GLU1130

TECHNICAL REPORT: VOLUME 77-3

Thermal Gradients and Heat Flow at Roosevelt Hot Springs

Energy Research and Development Administration Contract EY-76-S-07-1601

> W. R. Sill J. Bodell

TABLE OF CONTENTS

Abstract

•

.

1.0	Introduction	1
2.0	Thermal Gradients at Roosevelt Hot Springs	3
3.0	Heat Flow at Roosevelt Hot Springs	6
4.0	Conclusions	8
	References	9
	List of Figures	0
	Appendix A	1

Abstract

Thermal gradient and electrical resistivity surveys both outline anomalous zones along the system of faults that control the near surface flow at Roosevelt Hot Springs. The source of both anomalies is the circulation of thermal water, which gives rise to the high heat flow and the lowered resistivity due to the hot brine and the associated hydrothermal alteration.

The nature of the temperature profiles and the asymmetry of the thermal gradient profile across the system are suggestive of a leakage and mixing of thermal water with the regional groundwater flow to the west. This interpretation is consistent with the resisitivty data in which conductive regions to the west of the fault system have been interpreted in terms of brine-saturated sediments.

The maximum conductive heat flow over the anomaly is 40 HFT $(1.7W/m^2)$ and the total conductive heat loss is estimated at 2 MW. Heat flow in the Mineral Mountains, to the east of the near-surface thermal anomaly, is low or near average for the Basin and Range. Recharge may be taking place in this region.

1.0 Introduction

Thermal gradient data from 39 drill holes in the Roosevelt Hot Springs KGRA area are presented in this report. Fifteen of these holes were drilled under subcontract to the University of Utah, permission to log another ten holes was granted by Phillips Petroleum Company and the remaining fourteen holes were provided by other sources. The locations of most of the holes are shown in Figures 1 through 3, along with the locations of test and production holes. These figures also show the contoured average thermal gradient in three depth intervals; shallow (30-60m), intermediate (60-100m) and deep (>100m).

Figure 4 displays a plan view of the interpreted faults in the area. Comparison of Figures 1 and 4 shows that the region of highest thermal gradients is aligned along the Dome Fault and Fault 1. To the south the high thermal gradients are terminated by several east-west trending faults. To the north there is a bending of the contours resulting in a ridge aligned along fault 5, which trends to the north west.

In Figures 1 and 2 there are isolated highs in the north and south that are probably the result of the sparseness of data in the central region. Considerations of the probable thermal gradient in the early steam well (drilled by Dr. E. N. Davie), based on the depth of blowout, and the near surface temperatures in sulfur pits in the bottom of Negro Mag Wash (North of 54-3) would indicate that the 900°C/km should run further to the west in the southern portion and is probably continuous with the high in the north.

Comparison of Figure 1 with the contoured apparent resistivity (Figure 5) shows that the resistivity and thermal gradient patterns are highly correlated. Both exhibit contours aligned along the Dome fault and a bending to the northwest along Fault 5. The obvious cause of the correlation is the hot water circulation along the faults which gives rise to both high thermal gradients and low resistivities due to the hot brine and the associated hydrothermal alteration.

With increasing depth (Figures 2 and 3) the thermal gradients decrease and the alignment along the faults is less clear. The smearing of the pattern is partly due to the lack of data at greater depths. The acquisition of deep thermal gradient data from small drill holes in regions of very high thermal gradients is hindered by fear of blowouts, among other things.

2.0 Thermal Gradients at Roosevelt Hot Springs

Figures 6 to 20 show the temperature vs depth curves for the holes drilled by the University of Utah. As can be seen in these figures, the thermal gradient in holes drilled in alluvium often decreases with depth, with the depth intervals used in Figures 1 to 3 being somewhat characteristic of the several regions of changing gradient. For example, hole UUTG6 (Figure 20) shows an abrupt change at 30m and hole UUTG3 (Figure 18) displays a more gradual transition with suggested breaks at 35m and 70m. Such changes in the thermal gradients can be caused by changes in thermal conductivity due to changes in the porosity, saturation and lithology among other things.

Gravity measurements over a wash in the alluvium (Crebs and Cook, 1976) indicate a porosity of about 25% in the near surface (25-50m). Some decrease in porosity with depth is to be expected due to the increase in load. A change in the porosity of saturated granite alluvium from 25% to 10% would give rise to a change in thermal conductivity (and gradient) of about 25%. The changes in thermal gradient caused by such variations in porosity are then rather modest.

