GL00939

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20 July 1987

Dr. Howard P. Ross, Project Manager
University of Utah Research Institute
391 Chipeta Way, Suite C
Salt Lake City, Utah 84108-1295

Dear Dr. Ross:

Enclosed herewith are five copies of the final report of our 1986-87 heat flow investigations in the Ozark Plateau area of Arkansas and Missouri. The work was performed under the sponsorship of UURI Purchase Order RI-1291, and this submission fulfills the requirements of that P.O.

We exploited available boreholes in the same geologic province, but across the state line and into Missouri in order to achieve a sufficient number of boreholes. I apologize for the relatively unrefined nature of the report; it has been assembled as data emerge from our laboratory measurements (some in the past few hours) in order to meet our extended deadline. Later work (e.g. more conductivity measurements) may yield better accuracy and some modifications of the final values. However, all results of continuing work will be submitted to you.

On behalf of my students, I want to express our profound appreciation for the support given us for this project and for your patience with this report. We are enthused by the data, and I hope that as other opportunities arise, we can be considered for future support.

Sincerely,

Douglas L. Smith

Douglas L. Smith
Professor

Encl

FINAL REPORT

HEAT FLOW IN ARKANSAS

UNIVERSITY OF FLORIDA

Douglas L. Smith, Principal Investigator

Copies:
- Marshall Reed
- Peggy Brookshier
- Patent Clearance
- UURI-SCP
- HRR-SCP.

20 July 1987

Submitted to

University of Utah Research Institute
391 Chipeta Way, Suite C
Salt Lake City, Utah 84108

Contract No. RI-1291

HEAT FLOW IN ARKANSAS

INTRODUCTION

This report fulfills the "deliverables" requirement of Purchase Order No. RI-1291 from the University of Utah Research Institute to the University of Florida, "Heat Flow in Arkansas." It summarizes previous heat flow measurements in Arkansas and those related to the Mississippi Embayment area. It also presents the results of new 1986-1987 heat flow measurements in Arkansas and southern Missouri.

PREVIOUS WORK

Previous measurements of geothermal properties of the Mississippi Embayment (Van Orstand, 1932; Spicer, 1964; Roy et al., 1980; Staub and Treat, 1981; Guffante and Nathenson, 1981; Smith et al., 1981; Jarrett, 1982; Smith and Dees, 1982a, 1982b; Swanberg et al., 1982) total 124 geothermal gradient values and 69 heat flow calculations. A summation of well locations, depths, geothermal gradients, thermal conductivity values, and heat flow values is given in table 1. These data are summarized in figures 1 and 2. The range of values suggests normal geothermal gradients and low to normal heat flux throughout the Mississippi Embayment.

Earlier reconnaissance surveys (Van Orstand, 1932; Spicer, 1964) reported geothermal gradients throughout portions of southern Arkansas, Louisiana, and Mississippi. A subset of their data, generally from well holes with gradient calculations for depths greater than 600 m, was used to produce a contoured temperature gradient map of the United States (Guffante and Nathenson, 1980).

Recent assessments of low-temperature geothermal resources in the Mississippi Embayment provide numerous calculations of geothermal gradients and heat flow throughout this area. Initial efforts (Smith et al., 1981; Smith and Dees, 1982a) reported 30 geothermal gradient and heat flow measurements in Louisiana and Mississippi. Heat flow values in Louisiana range from 43.47 mW/m^2 at Bogalusa to 89.03 mW/m^2 at Truxno. Measurements of the geothermal gradient in Louisiana vary from 17.71 $^oC/km$ at Bogalusa to 44.23 $^oC/km$ at Kelly. Values reported for wells in Mississippi are generally lower than those measured in Louisiana. The initial studies yielded values for heat flow and geothermal gradients in Mississippi which varied from 19.65 mW/m^2 and 12.64 $^oC/km$ at Columbus to higher values of 61.86 mW/m^2 and 45.78 $^oC/km$ at Utica.

Forty additional geothermal gradient and heat flow values (Jarrett, 1982) were determined for well sites throughout Arkansas, Tennessee, and Mississippi. Nine Measurements in Arkansas range from 13.76 $^oC/km$ and 24.66 mW/m^2 at Helena to 36.41 $^oC/km$ and 86.94 mW/m^2 at Pine Bluff. Collins (1985) added a tenth heat flow value for Arkansas at Jerome. Roy et al. (1980) reported several heat flow values for Arkansas, but later (personal communication, 1984) expressed confidence in only two of the values (listed in table 1).

METHODS

Two data-measuring expeditions to Arkansas were conducted to fulfill the requirements of this contract. The Principal Investigator and two graduate students participated in each trip. Additional measurements of geothermal gradients and surface heat flux were sought in portions of the study area previously void of thermal data. The availability of suitable well sites in the region of interest is sparse, but generous cooperation was realized from the Arkansas Geological Commission, the U.S. Geological Survey Water Resources Division in Little Rock, and the Big Rock Petroleum Corporation. Virtually no boreholes are presently available in southwestern Arkansas or the Ouachita Mountain area, efforts were concentrated in the Ozark Mountain region of northern Arkansas. Because the geological province of the southern Ozark Mountains which characterizes northern Arkansas extends into southern Missouri, data from drill holes in southern Missouri were included in this project. To that end, the Missouri Geological Survey provided valuable assistance.

Temperature measurements were made with a thermistor probe assembly and a Mueller-type Wheatstone Bridge coupled to a 1000 m, four-conductor cable with reel. Values were recorded at discrete intervals (usually every 20 m), and least squares gradients were computed. Based on laboratory calibrations of the probe assembly, the accuracy of individual temperature values is placed at $\pm 0.1^{\circ}C$, and the accuracy of gradient values is estimated to be $\pm 0.01\ ^{\circ}C/km$.

Only nonflowing boreholes were used in this study, but certain hydrologic conditions within the sequences of sedimentary rocks were significant. Drillers' verbal reports of subsurface "springs' and deviations at depth from uniform temperature gradients as determined from recorded values suggested variations in permeability within certain depth zones. Although some component of convective heat transfer must be assumed to augment the conductive heat conveyance, the proportional amount is not considered to be significant. The number of individual heat flow determinations now available tends to temper uncertainities regarding the applicability of individual values as characteristic.

Thermal conductivity values were determined on a standard divided-bar apparatus using crystalline quartz and fused quartz standards. Measurements were made on core cuttings from the boreholes logged or nearby representative boreholes exhibiting the same lithology. Porosity values were placed at 30% for sandstone, and 15% for shale and limestone samples. Conductivity values are estimated to be accurate to within 15%.

RESULTS

During the course of this project, approximately 70 boreholes in northern Arkansas were sought and actually located. Only six proved suitable for temperature logging for scientific purposes. Others were in use, too shallow, plugged, or otherwise unavailable. Temperature values at Leslie were determined by the U.S. Geological Survey. Six existing boreholes in southern Missouri were also located, and useful measurements were completed in three of them.

Figures 3 and 4 show the locations of the boreholes logged for this study. Figures 5-14 display the temperature depth profiles. The actual temperature values recorded in the bore holes are listed in Appendix I. Appendix II contains the results of thermal conductivity measurements on individual rock samples from the various core cuttings analyzed.

Heat flow values were calculated as the product of the temperature gradient and the mean harmonic conductivity values. Weighted average heat flow values were computed where different depth zones in a borehole exhibited different geothermal gradients and those variations were not compensated by conductivity changes. All locations, gradient values, thermal conductivity mean harmonic values, and heat flow computations are shown in table 2.

The new values reported herein are significant in several aspects. They represent the first heat flow measurements for the Ozark Plateau, and they depict the Ozarks as an anomalously low heat flow province, perhaps similar in magnitude to the

Sierra Nevada Batholith or the Black Warrior Basin. The bore hole logged at Green Forest, Arkansas, is the deepest hole used for heat flow measurements in Arkansas, and the borehole logged at Atlas, Missouri, is the deepest hole logged for heat flow purposes in Missouri.

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TABLE I. Thermal data for well sites in the study area. Conductivity units (C.U.) are 10^{-3} cal/cm sec °C. Heat flow units (h.f.u.) are 10^{-6} cal/cm^2 sec and (H.F.U.) are mW/m^2. Model refers to thermal model used in one-dimensional modeling.

LOCATION	LATITUDE	LONGITUDE	DEPTH m	GRADIENT °C/km		C.U.		h.f.u.		H.F.U.		MODEL	SOURCE
Arkansas													
Blytheville	35°55'22"	89°54'19"	420	19.93	±.75	6.60	±.65	1.31	±.014	54.76	±.59	1	2
Evadale	35°33'06"	90°05'08"	360	15.78	±.30	6.60	±.65	1.04	±.011	43.47	±.46	1	2
Helena	34°32'43"	90°38'43"	186	13.76	±.47	4.61	±.25	.59	±.006	24.66	±.17	3	2
International Paper	34°32'43"	91°55'16"	337	32.67	±.66	5.71	±.47	1.87	±.016	78.00	±.67	1	2
Jerome	33°21'36"	91°56'31"	240	41.41		3.91		1.62		67.72		1	10
Marianna	34°46'31"	90°45'58"	180	19.99	±.26	4.61	±.25	.92	±.005	38.54	±.21	3	2
Pine Bluff #1	34°12'40"	91°55'30"	220	32.06	±.54	5.71	±.47	1.83	±.15	76.49	±.61	1	2
Pine Bluff #2	34°12'39"	91°55'30"	240	24.67	±.73	5.71	±.47	1.41	±.12	58.9	±.50	1	2
Pine Bluff #3	34°12'19"	91°55'30"	265	36.41	±2.96	5.71	±.47	2.08	±.024	86.94	±1.00	1	2
Thompson Grove	34°56'29"	90°20'06"	500	22.09	±.15	6.66	±.58	1.02	±.013	42.68	±.54	1	2
Wilson	35°33'12"	90°02'14"	430	27.65		6.45		1.44		60.19		1	6
Well #21	35°33'12"	90°03'46"	430	18.60		–		1.39		58.10		1	5,6
Well #26	34°42'00"	92°15'00"	175	25.50		4.16		1.06		44.31		1	9
Well #28	34°23'00"	93°30'00"	530	18.70		5.92		1.09		45.56		1	9
Well #29	34°13'00"	92°01'00"	265	31.05		–		–					5
Well #31	33°20'27"	92°40'47"	333	31.22		–							8
Well #33	33°06'12"	92°19'36"	650	40.00		–							3,4,7

TABLE 1. (CONTINUED)

LOCATION	LATITUDE	LONGITUDE	DEPTH m	GRADIENT °C/km	C.U.	h.f.u.	H.F.U.	MODEL	SOURCE
Louisiana									
Bastrop	32°43'52"	91°53'10"	258	37.45	4.92	1.72	71.90	2	1
Baton Rouge (North)	30°26'14"	91°08'30"	500	22.06	5.07	1.21	50.58	2	1
Baton Rouge (South)	30°25'09"	91°08'27"	500	23.64	4.42	1.10	45.98	2	1
Bernice CL-151	32°49'08"	92°44'35"	220	32.17	6.17	1.76	73.57	2	1
Bogalusa	30°49'00"	89°54'26"	440	17.71	3.90	1.06	43.47	2	1
Bonco OU-402	32°17'14"	92°04'14"	236	29.00	4.07	1.07	44.73	2	1
Calhoun OU-443	32°31'00"	92°16'58"	260	31.08	5.12	1.59	66.46	2	1
Deville R-893	31°23'39"	92°09'45"	250	24.94	4.31	1.12	46.82	2	1
Halle BB-72	32°49'55"	92°08'40"	236	34.98	6.46	2.08	86.74	2	1
Junction City CL-169	33°00'07"	92°44'59"	230	24.94	6.02	1.50	62.70	2	1
Kelly CA-868	32°01'34"	92°16'46"	172	44.23	5.72	1.99	83.18	2	1
Marsalis CL-136	32°39'43"	92°57'36"	258	27.48	6.50	1.79	74.82	2	1
North Hodge JA-156	32°17'30"	92°37'37"	200	23.74	5.40	1.28	53.50	2	1
Scotlandville	30°32'51"	91°11'50"	500	19.37	6.10	1.24	51.83	2	1

TABLE 1. (CONTINUED)

LOCATION	LATITUDE	LONGITUDE	DEPTH m	GRADIENT °C/km	C.U.	h.f.u.	H.F.U.	MODEL	SOURCE
Sikes W-172	32°05'41"	92°29'16"	200	30.30	5.93	1.80	75.24	2	1
Simpson	31°15'44"	93°00'25"	378	26.82	4.78	1.28	53.50	2	1
Truxno UN-80	32°49'17"	92°24'20"	215	33.13	6.49	2.13	89.03	2	1
Vernon	32°23'37"	92°34'17"	217	29.11	4.92	1.26	52.67	2	1
Winnfield W-177	31°53'38"	92°40'00"	215	27.65	5.73	1.30	54.34	2	1
Well #528	32°30'45"	94°00'36"	686	41.34	-	-	-	-	3,4,7
Well #532	32°48'36"	93°53'24"	1067	36.00	-	-	-	-	3,4,7
Well #533	32°46'36"	90°00'36"	604	53.44	-	-	-	-	3,4,7
Well #536	32°44'18"	93°53'24"	610	39.37	-	-	-	-	3,4,7
Well #538	32°27'24"	93°08'00"	503	42.34	-	-	-	-	4,7
Well #540	32°22'24"	94°01'00"	686	42.14	-	-	-	-	3,4
Well #542	32°12'00"	93°34'24"	3486	34.58	-	-	-	-	8
Well #546	31°36'42"	93°29'12"	762	38.33	-	-	-	-	3,4,7
Well #547	31°35'30"	93°46'12"	533	47.00	-	-	-	-	3,4,7
Well #550	30°63'00"	92°45'00"	6096	32.76	-	-	-	-	8
Well #551	30°31'00"	91°54'36"	5488	24.93	-	-	-	-	8
Well #553	30°46'48"	92°24'00"	3962	31.85	-	-	-	-	8
Well #554	30°45'00"	91°39'00"	6706	29.12	-	-	-	-	8
Well #555	30°42'00"	93°18'00"	5791	30.12	-	-	-	-	8

TABLE 1. (CONTINUED)

LOCATION	LATITUDE	LONGITUDE	DEPTH m	GRADIENT °C/km	C.U.	h.f.u.	H.F.U.	MODEL	SOURCE
Well #556	30°37'48"	91°54'00"	6097	29.12	-	-	-	-	8
Well #557	30°34'12"	91°06'00"	6096	25.48	-	-	-	-	8
Well #560	30°18'00"	92°45'00"	5182	38.22	-	-	-	-	8
Well #561	30°18'00"	92°24'36"	5488	33.67	-	-	-	-	8
Well #562	30°13'12"	93°21'00"	5486	32.76	-	-	-	-	8
Well #563	30°12'36"	91°21'00"	3182	34.58	-	-	-	-	8
Well #564	30°06'00"	90°30'00"	3962	40.95	-	-	-	-	8
Well #565	29°58'48"	90°46'48"	5182	31.85	-	-	-	-	8
Well #566	29°57'00"	91°43'48"	6400	28.03	-	-	-	-	8
Well #567	29°57'00"	90°23'24"	4878	33.67	-	-	-	-	8
Well #568	29°54'36"	91°05'24"	5486	24.21	-	-	-	-	8
Well #569	29°54'00"	93°09'00"	5791	33.31	-	-	-	-	8
Well #570	29°50'24"	91°18'00"	6096	28.03	-	-	-	-	8
Well #571	29°49'48"	92°15'00"	6706	32.03	-	-	-	-	8
Well #572	29°42'00"	91°30'00"	6400	27.30	-	-	-	-	8
Well #573	29°36'00"	90°24'00"	6395	22.75	-	-	-	-	8
Well #574	29°36'00"	89°48'00"	5486	22.75	-	-	-	-	8
Well #575	29°30'00"	90°48'36"	6706	23.84	-	-	-	-	8
Mississippi									
Brooklyn	31°01'35"	89°09'31"	218	20.08	5.06	1.06	44.31	2	1
Cary G-44	32°48'21"	90°55'31"	190	17.11	4.68	.00	33.44	1	1

TABLE 1. (CONTINUED)

LOCATION	LATITUDE	LONGITUDE	DEPTH m	GRADIENT °C/km	C.U.	h.f.u.	H.F.U.	MODEL	SOURCE
Columbus G-185	33°25'40"	88°23'53"	268	12.64 ±.18	3.68 ±.57	.47 ±.007	19.65 ±.29	3	1
Columbus L-22	33°25'38"	88°23'53"	295	15.45 ±.32	3.31 ±.51	.51 ±.008	21.32 ±.33	3	2
Dunleith F-6	33°24'31"	90°49'54"	278	28.96 ±.33	4.578 ±.92	1.33 ±.027	55.43 ±1.13	1	2
Elliott H-113	33°41'44"	89°42'57"	160	13.34 ±.45	6.412 ±.62	.855 ±.099	35.74 ±.38	3	2
Ervin H-20	33°06'02"	91°02'20"	111	17.21 ±.95	4.578 ±.92	.79 ±.016	32.94 ±.67	3	2
Forest L-13	32°21'45"	89°30'05"	240	19.83 ±.46	4.49 ±.54	.89 ±.11	37.20 ±.21	3	1
Greenville	33°24'00"	91°05'03"	114	25.14 ±.12	4.76 ±.46	1.20 ±.012	50.16 ±.50	1	1
Holly Springs F-77	34°47'11"	88°25'16"	214	20.90 ±.27	6.07 ±.70	1.27 ±.015	53.09 ±.63	1	1
Jackson H-21	32°17'44"	90°11'03"	215	38.80 ±3.99	3.30 ±.88	1.28 ±.017	53.50 ±1.55	2	2
Jackson H-41	32°17'41"	90°11'03"	249	35.08 ±2.10	3.30 ±.88	1.16 ±.012	48.49 ±1.34	2	2
Jackson H-35	32°17'45"	90°11'44"	215	39.70 ±1.69	3.302 ±.88	1.29 ±.015	53.92 ±1.46	2	2
Jackson U-87	32°16'14"	90°04'07"	400	19.29 ±.52	5.75 ±.80	1.11 ±.016	46.40 ±.67	2	2
Long Creek H-122	32°20'22"	88°16'32"	229	15.97 ±.13	5.34 ±.32	.85 ±.005	35.53 ±.21	3	2
Lyon K-22	34°12'30"	90°32'31"	392	24.62 ±.24	7.12 ±.27	1.75 ±.007	73.15 ±.29	1	2
Natchez	31°27'52"	91°20'22"	260	27.96	5.07	1.42	59.16	2	1

TABLE 1. (CONTINUED)

LOCATION	LATITUDE	LONGITUDE	DEPTH m	GRADIENT °C/km		C.U.		h.f.u.		H.F.U.		MODEL	SOURCE
Pace WW-643	33°47'37"	90°51'18"	280	16.23		5.55		.90		37.62		3	1
Pineview Lake J-5	32°02'40"	86°16'08"	158	32.54	±1.09	2.64	±.13	.86	±.005	35.86	±.21	3	2
Rienzi K-11	34°46'42"	88°34'05"	164	11.70	±.07	4.18	±.40	.49	±.005	20.44	±.21	3	2
Sanders	34°30'51"	88°58'06"	165	28.11	±.73	2.832	±.49	.81	±.014	33.65	±.58	3	2
Senatobia	34°37'24"	89°58'12"	334	19.94		5.10		1.01		42.22		3	1
Shelby D-31	33°56'30"	90°46'15"	500	23.97		4.86		1.33		55.59		1	1
Starkman	33°10'54"	88°28'25"	215	14.38	±.27	7.22	±.51	1.04	±.0074	43.36	±.308	3	2
Utica	32°06'30"	90°37'30"	380	45.98		3.09		1.48		61.86		2	1
West Point H-46	33°37'12"	88°38'46"	245	12.63	±.12	2.64	±.58	.33	±.007	13.79	±.29	3	2
Yazoo C-126	32°51'00"	90°24'38"	294	26.79	±.37	6.43	±.60	1.72	±.016	72.06	±.67	1	2
Well #641	33°58'12"	88°25'30"	762	17.72		-		-		-		-	3,4
Well #644	33°44'13"	88°18'31"	533	16.80		-		-		-		-	4
Well #651	32°27'00"	88°46'48"	240	24.00		-		-		-		-	5
Well #652	32°22'00"	90°12'00"	249	37.69		-		-		-		-	5
Well #655	32°18'06"	90°11'48"	610	45.00		-		-		-		-	5
Well #657	32°06'14"	90°04'07"	400	36.13		-		-		-		-	5
Missouri													
Caruthersville	36°11'38"	89°39'30"	370	31.9	±.4	4.90		1.56		65.21		1	6

TABLE 1. (CONTINUED)

LOCATION	LATITUDE	LONGITUDE	DEPTH m	GRADIENT °C/km	C.U.	h.f.u.	H.F.U.	MODEL	SOURCE
Tennessee									
Braden	35°22'26"	89°33'01"	320	27.10 ±.30	6.60 ±.65	1.79 ±.018	74.82 ±.75	1	2
Fort Pillow	35°38'39"	80°49'35"	488	20.38	6.05	1.20 ±.21	50.16	1	6
Memphis H:P-113	35°14'39"	89°57'23"	161	10.79 ±.36	3.92 ±.80	.64 ±.009	26.75 ±.38	3	2
Memphis SH:J-160	35°01'24"	90°07'22"	166	12.51 ±.19	3.92 ±.80	.74 ±.01	30.93 ±.47	3	2
Memphis SH:K-45	35°06'58"	89°56'04"	380	20.52 ±.13	6.37 ±.68	1.35 ±.014	56.43 ±.58	3	2
Memphis SH:O-181	35°09'14"	90°01'05"	420	18.78 ±.21	6.60 ±.65	1.24 ±.012	51.83 ±.50	3	7
Memphis SH:Q-58	35°11'04"	89°51'29"	251	17.92 ±.62	6.10 ±.80	.79 ±.011	32.98 ±.46	1	7
Ridgely	36°15'43"	89°29'40"	173	23.6 ±.1	3.59	1.32	55.10	1	6

Sources: 1. Smith and Dees (1982a; 1982b; 1981); 2. Jarrett (1982); 3. Guffante and Nathenson (1981); 4. Spicer (1964); 5. Staub and Treat (1981); 6. Swanberg et al. (1982); 7. Van Orstrand (1932); 8. Kron and Stix (1982); 9. Roy et al. (1980); 10. Collins (1985)

Table 2. New Heat Flow Data

Site	Latitude	Longitude	Depth,m	Grad, $^{o}C/km$	Cond, $W/m^{o}K$	# smpls	Heat Flow, mW/m
Murphy #1	Goshen Quad		20-100	31.85			
Fayetteville, AR	Sec27 T17N R29W		120-195	17.90			
					1.64	8	41.2
Chickenbristle	Elkins Quad		100-180	16.6			
Elkins, AR	Sec33 T16N R28W		180-215	27.92			
					1.53	13	30.4
Prairie Grove, AR	Prairie Grove Quad						
	Sec17 T15S R31W		220-573	12.47	1.42	4	17.8
Bull Shoals, Ar	Yellville Quad		60-137	4.02	2.05	5	8.2
Leslie, AR	Sec8 T20S R15W			11.4	2.12	7	24.2
	Leslie Quad						
	T14N R15W						
Green Forest, Ar							
	36°19'12"	93°26'33"	120-715	11.25	2.18	9	24.5
Talley #1	Winslow Quad		120-300	33.23	1.85	7	61.5
Winslow, Ar	Sec3 T13N R30W						
Winona, MO	36°57'16"	91°22'42"	180-260	14.2	2.45	4	34.8
Atlas, Mo	37°02'43"	94°28'14"	180-360	13.6	2.18	24	29.7
Fredricktown, MO							
	37°31'37"	90°24'30"	40-140	10.2	2.27	10	23.2

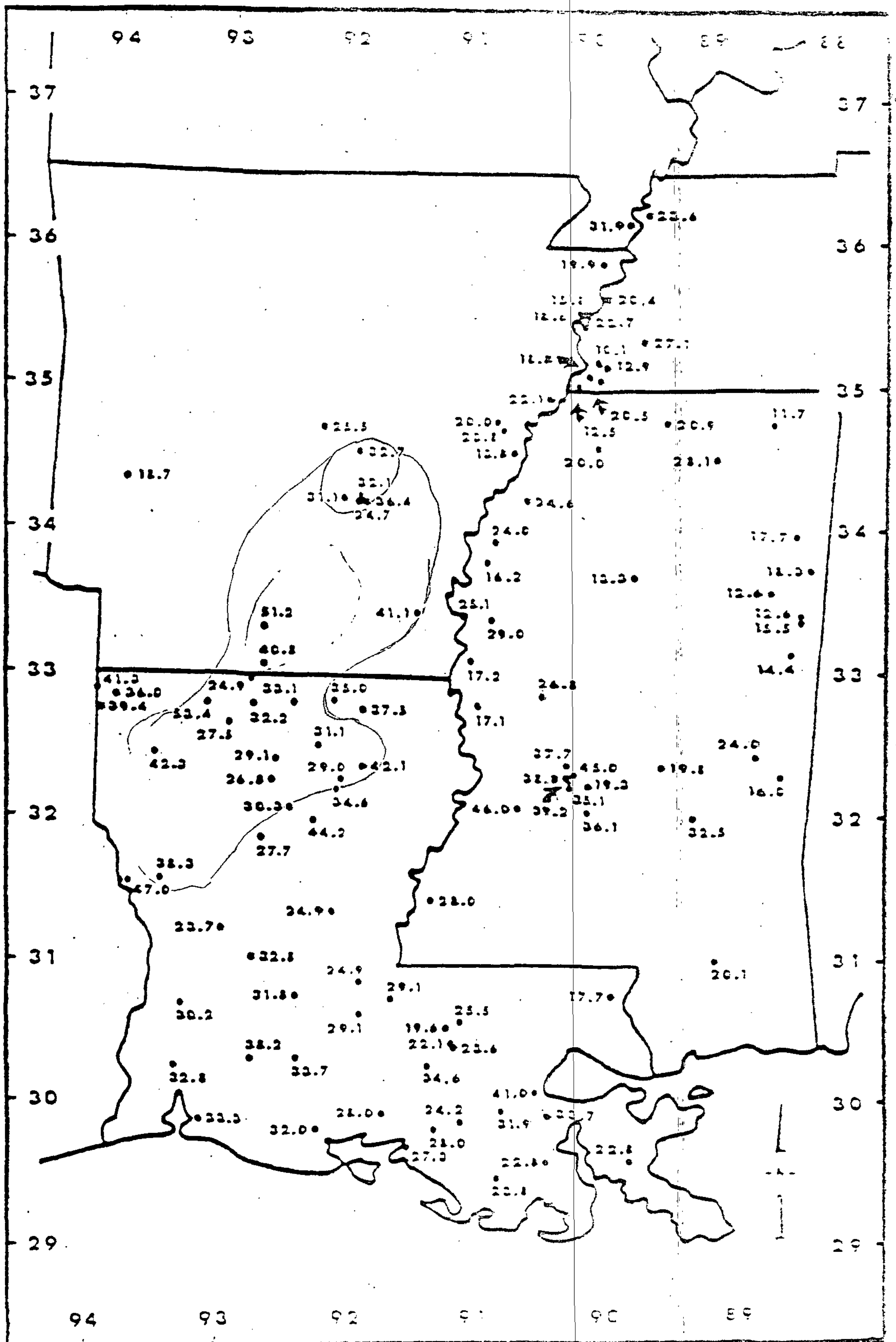


Figure 1. Geothermal gradient values (in $^{o}C/km$) for the Mississippi Valley area (from Smith, Jarrett, and Collins, in prep.)

