SPRINGERVILLE-ALPINE GEOTHEMAL PROJECT: RESULTS OF HEAT FLOW DRILLING

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Springerville-Alpine Geothermal Project
Heat Flow

Introduction

Eighteen sites were selected for heat flow drilling in the Springerville-Alpine geothermal project area (Fig. 1). The site locations were selected on the basis of a preliminary site evaluation (Stone, 1979, Appendix A) and a reconnaissance electrical resistivity survey (Young, 1979, Appendix C). Justification for site locations was submitted to the Bureau of Reclamation, Boulder City, Nevada, in March, 1979 (Appendix D). Four holes, Nos. 107, 114, 116, and 118, were to be drilled to 450 m depth; the remaining holes were to be drilled to 150 m. Extended cold weather and snow in the project area delayed the start of drilling until May, 1979, and even by that date poor access necessitated revising some drillsite priorities.

Five heat flow holes were completed by August, 1979 (Fig. 2), at which time the drilling operation was moved to Clifton, Arizona. Drilling dates, total depths, and hole locations are presented in Table 1.

Hole Completion

All holes were drilled using conventional rotary-mud techniques except the upper 120 m of hole No. 116, which was drilled using an air compressor and downhole hammer. Considerable difficulty was encountered in holes No. 112, 113, and 114 as a result of the voluminous water moving through the permeable volcanic layers.

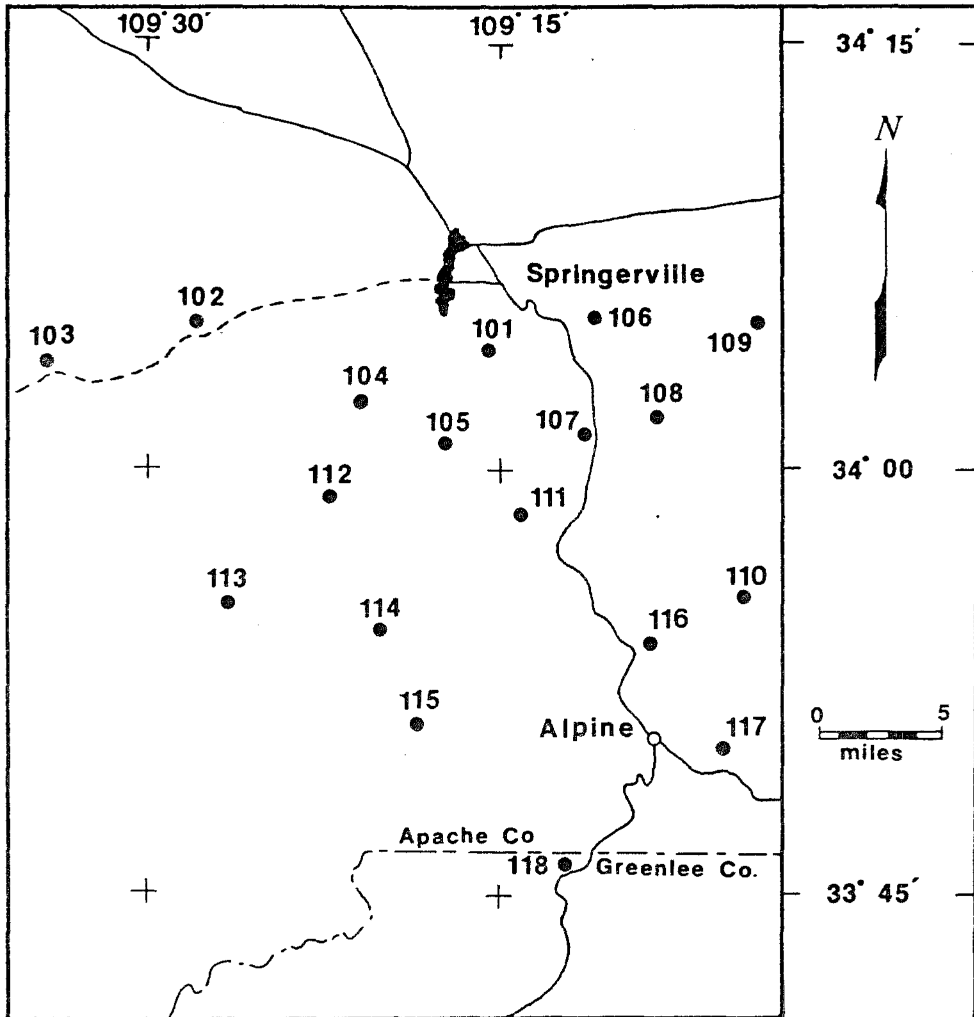


FIGURE I. Proposed heat flow drill sites.

