (1) and b. (2)]*	$ 17,595

17. TOTAL ESTIMATED COST OF PROJECT $

(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)* N/A *(Date)*

c. DOE Assistance Regulations, 10 CFR Part 600, as amended, Subparts A and ☒ B (Grants) or ☐ C (Cooperative Agreements).

d. Application/proposal dated 2/8/85, ☐ as submitted ☒ with changes as negotiated

19. REMARKS
This Grant consists of this NFAA, the Budget Plan, the Statement of Work, Special Terms and Conditions for Research Grants, General Terms and Conditions for Research Grants, 10 CFR Part 600, DOE Order 1332.2, and OMB Circulars A-110 and A-21.

20. EVIDENCE OF RECIPIENT ACCEPTANCE
James E. Todd 10/10/85
(Signature of Authorized Recipient Official) *(Date)*
James E. Todd
(Name)
Vice President for Finance
(Title)

21. AWARDED BY
William C Drake 9/27/85
(Signature) *(Date)*
William C. Drake
(Name)
Contracting Officer
(Title)

BUDGET PLAN

Grantee: University of Wyoming

Direct Labor (including F.B.)	$ 9,900
Computer Time	1,500
Travel - Domestic	600
Other	658
Indirect Costs	4,937
Total	$17,595

STATEMENT OF WORK

UNIVERSITY OF WYOMING, DEPT. GEOLOGY AND GEOPHYSICS

The purpose of these geothermal energy investigations will be accomplished by performing the following tasks in the greater Jackson Hole area:

Task 1. Compile existing data, including hydrologic information, subsurface temperatures, general geology, thermal spring (temperature, flow, water chemistry, and appropriate other information) data, tectonic history, thermal conductivity data, and heat flow information.

Task 2. Add appropriate new data, which will be gathered during one field trip.

Task 3. Using existing and new data, develop a finite difference numerical model of the thermal regime in the Jackson Hole area.

Task 4. Prepare a final report, which will include all data gathered during Tasks 1 and 2, and documentation, and results of the model. Interpretations of the model in terms of hydrologic circulation and the nature and temperature of the heat source for the thermal springs will be made.

Task 5. Provide overall project management and complete and report on tasks in a timely manner. Management reports shall be provided as defined by the attached DOE Form EIA 459A - Reporting Requirements Checklist. The required reports are also summarized as follows:

	REPORT	DUE
(1)	Form DOE 538 Notice of Energy RD&D	30 days after award of grant
(2)	Quarterly Management Summary Report	15 days after calendar quarter end
(3)	Project Status Report	15 days after calendar quarter end
(4)	Final Report (Draft)	Due 45 days prior to completion date
(5)	Final report	Due on completion date
(6)	Financial Status Report - OMB Form 269	Due annually and upon completion

The deliverables resulting from the tasks outlined above which will be delivered to DOE are summarized as follows:

1. The Final report--one camera-ready copy plus twelve additional copies--will be distributed as specified in the attached DOE Form EIA 459A.

2. Reports previously described under Task 5 above will be prepared and issued in the amounts and at the frequency shown.

U.S. DEPARTMENT OF ENERGY

FEDERAL ASSISTANCE REPORTING CHECKLIST

FORM EIA-459A (10/80)

FORM APPROVED OMB NO. 1900-0127

1. Identification Number: DE-FG07-85ID12607

2. Program/Project Title: Geothermal Studies in the Jackson, Wy. area.

3. Recipient: University of Wyoming

4. Reporting Requirements:

PROGRAM/PROJECT MANAGEMENT REPORTING	Frequency	No. of Copies	Addressees
[ ] Federal Assistance Milestone Plan			
[ ] Federal Assistance Budget Information Form			
[X] Federal Assistance Management Summary Report	Q		A,B,C
[X] Federal Assistance Program/Project Status Report	Q		A,B,D
[X] Financial Status Report, OMB Form 269	Y,F		A,C
TECHNICAL INFORMATION REPORTING			
[X] Notice of Energy RD&D	Y		A,E
[ ] Technical Progress Report			
[X] Topical Report	A*		A,B,D
[X] Final Technical Report	F*		A,B,D

FREQUENCY CODES AND DUE DATES:

- A - As Necessary; within 5 calendar days after events.
- F - Final; 90 calendar days after the performance of the effort ends.
- Q - Quarterly; within 30 days after end of calendar quarter or portion thereof.
- O - One time after project starts; within 30 days after award.
- X - Required with proposals or with the application or with significant planning changes.
- Y - Yearly; 30 days after the end of program year. (Financial Status Reports 90 days).
- S - Semiannually; within 30 days after end of program fiscal half year.

5. Special Instructions:

*Draft copy due 45 days prior to completion date.
One camera-ready copy of final report should be included.

6. Prepared by: (Signature and Date)

7. Reviewed by: (Signature and Date)

REPORT DISTRIBUTION LIST

U. S. Department of Energy
Idaho Operations Office
785 DOE Place
Idaho Falls, ID 83402

A. ATTN: R. A. King, CMD

B. ATTN: P. A. Brookshier, ATD

C. ATTN: E. G. Jones, FMD

D. University of Utah Research Institute
Earth Science Laboratory
391 Chipeta Way, Suite A
Salt Lake City, UT 84108
ATTN: Duncan Foley

E. U. S. DOE
Technical Information Center
P. O. Box 62
Oak Ridge, TN 37830

W40

ASSURANCES

The Applicant hereby assures that it will comply with the regulations, policies, guidelines and requirements, including the applicable OMB Circulars as they relate to the application, acceptance and use of Federal funds for this federally-assisted project. Also the Applicant assures and certfies that:

1. It possesses legal authority to apply for the grant; that a resolution, motion or similar action has been duly adopted or passed as an official act of the applicant's governing body, authorizing the filing of the application including all understandings and assurances contained therein, and directing and authorizing the person identified as the official representative of the applicant to act in connection with the application and to provide such additional information as may be required.

2. It will comply with Title VI of the Civil Rights Act of 1964 (P.L. 88-352) and in accordance with Title VI of that Act, 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 otherwise subjected to discrimination under any program or activity for which the applicant receives Federal financial assistance and will immediately take any measures necessary to effectuate this agreement.

3. It will comply with Title VI of the Civil Rights Act of 1964 (42 USC 2000d) prohibiting employment discrimination where (1) the primary purpose of a grant is to provide employment or (2) discriminatory employment practices will result in unequal treatment of persons who are or should be benefiting from the grant-aided activity.

4. It will comply with requirements of the provisions of the uniform Relocation Assistance and Real Property Acquisitions Act of 1970 (P.L. 91-646) which provides for fair and equitable treatment of persons displaced as a result of Federal and federally assisted programs.

5. It will comply with the provisions of the Hatch Act which limit the political activity of employees.

6. It will comply with the minimum wage and maximum hours provisions of the Federal Fair Labor Standards Act, as they apply to hospital and educational institution employees of State and local governings.

7. It will establish safeguards to prohibit emmployees from using their positions for a purpose that is or gives the appearance of being motivated by a desire for private gain for themselves or others, particularly those with whom they have family, business, or other ties.

8. It will give the sponsoring agency or the Comptroller General through any authorized representative the access to and the right to examine all records, books, papers, or documents related to the grant.

9. It will comply with all requirements imposed by the Federal sponsoring agency concerning special requirements of law, program requirements, and other administrative requirements.

10. It will insure that the facilities under its ownership, lease or supervision which shall be utilized in the accomplishment of the project are not listed on the Environmental Protection Agency's (EPA) list of Violating Facilities and that it will notify the Federal grantor agency of the receipt of any communication from the Director of the EPA Office of Federal Activities indicating that a facility to be used in the project is under consideration for listing by the EPA.