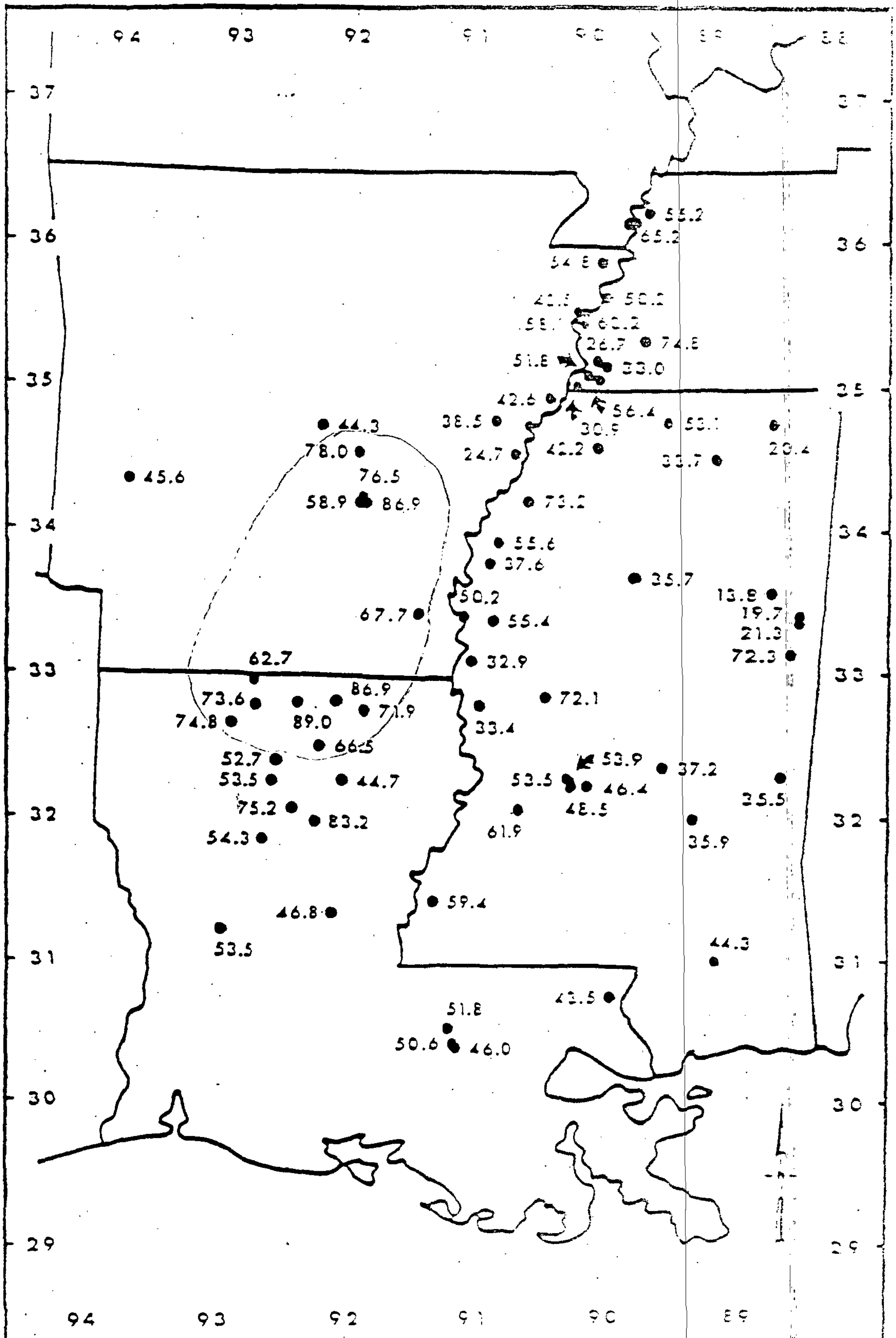


Figure 2. Heat flow values (in mW/m^2) for the Mississippi Valley region (from Smith, Jarrett, and Collins, in prep.).

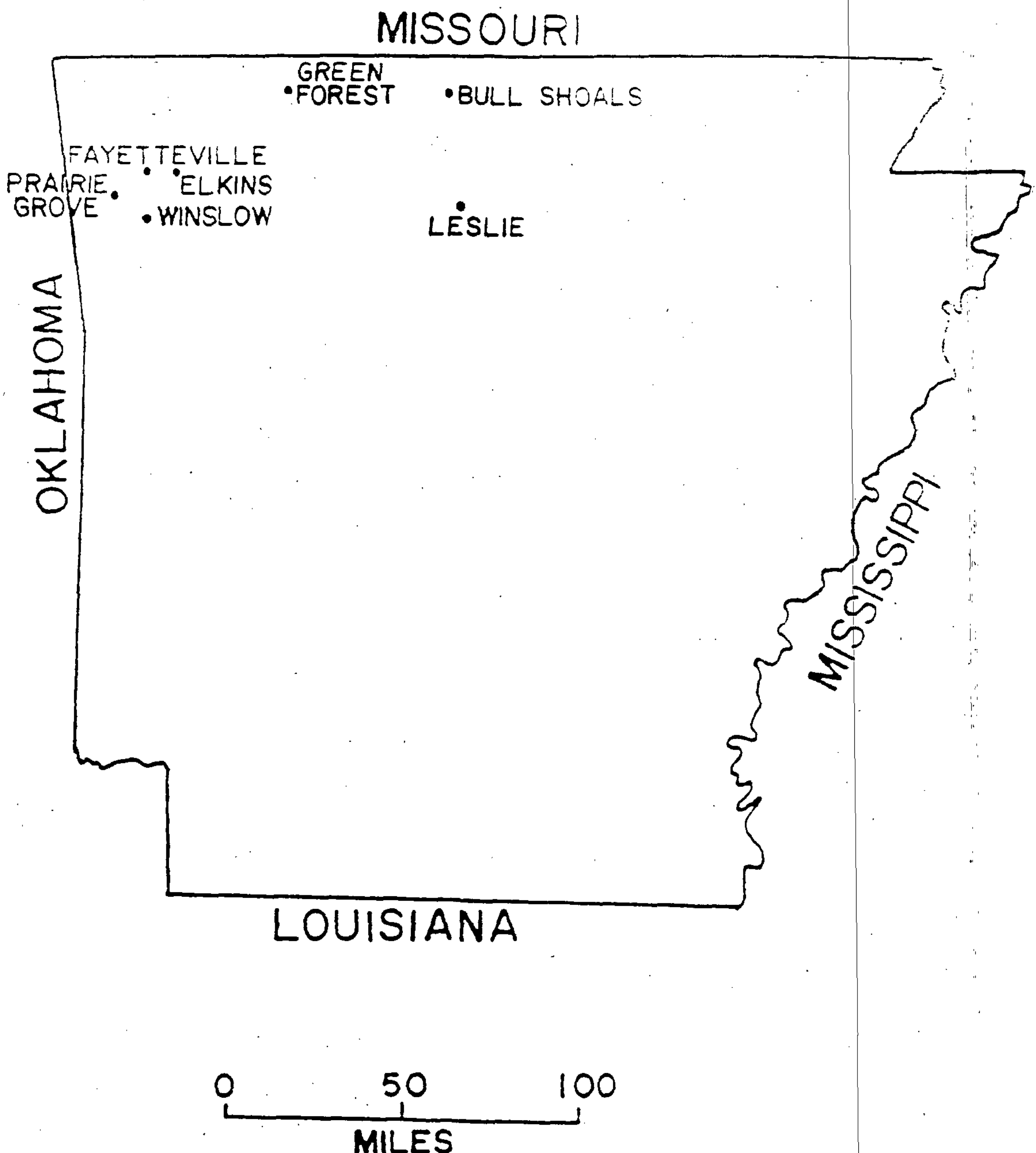


Figure 3. Distribution of new heat flow values in Arkansas

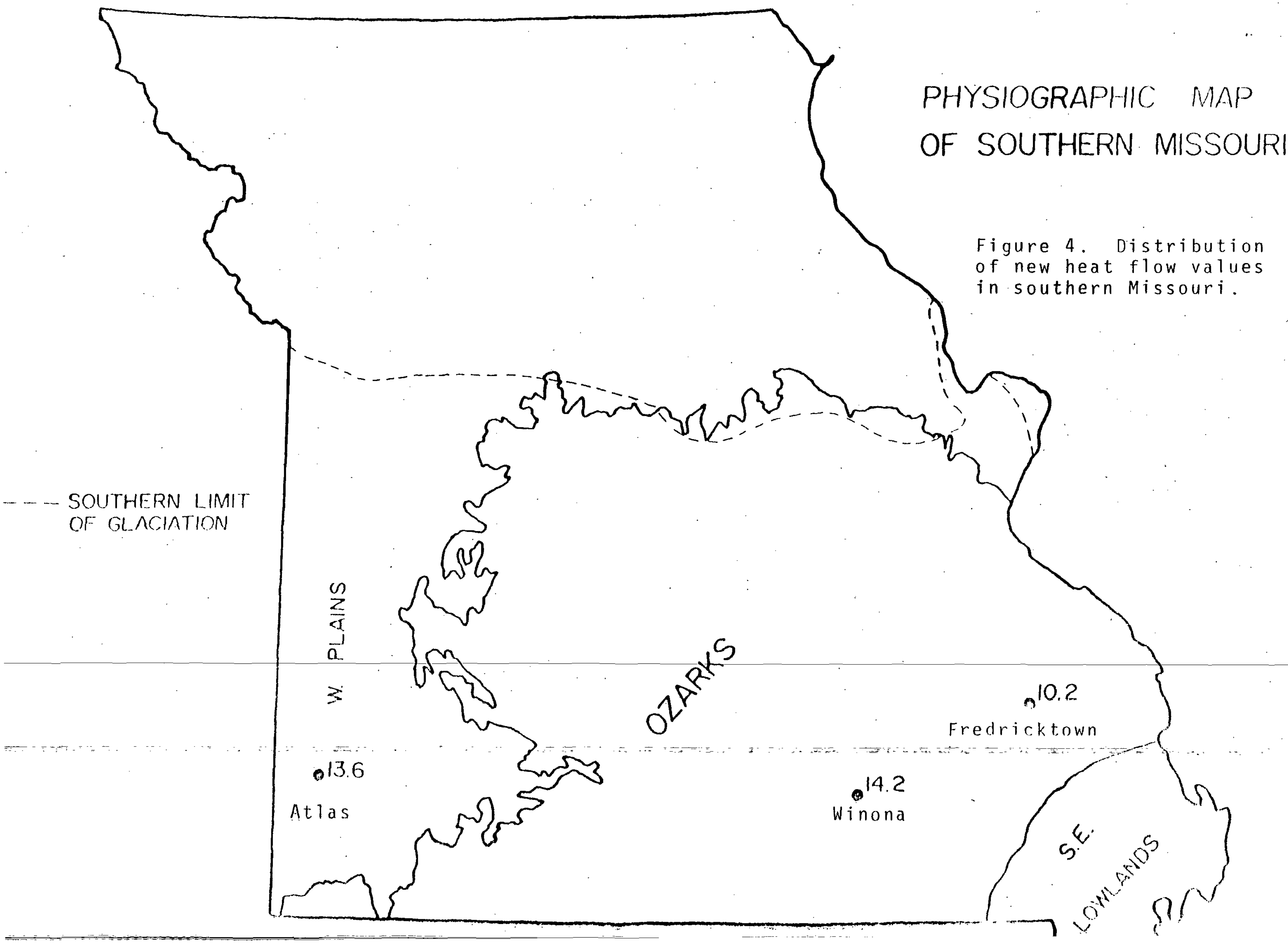


Figure 4. Distribution of new heat flow values in southern Missouri.

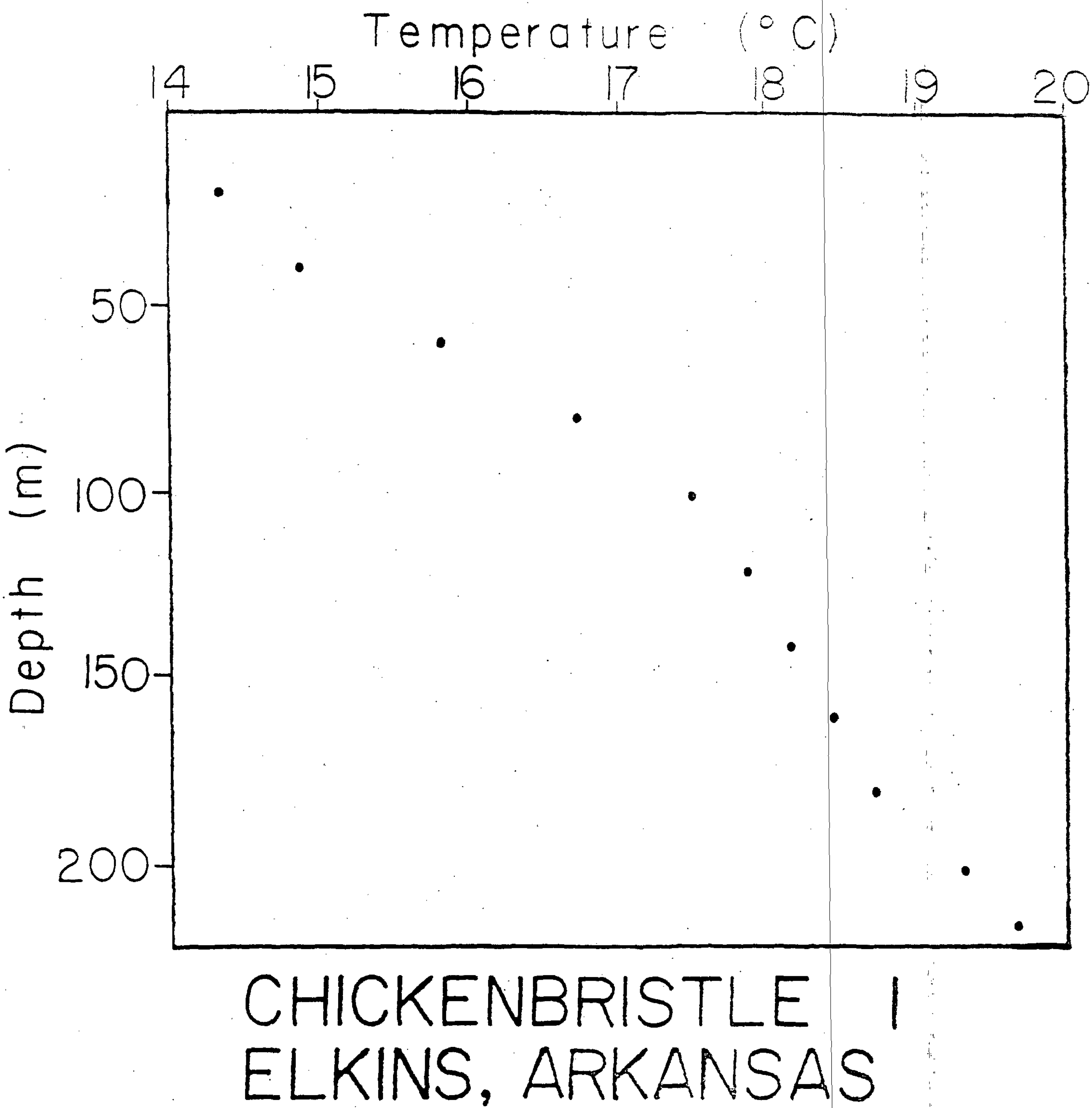

Temperature (°C)
14
15
16
17
18
19
20
Depth (m)
50
100
150
200
CHICKENBRISTLE I
ELKINS, ARKANSAS

Figure 5.

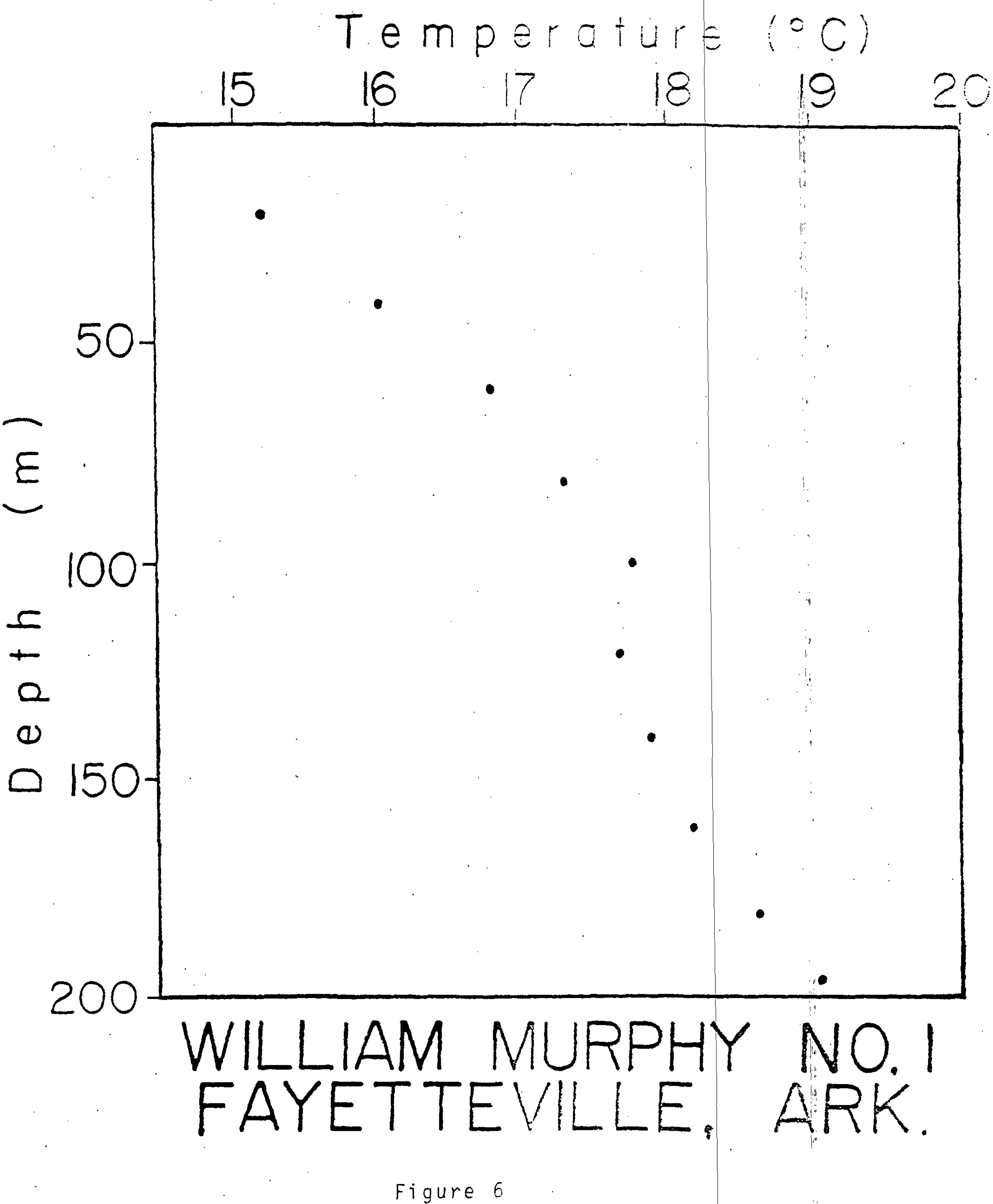

Temperature (°C)
15
16
17
18
19
20
Depth (m)
50
100
150
200
WILLIAM MURPHY NO. 1
FAYETTEVILLE, ARK.

Figure 6

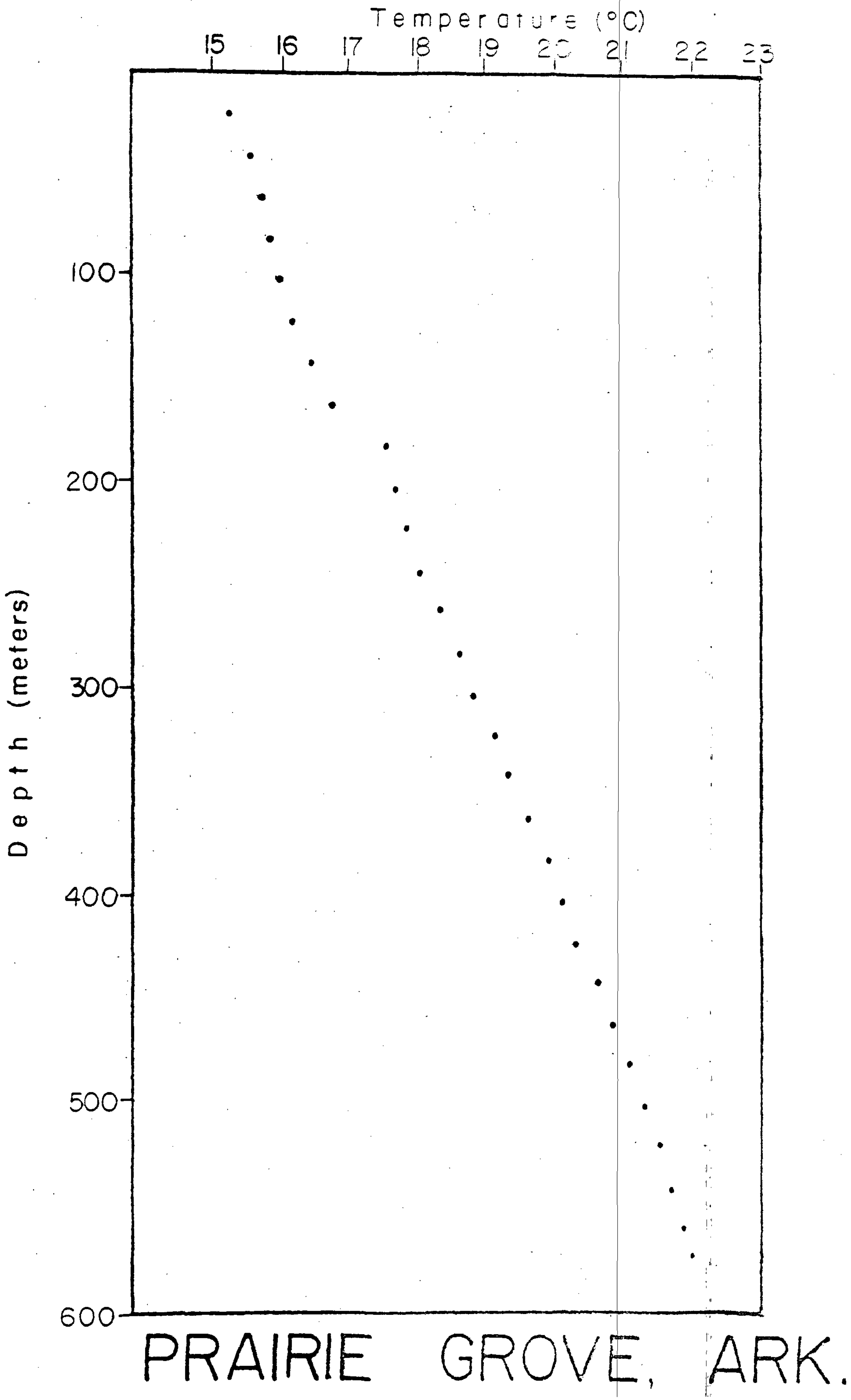

Temperature (°C)
15
16
17
18
19
20
21
22
23
Depth (meters)
100
200
300
400
500
600
PRAIRIE GROVE, ARK.

Figure 7.

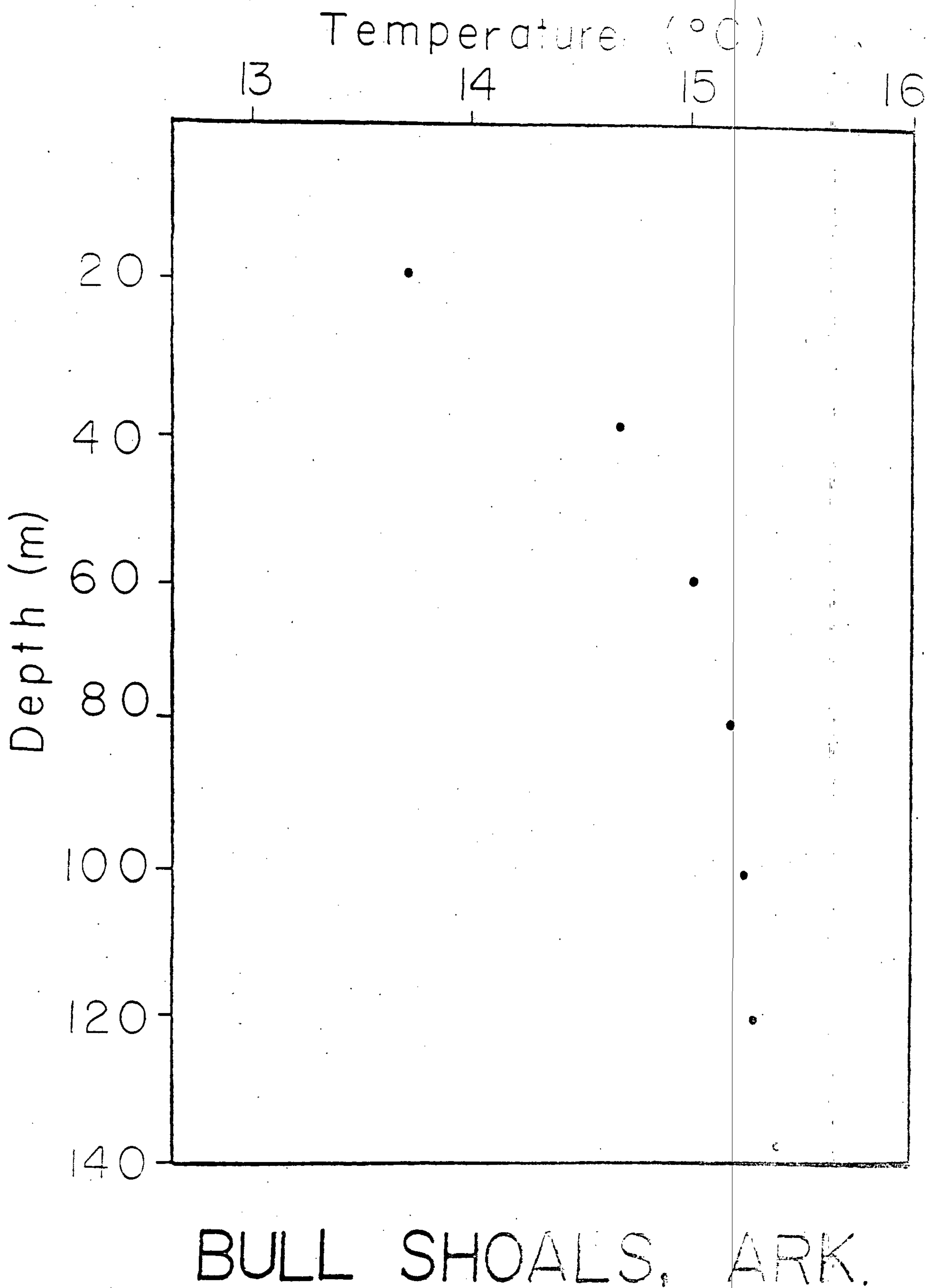
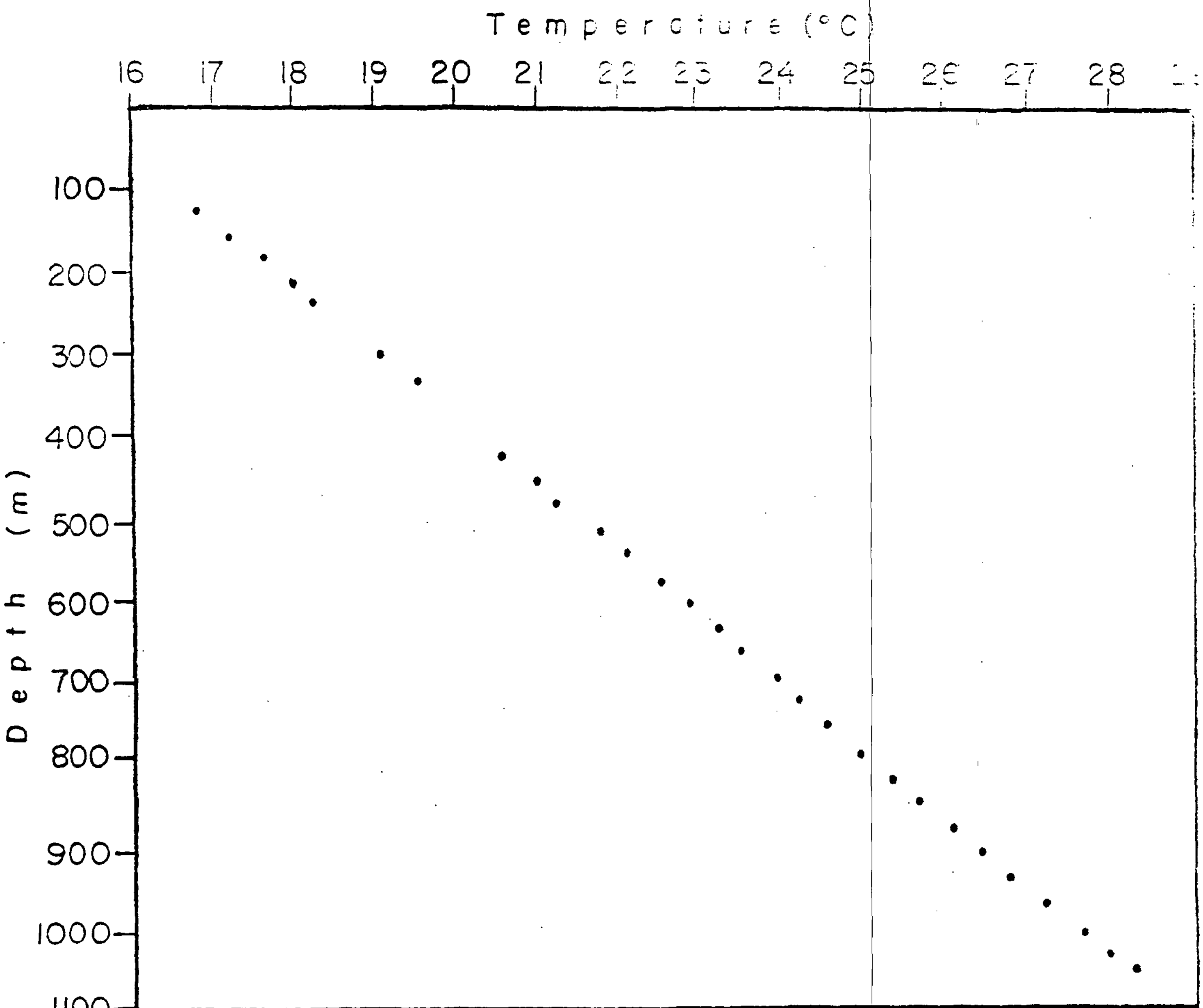
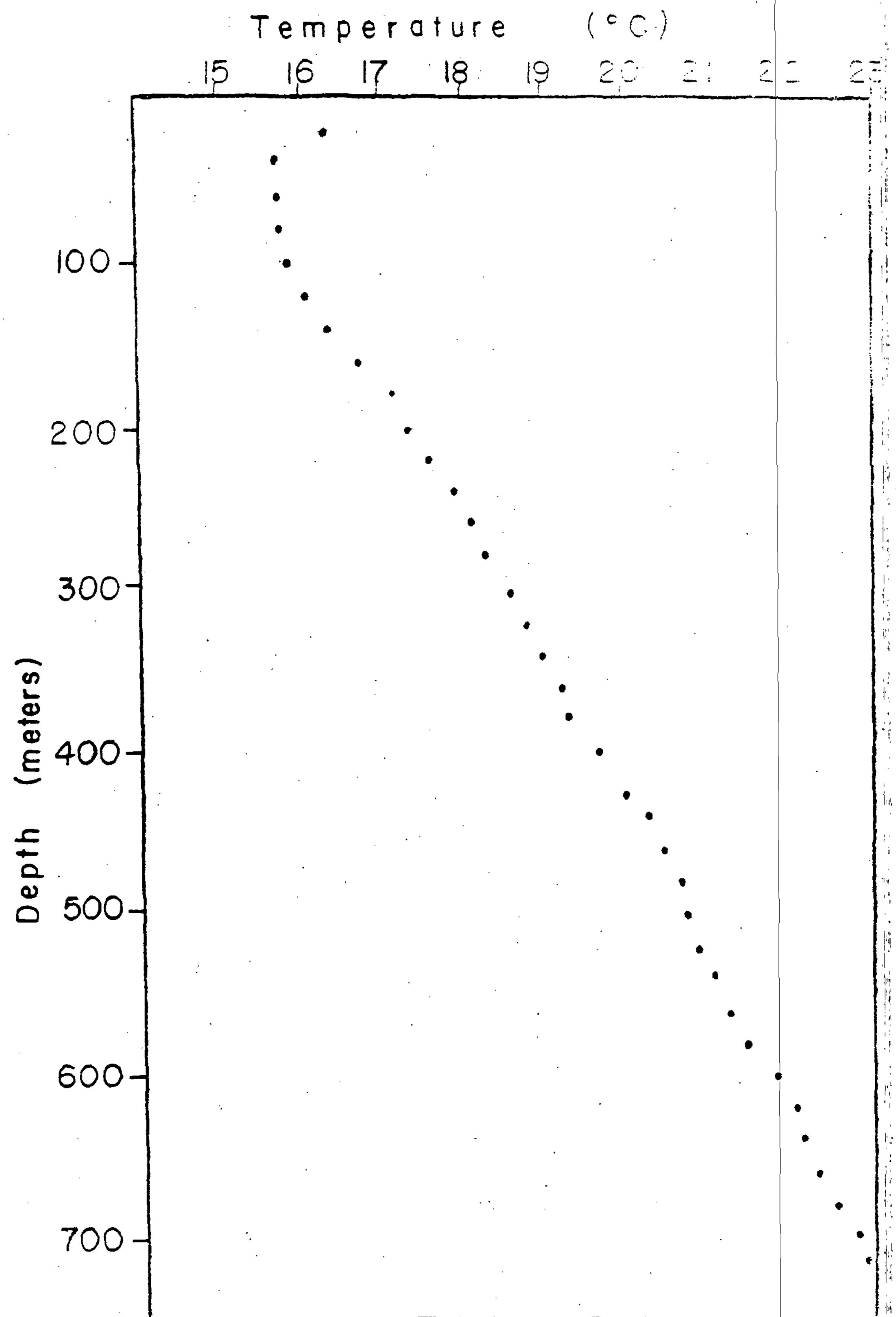

Temperature (°C)
13
14
15
16
20
40
60
80
100
120
140
Depth (m)
BULL SHOALS, ARK.

