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HEAT-FLOW STUDIES IN WYOMING, 1979 to 1981

by

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INTRODUCTION

This report tabulates thirty heat flow values completed during May 1981 for Wyoming and presents updated maps of heat flow in Wyoming and adjacent areas. Also, plotted on the maps are 48 new heat flow values gathered from January 1979 to May 1981.

The following abbreviations and units are used in this report:

Cond. = Average thermal conductivity. $1 \text{ CDU} = 1 \times 10^{-3} \text{ cal/cm sec}^{\circ}\text{C} = .4184 \text{ W/m}^{\circ}\text{K}$

Grad. = Least squares gradient of temperature $1^{\circ}\text{C/km} = 1^{\circ}\text{K/km}$

The heat flow unit is expressed in HFU and mW/m^2 , where $1 \text{ HFU} =$

$$41.84 \text{ mW/m}^2 = 1 \times 10^{-6} \text{ cal/cm}^2 \text{ sec.}$$

The heat generation unit is expressed in HGU and W/m^2 , where $1 \text{ HGU} =$

$$.418 \text{ mW/m}^3 = 10^{-13} \text{ cal/cm}^3 \text{ sec.}$$

Standard errors are tabulated below mean values as measures of the internal consistency of the conductivity, least-squares gradient and heat flow values.

DATA

Table 1 is a list of locations and basic geothermal data for thirty recently completed heat flow stations in Wyoming. Localities are identified by U.S.G.S. topographic quadrangle names and are grouped together in sets of adjacent quadrangles. Temperature-depth plots for all stations are shown in Appendix I. The least-squares gradients (Grad.) in Table 1 were calculated from observed temperatures and depths in the holes; Decker (1973) describes the temperature measurement techniques and the methods

Table 1. Summary of basic heat flow data for drill holes in sediment. No. refers to number of conductivity samples.

Locality	UW No.	N. Lat., W. Long.	No.	Cond. CDU (st. err.)	Depth M	Grad. °C/km (st. err.)	Heat Flow HFU (st. err.)	mW/m ² (st. err.)
Baggs	A-1	41° 3.8', 107° 45.9'	24	6.0 (.9)	219	20.0 (.4)	1.20 (.18)	50.2 (7.5)
Finley Reservoir	A-21	41° 27.5', 106° 40.0'	8	5.9	82	34.7 (.7)	2.05 (.32)	85.8 (13.4)
Walck Ranch	A-24	41° 26.2', 106° 53.8'	18	6.0 (.9)	168	20.0 (.2)	1.20 (.18)	50.2 (7.5)
Boot Heel Quad.	B-56	42° 9.3', 105° 45.8'	10	6.7 (2.0)	91	14.1 (.6)	.94 (.38)	39.3 (11.7)
	B-57	42° 9.1', 105° 46.1'	18	5.8 (.8)	155	21.0 (.6)	1.22 (.17)	51.0 (7.1)
	B-58	42° 9.1', 105° 46.1'	15	5.8 (1.3)	146	23.2 (.7)	1.35 (.30)	56.5 (12.5)
	B-59	42° 8.4', 105° 47.8'	11	5.7 (1.6)	101	30.0 (1.0)	1.71 (.48)	71.5 (20.1)
	B-61	42° 10.5', 105° 49.4'	10	5.8 (.9)	91	23.5 (1.0)	1.36 (.22)	56.9 (9.2)
	B-65	42° 10.5', 105° 49.7'	10	6.5 (1.5)	91	25.8 (.9)	1.68 (.39)	90.3 (16.3)
	B-74	42° 9.9', 105° 58.0'	10	5.7 (1.3)	91	22.3 (.5)	1.27 (.29)	53.1 (12.1)
	Mean Values						1.36	56.9
Bringolf Ranch	B-16	42° 17.1', 108° 52.1'	11	6.0 (.9)	274	17.8 (.2)	1.07 (.16)	44.8 (6.7)
	B-17	42° 17.3', 108° 50.6'	27	6.0 (.9)	274	18.1 (.2)	1.09 (.16)	45.6 (6.7)
	B-18	42° 18.4', 108° 52.2'	20	6.0 (.9)	201	19.2 (.2)	1.15 (.17)	48.1 (7.1)
	B-19	42° 18.6', 108° 51.4'	14	6.0	165	19.6 (.3)	1.18 (.18)	49.4 (7.5)
	Mean Values						1.12	47.0