11. It will comply with the flood insurance purchase requirements of Section 102(a) of the Flood Disaster Protection Act of 1973, Public Law 93-234, 87 Stat. 975, approved December 31, 1976. Section 102(a) requires, on and after March 2, 1975, the purchase of flood insurance in communities where such insurance is available as a condition for the receipt of any Federal financial assistance for construction or acquisition purposes for use in any area that has been identified by the Secretary of the Department of Housing and Urban Development as an area having special flood hazards.

    The phrase "Federal financial assistance" includes any form of loan, grant, guaranty, insurance payment, rebate, subsidy, disaster assistance loan or grant, or any other form of direct or indirect Federal assistance.

12. It will assist the Federal grantor agency in its compliance with Section 106 of the National Historic Preservation Act of 1966 as amended (16 U.S.C. 469a-1 et seq.) by (a) consulting with the State Historic Preservation Officer on the conduct of investigations, as necessary, to identify properties listed in or eligible for inclusion in the National Register of Historic Places that are subject to adverse effects (see 36 CFR Part 800.8) by the activity, and notifying the Federal grantor agency of the existence of any such properties, and by (b) complying with all requirements established by the Federal grantor agency to avoid or mitigate adverse effects upon such properties.

The Applicant certifies that it will comply with the above assurances if the assistance is approved.

Grant Applicant: University of Wyoming

Project Title: Preliminary Numerical Analysis of the Thermal Regime South of Yellowstone....

Certifying Representative: [signature]
Signature

James E. Todd
Vice President for Finance
Name and Title

August 9, 1985
Date

H3c-3950H

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

13 August 1986

Mr. R.A. King, CMD
U.S. Department of Energy
Idaho Operations Office
785 DOE Place
Idaho Falls, ID 83402

Dear Mr. King:

Enclosed are copies of the Federal Assistance Management Summary Report and the Federal Assistance Program Status Report for Project DE-FC07-85ID12607. Copies are enclosed for the third quarter reporting period.

At this time, I would like to request a two-month, no-cost extension for this project. A no-cost extension would allow me to complete field work in September. A September completion date for the field work is desirable because it will allow me to contact individuals in the Jackson area who have been away from Jackson this summer.

In addition to the no-cost extension, I am requesting that $1,500.00 allotted for computer time be changed to the salary category. Less money is needed for computer time because I have been using a Geology Department computer rather than the University's Cyber 760 computer.

Sincerely,

Henry P. Heasler

Henry P. Heasler

HH/nf

FORM EIA-459E (10/80)

U.S. DEPARTMENT OF ENERGY

FEDERAL ASSISTANCE MANAGEMENT SUMMARY REPORT

FORM APPROVED OMB No. 1900-0127

Page 1 of ___

1. Program/Project Identification No. DE-FG07-85ID12607	2. Program/Project Title: Geothermal Studies in Jackson Hole, WY
3. Reporting Period: 4/86 through 6/86	
4. Name and Address: Henry P. Heasler, Dept. of Geology, P.O. Box 3006, University of Wyoming, Laramie, WY 82070	5. Program/Project Start Date: 9/30/85
	6. Completion Date: 9/30/86

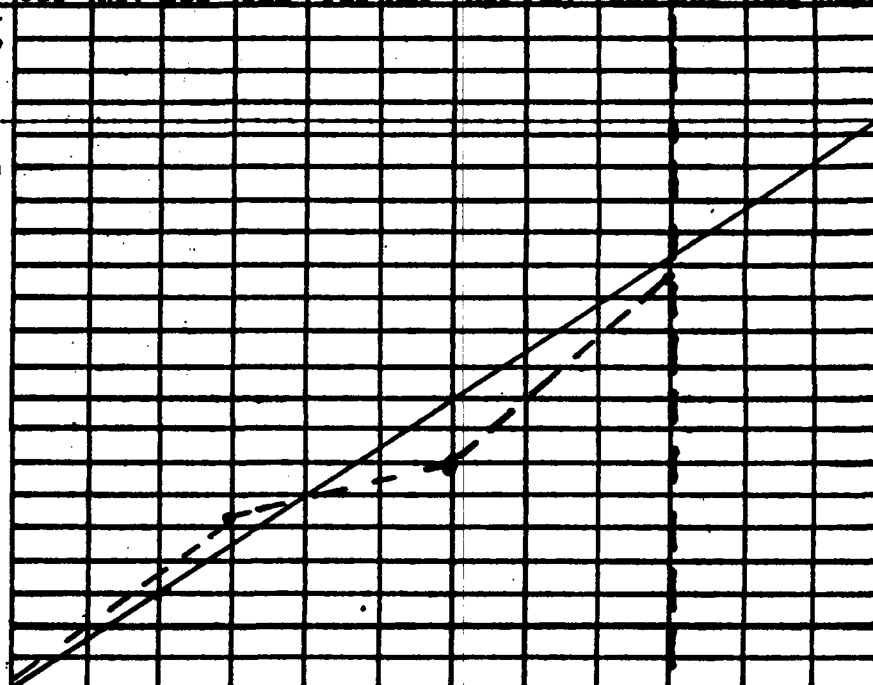
7. FY: 86

8. Months or Quarters: Quarters

Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sept

9. Cost Status — a. Dollars Expressed in: Hundreds

b. Dollar Scale: 180, 160, 140, 120, 100, 80, 60, 40, 20



10. Cost Chart

Fund Source		Quarter 1st	2nd	3rd	4th	Cum. to Date	Tot. Plan
DOE	P	44	44	44	43.9		175.9
	A	52.1	18	127			
	P						
	A						
	P						
	A						
	P						
	A						
Total P		44	88	132	175.9	132	175.9
Total A		52.1	70	127		127	
Variance		-8.1	18	5			

P = Planned A = Actual

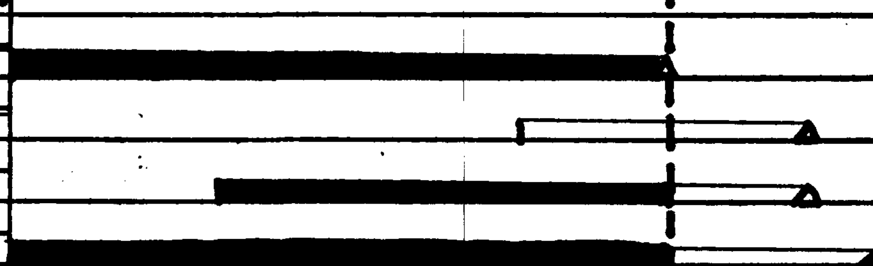
c. Cumulative Accrued Costs

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept
Planned			44			88			132			175.9
Actual			52.1			70			127			
Variance			-8.1			18			5			

Total Planned Costs for Program/Project: 175.9 hundreds

11. Major Milestone Status (Units Planned / Units Complete)

Milestone	
Compile existing data	P / C
Add new data	P / C
Computer Modeling	P / C
Reporting	P / C



12. Remarks

13. Signature of Recipient and Date: Henry P. Heasler Aug 12, 1986

14. Signature of DOE Reviewing Representative and Date

FORM EIA-459F (10/80)

U.S. DEPARTMENT OF ENERGY

FEDERAL ASSISTANCE PROGRAM/PROJECT STATUS REPORT

FORM APPROVED OMB No. 1900 0127

1. Program/Project Identification No.: DE-FG07-85ID12607

2. Program/Project Title: Geothermal Studies in Jackson Hole, WY

3. Reporting Period: 4/86 through 6/86

4. Name and Address: Henry P. Heasler, Dept. of Geology, P.O. Box 3006, University of Wyo., Laramie, WY 82071

5. Program/Project Start Date: 9/30/85

6. Completion Date: 9/30/86

7. Approach Changes

[X] None

8. Performance Variances, Accomplishments, or Problems

Computer modeling of heat transfer in Jackson Hole continued with the input of thermal conductivities, heat flow, and water flow parameters.