Figure 8



LESLIE
SEARCY CO.
ARKANSAS

Figure 9



GREEN FOREST
CARROLL CO.

Figure 10

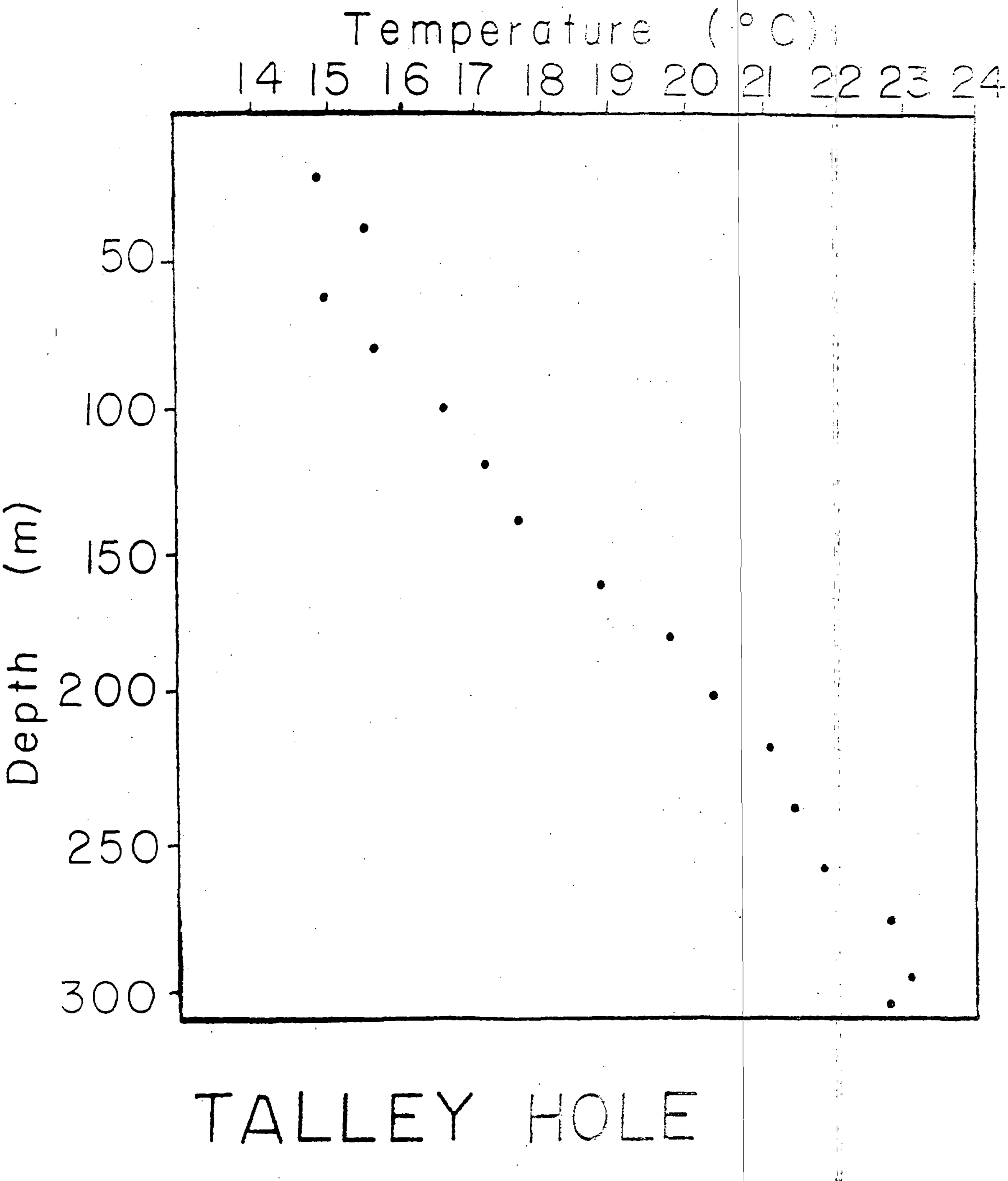

Temperature (°C)
14 15 16 17 18 19 20 21 22 23 24
Depth (m)
50
100
150
200
250
300
TALLEY HOLE
WASHINGTON CO.

Figure 11

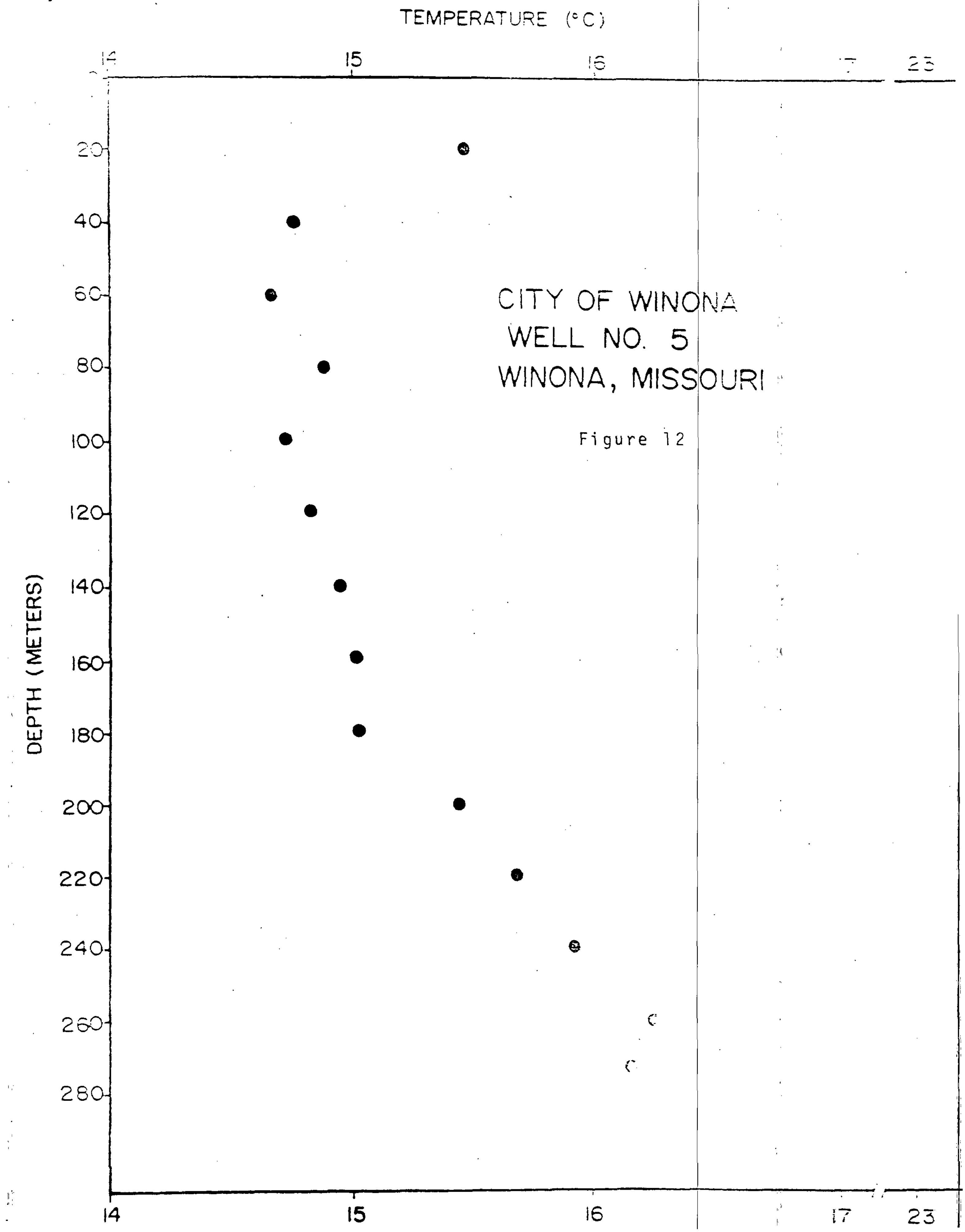

TEMPERATURE (°C)
14
15
16
17
23
DEPTH (METERS)
20
40
60
80
100
120
140
160
180
200
220
240
260
280
CITY OF WINONA
WELL NO. 5
WINONA, MISSOURI

Figure 12

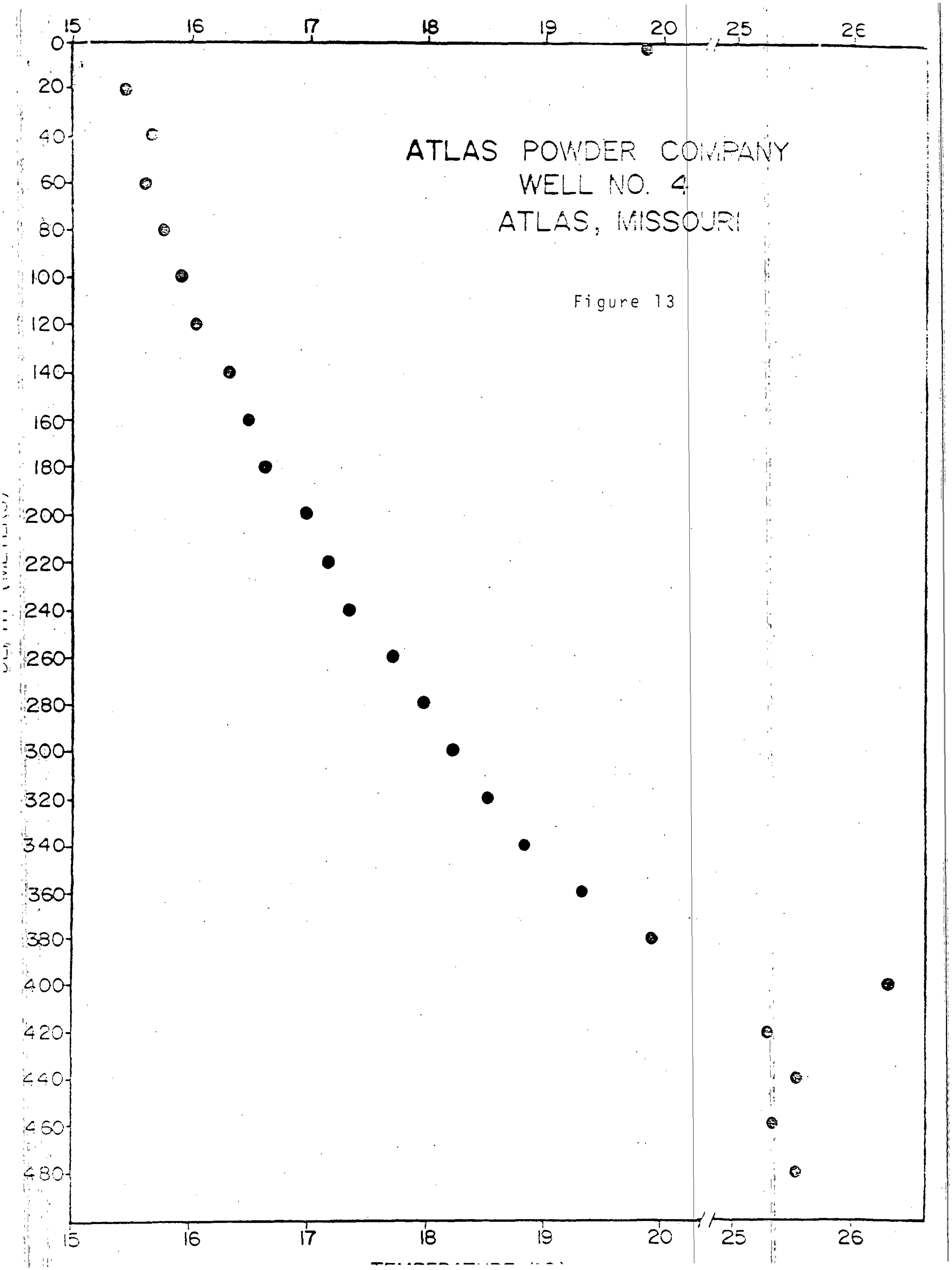
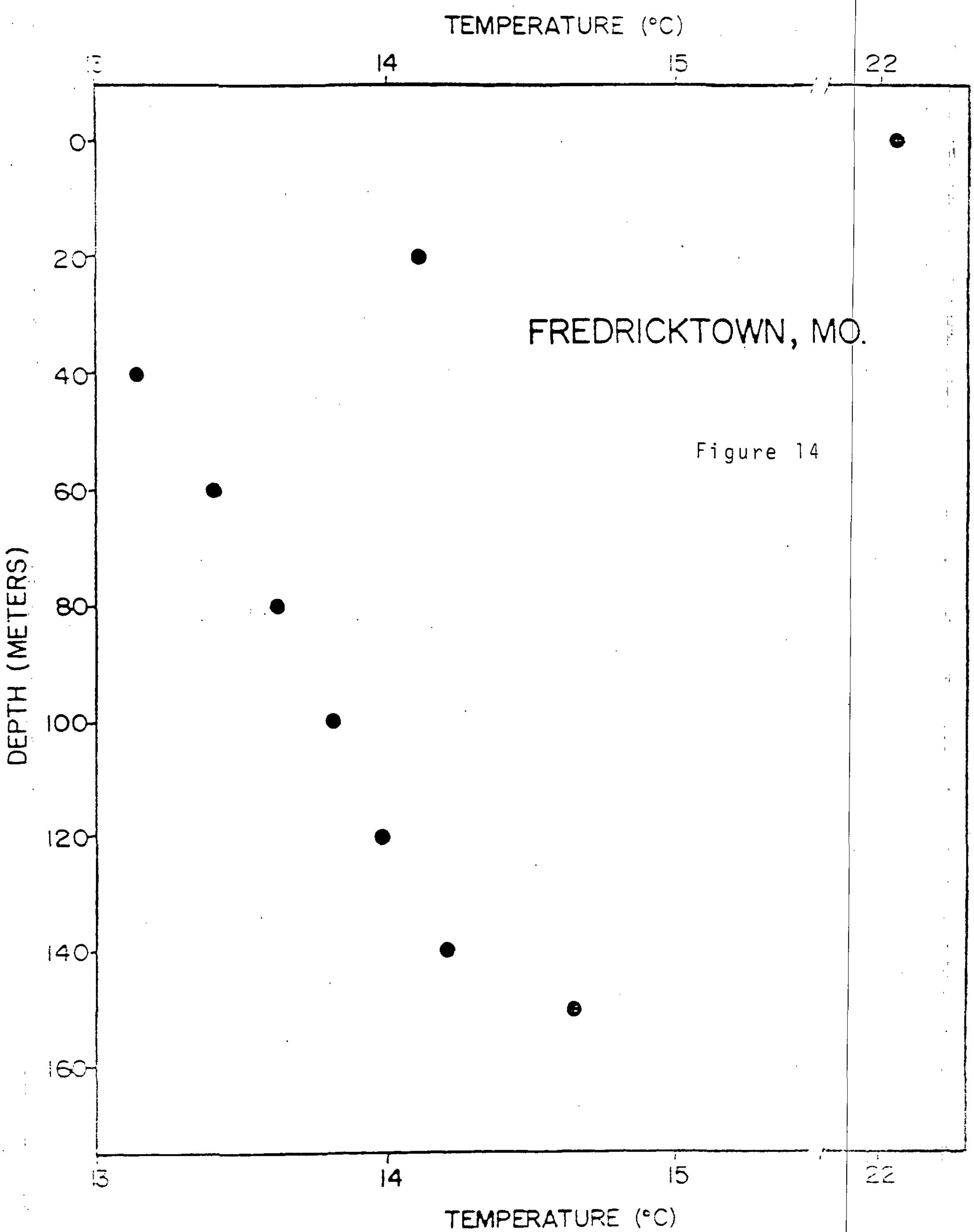

ATLAS POWDER COMPANY
WELL NO. 4
ATLAS, MISSOURI
15
16
17
18
19
20
25
26
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
320
340
360
380
400
420
440
460
480

Figure 13


TEMPERATURE (°C)
13
14
15
22
0
20
40
60
80
100
120
140
160
DEPTH (METERS)
FREDRICKTOWN, MO.
Figure 14

APPENDIX I

TEMPERATURE - DEPTH VALUES

William Murphy Hole #1
Fayetteville, Washington Co., Arkansas

Depth (m)	Temp (°C)
20	15.245
40	16.042
60	16.720
80	17.310
100	17.796
120	17.680
140	17.904
160	18.180
180	18.619
195	19.037

Chickenbristle Hole #1
Elkins, Washington Co., Arkansas

Depth (m)	Temp (°C)
20	14.323
40	14.875
60	15.706
80	16.726
100	17.238
120	17.878
140	18.141
160	18.413
180	18.702
200	19.293
215	19.676

Bull Shoals, Marion Co., Arkansas

Depth (m)	Temp (°C)
20	13.712
40	14.676
60	15.048
80	15.182
100	15.244
120	15.266
137	15.398

TEMPERATURE - DEPTH VALUES (Continued)

Prairie Grove Battlefield
Prairie Grove, Washington Co., Arkansas

Depth (m)	Temp (^{o}C)
20	15.173
40	15.467
60	15.628
80	15.713
100	15.832
120	16.079
140	16.394
160	16.669
180	17.436
200	17.539
220	17.748
240	17.968
260	18.218
280	18.511
300	18.748
320	19.033
340	19.271
360	19.521
380	19.834
400	20.053
420	20.280
440	20.561
460	20.834
480	21.083

Depth (m)	Temp (^{o}C)
500	21.310
520	21.553
540	21.746
560	21.926
573	22.023

Talley Hole #1
Winslow, Washington Co., Arkansas

Depth (m)	Temp (^{o}C)
20	14.911
40	15.602
60	15.048
80	15.759
100	16.660
120	17.217
140	17.713
160	18.856
180	19.807
200	20.426
220	21.212
240	21.512
260	21.875
280	22.804
300	23.090
307	22.782

TEMPERATURE - DEPTH VALUES (Continued)

City Well #1
Green Forest City, Carroll Co., Arkansas

Depth (m)	Temp (^oC)	Depth (m)	Temp (^oC)
20	16.278	500	20.753
40	15.683	520	20.901
60	15.684	540	21.089
80	15.700	560	21.284
100	15.832	580	21.474
120	16.053	600	21.844
140	16.311	620	22.030
160	16.711	640	22.192
180	17.096	660	22.333
200	17.425	680	22.587
220	17.589	700	22.899
240	17.845	715	22.950
260	18.073		
280	18.236		
300	18.479		
320	18.738		
340	18.967		
360	19.184		
380	19.234		
400	19.636		
420	19.833		
440	20.282		
460	20.474		
480	20.658		

TEMPERATURE - DEPTH VALUES (Continued)

Leslie, Searcy Co., Arkansas

Depth (ft)	Temp (°C)	Depth (ft)	Temp (°C)
400	16.83	2000	22.77
500	17.21	2100	23.12
600	17.61	2200	23.48
700	18.08	2300	23.87
800	18.21	2400	24.18
1000	19.04	2500	24.53
1100	19.52	2600	24.90
1400	20.57	2700	25.28
1500	20.95	2800	25.61
1600	21.38	2900	25.96
1700	21.72	3000	26.39
1800	22.07	3100	26.73
1900	22.43	3200	27.06
		3300	27.54
		3400	27.81
		3482	28.13

APPENDIX II

William Murphy Hole #1
Fayetteville, Washington Co., Arkansas

Depth (ft)	Rock Type	Cond. (W/m°K)
150-160	Shale	1.05
210-220	Shale	1.17
280-290	Limestone	1.97
330-340	Limestone	1.89
390-400	Limestone	2.17
445-450	Limestone	1.91
510-515	Limestone	1.88
545-550	Limestone	1.90

Bull Shoals, Marion Co., Arkansas

Depth (ft)	Rock Type	Cond. (W/m°K)
100-105	Sandstone	1.70
250-255	Sandstone	1.76
450-455	Sandstone	2.31
650-655	Sandstone Shale	2.74

Chickenbristle Hole #1
Elkins, Washington Co., Arkansas

Depth (ft)	Rock Type	Cond. (W/m°K)
140-160	Siltstone	1.32
160-180	Siltstone	1.10
180-200	Siltstone	1.19
200-210	Siltstone	1.14

ROCK TYPE & CONDUCTIVITIES (Continued)

Depth (ft)	Rock Type	Cond. (W/m°K)
240-260	Siltstone Limestone Chert	1.53
300-310	Limestone	2.05
340-360	Limestone Chert	2.17
380-400	Limestone	2.07
460-480	Limestone Chert	1.84
500-520	Limestone	1.98
580-600	Limestone Chert	1.65
620-640	Shale	1.15
660	Limestone Chert	1.95

Prairie Grove Battlefield
Prairie Grove, Washington Co., Arkansas

Depth (ft)	Rock Type	Cond. (W/m°K)
200-210	Limestone	1.19
500-510	Limestone	1.48
800-810	Sandstone	1.26
1300-1310	Sandstone	1.28
2000-2010	Dolomite Chert	2.38

Talley Hole #1
Winslow, Washington Co., Arkansas

Depth (ft)	Rock Type	Cond. (W/m°K)
910-920	Limestone	1.62
920-930	Limestone Shale	1.84

ROCK TYPE & CONDUCTIVITIES (Continued)

Depth (ft)	Rock Type	Cond. (W/m°K)
930-940	Limestone	2.19
940-950	Limestone	2.07
950-960	Limestone	1.87
960-970	Limestone	1.81
970-980	Limestone	1.66

City Well #1
Green Forest City, Carroll Co., Arkansas

Depth (ft)	Rock Type	Cond. (W/m°K)
125-202	Limestone	1.99
687-693	Limestone Chert	2.33
795-800	Chert	2.23
898-905	Chert	2.14
996-1001	Chert	2.41
1096-1121	Chert Limestone	2.51
1200-1206	Chert	1.96
1295-1302	Sandstone	1.86
1498-1502	Chert Quartz	2.40

Leslie, Searcy Co., Arkansas

Depth (ft)	Rock Type	Cond. (W/m°K)
400-410	Limestone	2.36
1100-1110	Dolomite	1.91
1400-1405	Dolomite Sandstone	1.90
1940-1960	Chert Dolomite	2.22

ROCK TYPE & CONDUCTIVITIES (Continued)

Depth (ft)	Rock Type	Cond. ($W/m^{o}K$)
2400-2415	Chert	2.04
2900-2905	Chert Oolites	2.23
3405-3410	Chert Dolomite	2.31

FINAL REPORT

HEAT FLOW IN ARKANSAS

UNIVERSITY OF FLORIDA

Douglas L. Smith, Principal Investigator

20 July 1987

Submitted to

University of Utah Research Institute
391 Chipeta Way, Suite C
Salt Lake City, Utah 84108

Contract No. RI-1291

HEAT FLOW IN ARKANSAS

INTRODUCTION

This report fulfills the "deliverables" requirement of Purchase Order No. RI-1291 from the University of Utah Research Institute to the University of Florida, "Heat Flow in Arkansas." It summarizes previous heat flow measurements in Arkansas and those related to the Mississippi Embayment area. It also presents the results of new 1986-1987 heat flow measurements in Arkansas and southern Missouri.

PREVIOUS WORK

Previous measurements of geothermal properties of the Mississippi Embayment (Van Orstand, 1932; Spicer, 1964; Roy et al., 1980; Staub and Treat, 1981; Guffante and Nathenson, 1981; Smith et al., 1981; Jarrett, 1982; Smith and Dees, 1982a, 1982b; Swanberg et al., 1982) total 124 geothermal gradient values and 69 heat flow calculations. A summation of well locations, depths, geothermal gradients, thermal conductivity values, and heat flow values is given in table 1. These data are summarized in figures 1 and 2. The range of values suggests normal geothermal gradients and low to normal heat flux throughout the Mississippi Embayment.

Earlier reconnaissance surveys (Van Orstand, 1932; Spicer, 1964) reported geothermal gradients throughout portions of southern Arkansas, Louisiana, and Mississippi. A subset of their data, generally from well holes with gradient calculations for depths greater than 600 m, was used to produce a contoured temperature gradient map of the United States (Guffante and Nathenson, 1980).

Recent assessments of low-temperature geothermal resources in the Mississippi Embayment provide numerous calculations of geothermal gradients and heat flow throughout this area. Initial efforts (Smith et al., 1981; Smith and Dees, 1982a) reported 30 geothermal gradient and heat flow measurements in Louisiana and Mississippi. Heat flow values in Louisiana range from 43.47 mW/m^2 at Bogalusa to 89.03 mW/m^2 at Truxno. Measurements of the geothermal gradient in Louisiana vary from 17.71 $^{o}C/km$ at Bogalusa to 44.23 $^{o}C/km$ at Kelly. Values reported for wells in Mississippi are generally lower than those measured in Louisiana. The initial studies yielded values for heat flow and geothermal gradients in Mississippi which varied from 19.65 mW/m^2 and 12.64 $^{o}C/km$ at Columbus to higher values of 61.86 mW/m^2 and 45.78 $^{o}C/km$ at Utica.

Forty additional geothermal gradient and heat flow values (Jarrett, 1982) were determined for well sites throughout Arkansas, Tennessee, and Mississippi. Nine Measurements in Arkansas range from 13.76 $^{o}C/km$ and 24.66 mW/m^2 at Helena to 36.41 $^{o}C/km$ and 86.94 mW/m^2 at Pine Bluff. Collins (1985) added a tenth heat flow value for Arkansas at Jerome. Roy et al. (1980) reported several heat flow values for Arkansas, but later (personal communication, 1984) expressed confidence in only two of the values (listed in table 1).

METHODS

Two data-measuring expeditions to Arkansas were conducted to fulfill the requirements of this contract. The Principal Investigator and two graduate students participated in each trip. Additional measurements of geothermal gradients and surface heat flux were sought in portions of the study area previously void of thermal data. The availability of suitable well sites in the region of interest is sparse, but generous cooperation was realized from the Arkansas Geological Commission, the U.S. Geological Survey Water Resources Division in Little Rock, and the Big Rock Petroleum Corporation. Virtually no boreholes are presently available in southwestern Arkansas or the Ouachita Mountain area, efforts were concentrated in the Ozark Mountain region of northern Arkansas. Because the geological province of the southern Ozark Mountains which characterizes northern Arkansas extends into southern Missouri, data from drill holes in southern Missouri were included in this project. To that end, the Missouri Geological Survey provided valuable assistance.