On the other hand, changes in saturation, from dry to completely saturated, would give rise to changes in thermal conductivity by a factor of 2.0 to 2.5 for porosities in the range from 20 to 30%.

Changes in the thermal conductivity due to lithology changes depends on the thermal conductivity of the components. For example, changing the thermal conductivity of the solid components by a factor of 2 results in a 1.7 change in conductivity at a porosity of 25%. Changes in lithology from a granite alluvium to a quartz rich sand are possible in this area. Measurements made on sands from the Roosevelt KGRA give solid component conductivities in the range from 10 to 11 HCU and samples of granite alluvium give values in the range from 6 to 7 HCU. Therefore, such changes in lithology can be expected to give rise to rather substantial changes in gradient.

Considering the thermal gradients in hole UUTG6 (Figure 21) we see that the average gradient in the 20-30m interval is about 200° C/km and below this depth it averages about 30° C/km, a factor of about 7 change is slope. Thermal conductivity measurements on samples from this hole average about 4 HCU, at a saturated bulk density of $2.2g/\text{cm}^3$, with no consistent changes above and below the break in the slope. The water table in a nearby well (2.4km) at about the same elevation is 26m (Mower and Cordova, 1974). This is near the break in the thermal gradient. However, the change in thermal conductivity due to undersaturation would only be a factor of 2 to 2.5 which is well below the observed value.

One possible explanation of the strong change in gradient is a leakage of thermal water into the groundwater flow to the west. Some leakage of thermal water is indicated by the chemical analysis of the seep west of Salt Cove, which has a cool temperature (25°C) but a Na-K-Ca temperature of 241°C (Parry et. al., 1976). For a uniform mixing of thermal water into the groundwater in a region of constant thermal conductivity, the thermal gradient should decrease smoothly with depth in the mixing zone. The two gradient regions in UUTG6 may result from a combination of effects due to the presence of the water table and mixing. On the other hand, the thermal gradient in hole UUTG3 (3km to the south) shows a more gradual change, with no sharp break at the water table (50m). The overall change in slope between the top and bottom of this hole is about a factor of 8, which seems too large to be explained by the effects of saturation alone.

In holes UU751A and UU751B, just to the west of the dome fault, the water tables were located at about 35m and 40m respectively, which are also the locations of the alluvium altered bedrock interface. In both cases the thermal gradients do not show an abrupt change at the water table.

However, there is gradual increase in thermal gradient above these depths (20% to 40%), perhaps due to gradual changes in the saturation.

Figure 21 shows a series of temperature profiles on a west-east line across the southern part of the system (the letter designation runs from West-A to East-I). The thermal gradients and the 10m depth temperatures increase as the Dome Fault is approached from the west (A to G) and the two eastern holes (H & I) show decreasing temperatures and gradients.

The five westernmost holes (AA to D) show a decreasing gradient with depth, as did the western holes to the north(UUTG6 and UUTG3) discussed previously. The two westernmost holes 5(AA) and 12(A) have a thermal gradient in the deeper part near 50°C/km, which is near normal for a thermal gradient in the alluvium. The water table is about 40m in this region (Mower and Cordova, 1974) and both curves show changes in slope (15 to 30%) at this depth, which could be due to changes in saturation. There is a change in slope to a near constant slope region at a depth of about 60m. The change in average gradient above and below this depth is a factor of 1.5 to 3. The lithologic log on a nearby water well notes a change in lithology at this point, from sands containing numerous "igneous" fragments (up to 30%) to sands free of such material. Considering the average abundance of such material, it would be difficult to account for the changes in slope by the change in lithology. Once again a possible explanation for the change in slope could be leakage of thermal waters to the west and mixing with the groundwater. With respect to this, it is interesting to note that the thermal gradients at depth in the westernmost holes are near normal and that the gradient in the easternmost hole is constant with depth although slightly above normal. More conclusive evidence for leakage mixing of thermal waters would be the presence of gradient reversals which have not been observed to date.

3.0 Heat Flow at Roosevelt Hot Springs

Thermal conductivity measurements on a limited number of alluvial samples, indicates an average value of 4 HCU (1 HCU - mcal/cm S°C - 0.418 W/m°k). Maximum conductive heat fluxes are then in the neighborhood of 40 HFU (1 HFU = μ cal/cm²S = 41.8 mW/m²). The total integrated conductive heat loss over the anomaly (6.5 km in length) is about 10⁷cal/S or 2MW.