Locality	UW No.	N. Lat., W. Long.	No.	Cond. CDU (st. err.)	Depth M	Grad. °C/km (st. err.)	Heat Flow HFU (st. err.)	mW/m ² (st. err.)
Squaw Springs	B-79	42° 27.4', 106° 3.9'	47	5.7 (.8)	299	29.0 (1.5)	1.65 (.25)	69.0 (10.5)
Bulb Springs	B-91	42° 6.4', 107° 35.9'	24	5.3 (.7)	229	14.4 (.3)	.76 (.10)	31.8 (4.2)
	B-93	42° 5.4', 107° 36.1'	15	5.0	152	18.5 (.4)	.93 (.11)	38.9 (4.6)
						Mean Values	.85	35.4
Hadsell Springs	B-102	42° 11.2', 107° 38.3'	49	5.8 (.6)	457	11.0 (.4)	.64 (.07)	26.8 (2.9)
Osborne Well	B-103	42° 10.4', 107° 45.8'	54	5.8 (.6)	503	17.3 (.2)	1.00 (.10)	41.8 (4.2)
Highland Flats	C-34	43° 2.9', 105° 42.1'	15	5.9 (.6)	140	15.6 (1.9)	.84 (.12)	35.1 (5.0)
North Butte	C-46	43° 48.2', 105° 59.0'	17	5.5 (1.1)	165	25.0 (.4)	1.38 (.28)	57.7
	C-49	43° 48.2', 105° 59.2'	9	5.0 (.5)	82	65.0 (2.3)	3.3 (.3)	188.0 (12.5)
	C-52	43° 48.4', 105° 59.6'	20	5.1 (.9)	183	17.9 (.5)	.91 (.16)	38.1 (6.7)
	C-53	43° 48.8', 105° 59.7'	19	5.5 (.9)	174	21.3 (.4)	1.17 (.19)	48.9 (7.9)
						Best Values	1.12	46.7
Fort Reno SE	C-55	43° 48.2', 106° 0.0'	18	5.0 (.9)	152	21.7 (.4)	1.09 (.20)	45.6 (8.9)
	C-56	43° 48.9', 106° 0.1'	9	4.4 (1.0)	82	26.7 (1.3)	1.17 (.27)	48.9 (11.3)
	C-57	43° 50.1', 106° 1.8'	9	5.5 (1.1)	82	23.5 (1.4)	1.29 (.27)	54.0 (11.3)
	C-58	43° 50.1', 106° 1.8'	8	5.1 (.7)	73	18.6 (1.7)	.95 (.16)	39.9 (6.7)
	C-52	43° 48.9', 106° 2.6'	13	4.8 (1.2)	119	6.9 (.8)	.33 (.09)	13.8 (3.3)

Locality	UW No.	N. Lat., W. Long.	No.	Cond. CDU (st. err.)	Depth M	Grad. °C/km (st. err.)	Heat Flow HFU (st. err.)	mW/m ² (st. err.)
Fort Reno (cont.)	C-74	43° 49.2', 106° 3.2'	17	5.1 (.9)	119	16.4 (.4)	.84 (.15)	35.1 (6.3)
					Best Values		1.07	44.7

of reduction. The average conductivities (Cond.) are taken from measurements on rotary drill chips using the techniques developed by Sass et al. (1971a). The heat flow values were calculated as the product of the average conductivity multiplied by the least-squares gradient for each hole. The standard error for each heat flow was calculated using expressions that combined the errors of the average conductivity and of the least-squares gradient.

Decker (1973) shows that gradient determinations are a very accurate part of the geothermal studies research program at the University of Wyoming. The accuracy of our "chip" conductivity measurements is more obscure because the porosities of the penetrated rocks were not always accurately known. A reasonable average porosity was assumed for most of the samples. Thus it is possible that some individual heat flow values are inaccurate or uncertain by a significant amount and that the changes of calculated flux in a studied area are artificial. The average flux for an area may be significant, however, and provides a reasonable estimate of the actual regional flux. For example, the 1.36 HFU (56.9 mW/m^2) average flux for the ten sites in the Boot Heel Quadrangle area suggests that heat flow in this region is normal, if it is assumed that conductivity errors are randomly distributed. We can not be more specific without accurate estimates of the porosities of the sediments at these and the other localities.

HEAT FLOW MAPS AND DISCUSSION

Figure 1 is a map of physiographic provinces, geography and heat flow in Wyoming and bordering areas. Generalized geology and generalized flux in these regions are plotted in Figure 2. The heat flow data in both

FIGURE 1. Map showing geography, physiographic provinces and heat flow in Wyoming and bordering areas.

FIGURE 2. Map showing generalized geology and generalized heat flow in Wyoming and bordering areas.

figures are after Table 1, Blackwell (1969), Sass et al., (1971b), Morgan et. al. (1977), Decker and Bucher (1979), Heasler (1978), Reiter et al. (1979), Decker et al. (1980), Buelow (1980), and unpublished values being reduced by various personnel at the University of Wyoming. The physiographic provinces are after Fenneman (1946), and the geology was generalized from the compilation for the United States by King and Beikman (1974). Both maps are considered reliable representations of the broad heat flow patterns in the depicted areas.

The widely spaced heat flow stations in Wyoming can not be used for reliable quantitative assessments of the geothermal resource potential of the State. However, the current data base does suggest useful broadly applicable generalizations of which brief discussions are given below.