Temperature measurements were made with a thermistor probe assembly and a Mueller-type Wheatstone Bridge coupled to a 1000 m, four-conductor cable with reel. Values were recorded at discrete intervals (usually every 20 m), and least squares gradients were computed. Based on laboratory calibrations of the probe assembly, the accuracy of individual temperature values is placed at $\pm 0.1^{o}C$, and the accuracy of gradient values is estimated to be $\pm 0.01\ ^{o}C/km$.

Only nonflowing boreholes were used in this study, but certain hydrologic conditions within the sequences of sedimentary rocks were significant. Drillers' verbal reports of subsurface "springs' and deviations at depth from uniform temperature gradients as determined from recorded values suggested variations in permeability within certain depth zones. Although some component of convective heat transfer must be assumed to augment the conductive heat conveyance, the proportional amount is not considered to be significant. The number of individual heat flow determinations now available tends to temper uncertainities regarding the applicability of individual values as characteristic.

Thermal conductivity values were determined on a standard divided-bar apparatus using crystalline quartz and fused quartz standards. Measurements were made on core cuttings from the boreholes logged or nearby representative boreholes exhibiting the same lithology. Porosity values were placed at 30% for sandstone, and 15% for shale and limestone samples. Conductivity values are estimated to be accurate to within 15%.

RESULTS

During the course of this project, approximately 70 boreholes in northern Arkansas were sought and actually located. Only six proved suitable for temperature logging for scientific purposes. Others were in use, too shallow, plugged, or otherwise unavailable. Temperature values at Leslie were determined by the U.S. Geological Survey. Six existing boreholes in southern Missouri were also located, and useful measurements were completed in three of them.

Figures 3 and 4 show the locations of the boreholes logged for this study. Figures 5-14 display the temperature depth profiles. The actual temperature values recorded in the bore holes are listed in Appendix I. Appendix II contains the results of thermal conductivity measurements on individual rock samples from the various core cuttings analyzed.

Heat flow values were calculated as the product of the temperature gradient and the mean harmonic conductivity values. Weighted average heat flow values were computed where different depth zones in a borehole exhibited different geothermal gradients and those variations were not compensated by conductivity changes. All locations, gradient values, thermal conductivity mean harmonic values, and heat flow computations are shown in table 2.

The new values reported herein are significant in several aspects. They represent the first heat flow measurements for the Ozark Plateau, and they depict the Ozarks as an anomalously low heat flow province, perhaps similar in magnitude to the

Sierra Nevada Batholith or the Black Warrior Basin. The bore hole logged at Green Forest, Arkansas, is the deepest hole used for heat flow measurements in Arkansas, and the borehole logged at Atlas, Missouri, is the deepest hole logged for heat flow purposes in Missouri.

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TABLE 1. Thermal data for well sites in the study area. Conductivity units (C.U.) are 10^{-3}cal/cm sec °C. Heat flow units (h.f.u.) are 10^{-6}cal/cm^2 sec and (H.F.U.) are mW/m^2. Model refers to thermal model used in one-dimensional modeling.

LOCATION	LATITUDE	LONGITUDE	DEPTH m	GRADIENT °C/km	C.U.	h.f.u.	H.F.U.	MODEL	SOURCE
Arkansas									
Blytheville	35°55'22"	89°54'19"	420	19.93 ±.75	6.60 ±.65	1.31 ±.014	54.76 ±.59	1	2
Evadale	35°33'06"	90°05'08"	360	15.78 ±.58	6.60 ±.65	1.04 ±.011	43.47 ±.46	1	2
Helena	34°32'43"	90°38'43"	186	13.76 ±.47	4.61 ±.25	.59 ±.004	24.66 ±.17	3	2
International Paper	34°32'43"	91°55'16"	337	32.67 ±.66	5.71 ±.47	1.87 ±.016	78.00 ±.67	1	2
Jerome	33°21'36"	91°56'51"	240	41.41	3.91	1.62	67.72	1	10
Marianna	34°46'31"	90°45'58"	180	19.99 ±.26	4.61 ±.25	.92 ±.005	38.54 ±.21	3	2
Pine Bluff #1	34°12'40"	91°55'30"	220	32.06 ±.54	5.71 ±.47	1.83 ±.15	76.49 ±.63	1	2
Pine Bluff #2	34°12'19"	91°55'30"	240	24.67 ±.73	5.71 ±.47	1.41 ±.12	58.9 ±.50	1	2
Pine Bluff #3	34°12'19"	91°55'30"	265	36.41 ±2.96	5.71 ±.47	2.08 ±.024	86.95 ±1.00	1	2
Thompson Grove	34°56'29"	90°20'06"	500	22.09 ±.15	6.66 ±.58	1.02 ±.013	42.68 ±.54	3	2
Wilson	35°33'12"	90°02'14"	430	22.65	6.45	1.44	60.19	1	6
Well #21	35°33'19"	90°03'46"	430	18.60	–	1.39	58.10	1	5,6
Well #26	34°42'00"	92°15'00"	175	25.50	4.16	1.06	44.31	1	9
Well #28	34°23'00"	93°50'00"	530	18.70	5.92	1.09	45.36	1	9
Well #29	34°13'00"	92°01'00"	265	31.05	–	–	–		5
Well #31	33°20'27"	92°40'49"	533	31.77	–				4
Well #32	33°06'12"	92°19'36"	630	40.80	–				3,4,7

TABLE 1. *(CONTINUED)*

LOCATION	LATITUDE	LONGITUDE	DEPTH m	GRADIENT °C/km	C.U.	h.f.u.	H.F.U.	MODEL	SOURCE
<u>**Louisiana**</u>									
Bastrop	32°43'52"	91°53'10"	258	37.45	4.92	1.72	71.90	2	1
Baton Rouge (North)	30°26'14"	91°08'30"	500	22.06	5.07	1.21	50.58	2	1
Baton Rouge (South)	30°25'09"	91°08'27"	500	23.64	4.42	1.10	45.98	2	1
Bernice CL-151	32°49'08"	92°44'35"	220	32.17	6.17	1.76	73.57	2	1
Bogalusa	30°49'00"	89°54'26"	440	17.71	5.90	1.04	43.47	2	1
Bosco OU-502	32°17'14"	92°04'14"	236	29.00	4.07	1.07	44.73	2	1
Calhoun OU-443	32°31'00"	92°16'58"	260	31.08	5.12	1.59	66.46	2	1
Deville R-893	31°23'39"	92°09'45"	250	24.94	4.51	1.12	46.82	2	1
Dolla OU-72	32°49'55"	92°08'40"	236	34.98	6.46	2.08	86.94	2	1
Junction City CL 169	33°00'02"	92°44'59"	230	24.94	6.02	1.50	62.70	2	1
Kelly CA 868	32°01'54"	92°16'46"	172	44.23	3.72	1.99	83.18	2	1
[illegible] CL-136	32°39'43"	92°57'36"	258	27.48	6.50	1.79	74.82	2	1
North Hodge JA 156	32°17'30"	92°17'17"	200	23.74	5.40	1.28	53.50	2	1
Scotlandville	30°32'31"	91°11'50"	500	19.57	6.10	1.24	51.83	2	1

TABLE 1. (CONTINUED)

LOCATION	LATITUDE	LONGITUDE	DEPTH m	GRADIENT °C/km	C.U.	h.f.u.	H.F.U.	MODEL	SOURCE
Sikes W-172	32°03'41"	92°29'16"	200	30.30	5.93	1.80	75.24	2	1
Simpson	31°15'44"	93°00'25"	378	26.82	4.78	1.28	53.50	2	1
Truxno UN-60	32°49'17"	92°24'20"	215	33.13	6.49	2.13	89.03	2	1
Vernon	32°23'57"	92°34'17"	217	29.11	4.92	1.26	52.67	2	1
Winnfield W-177	31°53'38"	92°40'00"	215	27.65	5.73	1.30	54.34	2	1
Well #528	32°30'45"	94°00'36"	686	41.34	-	-	-	-	3,4,7
Well #532	32°48'36"	93°53'24"	1067	36.00	-	-	-	-	3,4,7
Well #533	32°46'36"	90°00'36"	604	53.44	-	-	-	-	3,4,7
Well #534	32°44'18"	93°53'24"	610	39.37	-	-	-	-	3,4,7
Well #538	32°27'24"	93°08'00"	503	42.34	-	-	-	-	4,7
Well #540	32°22'24"	94°01'00"	686	47.14	-	-	-	-	1,4
Well #542	32°12'00"	93°34'24"	5486	34.58	-	-	-	-	8
Well #546	31°36'42"	93°29'12"	762	38.33	-	-	-	-	3,5,7
Well #547	31°35'30"	93°46'12"	533	47.00	-	-	-	-	3,4,7
Well #550	30°63'00"	92°45'00"	6096	32.76	-	-	-	-	8
Well #551	30°51'00"	91°54'36"	5488	24.93	-	-	-	-	8
Well #553	30°46'48"	92°24'00"	3962	31.85	-	-	-	-	8
Well #554	30°43'00"	91°39'00"	6706	29.12	-			-	8
Well #555	30°42'00"	93°18'00"	5791	30.12	-	-	-	-	8

TABLE 1. (CONTINUED)

LOCATION	LATITUDE	LONGITUDE	DEPTH m	GRADIENT °C/km	C.U.	h.f.u.	H.F.U.	MODEL	SOURCE
Well #556	30°37'48"	91°54'00"	6097	29.12	-	-	-	-	8
Well #557	30°34'12"	91°06'00"	6096	25.48	-	-	-	-	8
Well #560	30°18'00"	92°45'00"	5182	38.22	-	-	-	-	8
Well #561	30°18'00"	92°24'36"	5488	33.67	-	-	-	-	8
Well #562	30°13'12"	93°21'00"	5486	32.76	-	-	-	-	8
Well #563	30°12'36"	91°21'00"	5182	34.58	-	-	-	-	8
Well #564	30°06'00"	90°30'00"	3962	40.95	-	-	-	-	8
Well #565	29°58'48"	90°46'48"	5182	31.85	-	-	-	-	8
Well #566	29°57'00"	91°43'48"	6400	28.03	-	-	-	-	8
Well #567	29°57'00"	90°23'24"	4878	33.67	-	-	-	-	8
Well #568	29°54'36"	91°05'24"	5486	24.21	-	-	-	-	8
Well #569	29°54'00"	93°09'00"	5791	33.31	-	-	-	-	8
Well #570	29°50'24"	91°18'00"	6096	28.03	-	-	-	-	8
Well #571	29°49'48"	92°15'00"	6706	32.03	-	-	-	-	8
Well #572	29°42'00"	91°10'00"	6400	27.30	-	-	-	-	8
Well #573	29°36'00"	90°24'00"	6395	22.75	-	-	-	-	8
Well #574	29°36'00"	89°48'00"	5486	22.75	-	-	-	-	8
Well #575	29°10'00"	90°48'36"	6706	23.84	-	-	-	-	8
Mississippi									
Brooklyn	31°01'35"	89°09'31"	218	20.08	5.06	1.06	44.31	2	1
Cary C-44	32°48'21"	90°55'31"	190	17.11	4.68	.00	33.44	1	1

TABLE 1. (CONTINUED)

LOCATION	LATITUDE	LONGITUDE	DEPTH m	GRADIENT °C/km	C.U.	h.f.u.	H.F.U.	MODEL	SOURCE
Columbus G-185	33°25'40"	88°23'53"	268	12.64 ±.18	3.68 ±.57	.47 ±.007	19.65 ±.29	3	1
Columbus L-22	33°25'38"	88°23'53"	295	15.45 ±.32	3.31 ±.51	.51 ±.008	21.32 ±.33	3	2
Dunlieth F-6	33°24'31"	90°49'54"	278	28.96 ±.33	4.578 ±.92	1.33 ±.027	55.43 ±1.13	1	2
Elliott H-111	33°41'44"	89°42'57"	160	13.34 ±.45	6.412 ±.62	.855 ±.099	35.74 ±.38	3	2
Erwin H-28	33°06'02"	91°02'20"	111	17.21 ±.95	4.578 ±.92	.79 ±.016	32.94 ±.67	3	2
Forest L-13	32°21'45"	89°30'05"	240	19.83 ±.46	4.49 ±.54	.89 ±.11	37.20 ±.71	3	1
Greenville	33°24'00"	91°05'03"	114	25.14 ±.12	4.76 ±.46	1.20 ±.012	50.16 ±.50	1	1
Holly Springs F-72	34°47'11"	88°25'16"	214	20.90 ±.27	6.07 ±.70	1.27 ±.015	53.09 ±.63	1	1
Jackson H-21	32°17'44"	90°11'03"	215	38.80 ±3.99	3.30 ±.88	1.28 ±.017	53.50 ±1.55	2	2
Jackson H-63	32°17'41"	90°11'03"	249	35.08 ±2.10	3.30 ±.88	1.16 ±.032	48.49 ±1.34	2	2
Jackson H-35	32°17'45"	90°11'44"	215	39.20 ±1.69	3.302 ±.88	1.29 ±.015	53.97 ±1.66	2	2
Jackson U-82	32°16'14"	90°04'07"	400	19.29 ±.52	5.75 ±.80	1.11 ±.016	46.40 ±.67	2	2
Long Creek H-127	32°20'22"	88°36'32"	229	15.97 ±.13	5.34 ±.32	.85 ±.005	35.53 ±.21	3	2
Lyon K-22	34°12'30"	90°12'31"	392	24.62 ±.24	7.12 ±.27	1.75 ±.007	73.15 ±.29	1	2
Natchez	31°27'52"	91°20'22"	260	27.96	5.07	1.42	59.36	2	1

TABLE 1. (CONTINUED)

LOCATION	LATITUDE	LONGITUDE	DEPTH m	GRADIENT °C/km	C.U.	h.f.u.	H.F.U.	MODEL	SOURCE
Pace WW-643	33°47'37"	90°51'18"	280	16.23	5.55	.90	37.62	3	1
Pineview Lake J-5	32°02'40"	86°16'08"	158	32.54 ±1.09	2.64 ±.13	.86 ±.005	35.86 ±.21	3	2
Rienzi K-11	34°46'42"	88°34'05"	164	11.70 ±.07	4.18 ±.40	.49 ±.005	20.44 ±.21	3	2
Sanders	34°30'51"	88°58'06"	165	28.11 ±.73	2.832 ±.49	.81 ±.014	33.65 ±.58	3	2
Senatobia	34°37'24"	89°58'12"	334	19.94	5.10	1.01	42.22	3	1
Shelby D-31	33°56'30"	90°46'15"	500	23.97	4.86	1.33	55.59	1	1
Starkman	33°10'54"	88°28'25"	215	14.38 ±.27	7.22 ±.51	1.04 ±.0074	43.36 ±.308	3	2
Utica	32°06'30"	90°37'30"	380	45.98	3.09	1.48	61.86	2	1
West Point H-56	33°37'12"	88°38'46"	245	12.63 ±.12	2.64 ±.58	.33 ±.007	13.79 ±.29	3	2
Yazoo C-176	32°51'00"	90°24'38"	294	26.79 ±.37	6.43 ±.60	1.72 ±.016	72.06 ±.67	1	2
Well #641	33°58'12"	88°25'30"	762	17.72	-	-	-	-	3,4
Well #644	33°44'13"	88°18'31"	533	16.80	-	-	-	-	4
Well #651	32°27'00"	88°46'48"	240	24.00	-	-	-	-	5
Well #652	32°22'00"	90°12'00"	249	37.69	-	-	-	-	5
Well #655	32°18'06"	90°11'48"	610	45.00	-	-	-	-	5
Well #657	32°06'14"	90°04'07"	400	36.13	-	-	-	-	5
<u>Missouri</u>									
Caruthersville	36°11'38"	89°39'30"	370	31.9 ±.4	4.90	1.56	65.21	1	6

TABLE 1. (CONTINUED)

LOCATION	LATITUDE	LONGITUDE	DEPTH m	GRADIENT °C/km		C.U.		h.f.u.		H.F.U.		MODEL	SOURCE
Tennessee													
Braden	35°22'26"	89°33'01"	320	27.10	±.30	6.60	±.65	1.79	±.018	74.82	±.75	1	2
Fort Pillow	35°38'39"	80°49'35"	488	20.38		6.05		1.20	±.21	50.16		1	6
Memphis H:P-113	35°14'39"	89°57'23"	161	10.79	±.36	5.92	±.80	.64	±.009	26.75	±.38	3	2
Memphis SH:J-140	35°01'24"	90°07'22"	166	12.51	±.19	5.92	±.80	.74	±.01	30.93	±.42	3	2
Memphis SH:K-45	35°06'58"	89°56'04"	380	20.52	±.13	6.57	±.68	1.35	±.014	56.43	±.58	3	2
Memphis SH:O-181	35°09'14"	90°01'05"	420	18.78	±.21	6.60	±.65	1.24	±.012	51.83	±.50	3	7
Memphis SH:Q-58	35°11'04"	89°51'29"	251	12.92	±.62	6.10	±.80	.79	±.011	32.98	±.46	3	7
Ridgely	36°15'43"	89°29'40"	175	23.6	±.1	5.59		1.32		55.18		1	6

Sources: 1. Smith and Dees (1982a; 1982b; 1981); 2. Jarrett (1982); 3. Guffanti and Nathenson (1981); 4. Spicer (1964); 5. Staub and Treat (1981); 6. Swanberg et al. (1982); 7. Van Orstrand (1932); 8. Kron and Stix (1982); 9. Roy et al. (1980); 10. Collins (1985)

Table 2. New Heat Flow Data

Site	Latitude	Longitude	Depth,m	Grad, °C/km	Cond, W/m°K	# smpls	Heat Flow, mW/m
Murphy #1	Goshen Quad		20-100	31.85			
Fayetteville, AR	Sec27 T17N R29W		120-195	17.90			
					1.64	8	41.2
Chickenbristle	Elkins Quad		100-180	16.6			
Elkins, AR	Sec33 T16N R28W		180-215	27.92			
					1.53	13	30.4
Prairie Grove, AR	Prairie Grove Quad						
	Sec17 T15S R31W		220-573	12.47	1.42	4	17.8
Bull Shoals, Ar							
	Yellville Quad		60-137	4.02	2.05	5	8.2
Leslie, AR	Sec8 T20S R15W			11.4	2.12	7	24.2
	Leslie Quad						
Green Forest, Ar	T14N R15W						
	36°19'12"	93°26'33"	120-715	11.25	2.18	9	24.5
Talley #1	Winslow Quad		120-300	33.23	1.85	7	61.5
Winslow, Ar	Sec3 T13N R30W						
Winona, MO	36°57'16"	91°22'42"	180-260	14.2	2.45	4	34.8
Atlas, Mo	37°02'43"	94°28'14"	180-360	13.6	2.18	24	29.7
Fredricktown, MO							
	37°31'37"	90°24'30"	40-140	10.2	2.27	10	23.2

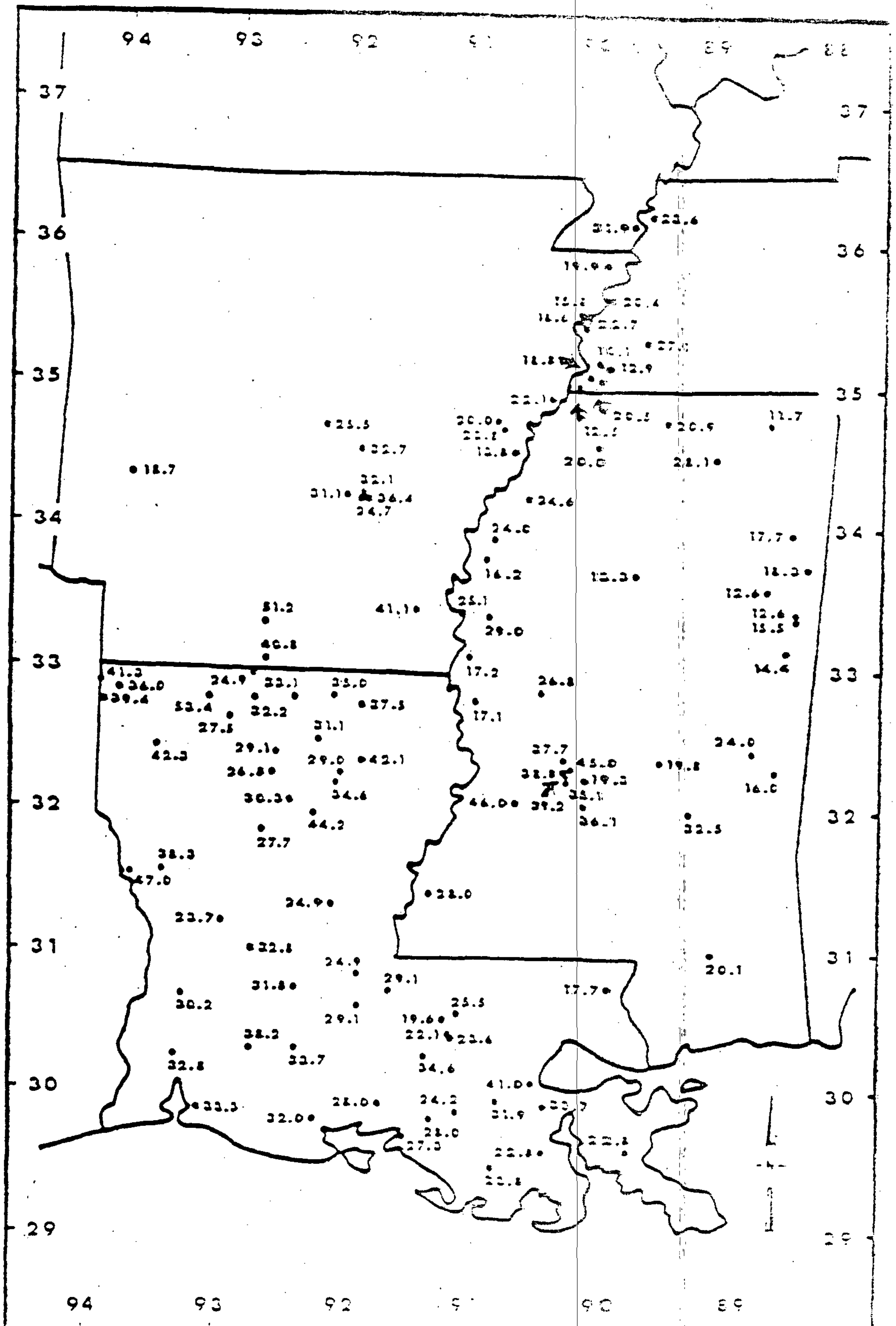


Figure 1. Geothermal gradient values (in °C/km) for the Mississippi Valley area (from Smith, Jarrett, and Collins, in prep.)

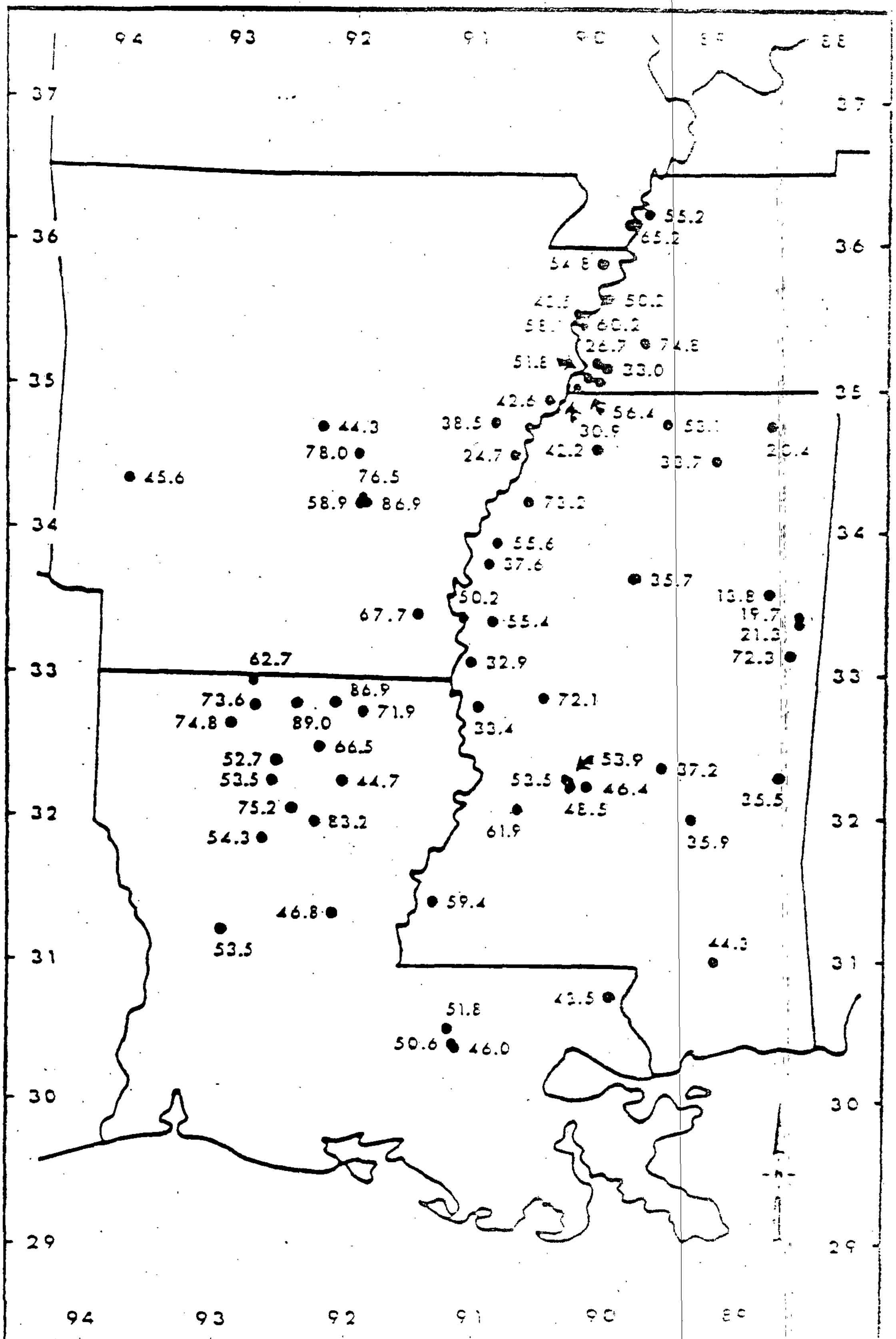


Figure 2. Heat flow values (in mW/m^2) for the Mississippi Valley region (from Smith, Jarrett, and Collins, in prep.).