Conferred with Dr. David Love of the U. S. Geological Survey concerning preliminary results of the computer modeling.

[ ] None

9. Open Items

[X] None

10. Status Assessment and Forecast

[X] No Deviation from Plan is Expected

11. Description of Attachments

[X] None

12. Signature of Recipient and Date: Henry P. Heasler Aug 12, 1986

13. Signature of DOE Reviewing Representative and Date

TECHNICAL EVALUATION
OF GRANT PROPOSAL

TITLE: Preliminary Numerical Analysis of the Thermal Regime South of Yellowstone National Park in Jackson Hole, Wyoming

SUBMITTED TO: DOE-ID

SUBMITTED BY: Department of Geology and Geophysics
University of Wyoming
Laramie, WY

AMOUNT REQUESTED: $17,595

AMOUNT SUGGESTED: $17,595

PROPOSED DURATION: July 1, 1985 to May 1, 1986

PROJECT DESCRIPTION: Compile hydrologic, geologic, thermal spring, tectonic, thermal gradient, thermal conductivity, and heat flow data in the Jackson Hole area. Use these data to develop a finite difference numerical model of the thermal regime in the Jackson Hole area. Evaluate the model in terms of deep circulation of fluids and, if possible, determine the nature and temperature of the heat source for the thermal springs.

GENERAL REMARKS:

1. Work Statement: As listed from the proposal, it adequately covers their efforts.

2. Task Changes: None required

3. Cost Information: Amounts appear reasonable.

SPECIFIC REMARKS:

1. Manhours: With anticipated match from WY Water Research Center, hours are adequate. DOE funding only will result in a less well refined model, rather than no model at all. The DOE-funded effort will be a significant contribution to knowledge.

2. Materials: None required

3. Subcontracts: None

4. Travel and Per Diem: Only 1 field trip, which is adequate to measure available gradients.

5. Other Direct Costs: Minimal and adequate

6. <u>Proposer's Capability to Meet the Objectives</u>: Dr. Heasler has been working on State Coupled Program projects in Wyoming for several years, and can easily meet these objectives. He is familiar with geothermal resources in Wyoming and has developed computer models to look at geothermal systems in Wyoming basins.

7. <u>Key Personnel Qualifications</u>: Dr. Heasler's reputation in ground water and heat flow is national (and growing). He is one of the few experts in this field.

8. <u>Anticipated Objectives and Probability of Success</u>: Objectives are well defined and have a 90% chance of success. Some data may not be available, which could leave the model less well constrained than is desired.

STATEMENT OF WORK

UNIVERSITY OF WYOMING, DEPT. GEOLOGY AND GEOPHYSICS

The purpose of these geothermal energy investigations will be accomplished by performing the following tasks in the greater Jackson Hole area:

Task 1. Compile existing data, including hydrologic information, subsurface temperatures, general geology, thermal spring (temperature, flow, water chemistry, and appropriate other information) data, tectonic history, thermal conductivity data, and heat flow information.

Task 2. Add appropriate new data, which will be gathered during one field trip.

Task 3. Using existing and new data, develop a finite difference numerical model of the thermal regime in the Jackson Hole area.

Task 4. Prepare a final report, which will include all data gathered during Tasks 1 and 2, and documentation, and results of the model. Interpretations of the model in terms of hydrologic circulation and the nature and temperature of the heat source for the thermal springs will be made.

Task 5. Provide overall project management and complete and report on tasks in a timely manner. Management reports shall be provided as defined by the attached DOE Form EIA 459A - Reporting Requirements Checklist. The required reports are also summarized as follows:

	REPORT	DUE
(1)	Form DOE 538 Notice of Energy RD&D	30 days after award of grant
(2)	Quarterly Management Summary Report	15 days after calendar quarter end
(3)	Project Status Report	15 days after calendar quarter end
(4)	Final Report (Draft)	Due 45 days prior to completion date
(5)	Final report	Due on completion date
(6)	Financial Status Report - OMB Form 269	Due annually and upon completion

The deliverables resulting from the tasks outlined above which will be delivered to DOE are summarized as follows:

1. The Final report--one camera-ready copy plus twelve additional copies--will be distributed as specified in the attached DOE Form EIA 459A.

2. Reports previously described under Task 5 above will be prepared and issued in the amounts and at the frequency shown.

U.S. DEPARTMENT OF ENERGY

FEDERAL ASSISTANCE REPORTING CHECKLIST

FORM EIA 459A (10-80)

FORM APPROVED OMB NO 1900-0127

1. Identification Number: DE-FG07	2. Program/Project Title: Geothermal
3. Recipient:	

4. Reporting Requirements:

	Frequency	No. of Copies	Addressees
PROGRAM/PROJECT MANAGEMENT REPORTING			
[ ] Federal Assistance Milestone Plan			
[ ] Federal Assistance Budget Information Form			
[X] Federal Assistance Management Summary Report	Q		
[X] Federal Assistance Program/Project Status Report	Q		
[X] Financial Status Report, OMB Form 269	Y, F		
TECHNICAL INFORMATION REPORTING			
[X] Notice of Energy RD&D	Y		
[ ] Technical Progress Report			
[X] Topical Report	A*		
[X] Final Technical Report	F*		

FREQUENCY CODES AND DUE DATES:

- A - As Necessary; within 5 calendar days after events.
- F - Final; Upon completion date
- Q - Quarterly; within 15 days after end of calendar quarter or portion thereof.
- O - One time after project starts; within 30 days after award.
- X - Required with proposals or with the application or with significant planning changes.
- Y - Yearly; 30 days after the end of program year. (Financial Status Reports 90 days).
- S - Semiannually; within 30 days after end of program fiscal half year.

5. Special Instructions:

* Draft copy due 45 days prior to completion date.

6. Prepared by: (Signature and Date)	7. Reviewed by: (Signature and Date)

U.S. DEPARTMENT OF ENERGY
IDAHO OPERATIONS OFFICE

REPORT DISTRIBUTION LIST

Addressees	Federal Assistance Milestone Plan	Federal Assistance Budget Information Form	Federal Assistance Management Summary Report	Federal Assistance Program/Project Status Report	Financial Status Report, OMB Form 269	Notice of Energy RD&D	Technical Progress Report	Topical Report	Final Technical Report
U. S. Department of Energy Idaho Operations Office 550 Second Street Idaho Falls, ID 83401									
Attn: Peggy Brookshier, Prog. Mgr. Energy & Technology Division			2	2				8*	8*
Attn: Elizabeth M. Hyster Contracts Management Div.			1	1	1	1		1	1
Attn: E. G. Jones, Director Financial Management Div.			1						
U. S. Department of Energy Forrestal Bldg., CE-324 1000 Independence Ave, S.W. Washington, DC 20585 Attn: Marshall Reed			1	1				2	2
University of Utah Research Institute Earth Science Laboratory 391 Chipeta Way, Suite A Salt Lake City, UT 84108 Attn: Duncan Foley			1	1				1	1
U. S. Department of Energy Technical Information Center P. O. Box 62 Oak Ridge, TN 37830						1			

Special Instructions

*One camera-ready copy must be included.

DETERMINATION OF RESTRICTED ELIGIBILITY

(Modification of Attached FY-84 Justification for Non-Competitive Awards)

I recommend that negotiations be conducted only with those organizations listed below for the services described herein in accordance with DOE Assistance Regulations Subpart 600.38 (b). Also, approximately five grants made to similar agencies in FY-84 will be amended and additional funds provided.

Organization

University of North Dakota, Geology Dept.