It is seen in both maps that most of the heat flow values in the southern half of the Wyoming Basin and the Southern Rocky Mountains in southern Wyoming are low or normal. Thus these data are not consistent with shallow, moderate or high temperature hydrothermal reservoirs in these regions. This generalization may appear to be inconsistent with hot springs (54°C) in the Saratoga Valley (Fig. 1)(Breckenridge and Hinckley, 1978). However, our 1.2 HFU (50.2 mW/m²) flux on the Walck Ranch about 5 km west of the town of Saratoga implies that the springs are not surface manifestations of a shallow, large subsurface hydrothermal reservoir. This view, in turn, is consistent with geologic evidence for faults in the neighborhood of these springs (Montagne, 1955) which may tap a deep, low-temperature hydrothermal reservoir. The recently calculated heat flow values in the Gas Hills area on the Sweetwater Arch are in the range

1.1-3.2 (48-134 mW/m²) (Figs. 1 and 2). The meaning of these data is obscure, but one speculation is that the large heat flow variation is explained by a complex distribution of circulating ground waters in this extensively faulted terrane. A similar mechanism could explain the low temperature (32°C) of the hot springs at Sweetwater Station in a nearby portion of the Hills (Breckenridge and Hinckley, 1978). Future investigations of the hydrothermal resource base in this region should focus on detailed studies of the correlations between faulting and ground water hydrology.

Decker et al. (1980) reported heat flows of 1.7 HFU (71.1 mW/m²) and 1.9 HFU (79.5 mW/m²) for two stations near Lysite, Wyoming. These data and the more recently obtained 1.6 to 1.9 HFU (66-80 mW/m²) values in this area suggest that the regional flux in this part of the Owl Creek Mountains is above normal (see Figs. 1 and 2). Additionally, our flux value from a 298m deep drill hole in Precambrian basement near the northern end of the Laramie Mountains (Hole B79, Table 1) is 1.7 HFU (69.0 mW/m²). High flux values also have been obtained for two 500m holes near Douglas, Wyoming about 70-100 km to the northeast (1.7 and 2.1 HFU (71.1 and 87.9 mW/m²)) (see Table 1, Fig. 1). There is evidence too for above-normal flux in parts of the Powder River Basin north, east and south of Douglas, although the range of calculated values is large (1.1-2.1 HFU (41.8-87.9 mW/m²)) (see Figs. 1 and 2). Thus the Lysite-northern Laramie Mountains-Springs-Douglas zone may be an east-west trending heat flow high that extends into parts of the Powder River Basin. Lachenbruch and Sass (1977) generalized estimated heat flow values and geologic data in these regions and inferred

that they were in a belt of above-normal flux that broadens out into the Thrust Belt-Yellowstone Park areas to the west and into the Black Hills to the northeast (see Figs. 1 and 2). One implication of this inferred high heat flow zone is that high yield aquifers (e.g. the Madison Limestone) at depth could be valuable reservoirs for moderate temperature hydrothermal fluids in large parts of the Powder River Basin. Another speculation is that potentially valuable hydrothermal reservoirs could exist in the postulated above-normal heat flow band between Douglas and Lysite, an area that contains one of the larger population centers (Casper) in Wyoming.

From combined heat flow and radioactivity data (1.8 HFU (75.3 mW/m^2), 4.29 HGU (1.79 W/m^3)), Buelow (1980) infers that the Meadow Creek Basin area in the Absaroka Mtns. in northwestern Wyoming is in a high heat flow zone. This view, in turn, agrees with Blackwell's (1969) above-normal flux of 1.8 HFU (75.3 mW/m^2) for the Kirwin Mine area about 10 km southeast of Meadow Creek Basin (Figs. 1 and 2). Continued studies are needed to confirm the presence of high surface and reduced heat flow in this part of the Absarokas.

Finally, currently available heat flow values in and near the Bighorn Basin (Figs. 1 and 2) are normal (1.3-1.6 HFU ($54.4\text{-}66.9 \text{ mW/m}^2$)). These values suggest that the Bighorn Basin is not characterized by large, shallow hydrothermal reservoirs.

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APPENDIX A

Temperature-Depth Plots for Drill Holes

(Holes are identified by U.W. No. and U.S.G.S. topographical quadrangle. See Table 1 for numerical listings.)

Fig. A1

Fig. A2

Fig. A3

Fig. A4

Fig. A5

Fig. A6

Fig. A7

Fig. A8

Fig. A9

Fig. A10

Fig. A11

Fig. A12

Fig. A13

Fig. A14

Fig. A15

Fig. A16

Fig. A17

Fig. A18

Fig. A19

Fig. A20

Fig. A21

Fig. A22

Fig. A23

Fig. A24

Fig. A25

Fig. A26

Fig. A27

Fig. A28

Fig. A29

Fig. A30