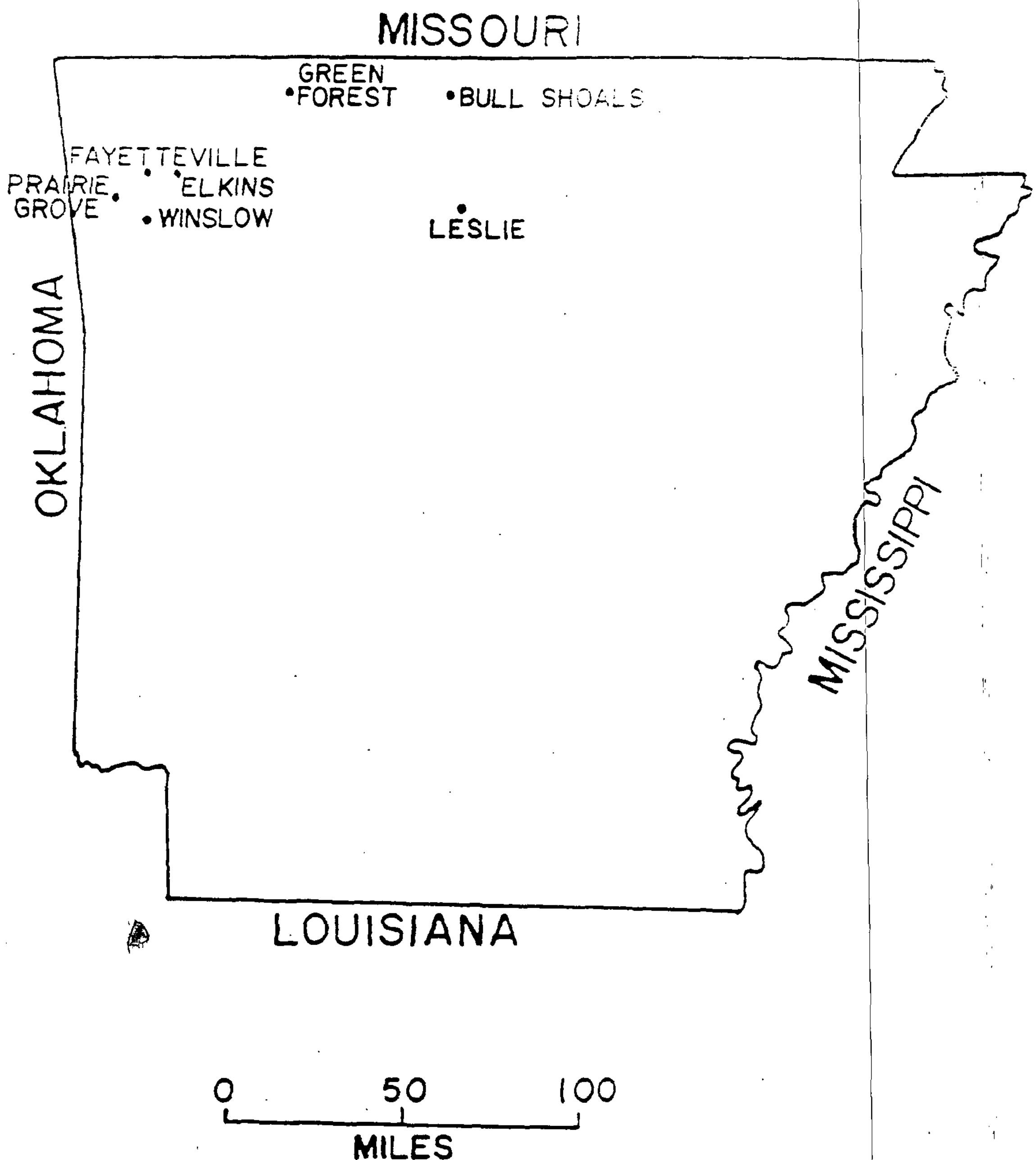


Figure 3. Distribution of new heat flow values in Arkansas

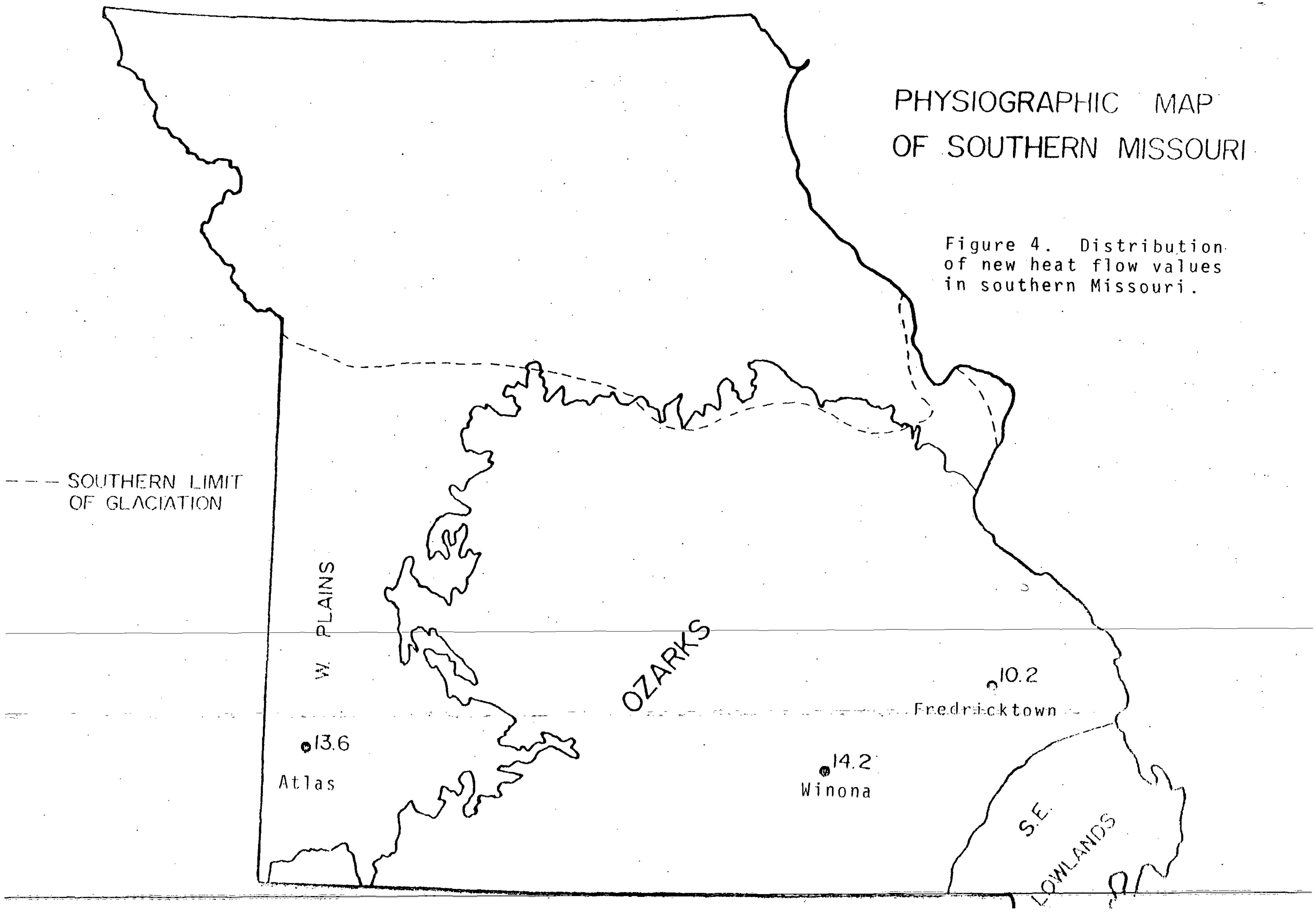


Figure 4. Distribution of new heat flow values in southern Missouri.

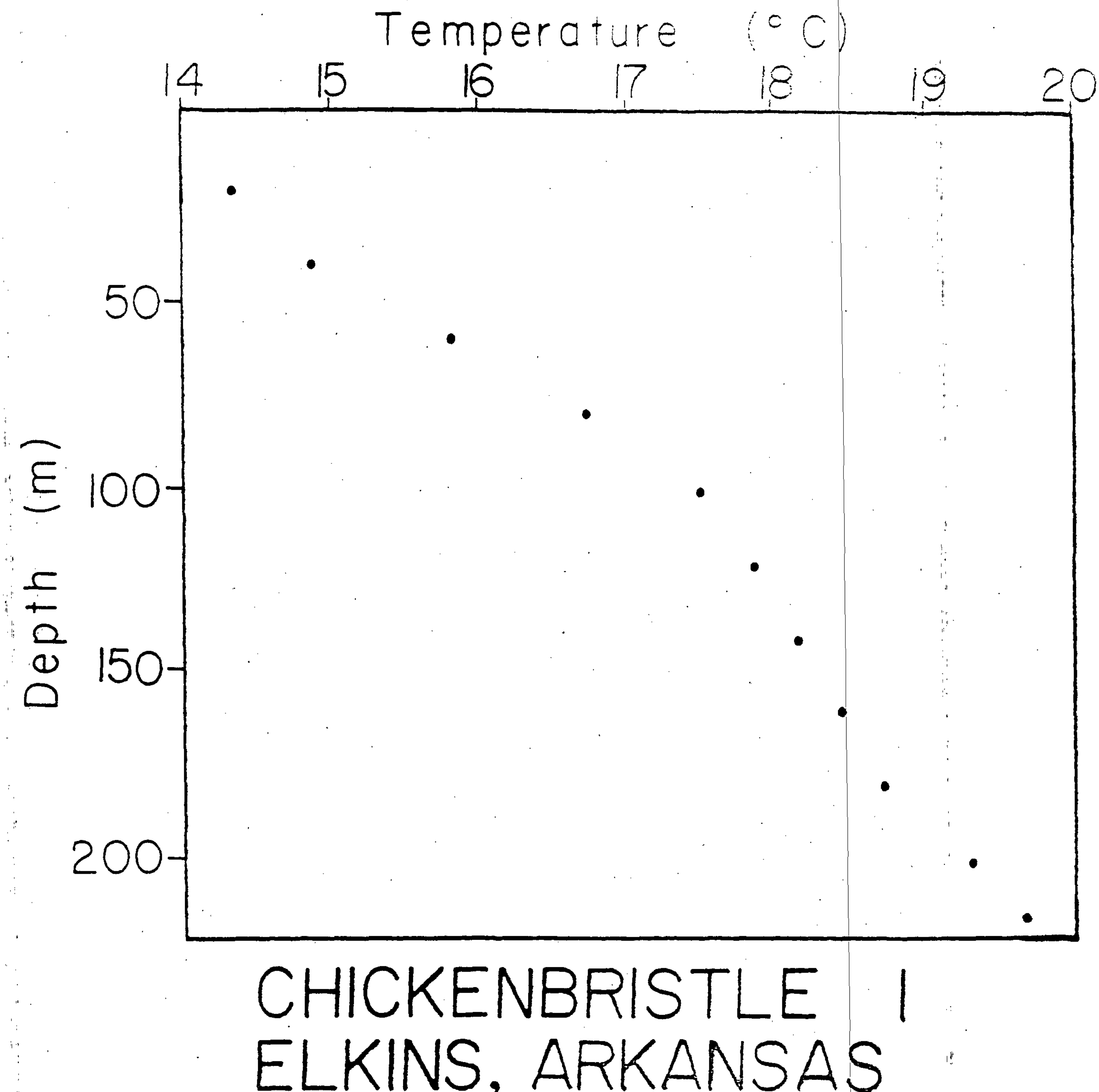

Temperature (°C)
14
15
16
17
18
19
20
Depth (m)
50
100
150
200
CHICKENBRISTLE I
ELKINS, ARKANSAS

Figure 5.

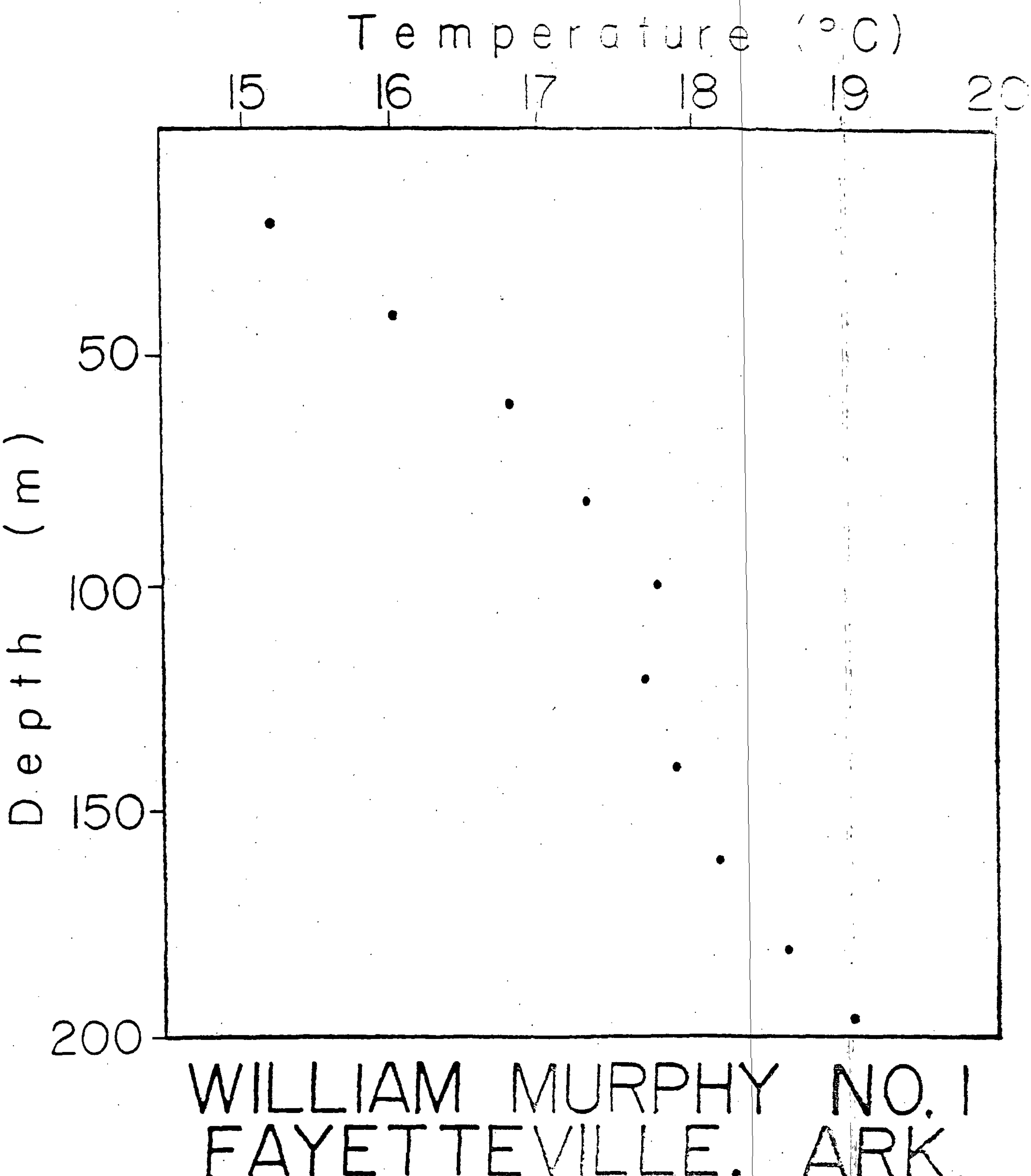

Temperature (°C)
15
16
17
18
19
20
Depth (m)
50
100
150
200
WILLIAM MURPHY NO. 1
FAYETTEVILLE, ARK.

Figure 6

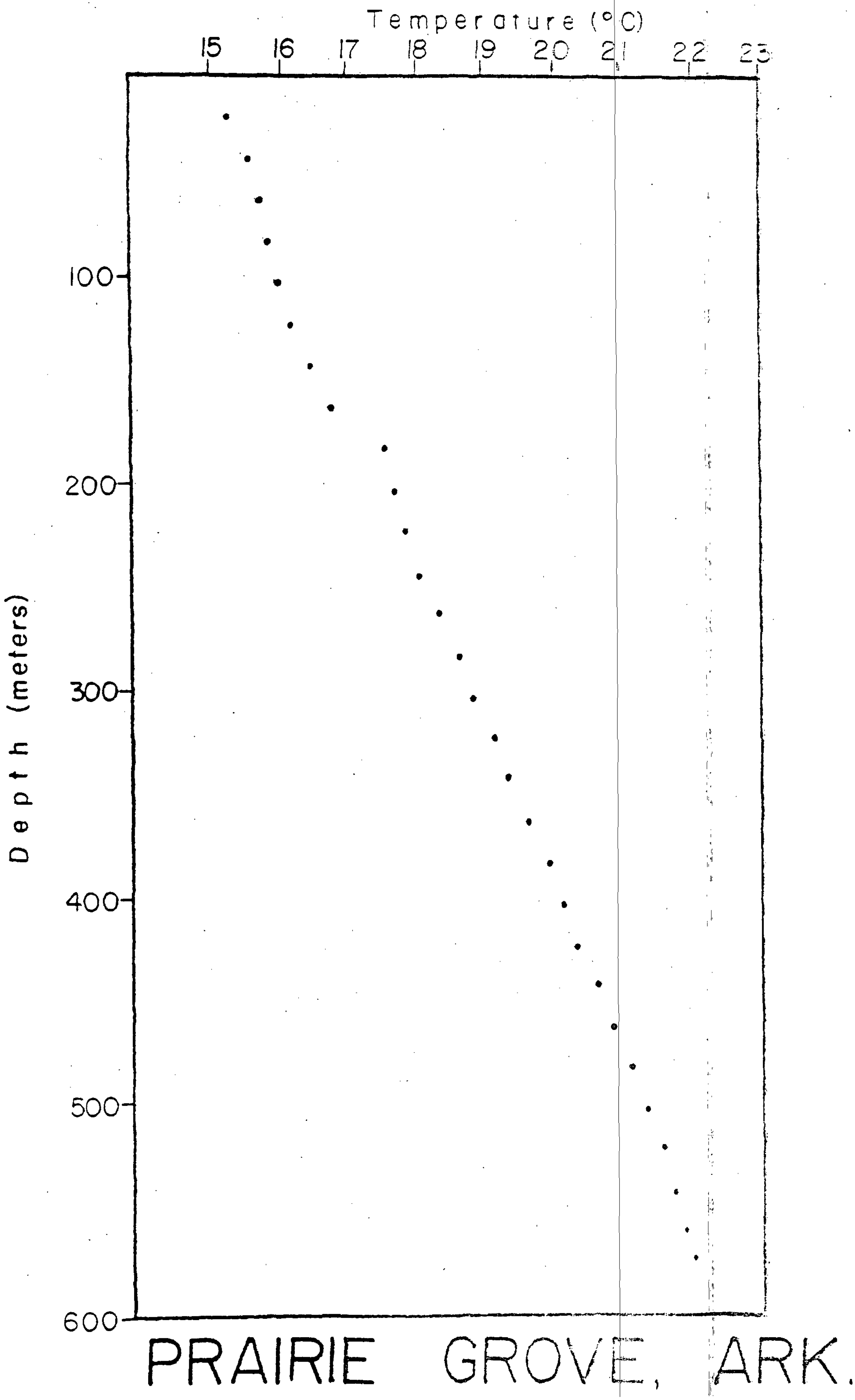
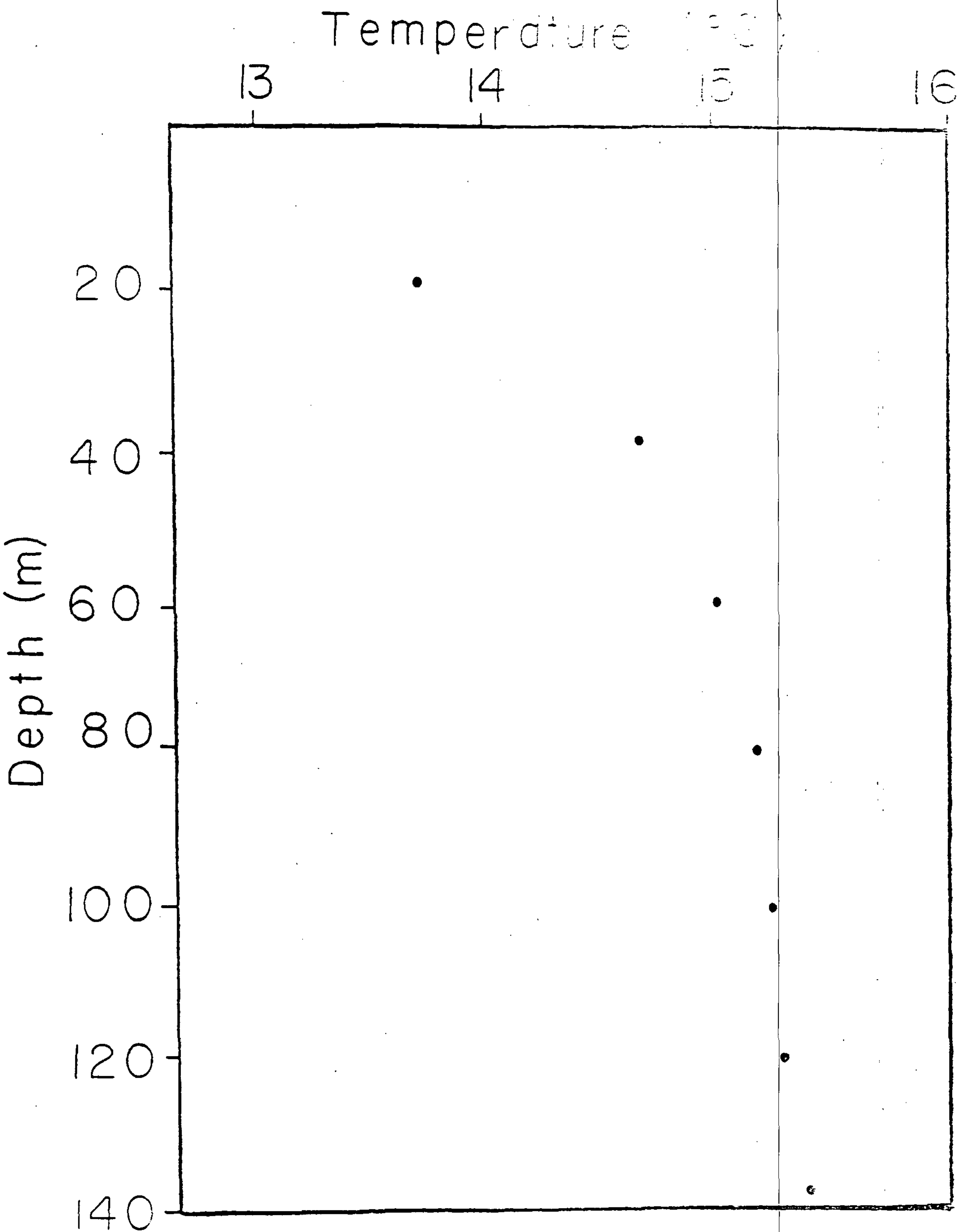
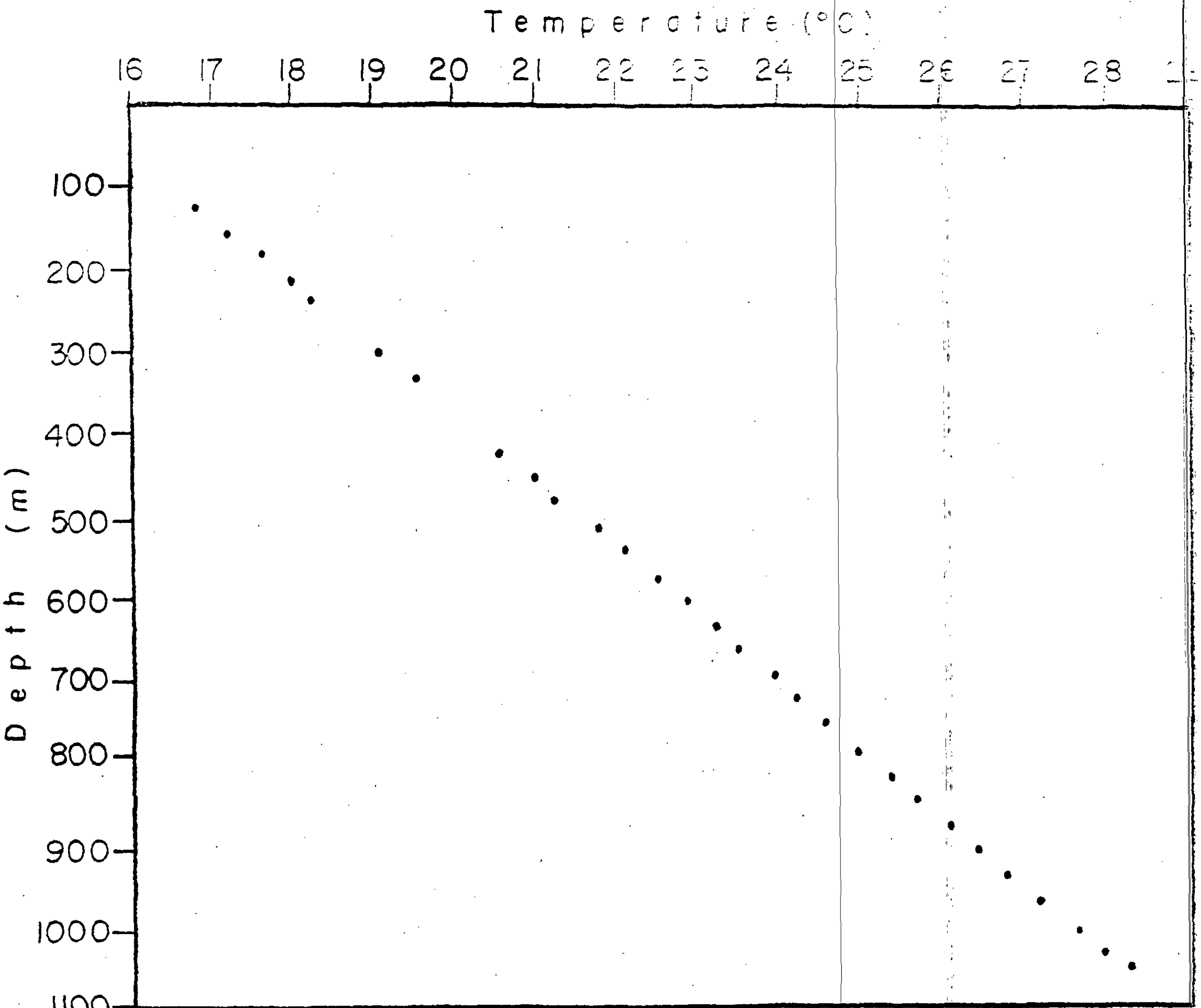

Temperature (°C)
15
16
17
18
19
20
21
22
23
Depth (meters)
100
200
300
400
500
600
PRAIRIE GROVE, ARK.

Figure 7.



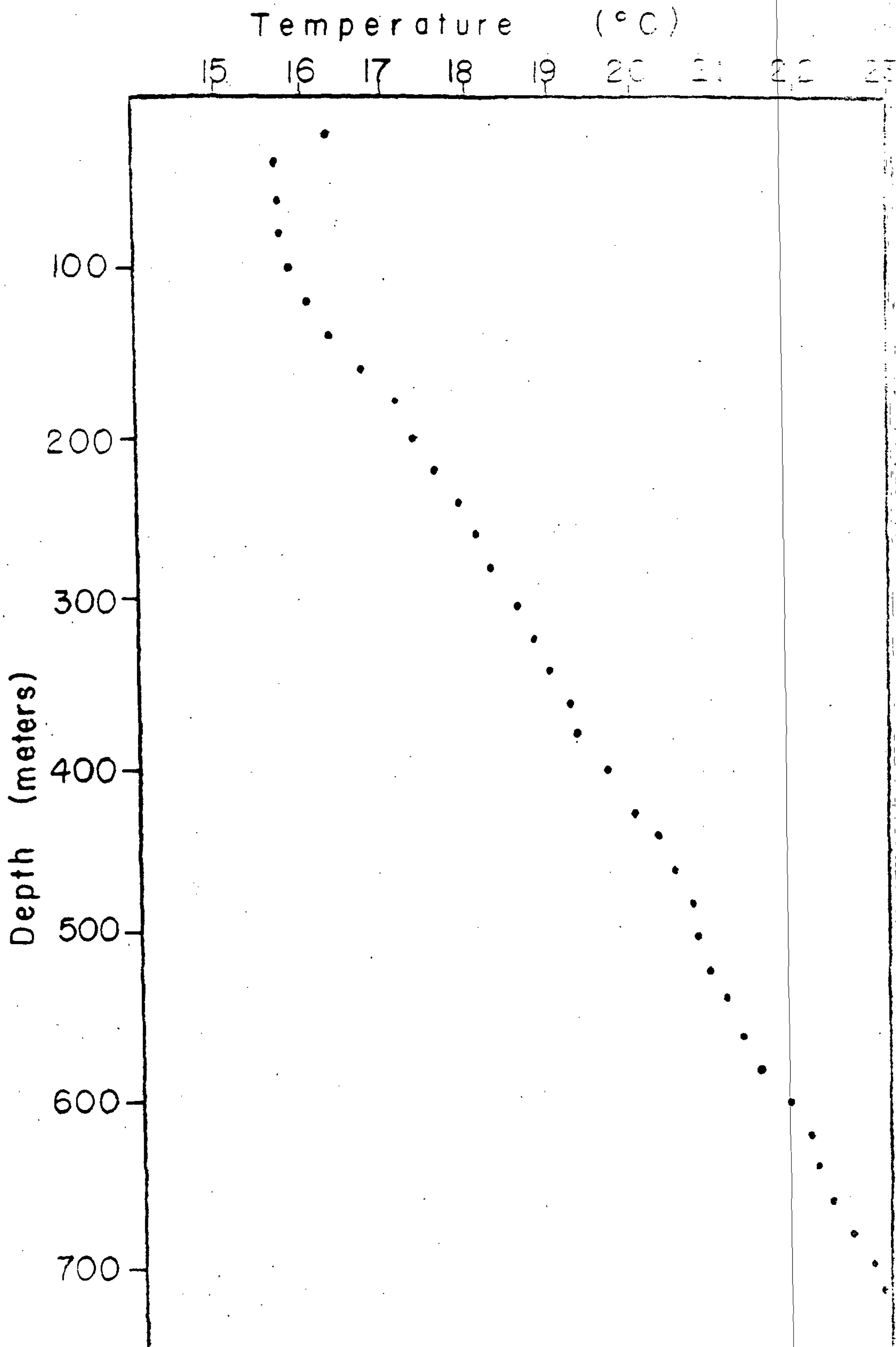
BULL SHOALS, ARK.

Figure 8



LESLIE
SEARCY CO.
ARKANSAS

Figure 9



GREEN FOREST
CARROLL CO.