State of South Dakota, Energy Office

University of Wyoming, Dept. of Geology & Geophysics

1. Assistance to be Furnished

   A. DOE will be providing financial assistance to the above named universities and state government agencies for geothermal resource assessment and to promote geothermal technology transfer within the participating states. Emphasis will be placed on detailed studies within areas with high temperature resources and/or expansion of work previously conducted within the states.

   B. The work to be provided by each university or state agency will be tailored to the needs within each state and DOE objectives for continued resource assessment and technology transfer.

2. Background

   A. The State Teams Programs were initiated approximately seven years ago. At the program peak DOE-ID was administering 39 geothermal contracts, cooperative agreements, or grants with universities and state agencies. Eight of the above mentioned organizations are at present in the final phases of their agreements with DOE; the remainder have completed the work, and their agreements were closed out. Ten new grants or contract additions were implemented in FY-84.

   B. This work is a continuation of the previous program in the sense that it is for geothermal resource assessment and technology transfer. However, the new emphasis will be in accordance with the generic guidelines set forth in "C" below and will generally investigate higher temperature systems.

   C. All work will be within the generic guidelines of DOE which are to implement these activities within states which:

      1. Have potential for high temperature geothermal resources
      2. Whose resource assessment efforts will support R&D investigations required by magma and Cascades research programs

3. Have existing resource and energy groups actively supporting geothermal development
4. Are currently providing outstanding technology transfer and institutional problem mitigation activities

D. It is not anticipated that DOE will be able to develop competition for this work. The performing state agencies and universities were designated by the Governor's Office of each participating state. An attempt to stimulate competition would be contrary to DOE's policy of cooperation with state governments.

3. Estimated Cost

A. The program funding level of $1,000,000 was designated by the FY-85 Appropriations Bill and DOE-HQ. The funding levels for the individual states range from $20,000 to $150,000 and were established by ID and HQ based on the prior state teams annual funding levels, the amount and quality of work previously accomplished at these levels, and the amount of productive work remaining to be done.

B. The FY-85 funding level for the portion of the program to be administered at DOE-ID is $620,000 of the total program funding of $1,000,000. This level of funding is lower than any of the previous seven years; the amount to be funded in future years is uncertain.

C. It is the intent of this program to expand the knowledge of higher temperature resources within individual states. This work was performed in previous years by the organizations within each state which were designated by the respective Governor's Office. Any change in contractors at this time would increase costs and delay the program and could only be undertaken with the consent of the Governor's Office in each state.

4. Schedule Requirements

A. The basis for the rapid emplacement of the subject program is the need by the agencies to commit funds several months in advance of the summer field season. Delay in emplacement of the grants could cause a 1-year postponement of field activities.

B. It is also important to get the work started as soon as possible because the existing expertise may be disbanded if the work presently contracted for is completed prior to the emplacement of this subject program. The existing expertise has been developed to a great extent under the previous DOE-ID assistance and a lapse in DOE funding could result in lack of financial support for the organizations. This cadre of experienced expertise is critical for high quality resource assessment and technology transfer, and it is doubtful that any other organizations can perform as well in the respective states as those which are listed above. Rapid emplacement of this program will help ensure the retention of the existing expertise.

C. It is doubtful that any savings can be realized or that competition can be increased by relaxing schedules.

5. Exclusive Capacity & Capability

It was determined at the beginning of the previous program to use universities and state agencies to perform the work because these organizations had already performed research in the particular areas, had basic staffs and departments capable of performing the research and were designated by the state executives. The experience of these organizations has been further enhanced by the work they have conducted for DOE during the past seven years.

In light of these facts, I consider the proposed sources as the only acceptable ones for the planned assistance and recommend authorization of negotiations without further competition.

RECOMMENDED:

R. E. Wood — 1/25/85

R. E. Wood, Assistant Manager
Projects and Energy Programs — Date

CONCUR:

George C. Wingerson — 1/25/85

George C. Wingerson
Office of the Chief Counsel — Date

J. F. Marmo — 2/11/85

J. F. Marmo, Director
Contracts Management Division — Date

APPROVED:

Troy E. Wade II, Manager
Idaho Operations Office — Date

JUSTIFICATION FOR NON-COMPETITIVE AWARDS

I recommend that negotiations be conducted only with those organizations listed below for the services described herein in accordance with DOE-PR 9-3.805-501.

<u>Organization</u>

State of Washington, Department of Natural Resources
State of Washington, Energy Office
State of Oregon, Dept. of Geology & Mineral Industries
State of Oregon, Department of Energy
State of Alaska, Department of Commerce & Economic Development, Office of Energy
University of Alaska, Geophysical Institute
State of Alaska, Department of Natural Resources
New Mexico State University, Energy Institute
State of New Mexico Energy & Minerals Department
Idaho Department of Water Resources
State of Utah, Utah Geological & Mineral Survey
State of Utah, Division of Water Rights
State of Montana, Dept. of Natural Resources & Conservation
State of Montana, College of Mineral Science & Technology

1. <u>Description of Supplies or Services to be Supported</u>

A. The actions with the above named universities and state government agencies are for geothermal resource assessment and to promote geothermal technology transfer within the participating states. Emphasis will be placed on detailed studies within areas with high temperature resources and/or expansion of work previously conducted within the states.

B. The work to be provided by each university or state agency will be tailored to the needs within each state and DOE objectives for continued resource assessment and technology transfer.

2. <u>History, Estimated Future Requirements, and Long-Range Objectives</u>

A. The State Teams Programs were initiated approximately seven years ago. At the program peak DOE-ID was administering 39 geothermal contracts, cooperative agreements, or grants with universities and state agencies. Eight of the above mentioned organizations are at present in the final phases of their agreements with DOE; the remainder have completed the work, and their agreements were closed out.

B. This work is a continuation of the previous program in the sense that it is for geothermal resource assessment and technology transfer. However, the new emphasis will be in accordance with the generic guidelines set forth in C below and will investigate higher temperature systems.

C. All work will be within the generic guidelines of DOE which are to implement these activities within states which:

1. Have potential for high temperature geothermal resources
2. Whose resource assessment efforts will support R&D investigations required by magma and Cascades research programs
3. Have existing resource and energy groups actively supporting geothermal development
4. Are currently providing outstanding technology transfer and institutional problem mitigation activities

D. It is not anticipated that DOE will be able to develop competition for this work. The performing state agencies and universities were designated by the Governor's Office of each participating state. An attempt to stimulate competition would be contrary to DOE's policy of cooperation with state governments.

3. Estimated Cost

A. The program funding level of $1,925,000 was designated by the FY-84 Appropriations Bill and DOE-HQ. The funding levels for the individual states range from $ 90,000 to $145,000 and were established by ID and HQ based on the prior state teams annual funding levels, the amount and quality of work previously accomplished at these levels, and the amount of productive work remaining to be done.

B. The FY-84 funding level for the portion of the program to be administered at DOE-ID is $1,295,000 of the total program funding of $1,925,000. This level of funding is lower than any of the previous seven years; the amount to be funded in future years is uncertain.

C. It is the intent of this program to expand the knowledge of higher temperature resources within individual states. This work was performed in previous years by the organizations within each state which were designated by the respective Governor's Office. Any change in contractors at this time would increase costs and delay the program and could only be undertaken with the consent of the Governor's Office in each state.

4. Schedule Requirements

A. The basis for the rapid emplacement of the subject program is the imminent close-out of the agreements DOE now has with several of the organizations we wish to have perform under the FY-84 program. The agreements presently in place are scheduled for various completion dates ranging from almost immediately to September 1984.