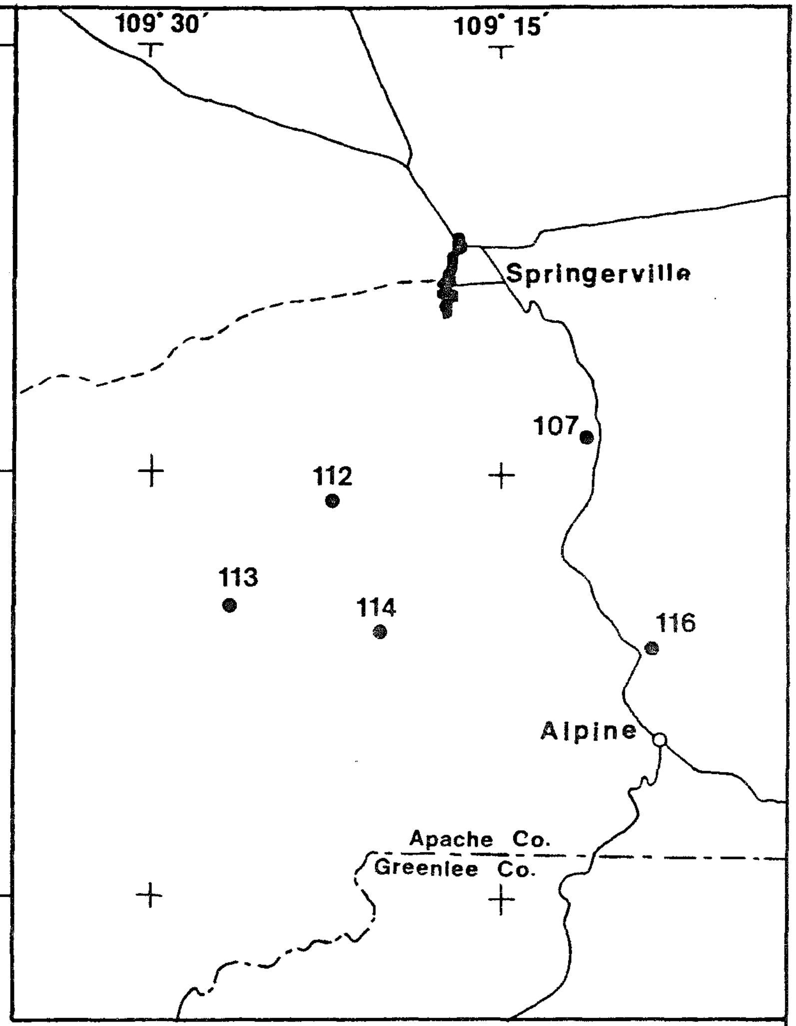


FIGURE 2. Completed heat flow drill sites.

TABLE 1

Heat flow hole locations, total depths, elevations, and drilling dates.

Hole No.	Location*	Spud Date	Completion Date	Ground Elev. m	Total Depth, m
SJ-107	(A-7-30) 7daa	5-22-79	6-15-79	2356	349
SJ-112	(A-7-28) 27bca	7-23-79	7-26-79	2817	155
SJ-113	(A-6-27) 12cdc			2805	107
SJ-114	(A-6-28) 13aaa	6-17-79		2695	219
SJ-116	(A-6-30) 23cac	7-31-79	8-8-79	2610	357

*Gila-Salt Meridian. "A" represents NE quadrant of state.

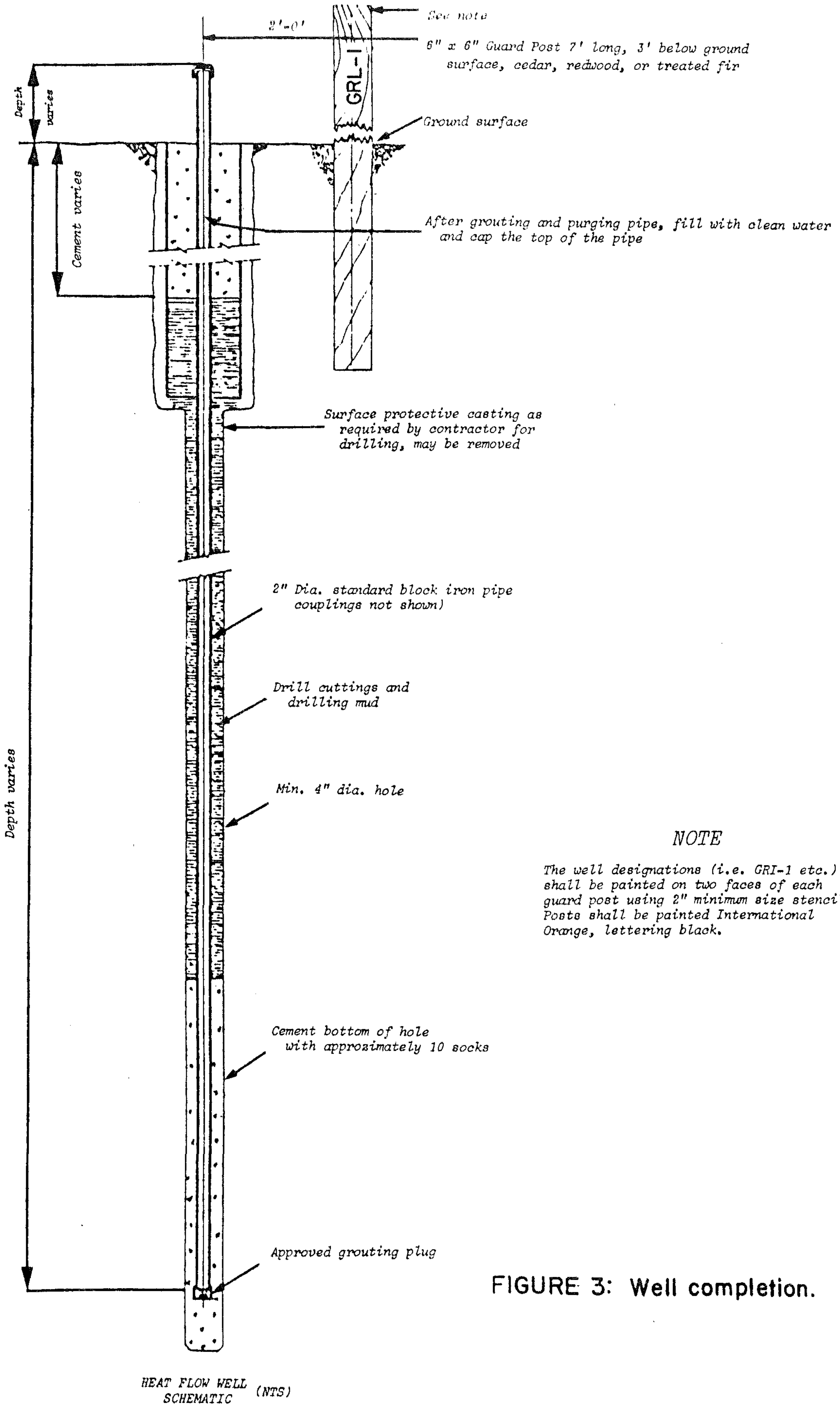
Each drill hole was completed by running two-inch diameter standard black iron pipe to total depth and pumping about ten sacks of cement grout through the pipe. This operation was followed by a grouting plug that cleaned the pipe and sealed the bottom. The pipe was then filled with clear water. The rest of the annulus was backfilled with drill cuttings and drilling mud. A cement plug of variable thickness was set at the top of each hole, and the pipe was closed with a metal screw cap (Fig. 3).

Lithology

Holes No. 112, 113, and 114 were drilled in interbedded basaltic lava flows and cinder, and encountered copious amounts of water. Hole 113 bottomed in about 12 m of fine to coarse sandstone. Hole 107 encountered medium- to fine-grained, pinkish-tan sandstone to total depth and was dry. Hole 116 penetrated 159 m of medium- to fine-grained, pinkish-tan sandstone, 92 m of orange-red coarse-grained sandstone, and 122 m of red-brown to black clay, siltstone, and black (basaltic ?) lithic fragments. This hole, No. 116, produced about 10 gpm of 16.7°C water at 70 m. A fence diagram (Fig. 4) shows the lithology of these and five other wells in the area.