Figure 10

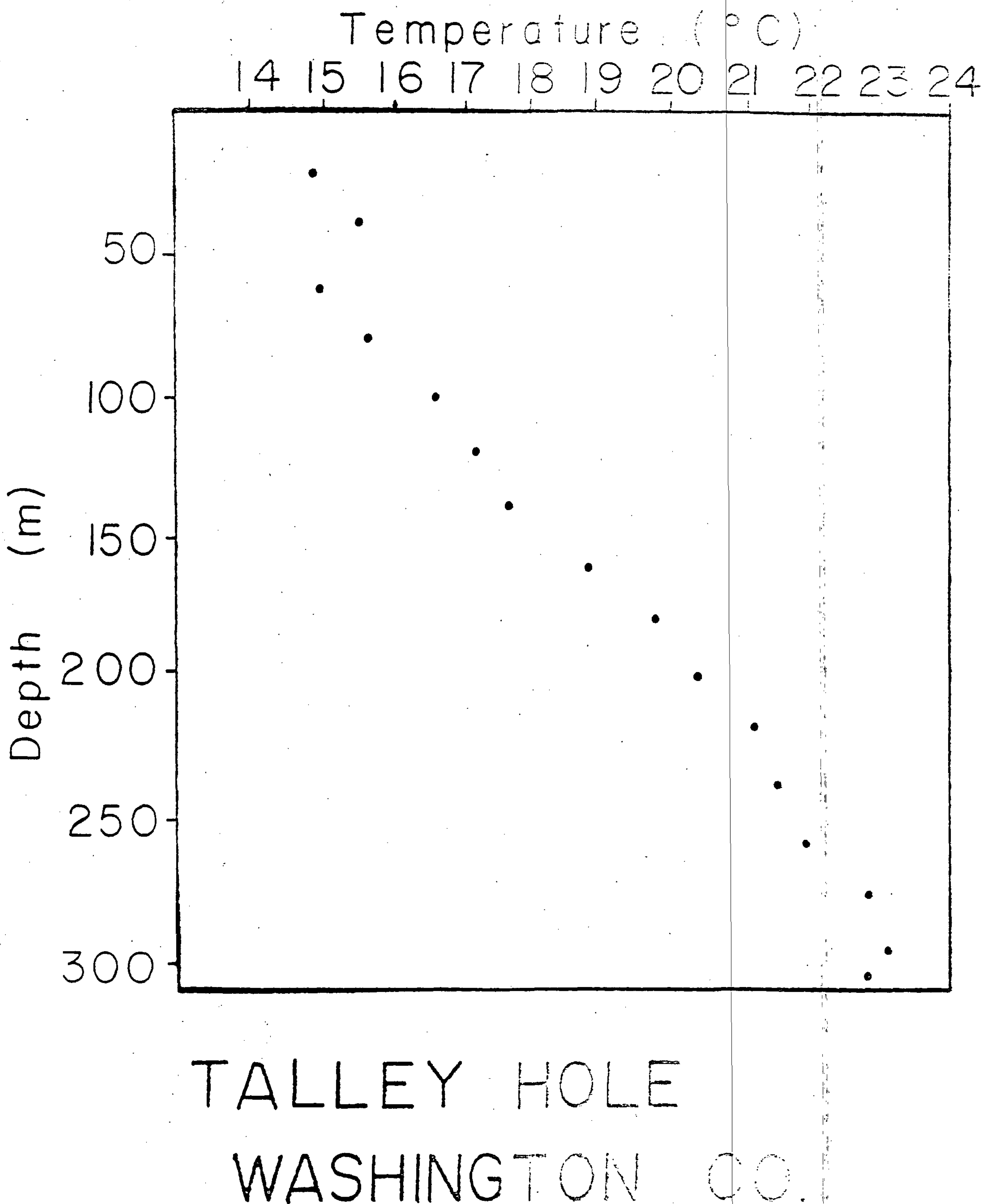

Temperature (°C)
14 15 16 17 18 19 20 21 22 23 24
Depth (m)
50
100
150
200
250
300
TALLEY HOLE
WASHINGTON CO.

Figure 11

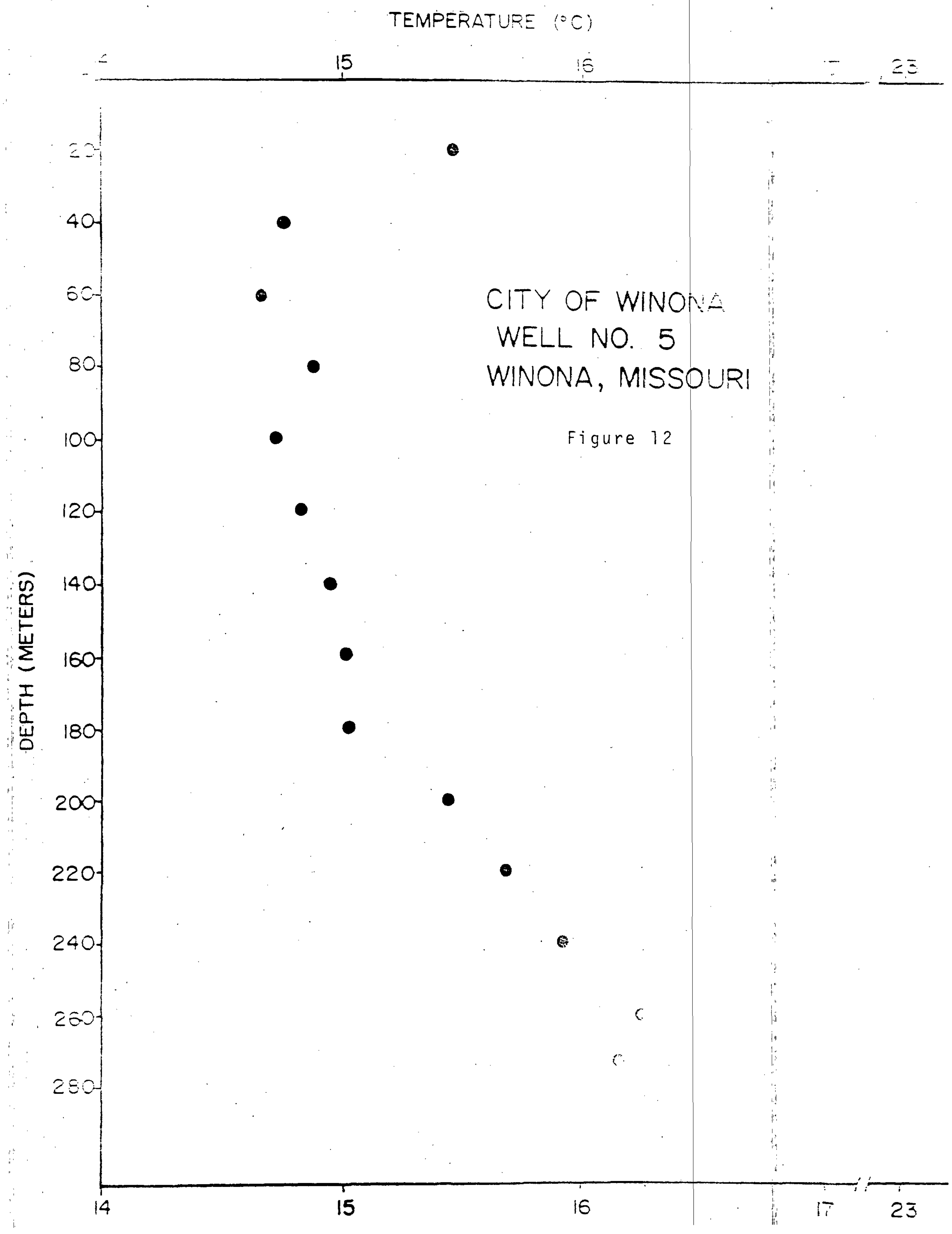
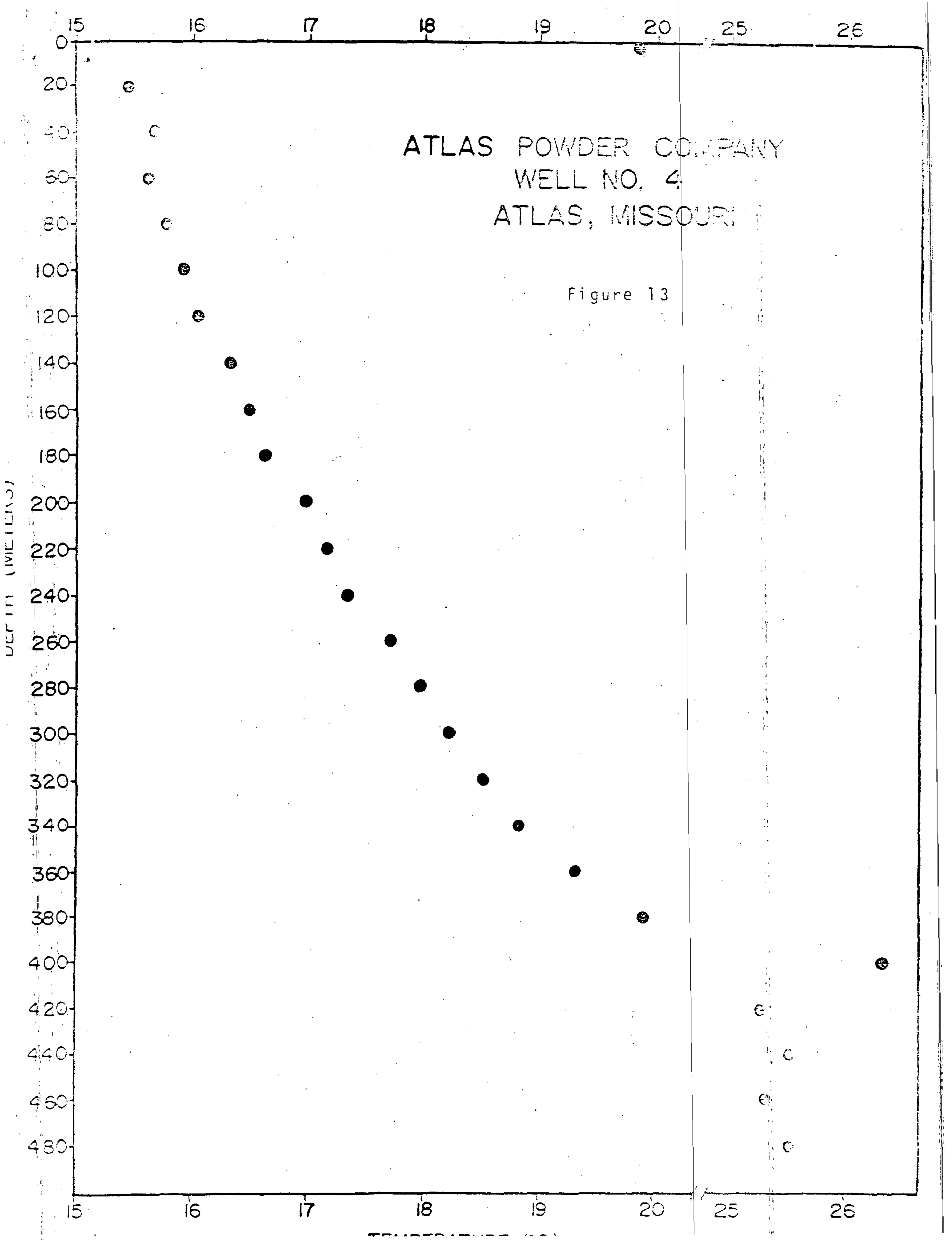

TEMPERATURE (°C)
15
16
23
DEPTH (METERS)
20
40
60
80
100
120
140
160
180
200
220
240
260
280
14
15
16
17
23
CITY OF WINONA
WELL NO. 5
WINONA, MISSOURI

Figure 12



ATLAS POWDER COMPANY
WELL NO. 4
ATLAS, MISSOURI
Figure 13
15
16
17
18
19
20
25
26
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
320
340
360
380
400
420
440
460
480

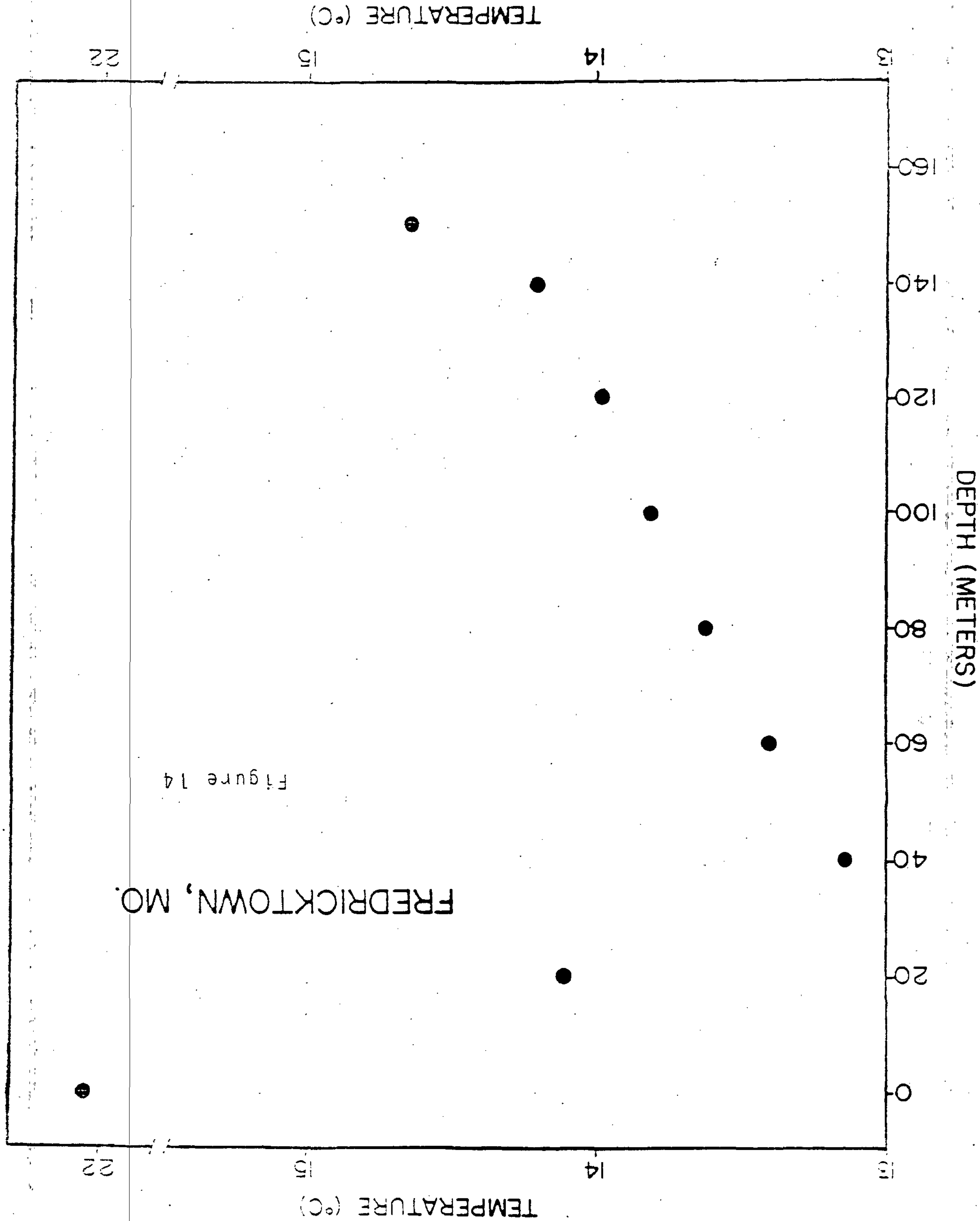

FREDRICKTOWN, MO.
DEPTH (METERS)
0
20
40
60
80
100
120
140
160
TEMPERATURE (°C)
13
14
15
22
TEMPERATURE (°C)
13
14
15
22

Figure 14

APPENDIX I

TEMPERATURE - DEPTH VALUES

William Murphy Hole #1
Fayetteville, Washington Co., Arkansas

Depth (m)	Temp (°C)
20	15.245
40	16.042
60	16.720
80	17.310
100	17.796
120	17.680
140	17.904
160	18.180
180	18.619
195	19.037

Chickenbristle Hole #1
Elkins, Washington Co., Arkansas

Depth (m)	Temp (°C)
20	14.323
40	14.875
60	15.706
80	16.726
100	17.238
120	17.878
140	18.141
160	18.413
180	18.702
200	19.293
215	19.676

Bull Shoals, Marion Co., Arkansas

Depth (m)	Temp (°C)
20	13.712
40	14.676
60	15.048
80	15.182
100	15.244
120	15.266
137	15.398

TEMPERATURE - DEPTH VALUES (Continued)

Prairie Grove Battlefield
Prairie Grove, Washington Co., Arkansas

Depth (m)	Temp (°C)
20	15.173
40	15.467
60	15.628
80	15.713
100	15.832
120	16.079
140	16.394
160	16.669
180	17.436
200	17.539
220	17.748
240	17.968
260	18.218
280	18.511
300	18.748
320	19.033
340	19.271
360	19.521
380	19.834
400	20.053
420	20.280
440	20.561
460	20.834
480	21.083
500	21.310
520	21.553
540	21.746
560	21.926
573	22.023

Talley Hole #1
Winslow, Washington Co., Arkansas

Depth (m)	Temp (°C)
20	14.911
40	15.602
60	15.048
80	15.759
100	16.660
120	17.217
140	17.713
160	18.856
180	19.807
200	20.426
220	21.212
240	21.512
260	21.875
280	22.804
300	23.090
307	22.782

TEMPERATURE - DEPTH VALUES (Continued)

City Well #1
Green Forest City, Carroll Co., Arkansas

Depth (m)	Temp (°C)	Depth (m)	Temp (°C)
20	16.278	500	20.753
40	15.683	520	20.901
60	15.684	540	21.089
80	15.700	560	21.284
100	15.832	580	21.474
120	16.053	600	21.844
140	16.311	620	22.030
160	16.711	640	22.192
180	17.096	660	22.333
200	17.425	680	22.587
220	17.589	700	22.899
240	17.845	715	22.950
260	18.073		
280	18.236		
300	18.479		
320	18.738		
340	18.967		
360	19.184		
380	19.234		
400	19.636		
420	19.833		
440	20.282		
460	20.474		
480	20.658		

TEMPERATURE - DEPTH VALUES (Continued)

Leslie, Searcy Co., Arkansas

Depth (ft)	Temp (^{o}C)	Depth (ft)	Temp (^{o}C)
400	16.83	2000	22.77
500	17.21	2100	23.12
600	17.61	2200	23.48
700	18.08	2300	23.87
800	18.21	2400	24.18
1000	19.04	2500	24.53
1100	19.52	2600	24.90
1400	20.57	2700	25.28
1500	20.95	2800	25.61
1600	21.38	2900	25.96
1700	21.72	3000	26.39
1800	22.07	3100	26.73
1900	22.43	3200	27.06
		3300	27.54
		3400	27.81
		3482	28.13

APPENDIX II

William Murphy Hole #1
Fayetteville, Washington Co., Arkansas

Depth (ft)	Rock Type	Cond. (W/m^{o}K)
150-160	Shale	1.05
210-220	Shale	1.17
280-290	Limestone	1.97
330-340	Limestone	1.89
390-400	Limestone	2.17
445-450	Limestone	1.91
510-515	Limestone	1.88
545-550	Limestone	1.90

Bull Shoals, Marion Co., Arkansas

Depth (ft)	Rock Type	Cond. (W/m^{o}K)
100-105	Sandstone	1.70
250-255	Sandstone	1.76
450-455	Sandstone	2.31
650-655	Sandstone Shale	2.74

Chickenbristle Hole #1
Elkins, Washington Co., Arkansas

Depth (ft)	Rock Type	Cond. (W/m^{o}K)
140-160	Siltstone	1.32
160-180	Siltstone	1.10
180-200	Siltstone	1.19
200-210	Siltstone	1.14

ROCK TYPE & CONDUCTIVITIES (Continued)

Depth (ft)	Rock Type	Cond. (W/m°K)
240-260	Siltstone Limestone Chert	1.53
300-310	Limestone	2.05
340-360	Limestone Chert	2.17
380-400	Limestone	2.07
460-480	Limestone Chert	1.84
500-520	Limestone	1.98
580-600	Limestone Chert	1.65
620-640	Shale	1.15
660	Limestone Chert	1.95

Prairie Grove Battlefield
Prairie Grove, Washington Co., Arkansas

Depth (ft)	Rock Type	Cond. (W/m°K)
200-210	Limestone	1.19
500-510	Limestone	1.48
800-810	Sandstone	1.26
1300-1310	Sandstone	1.28
2000-2010	Dolomite Chert	2.38

Talley Hole #1
Winslow, Washington Co., Arkansas

Depth (ft)	Rock Type	Cond. (W/m°K)
910-920	Limestone	1.62
920-930	Limestone Shale	1.84

ROCK TYPE & CONDUCTIVITIES (Continued)

Depth (ft)	Rock Type	Cond. (W/m^{o}K)
930-940	Limestone	2.19
940-950	Limestone	2.07
950-960	Limestone	1.87
960-970	Limestone	1.81
970-980	Limestone	1.66

City Well #1
Green Forest City, Carroll Co., Arkansas

Depth (ft)	Rock Type	Cond. (W/m^{o}K)
125-202	Limestone	1.99
687-693	Limestone Chert	2.33
795-800	Chert	2.23
898-905	Chert	2.14
996-1001	Chert	2.41
1096-1121	Chert Limestone	2.51
1200-1206	Chert	1.96
1295-1302	Sandstone	1.86
1498-1502	Chert Quartz	2.40

Leslie, Searcy Co., Arkansas

Depth (ft)	Rock Type	Cond. (W/m^{o}K)
400-410	Limestone	2.36
1100-1110	Dolomite	1.91
1400-1405	Dolomite Sandstone	1.90
1940-1960	Chert Dolomite	2.22

ROCK TYPE & CONDUCTIVITIES (Continued)

Depth (ft)	Rock Type	Cond. (W/m°K)
2400-2415	Chert	2.04
2900-2905	Chert Oolites	2.23
3405-3410	Chert Dolomite	2.31

University of Florida
Department of Geology

1112 Turlington Hall • Gainesville, Florida 32611 • (904) 392-2231

June 11, 1987

Dr. Howard P. Ross
Geophyics
University of Utah
Research Institute
391 Chipeta Way
Suite C
Salt Lake City, UT 84108-1295

Dear Mr. Ross:

Pursuant to our phone conversation on the 8th of June, I want to provide you with this letter update in research accomplished through.

Two M.S. graduate students and I are accumulating geothermal (temperature gradient, thermal conductivity, heat flow) measurements for Arkansas. At present, we are completing an initial series of conductivity measurements in our laboratory of several doten core/cuttings samples from deep wells in Arkansas. We have recorded in the field, temperature gradient values for five bore holes in northern and western Arkansas at this time.

Another field expedition to Arkansas to acquire additional temperature measurements and core/cutting samples is scheduled for 18-26 of June. We anticipate that the associated labortory measurements for that expedition to be completed by the 5th of July, and our final reports should be to you by the 15th of July. We hope you can accomodate this brief extension, and appreciate your interest.

Sincerely,

Douglas L. Smith
Professor

UNIVERSITY OF UTAH RESEARCH INSTITUTE
UURI
EARTH SCIENCE LABORATORY
391 CHIPETA WAY, SUITE C
SALT LAKE CITY, UTAH 84108—1295
TELEPHONE 801-524-3422

June 22, 1987

Dr. Douglas L. Smith
Department of Geology
University of Florida
1112 Turlington Hall
Gainesville, FL 32611

Reference: P.O. No. RI 1291

Dear Dr. Smith:

Thank you for your letter of June 11 which indicated the current status of your geothermal studies in Arkansas. We understand that you are completing another field trip to Arkansas during June 18-26 and that a few weeks of additional time will be required for laboratory measurements and report preparation.

Through this letter UURI authorizes a no cost time extension for the completion of your studies now in progress under University of Utah Research Institute Purchase Order Agreement No. RI-1291. The delivery date of the final report is extended from June 30, 1987 to July 20, 1987.

Sincerely,

Howard P. Ross
Project Manager

Wilford L. Forsberg
Director, Administrative Services

HR

University of Florida
Department of Geology

1112 Turlington Hall • Gainesville, Florida 32611 • (904) 392-2231

June 11, 1987

Dr. Howard P. Ross
Geophyics
University of Utah
Research Institute
391 Chipeta Way
Suite C
Salt Lake City, UT 84108-1295

Dear Mr. Ross:

Pursuant to our phone conversation on the 8th of June, I want to provide you with this letter update in research accomplished through.

Two M.S. graduate students and I are accumulating geothermal (temperature gradient, thermal conductivity, heat flow) measurements for Arkansas. At present, we are completing an initial series of conductivity measurements in our laboratory of several doten core/cuttings samples from deep wells in Arkansas. We have recorded in the field, temperature gradient values for five bore holes in northern and western Arkansas at this time.

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Sincerely,

Douglas L. Smith
Professor

UURI

University of Utah Research Institute
391 Chipeta Way Suite C
Salt Lake City, Utah 84108
Telephone 524-3422

REQUISITION

THIS IS NOT A PURCHASE ORDER

RI 1410

PURCHASE ORDER NO.	1 REQUISITION DATE	EXPECTED DEL. DATE	2 DELIVERY CODE	9 SUGGESTED SOURCE(S)	VENDOR NUMBER
RI 1291	3-25-87		99300	University of Florida	

3 REQUESTING DEPARTMENT: Earth Science Lab — RM. # / BLDG.: 391-C Chipeta Way

4 DELIVER TO ATTENTION OF: W. L. Forsberg — RM. # / BLDG.: 391-C Chipeta Way

5 DATE NEEDED BY: June 30, 1987

6 SPECIAL DELIVERY INSTRUCTIONS:

Suggested source (cont.):
Dept. of Sponsored Research
Gainesville, FL 32611
Attn: Dr. Donald Price, V.P.

7 ACCOUNT(S) TO BE CHARGED: 5-85102-4890

8 ACCOUNT EXPIRATION DATE: 9-30-87

BID ___ YES X NO — PUBLIC OPENING ___ YES X NO

BUYER NO. | TERMS | F.O.B. | S.C. NO. | BUYER INITIAL AND DATE

10 ORDER BY: ☒ MAIL ☐ TELEPHONE ☐ PICK UP ☐ TWX

11 SHIP BY: ☐ MOTOR FREIGHT ☐ AIR ☐ U.P.S. ☐ PARCEL POST — Best FOB.

12 Questions regarding this request should be directed to:

Name	Phone
H. P. Ross	(801) 524-3444
W. L. Forsberg	(801) 524-3442

13 ITEM	C/S - PROD. CODE	14 QUANTITY	15 UNIT ISSUED	16 CATALOG NUMBER / DESCRIPTION (INCLUDING STYLES, SIZE, COLOR, ETC.)	17 EST. UNIT PRICE	UNIT PRICE	TOTAL PRICE
1		5		Fixed Price - Purchase of technical report containing			
				Thermal Gradient and Heat Flow Data, State of Arkansas	$2,158.00		
				(see attached specifications.)			
				Attn: Dr. Douglas Smith, Dept. of Geology			

QUOTATION NO.	QUOTATION DATE	TELEPHONE CONFIRMATION TO	DATE	EST. TOTAL $
				$2,158.00

18 THIS IS TO CERTIFY THAT THERE IS NO LIKE EQUIPMENT IN THIS DEPARTMENT, AVAILABLE FOR USE IN LIEU OF ITEM(S) REQUESTED AND TO THE BEST OF MY KNOWLEDGE, THE PURCHASE WILL NOT RESULT IN A PROHIBITIVE CONFLICT OF INTEREST AS DEFINED IN PPM4.1.1

Doris A. Pettz — 3-25-87 — Howard P. Ross — 3/25/87

DEPARTMENT HEAD OR ACCOUNT EXECUTIVE | DATE | ADDITIONAL AUTHORIZATION - SIGNATURE | DATE

SUBTOTAL $
FREIGHT $
TOTAL $

PURCHASE ORDER SPECIFICATIONS

Purchase of a technical report in five (5) copies which summarizes: a) historical (pre-1986) heat flow and thermal gradient measurements in the state of Arkansas; and b) presents the facts for a minimum of eight 1986, 1987 thermal gradient and heat flow determinations conducted by the Univ. of Florida in the state of Arkansas.

The University of Florida will retain exclusive publication rights until December 31, 1987 but the data will be made available on an unrestricted basis through the technical report to the U.S. Department of Energy, and the University of Utah Research Institute. A copy of the report will also be made available to Dr. David Blackwell of Southern Methodist University for inclusion of the data in the Geothermal Map of the United States.

PAYMENT SCHEDULE: Payment in full of $2158.00 upon receipt and acceptance of a final technical report. The report shall not be delivered later than June 30, 1987 without prior written approval of the University of Utah Research Institute.

PURCHASE ORDER REQUEST

TO: Department of Sponsored Research
Attn: Dr. Donald Price
Vice President, Research
University of Florida
Gainesville, FL 32611

FOR: Department of Geology
Attn: Dr. Douglas Smith (904) 392-6766
University of Florida
Gainesville, FL 32611

Charge: State Cooperative Program, DOE-ID
Account No. 5-85102

Amount: ~~$2158.00~~ $2160.—

FOR: Thermal Gradient and Heat Flow Data, State of Arkansas.

The Department of Geology, University of Florida, will deliver a technical report which : a) summarizes the historical (pre-1986) heat flow and thermal gradient measurements in the state of Arkansas; and b) presents the principal facts for a minimum of eight new (1986-87) thermal gradient and heat flow determinations conducted by the University of Florida in the state of Arkansas. The final report will include well or drill site locations, depths, temperature profiles, thermal conductivity determinations, heat flow determinations, and a discussion of the results.

The University of Florida will retain exclusive publication rights until December 31, 1987 but the data will be made available on an unrestricted basis through the technical report to the U. S. Department of Energy, and the University of Utah Research Institute. A copy of the report will also be made available to Dr. David Blackwell of Southern Methodist University for inclusion of the data in the Geothermal Map of the United States.

PAYMENT SCHEDULE: Payment in full of $2158.00 upon receipt and acceptance of a final technical report. The report shall not be delivered later than June 30, 1986 without prior written approval of the University of Utah Research Institute.

reaomore hardcopy

To: E.FEINAUER (DOE3401)
To: P.WRIGHT (DOE4433)
From: P.WRIGHT (DOE4433) Posted: Tue 2-Dec-86 17:08 EST Sys 64 (59)
Subject: PR FOR U OF FLORIDA
Acknowledgment Sent

--More--

MEMO TO: PEGGY BROOKSHIER
FROM: HOWARD ROSS
SUBJECT: STATE COUPLED FUNDING FOR DR. DOUGLAS SMITH

Peggy, could you please review this PO and give us your comments? Also, we will need a letter from Ron King giving us authorization for this expenditure. Will this amount be added to our contract?