B. It is important to get the work started as soon as possible because the existing expertise may be disbanded if the work presently contracted for is completed prior to the emplacement of this subject program. The existing expertise has been developed to a great extent under the previous DOE-ID contracts and a lapse in DOE funding could result in lack of financial support for the organizations. This cadre of experienced expertise is critical for high quality resource assessment and technology transfer, and it is doubtful that any other organizations can perform as well in the respective states as those which are listed above. Rapid emplacement of this program will help ensure the retention of the existing expertise.

C. It is doubtful that any savings can be realized or that competition can be increased by relaxing schedules.

5. <u>Exclusive Capacity & Capability</u>

It was determined at the beginning of the previous program to use universities and state agencies to perform the work because these organizations had already performed research in the particular areas, had basic staffs and departments capable of performing the research, and were designated by the state executives. The experience of these organizations has been further enhanced by the work they have conducted for DOE during the past seven years.

RECOMMENDED:

R E Wood

R. E. Wood, Director
Energy and Technology Division

CONCUR:

G C Wingerson

George C. Wingerson
Office of the Chief Counsel

J. F. Marmo 2/5/84

J. F. Marmo, Director
Contracts Management Division

APPROVED:

Troy E. Wade — 2/7/84

Troy E. Wade, Manager
Idaho Operations Office

Date

☆ U.S. GOVERNMENT PRINTING OFFICE: 1980-626-609

U.S. DEPARTMENT OF ENERGY

DOE F 4220.2 (6-80) (Formerly PR-415)

SMALL BUSINESS/LABOR SURPLUS SET-ASIDE REVIEW | **I.D. NO.**

ITEM TITLE/DESCRIPTION
University of Wyoming
Department of Geology & Geophysics
FY85 Grant - Geothermal

SMALL BUSINESS SIZE STANDARD RECOMMENDED BY S.B. SPECIALIST
EMPLOYEES NUMBER ________
DOLLAR $ ________
SIC CODE: ________

PROGRAM OFFICE: Advanced Technology

PROCURING ACTIVITY: Contracts

SB/LS PARTICIPATION WAS CONSIDERED IN THE PREPARATION OF THIS PROCUREMENT ITEM AND FOLLOWING IS RECOMMENDED:

- ☐ Small Business Set-Aside ______ % $______
- ☐ Labor Surplus Set-Aside ______ % $______
- ☐ SBA Section 8(a) Procurement
- ☒ Set-Aside Action Not Recommended

NAME AND LOCATION OF PROPOSED SOURCE: (If Sole Source)

- ☐ Small Business ☐ Minority
- ☐ Labor Surplus Firm ☐ Other

SET-ASIDE NOT FEASIBLE BECAUSE:

- ☐ No Reasonable Expectation of Receiving Sufficient Offers from SB/LS Firms to Assure Award*
- ☐ Program Objectives Dictate Broadest Possible Solicitation to Obtain "Best Available" Expertise*
- ☐ Solicitation if for "Best Idea/Approach" R&D Effort
- ☐ Continuing and Directly Related R&D Effort. Competitive Procurement Not Feasible for Economic and/or Technical Reasons
- ☐ Procurement is for Completion or Within-Scope Expansion of Current Contract
- ☐ This is for Extension of Current Services to Allow Preparation/ Award of Competitive Follow on Procurement
- ☐ Sole Source as Determined Under Current DOE Policy Directives
- ☐ Funding of Unsolicited Proposal Under Current DOE Policy Directives
- ☒ Other*

*Explanation Required

EXPLANATION/ADDITIONAL COMMENT:
State Teams Geothermal activity to promote technology utilization within participating states. A Justification for Restricted Eligibility has been approved

SMALL BUSINESS SPECIALIST CONSULTED (Check One) ☒ Yes ☐ No

[signature] 583-1403
TELEPHONE
P.R. REQUESTOR 5/21/85
DATE

SMALL BUSINESS SPECIALIST'S ENDORSEMENT

- ☐ Accepts ☐ Requests Reevaluation
- ☐ Request Solicitation of SB/LS Sources Attached
- ☐ Request Special SB/LS/MB Incentive Provisions (Attached)
- ☐ Other Comments/Attached

________ SMALL BUSINESS SPECIALIST ________ DATE

REEVALUATION OF RECOMMENDATIONS/FINDINGS

- ☐ Reaffirmed
- ☐ Set-Aside Feasible

________ AUTHORIZING PROGRAM OFFICIAL ________ DATE

REVIEWED BY SBA

- ☐ Request Solicitation of SB Sources Attached
- SBA Form 70 Attached ☐ Yes ☐ No

________ SBA REPRESENTATIVE ________ DATE

PROCUREMENT OFFICER'S ACTION

- ☐ SB/LB Set-Aside ☐ Set-Aside Not Initiated
- ☐ Other Recommendations/Request Noted and Appropriate Action Taken

________ PROCUREMENT OFFICER ________ DATE

CONTRACT NO.(S) SB/MB/OTHER

ORIGINAL-CONTRACT FILE (FULLY EXECUTED)

DOE F 4200.33
(Rev. 11-82)

U.S. Department of Energy

Procurement Request-Authorization

Formerly PR-799A
(Previous editions are obsolete)

1. To Awarding Office: Contracts Management Div.

2. From Initiating Office: Advanced Technology Div.

3. PR Number — •

4. Change/Correction to a PR in Process? ☐ Yes ☒ No

5. If Item 4 is yes, enter PR correction Letter

6. ☐ Procurement ☒ Assistance

7. Consistent with Principal Purpose of Program? ☒ Yes ☐ No

8. Action Description/Title (180 char. max.) Geothermal Research Grant

If award is competitive, has list of sources been attached? ☐ Yes ☐ No

If Non-Competitive, Complete Items 9-11.

9. Name: University of Wyoming

10. Division: Dept. of Geology & Geophysics

11. Address: P.O. Box 3006, Laramie, WY 82071

12. For Procurement Actions Only: Product or Service Code

13. For Assistance Actions Only: CFDA Number 81.087

14. Cooperative Agreement ☐

15. Grant ☒

16. Controlled Deliverable For All Actions

17. Kind of Award Action (Recommended): 1A

18. Master Bin

19. Desired Award Date — Mo: 7, Day: 1, Year: 85

20. Unsolicited Proposal Number

21. Project Number

22. Government Property ____ F-Furnished, P-Purchased, N-Not involved

FINANCIAL DATA

23. Government Share: 17,595

24. Awardee Share

25. Total: 17,595

FY FUNDS COMMITTED

26. Approp. Symbol	27. B&R Number	28. Dollar Amt.	29. Allotment	30. Object Class	31. AFP	32. CFA

33. From Continuation Sheet

34. Total Funds this PR: 17,595

35. Project Period from 7/1/85 thru 8/1/86

36. Budget Period from 7/1/85 thru 8/1/86

PROJECT MANAGER/INITIATOR

37. Name: Peggy A.M. Brookshier

38. Signature: Peggy A.M. Brookshier

39. Date: 5/21/85

40. Office Code

41. FTS Telephone Number: 583-1403

PROGRAM REVIEWING OFFICIAL

42. Name: Charles E. Gilmore

43. Signature: Charles E. Gilmore

44. Date: 5-21-85

PROGRAM OFFICE BUDGET OFFICIAL

45. Name: Dennis R. Bell

46. Signature

CERTIFYING OFFICIAL. I hereby certify that the funds cited in item 34 are available

47. Name: Frank S. Smith

48. Signature

49. Date

CONTRACTING OFFICE

DF 16 Apr 85

TECHNICAL EVALUATION OF GRANT PROPOSAL

TITLE: Preliminary Numerical Analysis of the Thermal Regime South of Yellowstone National Park in Jackson Hole, Wyoming

SUBMITTED TO: DOE-ID

SUBMITTED BY: Department of Geology and Geophysics
University of Wyoming
Laramie, WY

AMOUNT REQUESTED: $17,595

AMOUNT ~~[illegible]~~ SUGGESTED: $17,595

PROPOSED DURATION: May 1, 1985 to May 1, 1986

PROJECT DESCRIPTION: Compile hydrologic, thermal, geological, thermal spring, tectonic, thermal conductivity, and heat flow data in the Jackson Hole area. Use these data to develop a finite difference numerical model of the thermal regime in the Jackson Hole area. Evaluate the model in terms of deep circulation of fluids, and, if possible, determine the nature and temperature of the heat source to the thermal springs.