Figure 22 is a west to east thermal gradient profile for two depth intervals, 30-60m and 60-100m. Based on a *conductive* heat flow model, these profiles indicate an equivalent line source at 1.0 to 1.5km depth. Also shown on the figure, as a dashed line, is the theoretical thermal gradient profile for a line source, scaled to the 30-60m data. From this it is easy to see that the observed curve is asymmetrical, with smaller gradients in the east and larger to the west. This asymmetry is also observed in the deeper (60-100m) gradients. The observed asymmetry is compatable with the leakage of thermal water to the west, as discussed in the previous section, but source configuration in a conductive model could also produce such asymmetry.

Several core holes were also drilled in the granite of the Mineral Range so that samples could be measured for thermal conductivity and heat flow values calculated. Figure 13 shows the temperature profile in one such hole (UU76SC) located in Salt Cove on the west side of the Mineral Range, about 3 km east of the center of the thermal gradient-resistivity anomaly. The thermal gradient is quite uniform at an average value of 29°C/km below a depth of 50m. The average thermal conductivity in this region is 6.6 HCU (16 samples) giving a heat flow of 1.92 HFU.

Another hole (UU76BS) was drilled in the central part of the Mineral Range just to the north of Bearskin Mountain, the temperature profile from the last log (Figure 14) still shows some drilling disturbances, but the

S.O. Head STM. C. D. Meyeau H. Her Swell D.S.

Thermails and consider accounterations from instances in a faster of the faster of the constant samples, indices a solution without of A bou () acts with the constant harman conducts a contificate are then in the constructiona () if if the () for a colverte of a with), the cost integrated constructive real cast over the anomaly (Cub be in Tength) is though 10⁷ are (S or the

Figure 27.3. A west to east thereal gradient provider a contribution intervals, 30.60m and 60-100m. Based on a conduction for the context, these profiles a drate an equivalent file source is for the file. This Also shown on the figure, as a distract file to the file file of the file gradient profile file of the source, analy analytic to the file of the file of a shown on the figure, as a distract for the file of the file gradient profile file of the source, analytic to the file of the source of the source of the source, and the source of a source of the file of the file of the source, and the source of the source of the observation of the source, and the source of the source of the file of the source of the source of the source of the observation of the source of theread water of the source of the source of the file of the source of the source of the source of the observation of the file of the source of the s

Several corr heles were also problem in the grants of the problem is a figure of the several correction of the analysis and the analysis of the fermal second of the analysis of the fermal second of the second of

Arothor here (UP+625) see antibut to the contral out: of the Minoral Pargo just to the north of Jearship (o state, and teapers one profile from the last tre (Figure 1) stall seams seat dath)ing day compast out the smoothed thermal gradient in the 80 to 150m interval is 17° C/km. The thermal gradient in a Phillips Petroleum Company hole, 1.5 km to the north (Figure 1) is similar (16° C/km) indicating that this is maybe representative of the area. The average thermal conductivity in this hole in the above depth interval is 7.65 HCU (11 samples) giving a heat flow of 1.28 HFU.

Two kilometers to the east of this hole, the hole at Ryans Ranch (UU75RR, Figure 11) has thermal gradient of 19.9^OC/km (50 to 80 m) and the average thermal conductivity of several samples is 7.1 HCU, resulting in a heat flux of 1.41 HFU.

Roy et al. (1968) report a heat flow of 2.22 HFU for a location on the west side of Milford valley, just about due west of Roosevelt Hot Springs. None of the above calculated heat flow values are large for the Basin and Range, in fact the measurements in the central part of the range seem somewhat low. However, none of the measurements have been corrected for topographic effects, which should be largest for the locations north of Bearskin and at Ryans Ranch.

If the Mineral Mountains and the area to the east are regions of significant recharge, then the downward movements of cool water may contribute to the low thermal gradient and heat flow.

4.0 Conclusions

Thermal gradients and electrical resistivity data at Roosevelt Hot Springs both outline the same anomalous region along the system of faults which control the near surface circulation. Depending on the circumstances, these techniques may provide complementary or redundant information.