Heat Flow Determinations

The heat flow holes were logged at 5-m intervals, three times each, with little apparent differences in gradients. The temperature data are shown in Figures 5 through 9. The most recent temperature logs, those measured September 5, 1979,



NOTE

The well designations (i.e. GRI-1 etc.) shall be painted on two faces of each guard post using 2" minimum size stencils. Posts shall be painted International Orange, lettering black.

FIGURE 3: Well completion.

FENCE DIAGRAM SHOWING SUBFACE LITHOLOGY IN SPRINGERVILLE ALPINE GEOTHERMAL PROJECT AREA

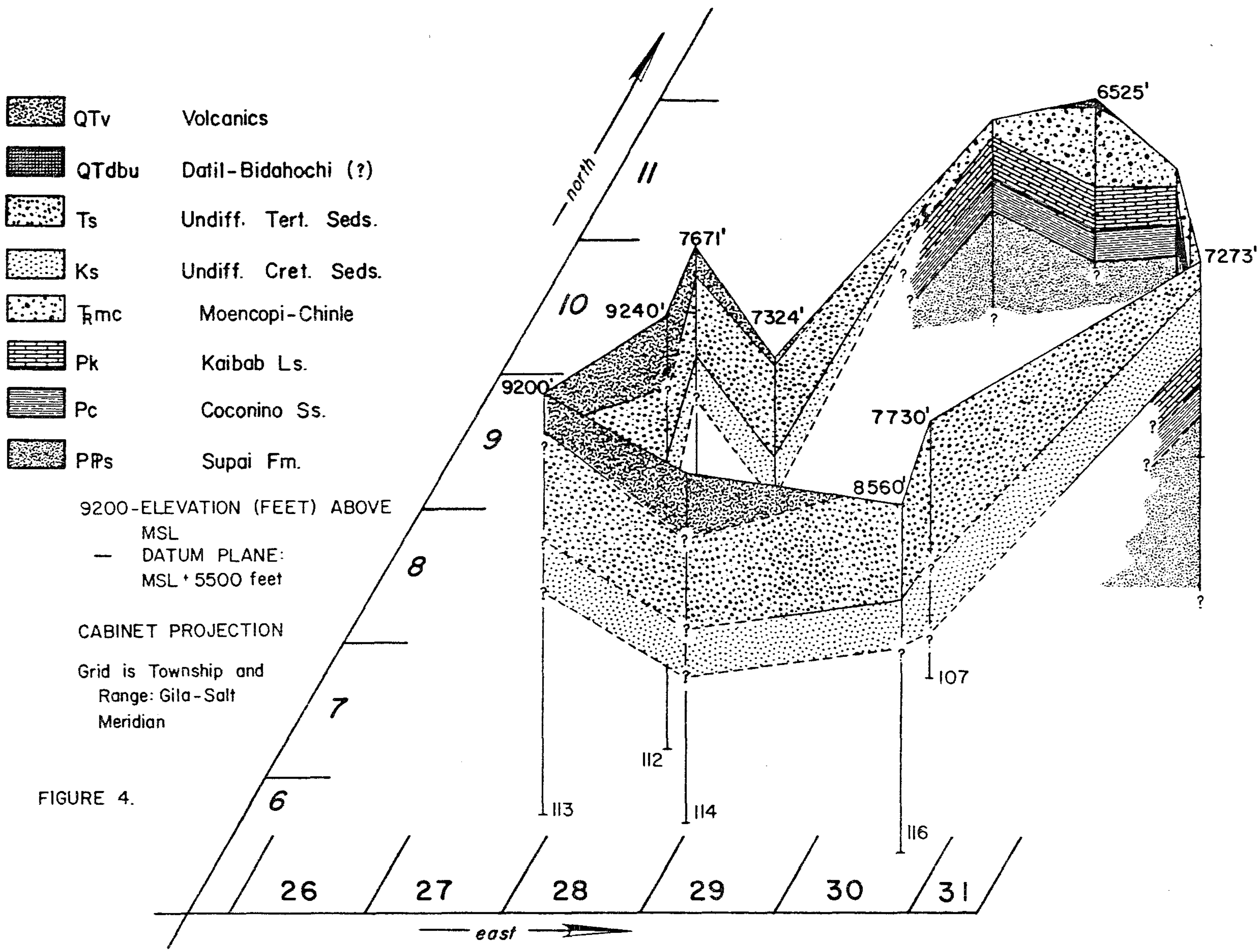


FIGURE 4.