GENERAL REMARKS:

1. Work Statement: As listed from the proposal, it adequately covers their efforts.

2. Task Changes: None required

SPECIFIC REMARKS:

1. Manhours: With anticipated match from Wy. Water Research Center, hours are adequate. DOE funding only will result in a less well refined model, rather than no model at all.
2. Materials: None required

3. Subcontracts: NONE

4. Travel and Per Diem: only 1 field trip, which is adequate to measure available gradients.

5. **Other Direct Costs:** minimal and adequate

6. **Proposer's Capability to Meet the Objectives:** Dr. Heasler has been working on State Coupled Program projects in Wyoming for several years, and can easily meet these objectives. He is familiar with geothermal resources in Wyoming and has developed computer models to look at geothermal systems in Wyoming basins.

7. **Key Personnel Qualifications:** see above

8. **Anticipated Objectives and Probability of Success:**
Objectives are well defined, and have a 90% chance of success. Some data may not be available, which could leave the model less well constrained than is desired.

Suggested Statement of Work - Wyoming DF 15 Apr. '85

In the greater Jackson Hole area:

1. Compile existing data, including hydrologic information, subsurface temperatures, general geology, thermal spring (temperature, flow, water chemistry, and appropriate other information) data, tectonic history, thermal conductivity data, and heat flow information.
2. Add appropriate new data, which will be gathered during one field trip.
3. Using existing and new data, develop a finite-difference numerical model of the thermal regime in Jackson Hole.
4. Prepare a final report, which will include all data gathered during Tasks 1 and 2, and documentation and results of the model. Interpretations of the model in terms of hydrologic circulation, and the nature and temperature of the heat source for the thermal springs will be made.

rec'd 12 Feb 85

A Proposal To
The United States Department of Energy
Division of Geothermal Energy
Idaho Falls, Idaho

For

PRELIMINARY NUMERICAL ANALYSIS OF THE THERMAL REGIME SOUTH OF YELLOWSTONE NATIONAL PARK IN JACKSON HOLE, WYOMING

Funding Requested: $17,595.00

Period of Research: May 1, 1985 to May 1, 1986

Submitted by: Henry P. Heasler 2/5/85
Henry P. Heasler — Date
Principal Investigator
Research Associate III
University of Wyoming

R. S. Houston 2/5/85
R. S. Houston, Head — Date
Department of Geology
and Geophysics
University of Wyoming

Donald L. Veal 850207
Donald L. Veal — Date
President
University of Wyoming

PURPOSE

Funding is requested to study the thermal regime south of Yellowstone National Park in Jackson Hole (Figure 1). The primary purpose of the study is to investigate the possibility of high-temperature heat sources (greater than 300 °C) in the area of Jackson Hole. This will be attempted through finite-difference numerical modeling of the conductive and convective transport of heat.

The study will encompass two phases. Phase one will be the gathering of existing data which will be used as constraints for the numerical models. These data will include hydrologic information, subsurface temperatures, general geology, thermal spring information, tectonic history, thermal conductivities of strata, and heat flow information.

Phase two will consist of the finite-difference numerical modeling of the thermal regime in Jackson Hole. The differential equation which will be modeled is

$$\frac{\partial K_x \frac{\partial T}{\partial x}}{\partial x} + \frac{\partial K_y \frac{\partial T}{\partial y}}{\partial y} + \rho c \left(V_x \frac{\partial T}{\partial x} + V_y \frac{\partial T}{\partial y}\right) = 0$$

This equation describes the steady-state conductive transport of heat and convective transport of heat by groundwater where T represents temperature, K_x and K_y are the thermal conductivity of the fluid-saturated rock in the x and y directions, V_x and V_y are the Darcian velocities of the groundwater in the x and y directions, ρ is the density of water, and c is the specific heat of water.

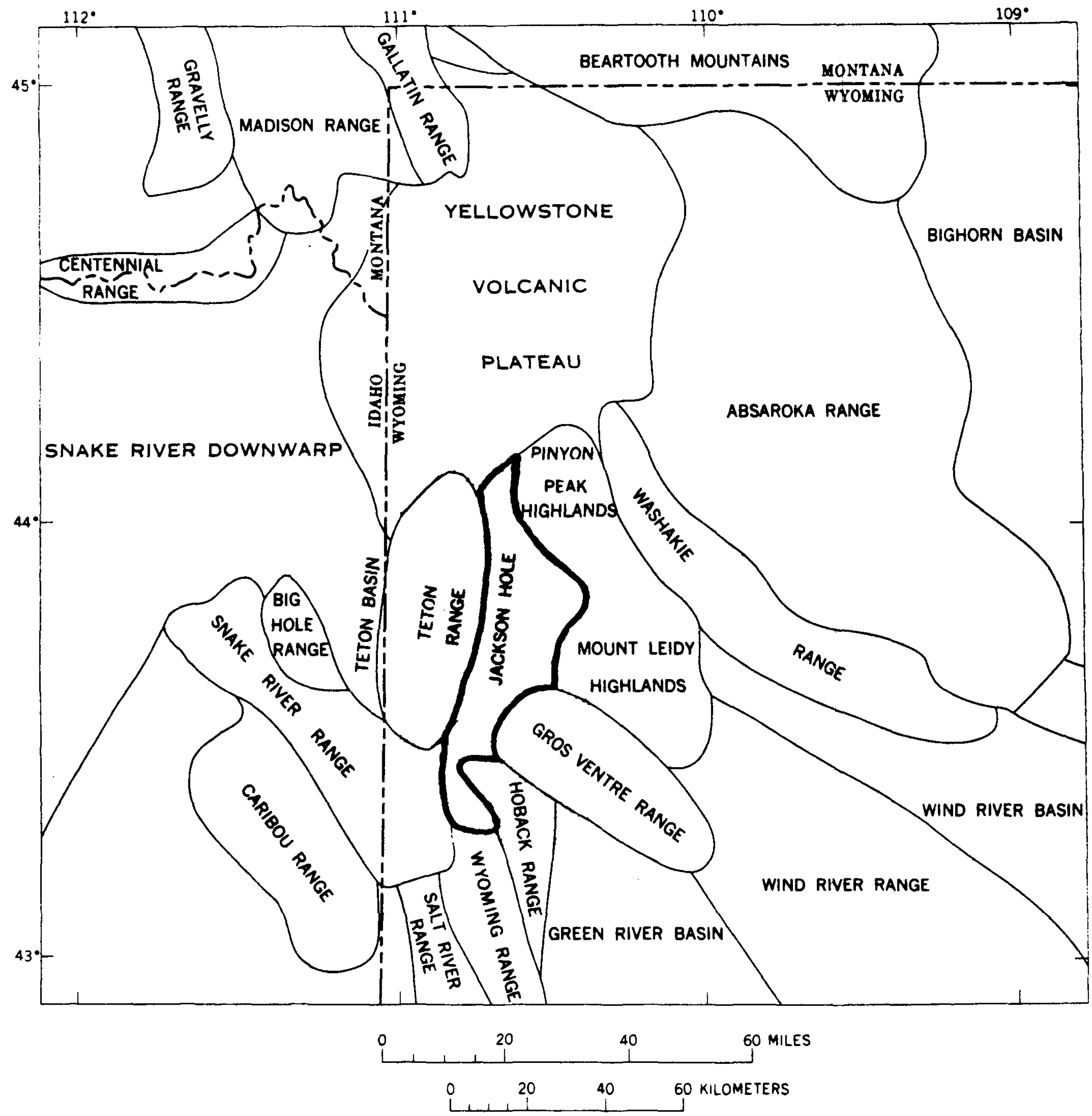


Figure 1. Location of Jackson Hole and surrounding tectonic features (taken from Behrendt et al., 1968).