PURCHASE ORDER REQUEST

TO: Department of Sponsored Research
Attn: Dr. Donald Price
Vice President, Research
University of Florida
Gainesville, FL 32611

FOR: Department of Geology
Attn: Dr. Douglas Smith
University of Florida
Gainesville, FL 32611

Charge: State Cooperative Program, DOE-ID
Account No. 5-85102

Amount: $2158.00

FOR: Thermal Gradient and Heat Flow Data, State of Arkansas.

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UNIVERSITY OF UTAH RESEARCH INSTITUTE
UURI
EARTH SCIENCE LABORATORY
391 CHIPETA WAY, SUITE C
SALT LAKE CITY, UTAH 84108—1295
TELEPHONE 801-524-3422

November 26, 1986

Dr. Douglas Smith
Department of Geology
University of Florida
Gainsville, Florida 32611

Dear Dr. Smith:

I enjoyed our discussion earlier today about your heat flow studies in Arkansas. I understand that DOE intends to provide some financial support for your work in the near future.

Enclosed is a copy of the State Cooperative Program solicitation announced in the October 27 issue of the Commerce Business Daily. I have asked Peggy Brookshier, Program Manager for DOE-Idaho to include you in the mailing list for the solicitation. We expect it to be released near the end of the year.

Sincerely,

Howard Ross

Howard P. Ross
Section Head/Geophysics

Enclosure

HPR:leo

UNIVERSITY OF WYOMING

Henry P. Heasler
Department of Geology and Geophysics
P. O. Box 3006
Laramie, Wyoming 82071-3006
(307) 766-4200, 766-3278 or message at (307) 766-3386
Fax: (307) 766-2737

Rec. 5/17/91 HPR

May 16, 1991

Dr. Howard P. Ross
Earth Science Laboratory
University of Utah Research Institute
391 Chipeta Way, Suite C
Salt Lake City, UT 84108-1295

Dear Dr. Ross:

Enclosed is a copy of the final report for contract No. DE-FG07-88ID12738 entitled "Improved Computational Schemes for the Numerical Modeling of Hydrothermal Resources in Wyoming."

Although the project was extended much longer than originally anticipated, I feel that it has been successful. For example, I am now able to accomplish finite-difference temperature models on my personal computer which are more precise than the models I developed five years ago to work on a CYBER 760 mainframe computer. The iterative scheme converges orders of magnitude faster, the differencing scheme is more precise, and the boundary conditions more realistic.

However, as with most research, this project has suggested even more ways to improve this type of modeling. I hope to pursue funding sources to continue this worthwhile research.

Sincerely,

Henry P. Heasler

Henry P. Heasler
Assistant Professor

HPH:asr

Enclosure

UNIVERSITY OF WYOMING

Henry P. Heasler
Department of Geology and Geophysics
P. O. Box 3006
Laramie, Wyoming 82071-3006
(307) 766-3278 or 4200
Fax: (307) 766-2737

March 12, 1991

Dr. Howard P. Ross
Earth Science Laboratory
University of Utah Research Institute
391 Chipeta Way, Suite C
Salt Lake City, UT 84108-1295

Dear Dr. Ross:

Enclosed is a draft copy of the final report for contract No. DE-FG07-88ID12738 entitled "Improved Computational Schemes for the Numerical Modeling of Hydrothermal Resources in Wyoming." The contract is scheduled to end April 15, 1991. Consequently, your review before that time would be appreciated.

Although the project was extended much longer than originally anticipated, I feel that it has been successful. For example, I am now able to accomplish finite-difference temperature models on my personal computer which are more precise than the models I developed five years ago to work on a CYBER 760 mainframe computer. The iterative scheme converges orders of magnitude faster, the differencing scheme is more precise, and the boundary conditions more realistic.

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Sincerely,

Henry P. Heasler

Henry P. Heasler
Assistant Professor

HPH:asr

Enclosure

UNIVERSITY OF WYOMING

Department of Geology and Geophysics
P.O. Box 3006
Laramie, Wyoming 82071-3006
(307) 766-3386

September 18, 1990

Ms. Ginger Sandwina
Contract Specialist
U.S. Department of Energy
785 DOE Place
Idaho Falls, Idaho 83042

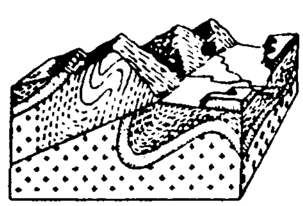
Dear Ms. Sandwina:

It has come to my attention that recent changes in Federal Regulations permit the recipients of research awards to extend the expiration date of the final budget period of the project. Therefore, for the medical reasons cited in my letter of September 13, 1990, The University of Wyoming, Department of Geology and Geophysics, has awarded itself a three month time extension, to January 31, 1991, for the completion of Grant DE-FG07-99ID12738, as provided for in 10 CFR Part 600, Section 600.31(d) as amended by FR doc. 89-24243, filed 10/12/89. No additional Federal funds are requested for this extension.

Sincerely,

Henry P. Heasler

cc: Howard Ross
Kenneth Taylor



UNIVERSITY OF WYOMING

Department of Geology and Geophysics
P.O. Box 3006
Laramie, Wyoming 82071-3006
(307) 766-3386

September 13, 1990

Ms. Ginger Sandwina
Contract Specialist
U. S. Department of Energy
785 DOE Place
Idaho Falls, Idaho 83042

Dear Ms. Sandwina:

This letter constitutes a request for a no-cost extension for grant DE-FG07-99ID12738.

Since May of 1990, I have had increasing medical problems with my eyes. The problems have worsened to the point that I have been unable to drive since June. This has precluded me from completing the field work as stated in the contract. My vision has degenerated to the point that I will be undergoing eye surgery within the next two weeks. If the surgery is successful, I should be able to complete the field work 4 to 6 weeks after surgery.

I am very much committed to completing this project, but would appreciate an extension until January 31, 1991.

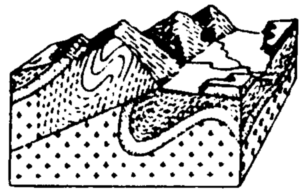
If you have any questions, please contact me at (307) 766-3278 or a message may be left at (307) 766-4200.

Sincerely,

Henry P. Heasler

Henry P. Heasler

cc: Howard Ross
Earth Science Lab
UURI



Ms. Alice Rush

Department of Geology and Geophysics
University of Wyoming

Dear Alice:

Some suggested wording:

> It has come to my attention that recent changes in Federal Regulations permit the recipients of research awards to extend the expiration date of the final budget period of the project. Therefore, for the medical reasons cited in my letter of September 13, 1990, The University of Wyoming, Department of Geology and Geophysics, has awarded itself a three month time extension, to January 31, 1991, for the completion of Grant _______________, as provided for in 10 CFR Part 600, Section 600.31(d) as amended by FR doc. 89-24243, filed 10/12/89. No additional Federal funds are requested for this extension.

Please send copies of this letter to:

> Howard P. Ross, Earth Science Laboratory, UURI
> Kenneth Taylor, DOE/ID

Please call me at (801) 524-3444 if you have any questions.

Sincerely,

Howard Ross
Project Manager

DOE F 4600.1
(7-81)

U.S. DEPARTMENT OF ENERGY

NOTICE OF FINANCIAL ASSISTANCE AWARD

(See Instructions on Reverse)

Under the authority of Public Law PL 93-410 and subject to legislation, regulations and policies applicable to *(cite legislative program title)*:
Geothermal Energy Research, Development, and Demonstration Act of 1974

1. PROJECT TITLE
Improved Computational Schemes

2. INSTRUMENT TYPE
☒ GRANT ☐ COOPERATIVE AGREEMENT

3. RECIPIENT *(Name, address, zip code, area code and telephone no.)*
University of Wyoming
Department of Geology and Geophysics
P. O. Box 3006, Laramie, WY 82071

4. INSTRUMENT NO. DE-FG07-88ID12738

5. AMENDMENT NO.

6. BUDGET PERIOD FROM: 7/1/88 THRU: 7/1/89

7. PROJECT PERIOD FROM: 7/1/88 THRU: 7/1/89

8. RECIPIENT PROJECT DIRECTOR *(Name and telephone No.)*
Henry P. Heasler (307) 766-3278

9. RECIPIENT BUSINESS OFFICER *(Name and telephone No.)*
Same as Blk #8

10. TYPE OF AWARD
☒ NEW ☐ CONTINUATION ☐ RENEWAL
☐ REVISION ☐ SUPPLEMENT

11. DOE PROJECT OFFICER *(Name, address, zip code, telephone No.)*
Kenneth J. Taylor (208) 526-9063
US DOE, Idaho Operations Office
785 DOE Place, Idaho Falls, Idaho 83402

12. ADMINISTERED FOR DOE BY *(Name, address, zip code, telephone No.)*
Trudy A. Thorne (208) 526-9519
U.S. Department of Energy
Idaho Operations Office
785 DOE Place
Idaho Falls, Idaho 83402

13. RECIPIENT TYPE
☐ STATE GOV'T ☐ INDIAN TRIBAL GOV'T ☐ HOSPITAL ☐ FOR PROFIT ORGANIZATION ☐ INDIVIDUAL
☐ LOCAL GOV'T ☒ 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
89X0224.91	AM1510000	YA 410	

15. EMPLOYER I.D. NUMBER/SSN

16. BUDGET AND FUNDING INFORMATION

a. CURRENT BUDGET PERIOD INFORMATION

(1) DOE Funds Obligated This Action	$ 45,511
(2) DOE Funds Authorized for Carry Over	$ -0-
(3) DOE Funds Previously Obligated in this Budget Period	$ -0-
(4) DOE Share of Total Approved Budget	$ 45,511
(5) Recipient Share of Total Approved Budget	$ 17,597
(6) Total Approved Budget	$ 63,108

b. CUMULATIVE DOE OBLIGATIONS

(1) This Budget Period [*Total of lines a.(1) and a.(3)*]	$ 45,511
(2) Prior Budget Periods	$ -0-
(3) Project Period to Date [*Total of lines b. (1) and b. (2)*]	$ 45,511

17. TOTAL ESTIMATED COST OF PROJECT $63,108
(This is the current estimated cost of the project. It is not a promise to award nor an authorization to expend funds in this amount.)

18. AWARD/AGREEMENT TERMS AND CONDITIONS

This award/agreement consists of this form plus the following:

a. Special terms and conditions (if grant) or schedule, general provisions, special provisions (if cooperative agreement)

b. Applicable program regulations *(specify)* ______ *(Date)* ______

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

d. Application/proposal dated June 10, 1987, ☐ as submitted ☒ with changes as negotiated

19. REMARKS This Grant consists of this NFAA (DOE Form 4600.1), Part I - Budget Plan; Part II - Special Conditions; Part III - General Conditions; Part IV - Statement of Work; and Part V - Reporting Requirements. DOE Financial Assistance Rules (10 CFR Part 600), OMB Circular A-110 and OMB Circular A-21 are hereby incorporated by reference.

20. EVIDENCE OF RECIPIENT ACCEPTANCE
Daniel L. Baccari 7/1/88
(Signature of Authorized Recipient Official) *(Date)*
Daniel L. Baccari
(Name)
Vice President for Finance
(Title)

21. AWARDED BY
J P Anderson 6/14/88
(Signature) *(Date)*
J. P. Anderson
(Name)
Contracting Officer
(Title)

FEDERAL ASSISTANCE BUDGET INFORMATION FORM

FORM EIA-459C (10/80)

FORM APPROVED OMB No. 1900-0127

1. Program/Project Identification No. DE-FG07-88ID12738	2. Program/Project Title Improved Computational Schemes
3. Name and Address University of Wyoming Department of Geology and Geophysics P.O. Box 3006, Laramie, Wyoming 82071	4. Program/Project Start Date July 1, 1988 5. Completion Date July 1, 1989

SECTION A - BUDGET SUMMARY

Grant Program, Function or Activity (a)	Federal Catalog No. (b)	Estimated Unobligated Funds		New or Revised Budget		
		Federal (c)	Non-Federal (d)	Federal (e)	Non-Federal (f)	Total (g)
1. 12693	81.087	$	$	$ 45,511	$ 17,597	$ 63,108
2.						
3.						
4.						
5. TOTALS		$	$	$	$	$

SECTION B - BUDGET CATEGORIES

6. Object Class Categories	Grant Program, Function or Activity				Total (5)
	(1) DOE	(2) Wyoming	(3)	(4)	
a. Personnel	$ 23,970	$ 9,000	$	$	$ 32,970
b. Fringe Benefits (20%)	4,794	1,800			6,594
c. Travel	1,678				1,678
d. Equipment Computer Time	1,500				1,500
e. Supplies Computer Software		1,860			1,860
f. Contractual					
g. Construction					
h. Other	800				800
i. Total Direct Charges	32,742	12,660			45,402
j. Indirect Charges (39%)	12,769	4,937			17,706
k. TOTALS	$ 45,511	$ 17,597	$	$	$ 63,108
7. Program Income	$	$	$	$	$

Special Terms and Conditions for Research Grants

The requirements of this attachment take precedence over all other requirements of this grant found in regulations, the general terms and conditions, DOE orders, etc. except requirements of statutory law. Any apparent contradiction of statutory law stated herein should be presumed to be in error until the Grantee has sought and received clarification from the Contracting Officer, whose signature appears on the face page of this award.

1. Payments and Cost-Share

a. The Grantee may request advance payment of cost to be incurred. Such requests should not exceed the expected outlays by the Grantee in the succeeding 30-day period.

b. Cost-Share Arrangement - The cost-share will be in accordance with Part I - Budget Plan. Invoices must include in-kind contributions and DOE's reimbursed costs. To be an invoiced cost, a cash or in-kind contribution must be allowable under the terms and conditions of the award and meet the applicable cost principle tests of allowability in 10 CFR 600.103.

The following salaries and fringe benefits will be paid by the Department of Energy: Henry P. Heasler, Principle Investigator, (salaries as incurred); J. George, Professor and M. Allen, Asst. Professor (one month beginning July 1, 1988); and clerical labor as incurred. All other salaries and fringe benefits will be paid by the University of Wyoming. Travel expenses, computer time, and other miscellaneous expenses will be paid by the Department of Energy. The University of Wyoming will provide all computer software. Indirect expenses will be paid by the Department of Energy and the University of Wyoming on total direct costs as outlined above.

c. Payments to the Grantee shall equal the Federal share of actual allowable costs of performance of this grant, provided however, and notwithstanding any other provision of this grant, that the Government's monetary liability under this grant shall not exceed the Government share of the total approved budget or an amount equal to the Federal share of actual allowable costs, whichever is less. The Grantee shall be obligated to perform under this grant throughout the agreed-upon period of performance, and to bear all costs which DOE has not agreed to pay. However, the Grantee shall have the right to cease to perform when or after the Federal share of actual allowable costs equals or exceeds the Government share of the total approved budget and if prior written notice to that effect has been provided to DOE.

d. The Government obligations may be increased unilaterally by DOE by written notice to the Grantee and may be increased or decreased by written agreement of the parties.

e. Upon termination or expiration of the total period of performance, the Grantee shall promptly refund to DOE (or make such disposition as DOE may in writing direct) any sums paid by DOE to the Grantee under this grant in excess of the cumulative Government allowable cost incurred in performance under the grant.

f. Method of Payment - Payments due for amounts properly invoiced in accordance with the terms and conditions specified elsewhere in the grant shall be made either by Treasury check(s) payable to the Grantee or designee or by electronic funds transfer(s) to a financial institution designated by the Grantee for that purpose. The method of payment shall be determined by the Government at the time of payment in accordance with applicable Treasury Department requirements.

After award but no later than fourteen (14) days before an invoice or bill is submitted for payment, the Grantee shall designate a financial institution for the receipt of electronic funds transfer payments hereunder; and provide the appropriate Government representative (contracting officer or finance official as determined by the Government) with the name of the designated financial institution, financial institution's or correspondent financial institution's 9-digit American Bankers Association identifying number, telegraphic abbreviation of such financial institution, and account number at the designated financial institution to be credited with funds.

In the event the Grantee during the performance of this grant elects to designate a different financial institution for the receipt of any payment made using electronic funds transfer procedures, notification of such change and the information as specified in paragraph (b) above must be received by the appropriate Government representative thirty (30) days prior to the date such change is to become effective.

The document furnishing the information required above must be dated and contain the signature, title, and telephone number of the Grantee official authorized to provide it, as well as the Grantee's name and grant number.

Grantee failure to properly designate a financial institution or to provide appropriate payee bank account information may delay payments of amounts otherwise properly due.

g. Applicable Credits. The Grantee agrees that any refunds, rebates, credits, or other amounts (including any interest thereon) accruing to or received by the Grantee or any assignee under this grant shall be paid by the Grantee to the Government, to the extent that they are properly allocable to costs for which the Grantee has been reimbursed by the Government under this grant. Reasonable expenses incurred by the Grantee for the purpose of securing such refund, rebates, credits, or other amounts shall be allowable costs hereunder when approved by the Contracting Officer.

h. Audit Adjustments. The Contracting Officer may have invoices or vouchers and statements of cost submitted under this grant audited at any time prior to the end of the required retention period for the grant records. Each payment made shall be subject to reduction for amounts included in the related invoice or voucher which are found by the Contracting Officer, on the basis of audit, not to constitute allowable cost. If a final audit of costs has not been performed prior to closeout of the grant, DOE or its successor agency, shall have the right to recover an appropriate amount after fully considering the recommendations on disallowed costs resulting from the final audit when conducted.

i. Cognizant Office. Invoices should be sent to the individual designated in Block 12. of the Notice of Financial Assistance Award Form (NFAA). In addition to the initial supply of forms made available with this award, appropriate payment forms and instructions will be provided by this office upon request.

2. Reporting Program Technical Performance

a. Copies. Copies of reports and all other related data and information generated under this grant shall be submitted in accordance with the attached Federal Assistance Reporting Checklist (DOE Form EIA-459A).

b. Publication of Results. The Grantee may publish the results of its work. However, publications and reports prepared under this grant shall contain the following acknowledgment statement, "This (material) was prepared with the support of the U.S. Department of Energy (DOE) Grant No. DE-FG07-88ID12738. However, any opinions, findings, conclusions, or recommendations expressed herein are those of the author(s) and do not necessarily reflect the views of DOE."

c. Reporting Requirements. The Federal-assistance recipient shall prepare and submit (postage prepaid) the plans and reports indicated on the Federal Assistance Reporting Distribution List. Preparation of the specified plans and reports shall be in accordance with DOE Order 1332.2. The level of detail the recipient provides in the plans and reports shall be commensurate with the scope and complexity of the task and shall be as delineated in Block 4 - Reporting Requirements and Block 5 - Special Instructions.

All reports delivered to DOE shall be the sole property of the DOE. The Grantee shall not claim that any report contains any trade secrets or commercial or financial information deemed by the Grantee to be privileged or confidential, or that the Grantee has any proprietary interest in any report.

3. Designated Key Personnel

The following individual is designated key personnel in accordance with General Condition No. 14:

Henry P. Heasler

4. Project Completion Date

The project completion date identified in Block 7. of the Notice of Financial Assistance Award includes an additional 90 days for completion of the final report. All R&D effort must be completed 90 days prior to the project completion date. Only costs associated with preparation of the final report will be allowed during the 90 days prior to the project completion date.

5. Technical Data

Except for technical data contained in pages N/A of the recipient's application, dated N/A, which are asserted by the Grantee as being proprietary data, it is agreed that as a condition of this award, and notwithstanding the provisions of any notice appearing on the application, the Government shall have the right to use, duplicate, disclose and have others do so for any purpose whatsoever the technical data not identified in the above blanks contained in the application upon which this award is based.

6. Prior Approval

The following actions or costs specified in the application require prior approval of DOE and are specifically disapproved in accordance with General Condition No. 3:

None

7. General Procurement Prior Approval

Article 17 of the General Terms and Conditions for Research Grants is hereby revoked. The Grantee must receive prior approval from DOE before entering into any sole source contract or a contract where only one bid or proposal is received, when the value of the contract in the aggregate is expected to exceed $25,000.

8. Patent Clauses

The following patent clauses and technical data requirements are applicable to this grant award:

600.118(b)(1) "Patent Rights (Small Business Firm or Nonprofit Organization)"

600.118(b)(3) "Rights in Technical Data (Short Form)"

600.118(b)(5) "Authorization and Consent"

600.118(b)(6) "Notice and Assistance"

600.118(c) "Reporting of Royalties"

9. Title to Equipment

a. Title to the following items of equipment shall vest with the Grantee upon completion of this grant:

None

b. Title to the following items of equipment shall vest with the Government at the end of the grant project period:

None

10. Advance Travel Agreement

It has been agreed by both parties that payment for a privately-owned conveyance used for official purposes shall be made on the basis of the actual travel performed computed at the mileage rate not to exceed $.21/mile.

General Terms and Conditions for Research Grants

Table of Contents

Number	Subject	Page
1	Explanation	1
2	Grantee Adherence to Grant Terms and Conditions	1
3	Definitions	1
	- Principal Investigator	1
	- Prior Approval	1
4	Authorized Grantee Signature for Prior Approval Requests	2
5	Allowable Costs/Applicable Cost Principles	2
6	Payment	3
7	Preaward Costs	3
8	Reporting Requirements	4
9	Cost-Sharing	4
10	Continuations, Renewals, and Extensions	4
11	Maximum DOE Obligation	5
12	Transfers of Funds Between Grants	5
13	Property	5
	- Real and Tangible Personal Property	5
	- Intangible Property	6
14	Change or Absence of Principal Investigator or Designated Key Personnel	6
15	Changes in Objectives or Scope	6
16	Transfer of Substantive Programmatic Effort	6
17	General Procurement Prior Approval	7
18	Equipment and Other Capital Expenditures	7
19	Travel	7
	- Foreign	7
	- Domestic	7
20	Consultant Services	7
21	Paperwork Reduction	7
22	Generally Applicable Requirements	8
	- Animal Welfare	8
	- Research Involving Recombinant DNA Molecules	8
	- Use of Human Subjects	8
23	Nondiscrimination	9
24	Public Access to Information	9
25	Acknowledgement of Support	9
26	National Security	9
27	Liabilities and Losses	10
28	Contracting Officer's Technical Representative (COTR)	10
29	Interest	11

General Terms and Conditions for Research Grants

1. Explanation

These general terms and conditions do not restate all the provisions of applicable statutes and regulations nor do they represent an exhaustive listing of all requirements applicable to this grant. Rather they highlight and are consistent with those requirements which are especially pertinent to research grants in general. They are being emphasized by inclusion here either because they are invoked with high frequency, their violation is a matter of especially serious concern (e.g., use of human subjects), and/or they have been restated in the research context to be more easily understood by the research community.

In addition to these general terms and conditions, the grantee must comply with all governing requirements, including those identified in Block 18 of the Notice of Financial Assistance Award and those included in the Special Terms and Conditions attached to this grant award.

2. Grantee Adherence to Grant Terms and Conditions

The grantee's signature on the application and on the Notice of Financial Assistance Award signifies the grantee's agreement to the terms and conditions of award. Should the grantee believe modification of any of the terms and conditions of this award is necessary, an authorized official of the grantee organization or, in the case of an individual, the grantee, must submit a written request on its own behalf or on behalf of any subgrant recipient or applicant to the Contracting Officer named on the face page of this award.

Following this procedure is very important because many of the terms and conditions of this grant are required by statute and must be enforced by the Department of Energy.

3. Definitions

Principal Investigator

As used herein, the scientist or other programmatic expert named in Block 8 of the Notice of Financial Assistance Award designated by the grantee organization to direct the scientific/technical efforts being supported (also called program director or project director/leader).

Prior Approval

A statement in writing, signed by the DOE Contracting Officer, that a cost may be incurred or an action may be taken. The approval may take the form of a letter or of a revision to the grant. If actions or costs requiring prior approval are specified in the application and are not expressly disapproved by DOE in the attached Special Terms and Conditions, the award of the grant constitutes such prior approval.

4. Authorized Grantee Signatures for Prior Approval Requests

All requests for prior approval must be signed by an individual who is authorized to act for the grantee organization. The signature of the Principal Investigator (unless also a corporate officer or otherwise authorized) is insufficient to obtain action on a prior approval request, although countersignature by the Principal Investigator is not discouraged. Requests for budget revisions shall be made on the same budget format as used in applying for this grant and must be supported by a narrative justification. Other prior approval requests may be made by letter. Prior approval requests should be addressed to the Contracting Officer named on the face page of this award.

5. Allowable Costs/Applicable Cost Principles

In accordance with the applicable cost principles cited below and up to the amount shown on the face page of this award for the total approved budget for the current budget period (line 16.a.(6)), the allowable costs of this grant shall consist of the actual allowable direct costs incident to performance of this project plus the allocable portion of the allowable indirect costs, if any, of the organization less applicable credits.

The allowability of costs for work performed under this grant and any subsequent subaward will be determined in accordance with the Federal cost principles applicable to the grantee or subrecipient in effect on the date of award or, for any subaward, in effect as of the date of that subaward, except as modified by other provisions of this grant or the subaward.

The Federal cost principles applicable to specific types of grantees and subrecipients are:

1. Institutions of Higher Education. OMB Circular A-21, Cost Principles Applicable to Grants, Contracts and Other Agreements with Institutions of Higher Education, is applicable to both public and private colleges and universities.

2. State and local governments and Indian tribal governments. OMB Circular A-87, Cost Principles Applicable to Grants, Contracts and other Agreements With State and Local Governments, is applicable to state, local, and Indian tribal governments (and shall also be used to the extent appropriate for foreign governments).

3. Hospitals. 4S CFR Part 74, Appendix E, Principles for Determining Costs Applicable to Research and Development under Grants and Contracts with Hospitals, applies to nonprofit and for-profit hospitals.

4. Other nonprofit organizations and individuals. OMB Circular A-122, Cost Principles Applicable to Grants, Contracts, and other Agreements with Nonprofit Organizations, applies to nonprofit organizations and individuals except for nonprofits specifically exempted by the terms of the circular or those nonprofits covered by the cost principles cited in items 1.- 3. above.

5. Commercial firms and certain nonprofit organizations. 48 CFR Subpart 31.2, Contracts with Commercial Organizations, as supplemented by 48 CFR Subpart 931.2, applies to those nonprofit organizations not covered by OMB Circular A-122, as specified by the terms of that circular, and to all commercial organizations other than those covered by the cost principles in item 3. above.

6. Payment

Payments under this award will be made by an advance payment method unless DOE determines that the grantee's financial management system does not meet the requirements of 10 CFR 600.109 or the grantee has not maintained, or demonstrated the willingness and ability to maintain, procedures that will minimize the time elapsing between transfer of funds from the U.S. Treasury and their disbursement for grant-related purposes.

The appropriate advance payment method or the reimbursement method and the cognizant finance office are specified in the attached Special Terms and Conditions.

Advances by the grantee to subgrantee and contractor organizations must conform substantially to the same standards of timing and amount that govern advances made by the Federal Government to the grantee. Excess cash advances erroneously withdrawn from the U.S. Treasury shall be promptly refunded to DOE unless the funds will be disbursed within seven calendar days or the amount is less than $10,000 and will be disbursed within 30 calendar days.

Interest earned on advance payments to other than state governments or their subgrantees shall be reported on the Report of Federal Cash Transactions (SF-272) and promptly remitted to the cognizant finance office (unless otherwise specified in the attached Special Terms and Conditions) by check payable to the Department of Energy.

7. Preaward Costs

Costs incurred prior to the beginning date of a new or renewal award are allowable only if they were approved in writing, prior to incurrence, by a DOE Contracting Officer. (Note - this provision does not apply to such bid and proposal costs as may be recovered through an indirect cost rate negotiated in accordance with the applicable Federal cost principles.)

8. Reporting Requirements

Attached to this grant award is EIA 459A, a checklist of the reports required under this grant.

The grantee shall submit a technical progress report (also called a performance report) as part of any application for continuation or renewal of DOE grant support. This report shall be in lieu of a separate annual performance report. Upon completion or termination of the project, the final technical report shall be prepared in accordance with the applicable program rule cited on the face page of this award or, in the absence of such program rule coverage, with the technical reporting format specified in the Uniform Reporting System for Federal Assistance (Grants and Cooperative Agreements) (DOE/MA-001).

The grantee shall submit an annual Financial Status Report (SF-269) within 90 days after the close of the budget period shown on the face page of this award. The grantee shall submit a final Financial Status Report within 90 days after the completion or termination of the project period shown on the face page of this award unless the project period is extended. In the latter case, the report for the last budget period of the existing project period shall be considered an annual report.

Instructions concerning reports to be submitted in conjunction with payment under this award are specified in the attached Special Terms and Conditions.

9. Cost-Sharing

Any cost-sharing as shown on the face page of this award shall defray allowable costs of the project only. Allowability of such costs shall be determined in accordance with the statutes, regulations, applicable cost principles, and other terms and conditions governing this award.

Cost-sharing contributions may be in the form of direct or indirect costs, including cash or in-kind contributions, incurred by the grantee, its subgrantees, or contractors. The cost sharing may be in any allowable budget category or combination of categories. When a direct cost item represents some or all of the non-Federal contribution, any associated indirect costs may not be charged to Federal funds but may be counted as part of the cost-sharing. The treatment of a contributed cost as direct or indirect must be consistent with the classification of similar items charged to DOE funds.

Valuation of in-kind contributions and documentation of cost-sharing shall be in accordance with 10 CFR 600.107.

10. Continuations, Renewals, and Extensions

Grantees are responsible for assuring that properly completed applications for continuation awards are received no later than 4 months prior to the expiration date of the current budget period shown on the Notice of Financial Assistance Award.

If a grantee wishes to apply for a renewal award in order to receive funding beyond the scheduled expiration of the existing project period, a properly completed application must be submitted to DOE no later than four months prior to the scheduled expiration date of the project period as shown on the Notice of Financial Assistance Award.