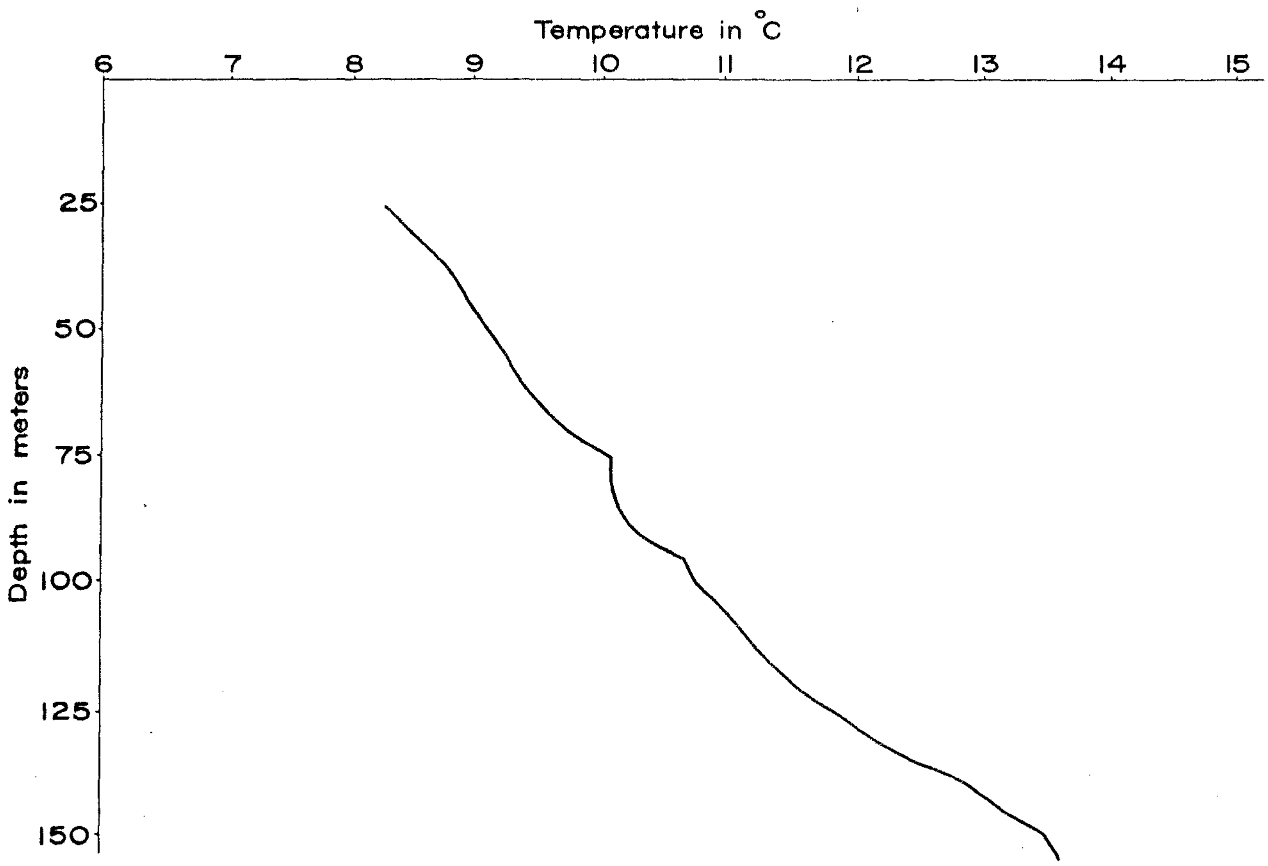


FIGURE 5: Springerville Area, Hole-112 (T7N, R28E, 27 NE SW NW).

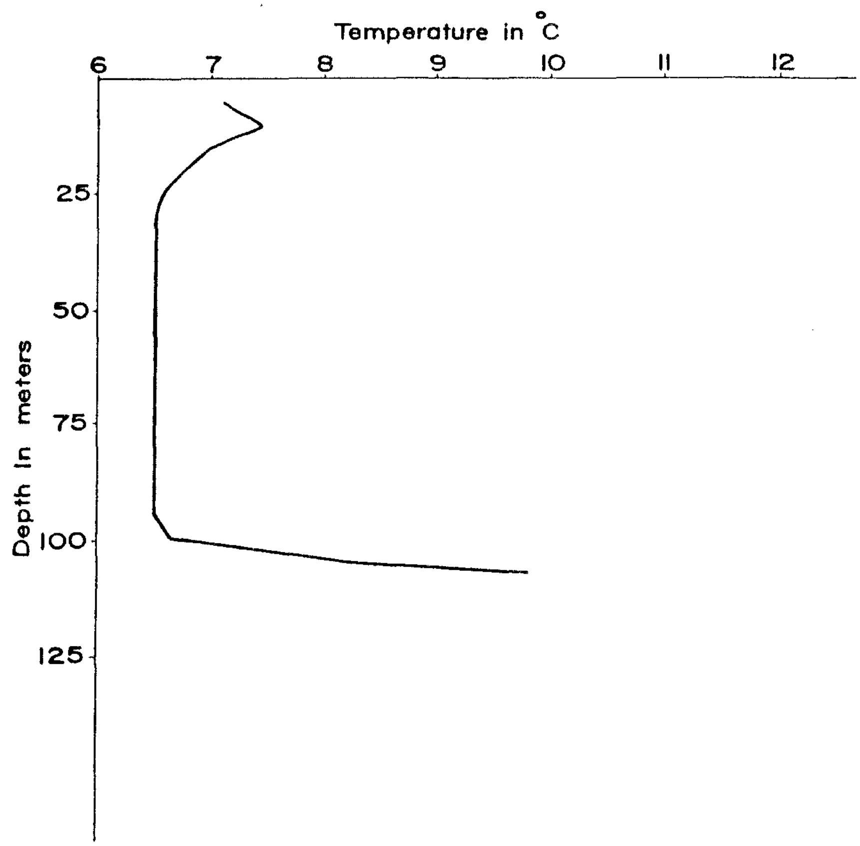


FIGURE 6: Springerville Area, Hole-113 (T6N, R27E, 12 SW SE SW).