If adequate model constraints exist, it may be possible to either deny or confirm that deep circulation of fluids is the heat source for the 8 thermal springs in the Jackson Hole area (see Figure 2). Thus, modeling may be able to determine the nature and temperature of the heat source for the thermal springs.

GENERAL GEOLOGY OF JACKSON HOLE

Jackson Hole is a 60 km by 15 to 30 km complexly folded and faulted basin. Within the basin are three structurally deep areas in which the Precambrian basement varies from 3 km to 4.5 km below sea level (Love in Behrendt et al., 1968). Sediments contained in Jackson Hole represent all systems except Silurian. The Cenozoic sedimentary section is the most complete of any Wyoming basin, due to the basin's subsidence during Cenozoic time.

Surrounding tectonic features include the Teton Mountain Range and the Yellowstone volcanic plateau (refer to Figure 1). The height of the Precambrian in the Teton Range exceeds 4 km above sea level. Love (in Behrendt et al., 1968) interprets the Teton Range as a horst between the two downfaulted blocks of the Teton Basin to the west and Jackson Hole to the east. The Yellowstone volcanic plateau terminates against the northern portion of Jackson Hole.

Yellowstone volcanism may have significantly effected the thermal structure of Jackson Hole. Within 5 km of the southern boundary of Yellowstone National Park are volcanic rocks of the Plateau Rhyolite which ranges in age from 70,000 to 600,000 years old (Christiansen and Blank, 1972). It may be possible that the high-temperature heat source associated with these volcanic rocks have effected Jackson Hole.

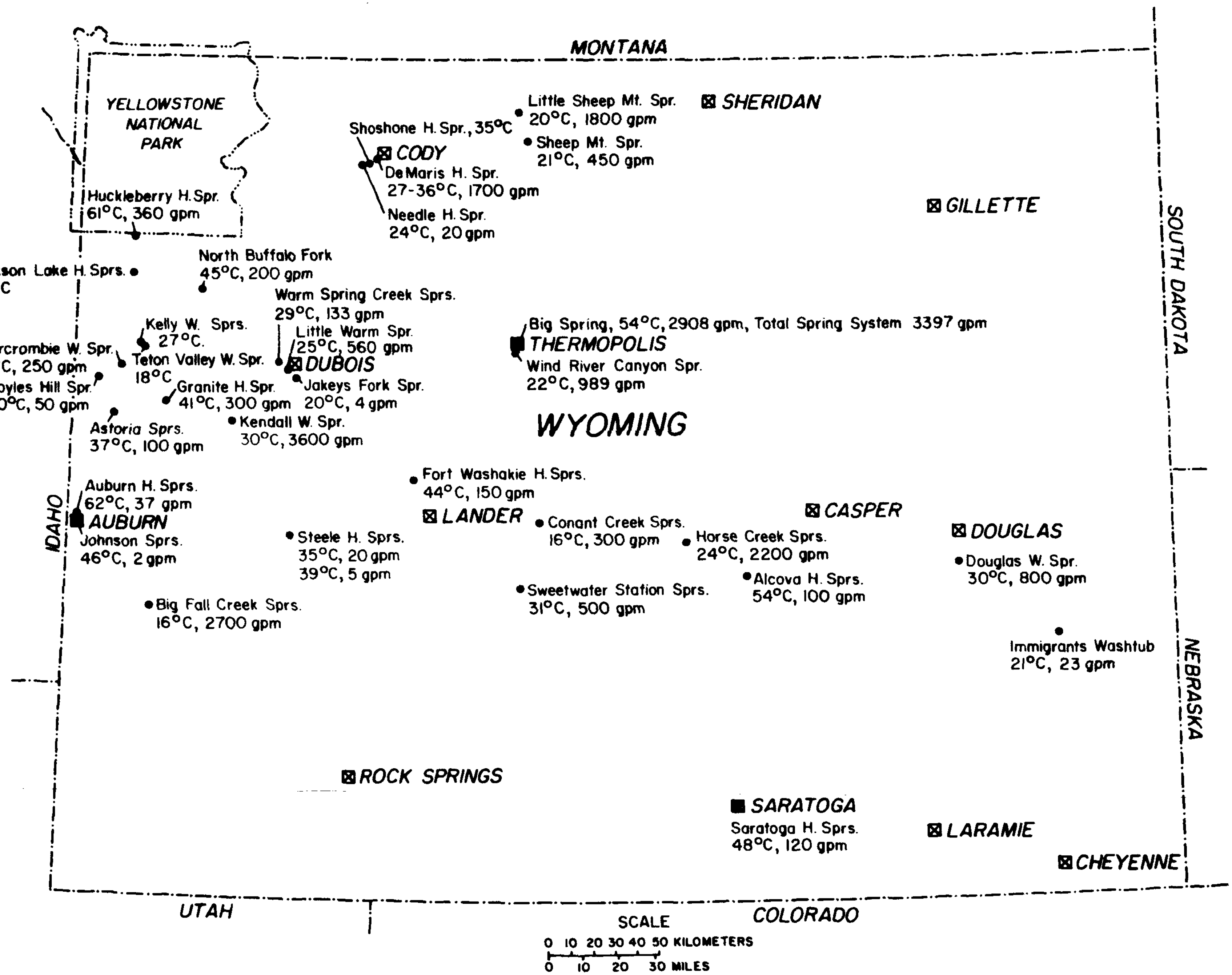


Figure 2. Thermal springs of Wyoming exclusive of Yellowstone National Park.

Important tectonic events effecting the thermal history of the area include the time of subsidence of Jackson Hole, the uplift of the Teton Mountains, and the timing and magnitude of volcanic activity. The subsidence of Jackson Hole appears to be contemporaneous with the uplift of the Teton Mountains. The movement originated in the last 10 million years and is still active (Love in Behrendt et al., 1968). Beginning in Miocene and continuing to the Pleistocene, there has been extensive volcanism in the Yellowstone region which coincides with the subsidence of Jackson Hole. This observation has led Love (in Behrendt et al., 1968, page E12) to postulate that "Jackson Hole sank as subcrustal material moved laterally into the area of greatest volcanism." The consequences of such subcrustal movement may have significantly effected the thermal structure of the area.

SUMMARY

This proposal requests funds to study the thermal regime of Jackson Hole. The area will be thermally modeled using existing data in an attempt to ascertain the presence of high-temperature heat sources. Results from this study may also be useful in determining the origin of thermal springs in the Jackson Hole area and potential groundwater circulation patterns.

REFERENCES

Behrendt, J. C., Tibbets, B. L., Bonini, W. E., and Lavin, P. M., 1968, A Geophysical Study in Grand Teton National Park and Vicinity, Teton County, Wyoming with Selections on Stratigraphy and Structure, by J. D. Love, and Precambrian Rocks, by J. C. Reed, Jr.: U. S. Geological Survey Professional Paper 516-E, 23 p.

Christiansen, R. L., and Blank, H. R., 1972, Volcanic Stratigraphy of the Quaternary Rhyolite Plateau in Yellowstone National Park: U. S. Geological Survey Professional Paper 729-B, 18p.

DELIVERABLES

This study will result in a report which will contain the following items.