Grantee requests for extensions (modifications extending an existing project period by 18 months or less in order to complete a project) must be submitted prior to the expiration date of the project period as shown on the face page of this award, and must include a budget for the use of any remaining funds or any additional funds requested. Any request for an extension, which includes a request for additional funds and any request for an extension of more than 90 days, should be submitted to DOE no later than four months prior to the scheduled expiration date of the project period.

11. Maximum DOE Obligation

This grant is subject to the requirement that the maximum DOE obligation to the recipient is the amount shown on the Notice of Financial Assistance Award as the amount of DOE funds obligated. DOE shall not be obligated to make any additional, supplemental, continuation, renewal or other award for the same or any other purpose.

12. Transfers of Funds Between Grants

Transfers of funds between DOE grants, and transfers of funds from a DOE grant to a project (or portion of a project) not supported by that grant require the prior approval of DOE. Transfer of funds into a DOE grant-supported project from a grant awarded by another Federal agency does not require DOE prior approval but may, of course, require the approval of the other Federal agency. Funds so transferred from the grant of another Federal agency may not be used to satisfy any cost-sharing requirement on a DOE grant.

13. Property

Real and Tangible Personal Property

No real property may be acquired under this award.

Title to any equipment (an article of tangible personal property that has a useful life of more than 2 years and an acquisition cost of $500 or more) or supplies acquired by a nonprofit institution of higher education or a nonprofit organization whose primary purpose is the conduct of scientific research shall vest in the grantee and such equipment shall be exempt from accountability except that DOE has the right to transfer ownership of any item of equipment having a unit acquisition cost of $1,000 or more under the conditions specified in 10 CFR 600.117(d)(2). This exemption is derived from Public Law 95-224. The Federal Grant and Cooperative Agreement Act of 1977, as amended.

Title to equipment and supplies acquired by all other grantees shall vest in the grantee. However, such grantees shall be accountable for equipment with a unit acquisition cost of $1,000 or more acquired under this grant as specified in 10 CFR 600.117(d)(2), (3) and (4). For such grantees, supplies need only be accounted for at closeout and then only if they are unused and exceed $1,000 in total aggregate current fair market value. In this case accountability requires that DOE be compensated in an amount computed in accordance with Section 600.117(e) if the supplies are retained for use on non-Federal activities.

All grantees shall follow property management policies and procedures which provide for adequate control of the acquisition and use of assets acquired under the grant.

Intangible Property

Treatment, including reporting, of patent and data rights and copyrights shall be as specified in the Special Terms and Conditions of this grant.

14. Change or Absence of the Principal Investigator or Designated Key Personnel

Since the DOE decision to fund a project is based, to a significant extent, on the qualifications and level of participation of the Principal Investigator, a change of Principal Investigator or of the level of effort of the Principal Investigator is considered a change in the approved project. The approval of DOE must be obtained prior to any change of the Principal Investigator or, in certain cases, other key personnel who have been identified as key personnel in the Special Terms and Conditions of this grant. In addition, any continuous absence of the Principal Investigator in excess of three months or plans for the Principal Investigator to become substantially less involved in the project than was indicated in the approved grant application requires DOE prior approval. Grantee is encouraged to contact DOE immediately upon becoming aware that any of these changes are likely to be proposed, but in any event must do so and receive DOE prior approval before effecting any such change.

15. Changes in Objectives or Scope

Any change in the objectives or scope of a grant-supported project requires the prior approval of DOE. Such changes include changes in the phenomenon or phenomena under study and in the methodology or experiment if they are a specific objective of the research work as stated in the application approved by DOE.

16. Transfer of Substantive Programmatic Effort

None of the substantive effort of this project may be transferred by contract or subgrant to another organization or person without the prior approval of DOE. This provision does not apply to the procurement of equipment, supplies, materials, or general support services which may, however, be subject to other prior approval requirements as found, for example, in the applicable cost principles or procurement standards.

17. General Procurement Prior Approval Requirements

A grantee must receive prior approval from DOE before entering into any sole source contract or a contract where only one bid or proposal is received when the value of the contract in the aggregate is expected to exceed 1) $10,000 and the grantee is a state, local, or Indian tribal government or 2) $5,000 for all other grantees.

18. Equipment and Other Capital Expenditures

Expenditures for equipment and other capital assets having a unit acquisition cost of $500 or more require the prior approval of DOE with one exception. For special purpose equipment, prior approval is required only when the unit acquisition cost is $1,000 or more. (Special purpose equipment means equipment which is used only for research, medical, scientific, or other technical activities.)

19. Travel

Foreign Travel - DOE prior approval is required for each separate foreign trip. Foreign travel must be directly related to the project objectives. Foreign travel is any travel outside Canada and the United States and its territories and possessions or, for grantees located in another country, travel outside that country.

Domestic Travel - Such costs are allowable to the extent provided in the approved budget. In addition, grantees may exceed the approved budget amount for domestic travel by up to 25% or $500 whichever is greater, without DOE prior approval. All other expenditures for domestic travel beyond these limits require prior approval.

20. Consultant Services

Costs of consultant services are allowable subject to satisfaction of the requirements of the applicable cost principles, including the requirement that the consultant not be an employee of the grantee organization. There is one exception to the requirement that the consultant not be an employee of the grantee organization which applies to colleges and universities only. For colleges and universities, in unusual cases, and only with the prior approval of DOE, intra-organizational consultation may be permitted where consultation is across departmental lines or involves a separate or remote operation.

21. Paperwork Reduction

This award is subject to the requirements of the Paperwork Reduction Act of 1980 as implemented by the Office of Management and Budget rules, "Controlling Paperwork Burdens on the Public," published at 5 CFR 1320 (48 FR 13666, 3/31/83) if the grantee will collect information from ten or more respondents either:

A. At the specific request of DOE, or

B. If the award requires specific DOE approval of the information collection or the collection procedures.

Any proposed sponsored information collection under item 21 B. above shall be submitted by the grantee to the Contracting Officer named on the face page of this award at least 90 days prior to the intended date of information collection. DOE will seek the requisite approval from the Office of Management and Budget and will promptly notify the grantee of the disposition of the request.

22. Generally Applicable Requirements

In accordance with 10 CFR 600.12, this grant is subject to a number of statutory and other generally applicable requirements. Those requirements most pertinent to research projects are highlighted below:

Animal Welfare

Any grantee performing research on warm-blooded animals shall comply with the Laboratory Animal Welfare Act of 1966 (Public Law 89-544, as amended) and the regulations promulgated thereunder by the Secretary of Agriculture at 9 CFR Chapter 1, Subchapter A, pertaining to the care, handling, and treatment of warm-blooded animals held or used for research, teaching, or other activities supported by Federal awards. The grantee is expected to ensure that the guidelines described in Department of Health and Human Services (DHHS) Publication No. [NIH] 78-23, "Guide for the Care and Use of Laboratory Animals," are followed (Copies are available from the Superintendent of Documents, Government Printing Office, Washington, DC 20024, Stock No. 017-040-00427-3).

Research Involving Recombinant DNA Modecules

Any grantee performing research involving recombinant DNA molecules and/or organisms and viruses containing recombinant DNA molecules agrees by acceptance of this grant to comply with the National Institutes of Health "Guidelines for Research Involving Recombinant DNA Molecules," June 1983 (48 FR 24556) or such later revision of those guidelines as may be published in the Federal Register.

Use of Human Subjects in Research, Development, and Related Activities

Any DOE grantee performing research, development, or related activities involving any use of human subjects must comply with DOE regulations found at 10 CFR Part 74S "Protection of Human Subjects" and any additional Provisions which may be included in the Special Terms and Conditions of this grant. Such provisions are intended to safeguard the rights and welfare of human subjects at risk of possible physical, psychological, or social injury as a consequence of their participation.

23. Nondiscrimination

This grant is subject to the provisions of 10 CFR Part 1040 "Nondiscrimination in Federally Assisted Programs."

24. Public Access to Information

The Freedom of Information Act, as amended, and the DOE implementing regulations (10 CFR Part 1004) require the release by DOE of certain documents and records regarding grants upon written request by any member of the public. The intended use of the information will not be a criterion for release. These requirements apply to information held by DOE, and do not require grantees, their subgrantees, or their contractors to permit public access to their records.

Records maintained by DOE with respect to grants are subject to the provisions of the Privacy Act and the DOE implementing regulations (10 CFR Part 1008) if those records constitute a "system of records" as defined in the Act and the regulations. Generally, records maintained by grantees, their subgrantees, or their contractors are not subject to these requirements.

25. Acknowledgement of Support

Publication of the results of this grant, subject to any applicable restrictions in 10 CFR 600.118 ("Patents, data, and copyrights"), is encouraged. Any article which is published shall include an acknowledgement that the research was supported, in whole or in part, by a DOE grant (including the grant number), but that such support does not constitute an endorsement by DOE of the views expressed in the article.

26. National Security

It is not expected that activities under this grant will generate or otherwise involve classified information (i.e., Restricted Data, Formerly Restricted Data, National Security Information).

However, if in the opinion of the grantee or DOE such involvement becomes expected prior to the closeout of the grant, the grantee or DOE shall notify the other in writing immediately. If the grantee believes any information developed or acquired may be classifiable, the grantee shall not provide the potentially classifiable information to anyone, including the DOE officials with whom the grantee normally communicates, except the Director of Classification, and shall protect such information as if it were classified until notified by DOE that a determination has been made that it does not require such handling. Correspondence which includes the specific information in question shall be sent by registered mail to U.S. Department of Energy, Attn: Director of Classification, DP-32, Washington, DC 20545. If the information is determined to be classified the grantee may wish to discontinue the project, in which case the grantee and DOE shall terminate the grant by mutual agreement. If the grant is to be terminated, all material deemed by DOE to be classified shall be forwarded to DOE, in a manner specified by DOE, for proper disposition. If the grantee and DOE wish to continue the grant, even though classified information is involved, the grantee shall be required to obtain both personnel and facility security clearances through the Office of Safeguards and Security. Costs associated with handling and protecting any such classified information shall be negotiated at the time the determination to proceed is made.

27. Liabilities and Losses

DOE assumes no liability with respect to any damages or loss arising out of any activities undertaken with the financial support of this grant.

28. Contracting Officer's Technical Representative (COTR)

The individual identified in Block 11. of the Notice of Financial Assistance Award as the DOE Project Officer is the Contracting Officer's Technical Representative (COTR). The COTR is responsible for 1) monitoring the research efforts being conducted by the Grantee under the scope of this award; 2) advising the Contracting Officer on technical matters related to administration of the grant, including progress and status of the Grantee's research; and 3) providing technical advice and guidance to the Grantee in order to assist both the research efforts of the Grantee and the Grantee's adherence to the grant terms and conditions.

The COTR does not have the authority to:

Cause an increase or decrease in the total estimated cost of, or the time required for, the research effort being supported;

Cause any change in the express terms and conditions of the grant;

Cause any change in the objectives or scope of the effort being supported;

Act in the capacity of the Contracting Officer by issuing any approval or disapproval required by the terms and conditions of the grant;

Interfere with the Grantee's right to perform under the terms and conditions of the grant.

29. Interest

(a) Notwithstanding any other term or conditions of this grant, all amounts that become payable by the recipient to the Government under this grant shall bear simple interest from the date due until paid unless paid within 30 days of becoming due. The interest rate shall be the interest rate established by the Secretary of Treasury (Secretary) as provided in Section 11 of the Debt Collection Act of 1982 (31 U.S.C. 3717), which is applicable to the period in which the amount becomes due, as provided in paragraph (b) of this provision, and then at the rate applicable for each three-month period as fixed by the Secretary until the amount is paid.

(b) Amounts shall be due at the earliest of the following dates:

(1) The date fixed under this grant.

(2) The date of the first written demand for payment consistent with this grant, including any demand resulting from a termination.

(3) The date the Government transmits to the recipient a proposed agreement to confirm completed negotiations establishing the amount of debt.

(c) The interest charge made under this provision may be reduced in accordance with the procedures prescribed in 4 CFR 102.13 or in accordance with agency regulations in effect on the date of original award of this grant.

STATEMENT OF WORK

1.0 INTRODUCTION

The goal of this grant is to support cost-shared research on geothermal resources in Wyoming and the Rocky Mountain region in general through the application of several new finite-difference computational schemes to the calculation of subsurface temperatures. Ground and water temperatures will be calculated by considering both conductive and forced convective heat-transport equations. The improved computational schemes will be used to model either the Cody or Thermopolis hydrothermal systems in Wyoming as a check on the validity of the numerical techniques. The ultimate aim of these calculations and studies is an understanding of hydrothermal resources typical of Wyoming and the Rocky Mountain region in general.

2.0 SCOPE

The technical objectives of this grant are to develop and test improved three-dimensional computational schemes for solving the combined heat-conduction and forced-convection equations for the purpose of determining subsurface temperatures. Both the speed and the precision of the three-dimensional finite difference modeling algorithm will be enhanced beyond existing routines. Temperature data from existing wells will then be used to determine geothermal groundwater parameters. The validity of the improved computational scheme will be determined by applying the model to either the Cody or the Thermopolis hydrothermal systems in the Bighorn Basin, Wyoming where both thermal and hydrologic data already exist. All tasks will be completed in a 12-month period.

3.0 APPLICABLE DOCUMENTS

The research described herein is abstracted from a proposal titled, "Improved Computational Schemes for the Numerical Modeling of Hydrothermal Resources in Wyoming," dated June 10, 1987, and submitted by the University of Wyoming. This proposal was submitted in response to a DOE-ID Program Research and Development Announcement (PRDA) for State Geothermal Research and Development - PRDA No. DE-PR07-87ID12662.

4.0 TECHNICAL TASKS

The following tasks will be accomplished under this grant.

4.1 Develop algorithms for the conjugate gradient solver.

4.2 Develop algorithms for heat transfer due to forced convection using a second-order difference representation.

4.3 Develop algorithms for heat transfer due to Newton's Law of Cooling using a second-order difference representation.

4.4 Develop algorithms for three dimensional heat transfer using operator-splitting or alternation-direction iterative methods.

4.5 Apply grid refinement methods to improve the precision of the solution in areas of large gradient change.

4.6 Gather additional temperature data from wells in either the Cody or Thermopolis area to supplement the existing data base.

4.7 Apply the developed finite-difference model to either the Cody or the Thermopolis hydrothermal system to test the improved computational schemes.

4.8 Complete the documentation for all computer algorithms, document all new temperature data, and present a discussion of the numerical methods and test results in a final report.

5.0 REPORTS, DATA, AND OTHER DELIVERABLES

5.1 Management Records

Reports will be due as indicated on the Federal Assistance Reporting Checklist and the Report Distribution List.

5.2 Final Report

A detailed final technical report will be published which will describe all computer algorithms, data tables, maps, methods of research and data reduction. All new data obtained as a result of this grant will be summarized in the technical report. A listing of the FORTRAN statements or other high-level language statements for all new computer programs which are developed will be included as appendices to the final report. A draft final report will be submitted for review and comment not less than 45 days prior to the scheduled delivery of the final report.

6.0 SPECIAL CONSIDERATIONS

The University of Wyoming will contribute computer software (three-dimensional plotting routines, and a FORTRAN update) to aid in algorithm development as part of the University of Wyoming cost-share. The level of quality assurance (QA) completed for new software developed under this grant will be described in the final report.

REPORT DISTRIBUTION LIST

No. DE- FG07-88ID12738

Report/Plan	Form No.	Frequency	No. of Copies	Address
Federal Assistance Management Summary Report	EIA-459E	Q	1,1,1,1,1	a,b,c,d,e
Notice of Energy RD&D	DOE 538	O	1,1	a,f
Technical Progress Report	N/A	Q	1,1,1,1	a,b,d,e
Topical Report	N/A	A	1,4,1,1	a,b,d,e
Final Technical Report	N/A	F	1,4,1,1	a,b,d,e
Financial Status Report	SF 269	F	1,1,1	a,b,c

LIST OF ADDRESSEES

a. U.S. Department of Energy
785 DOE Place
Idaho Falls, ID 83402
Attn: Trudy A. Thorne

b. Same as above
Attn: Kenneth J. Taylor

c. Same as above
Attn: Earl Jones

d. U.S. Department of Energy
Forrestal Bldg., CE-342
1000 Independence Ave, SW
Washington, DC 20585
Attn: Marshall Reed

e. University of Utah Research Institute
Earth Science Laboratory
391 Chipeta Way, Suite C
Salt Lake City, UT 84108-1295
Attn: Howard Ross

f. U.S. Department of Energy
Technical Information Center
P.O. Box 62
Oak Ridge, TN 37830

Grant No. DE-FG07-88ID12738

U.S. DEPARTMENT OF ENERGY

FEDERAL ASSISTANCE REPORTING CHECKLIST

FORM EIA-459A (10/80)

FORM APPROVED OMB NO 1900-0127

1. Identification Number:	2. Program/Project Title:
DE-FG07-88ID12738	Geothermal Research & Development Asst.

3. Recipient:
University of Wyoming

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	1,1,1,1,1	a,b,c,d,e
[ ] Federal Assistance Program/Project Status Report			
[X] Financial Status Report, OMB Form 269	F	1,1,1	a,b,c
TECHNICAL INFORMATION REPORTING			
[X] Notice of Energy RD&D	0	1,1	a,f
[X] Technical Progress Report	Q	1,1,1,1	a,b,d,e
[X] Topical Report	A	1,4*,1,1	a,b*,d,e
[X] Final Technical Report	F	1,4*,1,1	a,b*,d,e

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:
*3 copies plus a camera-ready copy

6. Prepared by: (Signature and Date)	7. Reviewed by: (Signature and Date)
[signature] 1-22-88	Trudy A. Thorne 1/26/88

UNIVERSITY OF WYOMING

Department of Geology and Geophysics
P.O. Box 3006
Laramie, Wyoming 82071-3006
(307) 766-3386

October 13, 1989

Kenneth J. Taylor
U. S. Department of Energy
785 DOE Place
Idaho Falls, ID 83042

Dear Mr. Taylor:

This letter constitutes a brief explanation for the no-cost extension which was requested for grant DE-FG07-99ID12738 on August 31, 1989.

Work on the mathematical model development has progressed more slowly than anticipated. This is primarily due to the physical scale of the models. The velocities of water flow, the spacing between node points, and rock thermal conductivity values make the problem more difficult to solve than originally anticipated. Some of the mathematical techniques which we hoped would solve these mathematical solution instabilities appear to have their own stability problems.

Work on the project was also slowed last April when we found an error while cross-checking results of the modeling. After 3 weeks of confirming our computer code, we traced the error to the Lahey fortran compiler we were using. The Lahey Company has sent a fix for the compiler and it is now working correctly.

We are hopeful that the modeling instabilities will be solved by late December.

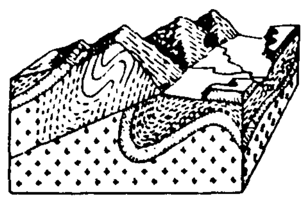
If you have any questions concerning this explanation, please contact me at (307)-766-3278 or a message may be left at (307)-766-3386.

Sincerely,

Henry P. Heasler

Henry P. Heasler

cc: Dr. Howard P. Ross



UNIVERSITY OF WYOMING

Department of Geology and Geophysics
P.O. Box 3006
Laramie, Wyoming 82071-3006
(307) 766-3386

August 31, 1989

Rec. 9/5/89
Howard P. Ross

Dr. Howard P. Ross
University of Utah Research Institute
Earth Science Laboratory
391 Chipeta Way, Suite C
Salt Lake City, UT 84108-1295

Dear Dr. Ross:

I am requesting a no-cost extension for grant DE-FG07-88ID12738. The proposed length of this extension would be until January 31, 1990.

I am also requesting that $1,500.00 originally budgeted for 5 hours of computer time on a Cyber 760 be reallocated to salary. This is because we will be able to complete all computing requirements either on personal computers or workstations available through the Institute for Scientific Computing at the University of Wyoming.

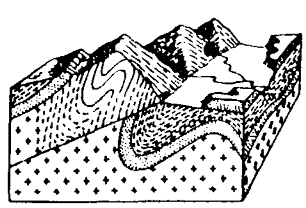
If you have questions on this request, please contact me.

Sincerely,

Henry Heasler

Henry P. Heasler

cc Trudy A. Thorne
Kenneth J. Taylor
Earl Jones



1990 Abstracts with Programs

43rd Annual Meeting

Rocky Mountain Section

The Geological Society of America
with the Rocky Mountain Section of
the Paleontological Society

May 21–23, 1990
Snow King Resort
Jackson, Wyoming

Volume 22, Number 6
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Nº 26118

PALEOCENE AND LOWER EOCENE NONMARINE MOLLUSCAN BIOSTRATIGRAPHY OF THE POWDER RIVER BASIN, WYOMING-MONTANA.

HARTMAN, Joseph H., Univ. North Dakota, Energy and Environmental Research Center, Box 8213 Univ. Station, Grand Forks, ND 58203

Paleocene and Lower Eocene strata of the Powder River Basin contain a diverse and generally abundant record of nonmarine Mollusca. Specimens from most of the over 200 localities were collected as part of coal mapping programs by geologists of the U.S. Geological Survey. Recent coal studies have focused on subsurface correlation that has permitted the retrofit of most fossil localities into coal-bed stratigraphy. T.-C. Yen and D.W. Taylor previously undertook molluscan biostratigraphy in the context of geographically extensive coal beds forming coal-bounded intervals in the basin. More precise stratigraphic placement of localities is, however, now possible for specifically delimiting taxon ranges.

Tullock-Lebo Member (Fort Union Formation) strata are poorly defined by molluscan taxa. Only about four localities are known, and they are represented by a poorly preserved and documented fauna. Molluscan abundance begins with the inception of Tongue River Member coal-forming environments in the basin. Each of the coal-bed intervals can be biostratigraphically recognized on the basis of the occurrence of new (to the basin) taxa, representing four subdivisions within the Tongue River, and two within the "Wasatch" Formation, which includes the transition from Paleocene to Eocene strata. The Kingsbury Conglomerate can probably also be recognized on the basis of its constituent Mollusca, but, as with most of the Powder River Basin fauna, much systematic study remains to be done. At present, described mammal local faunas are known only from the "below-Wall" coal bed interval (early? [Ti1?, Newell's Nook] to late [Ti4, Olive] Tiffanian) of the Tongue River Member and from the "main body" (Wasatchian, Pumpkin Butte localities) of the "Wasatch" Formation. These bounding ages indicate that the coal-bed-organized molluscan assemblages represent latest Paleocene (Ti4 through the Clarkforkian), an interval that is not otherwise well-documented by mollusks in the northern Great Plains.

Nº 17002

LANDSLIDES ALONG THE WEST FLANK OF THE OQUIRRH MOUNTAINS, TOOELE COUNTY, UTAH.

HARTY, Kimm M., Utah Geological and Mineral Survey, 606 Black Hawk Way, Salt Lake City, UT 84108

Over 90 landslides have been identified on the west flank of the north-south trending Oquirrh Mountains of north-central Utah. Most occurred during a period of record-breaking, above-average precipitation from 1983-1986, and all but a few are shallow (slide plane generally less than 3 m deep) debris slides and debris flows. A lack of deep-seated failures, such as rotational slumps, is due to the general absence of slide-prone shales in the largely Upper Paleozoic rocks that compose the Oquirrh Mountains.

Debris slides and flows occurred in colluvium and soil mantle derived from Middle Pennsylvanian to Lower Permian orthoquartzite, calcareous quartzite and sandstone, and limestone. Forty-four percent of these debris slides and flows occurred within two geologic formations that crop out over limited areas. Most of the remaining landslides are broadly scattered within a third formation of larger areal extent.

Debris slides and flows are on slopes ranging from 29° to 39°, averaging 33°. Nearly 75 percent of these failures occurred on slopes facing south to west, with 57 percent facing south to southwest. Only 13 percent showed a north-facing component. Slope-stability maps of the Oquirrh Mountains will be prepared using factors of geology, structure, local hydrology, elevation, slope, topography, and aspect. These maps will aid in the preparation of hazard-susceptibility maps for downstream areas.

Nº 02637

GEOTHERMAL MODELING OF JACKSON HOLE, NORTHWESTERN WYOMING.

HEASLER, Henry P., Dept. of Geology and Geophysics, P.O. Box 3006, University of Wyoming, Laramie, WY 82071

Analytical and finite-difference numerical models describing conductive and convective heat transport were used in an attempt to define the thermal regime of the Jackson Hole area. The purpose of the modeling was to investigate the possibility of shallow (<5 km), high-temperature (> 300 °C) heat sources.

Data used to constrain the models include 34 oil well bottom-hole temperatures, flow rates and temperatures from four thermal springs, measured temperature-depth profiles for 3 wells, and published geologic and hydrologic interpretations.

Results of the modeling indicate that the temperature of the deepest Paleozoic aquifers in the Jackson Hole area are greater than the observed thermal springs temperatures. Thus, the heating mechanism for the thermal springs waters appears to be deep circulation of groundwater.

Modeled maximum temperatures of water contained in the Paleozoic aquifers range from 100 to 220 °C but are poorly constrained. This is due to uncertainties in the local heat flow, rock thermal conductivities, and Darcian velocity of water in the Paleozoic aquifers.

Nº 17544

MULTIPLE HOLOCENE SURFACE RUPTURE EVENTS ALONG THE ALVORD SEGMENT OF THE STEENS FAULT ZONE, SOUTHEASTERN OREGON.

HEMPHILL-HALEY, Mark A., and PAGE, William D., Woodward-Clyde Consultants, 500 12th Street, Suite 100, Oakland, CA 94607; CARVER, Gary A., and BURKE, Raymond (Bud) M., Humboldt State University, Arcata, CA 95521

The 27-km-long Alvord segment of the north-trending Steens Fault Zone (SFZ) forms the range front fault along the eastern side of Steens Mountain in the northern Basin and Range province. Two paleoseismic trenches excavated in 1987 along the central and southern portions of the Alvord segment suggest that the fault has had multiple surface rupture events in Holocene time.

A trench excavated across the central portion of the fault, primarily in alluvial fan deposits, is interpreted to expose a single rupture event with an apparent normal offset of 1.5 m accompanied by 1.8 m of warping. A charcoal sample located within the upper portion of a colluvial wedge formed shortly after the event provides an age estimate of 470 ± 350 years B.P. A possible additional scarp-forming event, not found in the trench, is expressed as a beveled upper slope in the scarp in older alluvial fan deposits immediately to the north. The fault at this location is a single splay.

Three faulting events appear to be exposed in the second trench, excavated at the southernmost end of the segment in dune and playa deposits. The oldest event faulted and folded a Mount St.Helens SG tephra (11,900 to 13,000 years B.P.). Estimation of displacements for the two oldest events were not possible because of erosion. The youngest event, however, consisting of about 70 cm of warping and 40 cm of apparent vertical offset, formed the present 1.1 m-high surface scarp. This portion of the Alvord segment is a 700 m-wide zone of small, discontinuous faults.

Magnitude vs fault length relationships suggest that the Alvord segment is capable of producing an M_s 6 3/4 earthquake. It appears, from the trench data, that the southernmost portion of the Alvord segment has had more events with smaller displacements than the central portion of the fault. The reduced amount of rupture per event may be the result of diminishing displacement at the terminus of the segment similar to other Basin and Range fault zones. This southern part of the segment overlaps the 22-km-long Fields segment along a right-step. The apparent increase in the number of events along the southern part of the fault may reflect a more complex faulting history because it is also activated by movement along the nearby Fields segment.

Nº 03625

ASPECTS OF LATE-PLEISTOCENE PALEOCLIMATES OF THE GREAT BASIN DERIVED FROM MODELS OF EVAPORATION, LAKE LEVEL, REGIONAL CLIMATE, AND THE GEOLOGIC RECORD

HOSTETLER, Steve, USGS-WRD, BENSON, Larry, USGS-WRD, GIORGI, Filippo, NCAR, National Center for Atmospheric Research, P.O. Box 3000, Boulder, CO 80307-3000

Based on previous AGCM simulations of a bifurcation of the polar jet stream during the late Pleistocene, we hypothesize that over the Great Basin (1) from 18 000 to 13 500 yr BP, seasonal variation in the latitudinal maximum of the polar jet stream (westerlies) led to an increase in effective moisture, and (2) between 13 500 and 12 000 yr BP, northward movement of the jet stream resulted in the onset of more arid conditions. This hypothesis was tested with evaporation/lake-level models and the late-Pleistocene lake-level chronology of Lake Lahontan.

Simulated evaporation rates were combined with various rates of precipitation and discharge in a lake-level model to determine if change in the hydrologic balance that would be expected to have been associated with the split jet stream could explain the rise and fall of Lake Lahontan. Our assumed ~18 000 yr BP climate, which consists of a 42% reduction (relative to present) in evaporation rate stemming from increased cloud cover, a 7 °C decrease in air temperature, combined with 1.8- and 3.6-fold increases in present-day, mean-annual rates of precipitation and discharge, respectively, resulted in a simulated highstand lake within 1400 yr. The model simulated a 135-m drop from the highstand level within 300 yr under the imposition of present-day conditions. These simulated changes in lake level are consistent with the Lake Lahontan lake-level chronology.

To explore possible sources of increased precipitation, we further hypothesized that, for the Lahontan and Bonneville basins, late-Pleistocene water inputs could have been supplied, in part, by precipitation that was generated by feedbacks between the large lakes and the atmosphere. The NCAR/PSU limited area (mesoscale) model of climate is being used to test this hypothesis. Preliminary modeling results indicate that significant precipitation could have been generated by the presence of large Great Basin lakes.