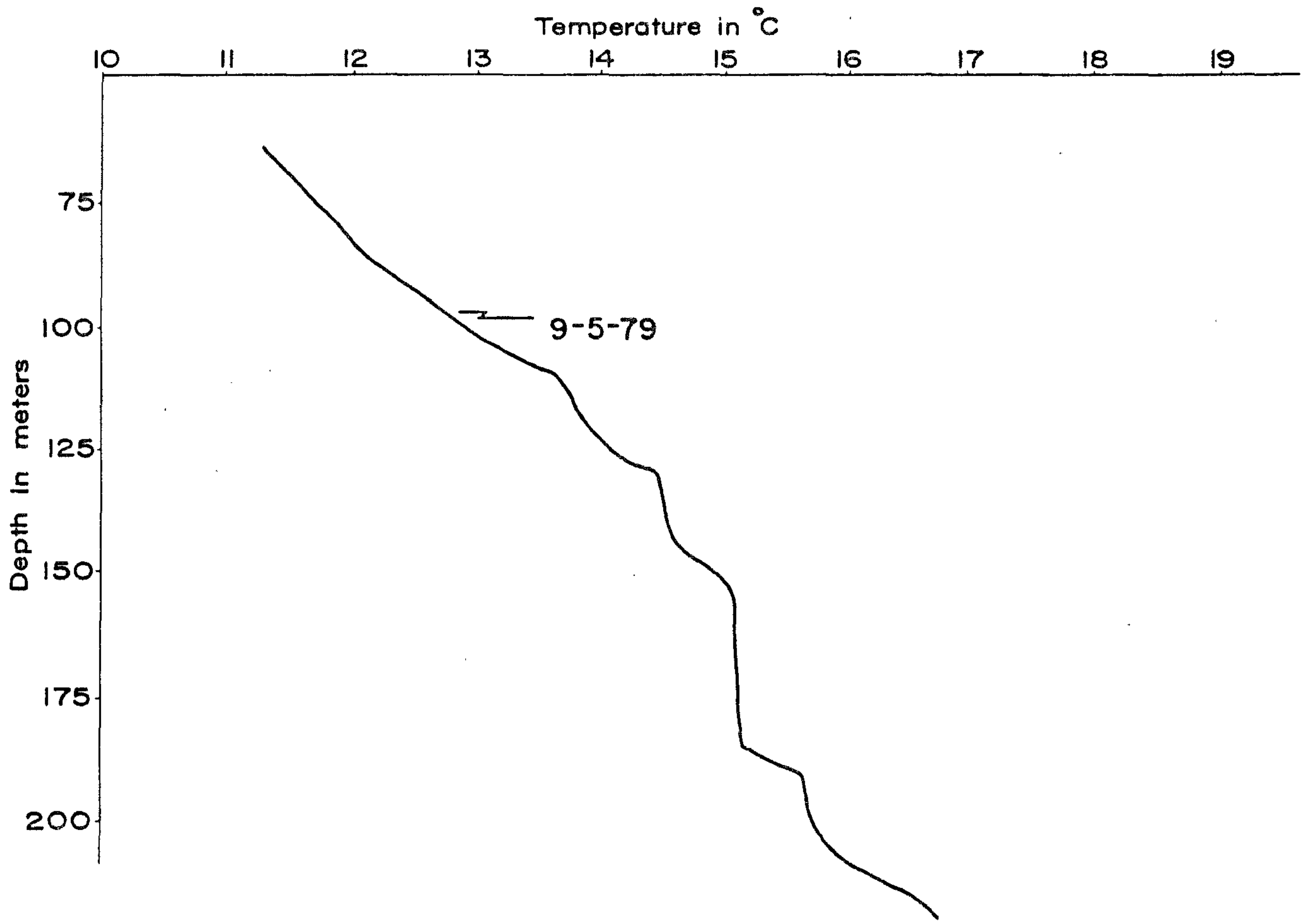


FIGURE 7: Springerville Report, Hole-114 (T6N, R28E, 13 NE NE NE)

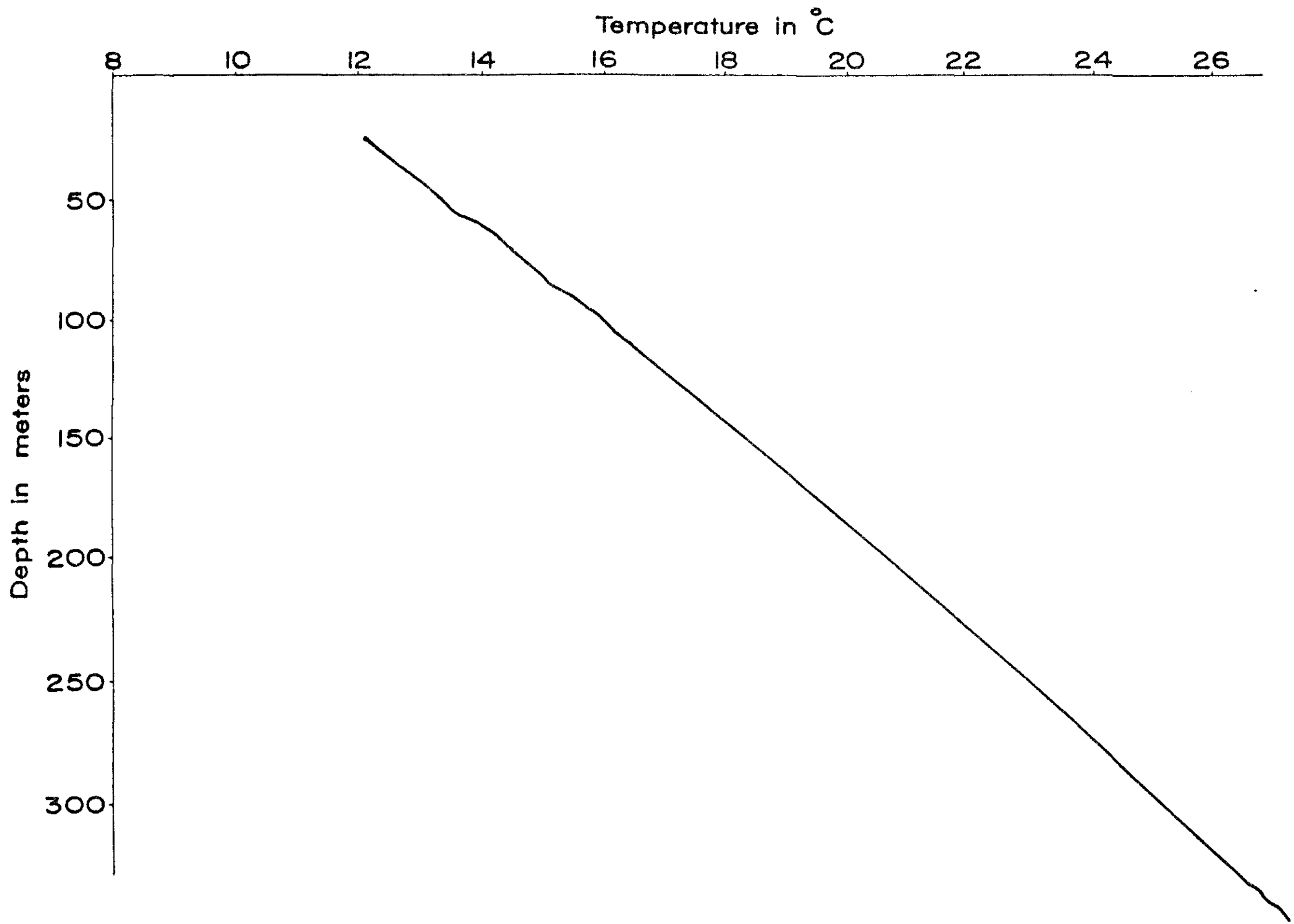


FIGURE 8: Springerville Area, Hole - 107 (T7N, R30E NE NE NE SE).