1. A discussion of existing data used as model constraints will be included.

2. Modeling procedures and results will be discussed.

3. An interpretaion of the modeling results integrated with geologic and hydrologic data will be given. The interpretation will specifically address the possibility of a high-temperature heat source in the area of Jackson Hole.

BUDGET: Funds are requested for May 1,1985 to May 1,1986.

	From D.O.E.	Potential contribution from the Wyoming Water Research Center
SALARIES		
Principal Investigator (Heasler)		
1/4 time for 1 year	7250.00	
1/4 time for 1 year		7250.00
Part-time	400.00	
Clerical	600.00	
Fringe (20%)	1650.00	1450.00
Total Salaries	9900.00	8700.00
COMPUTER TIME		
5 hours at $300.00/hour	1500.00	
TRAVEL		
One field trip to Jackson Hole	600.00	
OTHER COSTS		
Drafting, telephone, copying, expendible computer supplies	750.00	
TOTAL DIRECT COSTS	12750.00	8700.00
INDIRECT COSTS (38 %)	4845.00	
TOTAL	17595.00	8700.00

VITA

Henry P. Heasler

Education:

1984 - Ph.D., Geology, University of Wyoming, (Dissertation - Thermal Evolution of Coastal California with Implications for Hydrocarbon Maturation).

1978 - M. S., Geology, University of Wyoming, (Thesis - Heat Flow in the Elk Basin Oil Field, Northwestern Wyoming).

1975 - B. S. with Honor, Physics, University of Wyoming.

Societies: Associate member Sigma Xi

Academic and Professional Appointments:

8/84 to 12/84	Principal investigator on a $10,425.00 grant from the Western Area Power Administration of D.O.E. to study the geothermal potential near WAPA's Thermopolis, Wyoming, facility.
12/83 to 12/84	Principal investigator on a $29,910.00 grant from the Wyoming Water Research Center to continue the geothermal assessment of Wyoming.
8/80 to 85	Principal investigator on a $600,000.00 Dept. of Energy contract studying the geothermal resources of Wyoming. Research included geologic, hydrologic, and geophysical studies.
11/82 to 4/83	Principal investigator, Temperature Measurements near Rico, Colorado. A $1,380.00 grant from Anaconda Minerals Company.
1/82 to 2/83	Principal investigator on a $9,000.00 contract from the Wyoming Water Development Commission. Responsible for siting, permitting, and surpervising the drilling of three geothermal test wells near Thermopolis, Wyoming.
6/78 to 1/79	Assistant Geologist, University of Utah Research Institute, Earth Science Lab. Began research on the geothermal resources of Wyoming.

PUBLICATIONS

Decker, E. R., Bucher, G. J., Buelow, K. L., and Heasler, H. P., 1984, Preliminary Interpretation of Heat Flow and Radioactivity in the Rio Grande Rift Zone in Central and Northern Colorado: New Mexico Geological Society Guidebook, 35th Field Conference, p. 45 - 50.

Decker, E. R., Heasler, H. P., and Blackstone, D. L. Jr., 1891, Heat Flow and Generalized Geology in Eastern Arizona, the Rio Grande Rift, the Southern Rocky Mountains, and the Northern and Central Rocky Mountains, in Touloukian, Y. S., Judd, W. R., and Roy, R. F., eds.,Physical Properties of Rocks and Minerals: McGraw-Hill Book Company, p.526 - 531.

Decker, E. R., Baker, K. R., Bucher, J. G., and Heasler, H. P., 1980, Preliminary Heat Flow and Radioactivity Studies in Wyoming: Journal of Geophysical Research, vol. 85, no. B1, P. 311 - 321.

Decker, E. R., Heasler, H. P., and King, J. K., 1980, Hydrothermal Resources in Wyoming, A Preliminary Report on the University of Wyoming's Research in 1979: Resource Assessment and Commercialization Planning Meeting, Salt Lake City, Utah, January 21 - 24, 1980, U. S. Department of Energy, Division of Geothermal Energy compilation, p. 70 - 78.

Heasler, H. P., 1982, The Cody Hydrothermal System: Wyoming Geological Association Guidebook, 33rd Annual Field Conference, p. 163 - 174.

Heasler, H. P., 1981, A Summary of Geothermal Potential and Development in Wyoming: The Interstate Oil Compact Commission Committee Bulletin, vol. 23, no. 1, p. 18 - 26.

Heasler, H. P., 1981, Conductive Thermal Modeling of Wyoming Geothermal Systems: Proceedings, U. S. Department of Energy, State Coupled Resource Assessment Meeting, May 4 - 7, 1981, Glenwood Springs, Colorado, DOE/ID/12079-39, p. 301 - 313.

Heasler, H. P., and Hinckley, B. S., 1985, Geothermal Resources of the Big Horn Basin, Wyoming: Geological Survey of Wyoming, Report of Investigations, in press.

Heasler, H. P., and Surdam, R. C., 1985, The Thermal Evolution of Coastal California with Implications for Hydrocarbon Maturation: submitted to the American Association of Petroleum Geologists Bulletin.

Heasler, H. P., Hinckley, B. S., Buelow, K. L., Spencer, S. A., and Decker, E. R., 1983, Geothermal Resource Map of Wyoming: National Oceanic and Atmospheric Administration, Publishers, available from the Geological Survey of Wyoming, P. O. Box 3008, Laramie, Wyoming, scale 1:500,000.

Heasler, H. P., and Surdam, R. C., 1983, A Thermally Subsiding Basin Model for the Maturation of Hydrocarbons in the Pismo Basin, California: Monterey Oil Fields Symposium, Special Publication of the Pacific Section of the Society of Economic Paleontologists and Mineralogists, p. 69 - 74.

Heasler, H. P., Decker, E. R., and Buelow, K. L., 1982, Preliminary Results of Heat Flow Studies in Wyoming: Proceedings, U. S. Dept. of Energy, State Coupled Resource Assessment Meeting, April 6 - 7, 1982, Salt Lake City, Utah, DOE/ID/12079-71, p. 290 - 312.

Hinckley, B. S., and Heasler, H. P., 1984, Geothermal Resources of the Laramie, Hanna, and Shirley Basins, Wyoming: Geological Survey of Wyoming, Report of Investigations, No. 26, 26 p.

Hinckley, B. S., Heasler, H. P., and King, J. K., 1982, The Thermopolis Hydrothermal System with an Analysis of Hot Springs State Park: Geological Survey of Wyoming, Preliminary Report No. 20, 42 p.

ABSTRACTS

Decker, E. R., Buelow, K. L., and Heasler, H. P., 1980, Geothermal Studies in Wyoming and Northern Colorado: EOS, vol. 61, no. 17, p. 363.

Furlong, K. P., and Heasler, H. P., 1983, Thermal Consequences of Emplacement of Volcanics - Implications for Hydrocarbon Maturation: American Association of Petroleum Geologists Research Conference on Basin Analysis, Tuscon, Arizona, February 8 to March 2, 1983.

Heasler, H. P., 1983, Geothermal Resources of Wyoming Sedimentary Basins: American Association of Petroleum Geologists Bulletin, vol. 67, no. 8, p. 1342.

Heasler, H. P., and Surdam, R. C., 1985, Thermal and Hydrocarbon Maturation Models for Coastal California: American Association of Petroleum Geologists Bulletin, in press.

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Heasler, H. P., Buelow, K. L., and Decker, K. L., 1983, Geothermal Studies in Wyoming, Colorado, and Montana: EOS, vol. 64, no. 18, p. 321.

Surdam, R. C., Crossey, L. C., Hagen, S. E., and Heasler, H. P., 1985, Time-Temperature Reconstructions of Diagenetic Systems: Abstract submitted for the 1985 American Association of Petroleum Geologists Rocky Mountain Section Meeting.