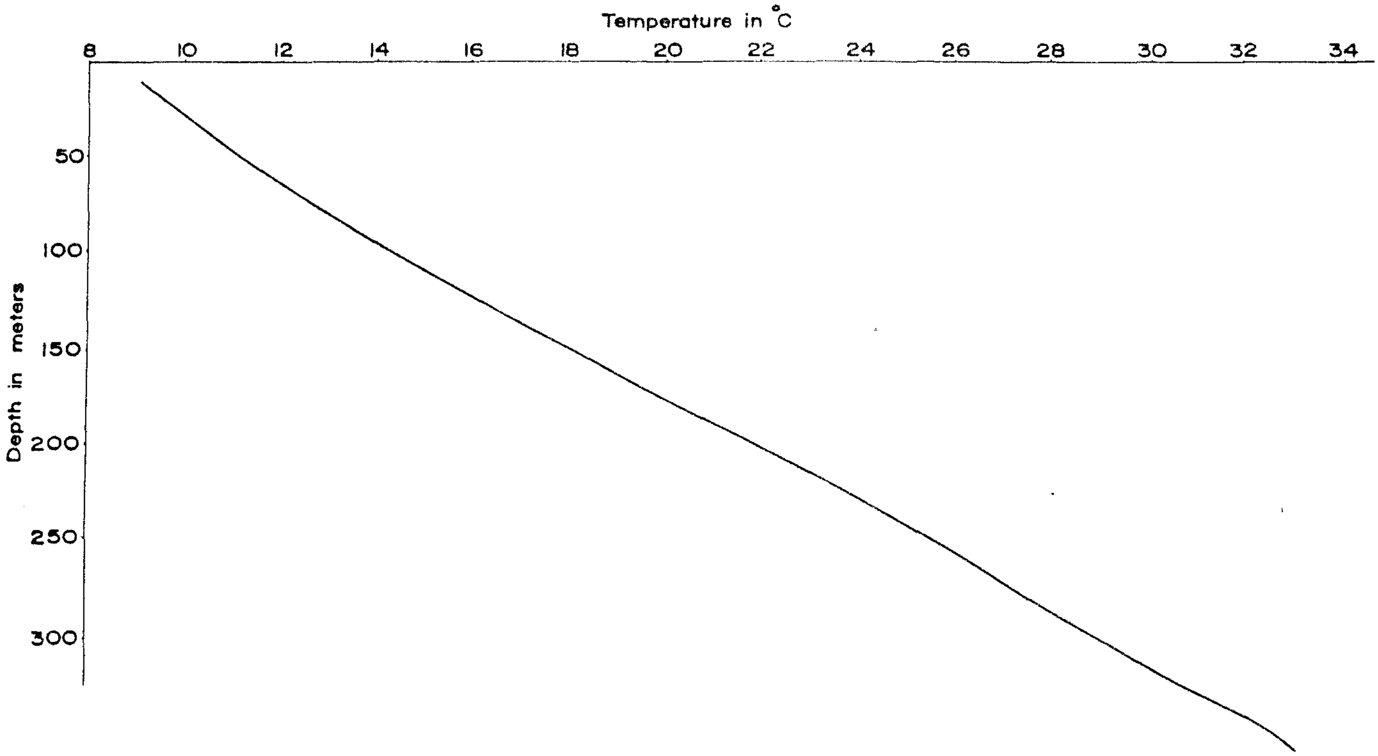


FIGURE 9: Springerville-Alpine Geothermal Project, Hole-116
(T6N, R30E, 23 SW NE SW)

are the thermal gradients used in the heat flow calculations.

The temperature logs of holes No. 112, 113, and 114 (Figs. 5, 6, and 7) confirm the high volume and velocity of water moving through the permeable volcanic layers. Such rapid ground-water movement renders these holes of poor quality for reliable heat flow estimates. Had the holes been grouted from top to bottom the problem may have been minimized, but a valid conductive heat flow value still could not have been obtained due to ground water circulation. The other two heat flow holes are essentially dry, and represent fairly reliable heat flow measurements. An additional, abandoned dry water well drilled several years ago, about three miles south of hole No. 107, has been temperature logged to a depth of 75 m (Fig. 10). This hole is designated DR-1 and for estimating the rock thermal conductivity, it is considered to have a lithology similar to that of hole No. 107.

The linear regression method was used to fit straight lines to the temperature data of each hole. The slope of the line is the thermal gradient and the y-intercept represents the MAT (mean annual temperature). Credible segments of data from holes No. 112, 113, and 114 yield thermal gradients that extrapolate back to reasonable MAT's for the project area, thereby providing a small degree of confidence in the gradients. The measured thermal gradients for holes No. 107, 116, and DR-1 are nearly linear (Figs. 8, 9, and 10). The thermal gradient data are presented in Table 2.

The thermal conductivity of representative drill cuttings was measured with a divided bar apparatus, using the chip method

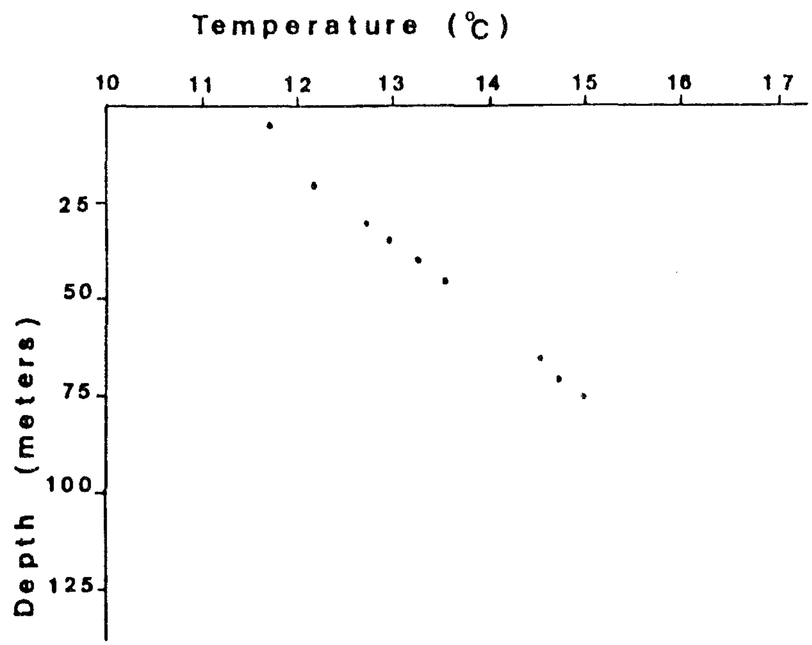


Figure 10. Hole DR-1
Springerville-Alpine Area

TABLE 2

Thermal Gradients

Hole No.	No. of Date Pts.	Depth Intervals, m	Thermal Gradients (°C/km)	MAT (°C) y-Intercept	Correlation Coefficient
112	10	25-75	33.1	7.43	0.9944
	6	95-120	35.9	7.18	0.9975
113	3	5, 10, and 107 only	25.3	7.07	0.9982
114	5	65-85	35.4	9.03	0.9999
107	63	23-345 (excluding 55+85)	43.9	12.07	0.9414
116	69	10-355 (excluding 15+355)	71.6	7.59	0.9994
DR-1	9	30-75	51.1	11.17	0.9993

of Sass, Lachenbruch, and Munroe (1971). Measurements were made in the laboratory of Dr. Robert F. Roy, University of Texas, El Paso. Thermal conductivity values are presented in Table 3. Heat flow data are presented in Table 4.

Discussion and Conclusions

Working in southern Colorado and New Mexico, Reiter and others (1975) recognized two generalized zones of heat flow in the eastern Colorado Plateau: (1) 63mWm^{-2} or less associated with major structural basins and (2) 84 mWm^{-2} and greater associated with some intrusions and perhaps major uplifts. Chapman and others (1978) determined a representative heat flow of 49±8 mWm^{-2} for the Utah portion of the Colorado Plateau province.

Swanberg and Morgan (1978/79) found a linear relation between temperatures based on the silica content of ground water and regional heat flow in the United States. This relationship enhances the validity of the 55 mWm^{-2} regional heat flow value determined for the Colorado Plateau province by Swanberg and others (1977) using the silica-geothermometry method.

The regional heat flow for eastern Arizona and western New Mexico, using the data from this report and from published reports, is shown in Figure 11. Several observations and conclusions can be made from these data, keeping in mind that the number of heat flow values along the Arizona-New Mexico border is too small to do anything more than generalize.

(1) A low-amplitude, heat-flow high does exist in the project area (Figs. 11 and 12), but the magnitude of the anomaly is

insufficient to indicate an economic high-temperature geothermal resource. (2) A heat flow anomaly of significant magnitude is believed to exist within or to the west or east of the project area, but definitive identification of such an anomaly will require detailed, state-of-the-art geological and geophysical exploration. (3) Little reliance can be placed on the three westernmost heat flow valued determined in volcanics. The importance of this area in terms of a geothermal resource is still unknown.

TABLE 3

Thermal Conductivity

Hole No.	Depth Range, m	K 10^{-3}cal/cm s ^{o}C	K W/mK	Density gm/cm^{3}
112	6-12	4.12	1.72	2.71
	37-43	4.04	1.69	2.82
	67-73	3.87	1.62	2.81
	98-104	3.81	1.59	2.68
113	37-43	4.13	1.72	2.85
	55-61	3.90	1.63	2.81
	97-104	3.96	1.65	2.68
114	6-12	4.58	1.91	2.94
	61-67	3.75	1.57	2.61
	85-92	3.13	1.31	2.49
107	18-24	4.27	1.78	2.47
	55-61	4.41	1.84	2.50
	92-98	4.66	1.95	2.41
	122-128	4.60	1.92	2.42
	183-189	5.88	2.46	2.40
	213-220	4.77	1.99	2.47
	244-250	5.17	2.16	2.41
	305-311	4.37	1.83	2.47
116	24-31	5.76	2.41	2.52
	61-67	4.44	1.86	2.43
	116-122	4.13	1.73	2.48
	152-159	3.59	1.50	2.37
	195-201	3.36	1.41	2.34
	232-238	3.02	1.26	2.27
	274-281	3.09	1.29	2.13
	311-317	3.42	1.43	2.28

TABLE 4

Summary of new heat flow data.

Locality	Hole	N. Lat.	W. Long.	Elev. (M)	Depth Range (M)	Gradient (°C/km)	K. mean (W/mK)	Q (mWm^{-2})
Rudd Knoll	112	33° 59'	109° 23'	2817	25-75 95-120	33.1 35.9	1.68 1.59	55.5 57.1
Crescent Lake	113	33° 55'	109° 27'	2805	5, 10, 107	25.3	1.67	42.2
Crosby Crossing	114	33° 55'	109° 20'	2695	68-85	35.4	1.44	51.0
Riggs Creek	107	34° 01'	109° 13'	2356	25-345	43.9	1.99	87.4
Alpine Divide	116	33° 54'	109° 09'	2610	10-355	71.6	1.61	115.4
Nutrioso	DR-1	34° 00'	109° 11'	2296	30-75	51.1	1.99	101.4

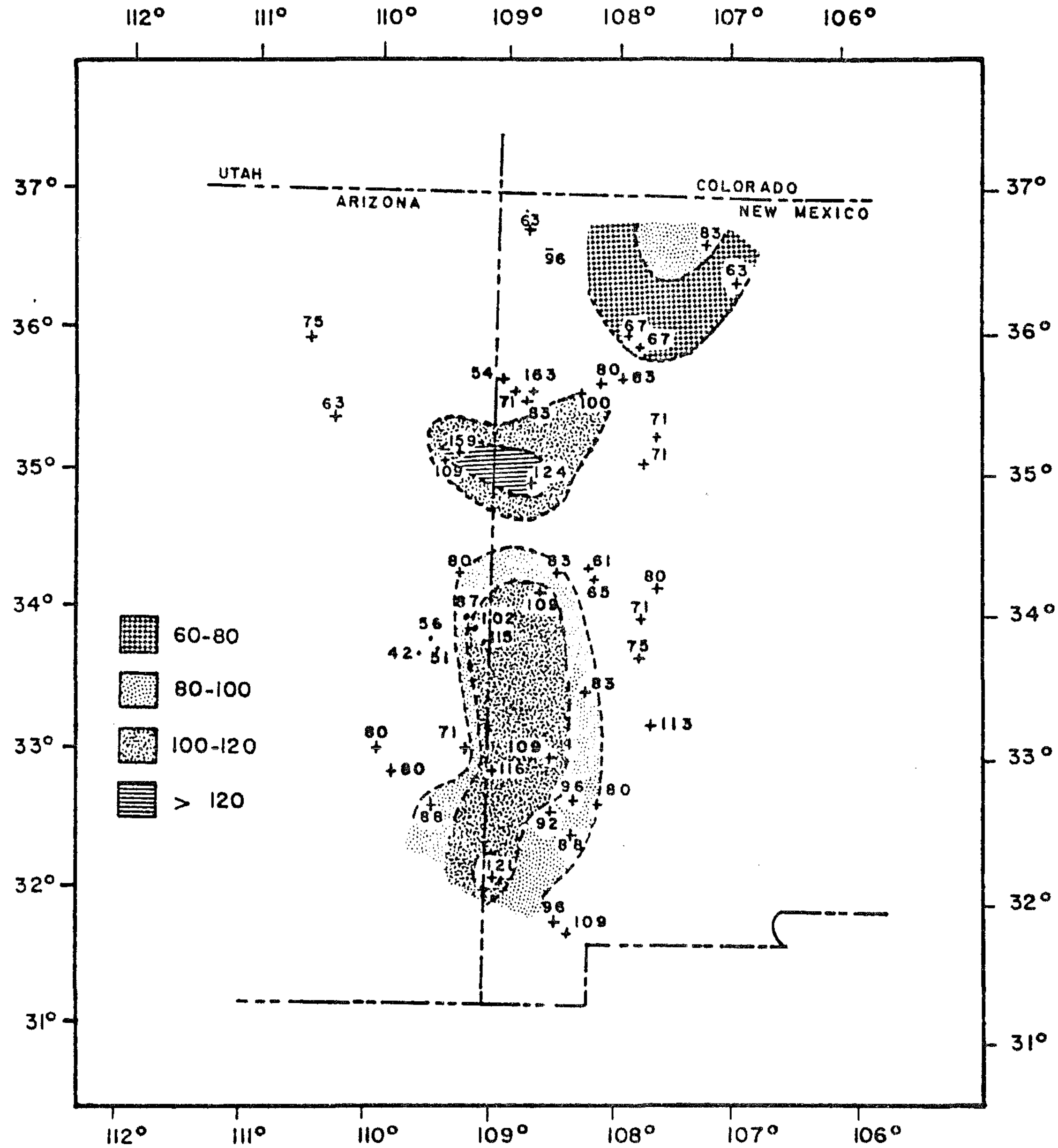


FIGURE 8: Heat flow contour map of eastern Arizona and western New Mexico (modified after Reiter and others, 1975). Dots represent sites measured for this report. Plus signs represent data from other investigators. Contour interval is 20 mWm-2.

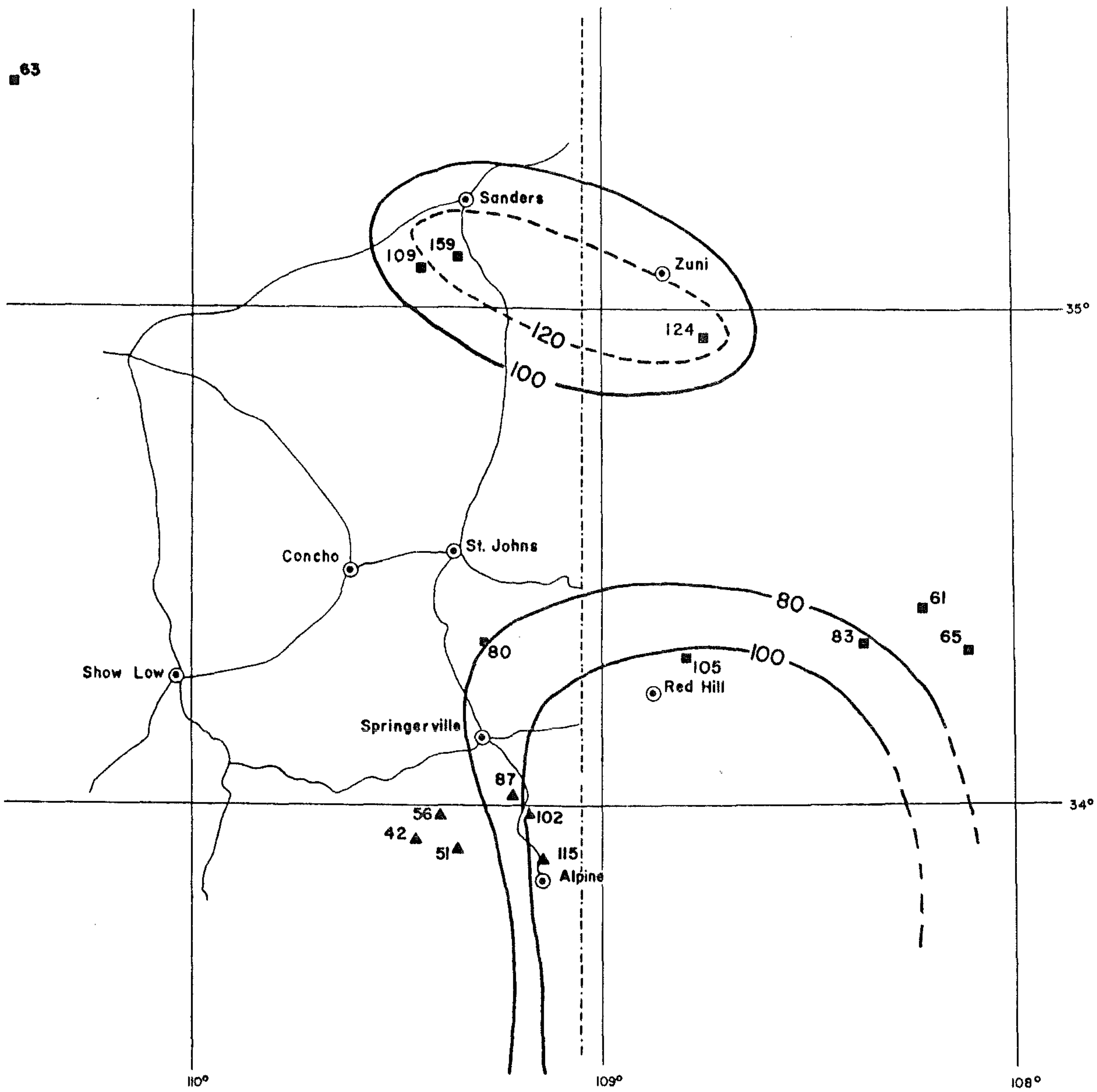


FIGURE 12: Heat flow in the Springerville-Alpine Geothermal Project Area. Countour interval is $20 mWm^{-2}$.

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