The character of the thermal gradients to the west of the fault system suggest that thermal waters are mixing with the ground water flow to the west. If so, this should be reflected in the water chemistry. Parry et al. (1976) show several anomalous Na-Ca-K temperatures to the northwest of Roosevelt Hot Springs but no data was available from wells in the immediate vicinity of the thermal gradient holes.

Heat flow values in the alluvium reach a maximum of about 40 HFU, and the estimated total conductive heat loss from the shallow part of the system is about 2MW. Heat flow values and thermal gradients in the Mineral Range are not high for the Basin and Range, and in fact several of the values seem low.

REFERENCES

- Crebs, T. J. and K. L. Cook, 1976; Gravity and ground magnetic surveys of the central Mineral Mountains, Utah, Volume 6, Grant GI-43741, National Science Foundation.
- Mower, R. W. and R.M. Cordova, 1974; Water resources of the Milford area, Utah, with emphasis on groundwater, State of Utah, Department of Natural Resources Technical Pub. No. 43.
- Parry, W. T., N. L. Benson and C. D. Miller, 1976; Geochemistry and hydrothermal alteration at selected Utah hot springs, volume 3, Grant GI-43741 National Science Foundation.
- Roy, R. F., E. R. Decker, D. D. Blackwell and F. Birch, 1968; Heat flow in the United States, J. Geophys. Res., 73,5207-5221.

LIST OF FIGURES

Thermal gradient Contour map, depth interval 30-60 meters, also Fig. 1 shown are the locations of test and production wells. Fig. 2 Thermal gradient contour map, depth interval 60-100 meters. Fig. 3 Thermal gradient contour map, depth greater than 100 meters. Fig. 4 Interpreted Fracture map. Fig. 5 Apparent resistivity contour map, first separation, 300 meter dipole-dipole. Fig. 6 Temperature profile hole UU75-12 п 11 H Fig. 7 0075-13 н 11 п Fig. 8 UU75-1A п п 11 Fig. 9 UU75-1B н н н Fig. 10 UU75-BCC 11 Ħ 11 Fig. 11 UU75-RR н н H Fig. 12 UU76-1A н 11 Fig. 13 -11 UU76-SC IE 11 Fig. 14 UU76-BS н н Fig. 15 11 UU76-TG0 Fig. 16 ŧ н 11 UU76-TG1 н н н Fig. 17 UU76-TG2 н 11 Fig. 18 н UU76-TG3 н н н Fig. 19 UU76-TG5 11 н # Fig. 20 UU76-TG6

Fig. 21 Temperature Profiles for a series of holes along an east-west line at approximately 2200N.

Fig. 22 Thermal gradients at two depth intervals (30-60m and 60-100m) along an east-west line at approximately 2200N. APPENDIX A

.

Temperature Logs

LOCATION: RYANS RANCH LOCATION: RYAN'S RANCH 27S 8W 4DCD HOLE NUMBER: UU75 DATE MEASURED: 11/6/76

DEPTH	TEMPERATURE	GRADIENT
METERS	DEG C	DEG C/KM
5.0	9.894	.0
10.0	8.803	-218.2
15.0	9.716	182.6
20.0	9.858	28.4
25.0	9.000	-171.6
30.0	9.007	1.4
35.0	9.170	32.6
40.0	9.280	22.0
45.0	9.370	18.0
50.0	9.391	4.2
55.0	9.492	20.2
60.0	9.569	15.4
65.0	9.681	22.4
70.0	9.781	20.0
75.0	9.886	21.0
80.0	9,987	20.2
85.0	10.116	25.8
90.0	10.292	35.2
95.0	10.381	17.8
100.0	10.492	22.2

Location:	BIG CEDAR COVE	
HOLE NUM	368: BU 75	
DATE MEAS	SURED: 9/22/75	
depth	TEMPERATURE	GRADIENT
meters	deg c	DEG C/KM
5.0	16.769	• 0
10.0	12.878	-758.2
15.0	13.421	88.6
20.0	13.543	24.4
25.0	13.873	9 6.4
30.0	14,427	90.8
35.0	14.693	53.2
40.0	15.073	76.0
45.0	15.526	90.6
50.0	15.957	86.2
55.0	16.437	96.0
60.0	16.754	63.4
65.0	17.132	75.6
70.0	17.481	69.8
75.0	17.908	84.8
90.0	18.280	75.D
85.0	18.579	59.8
90.0	18.858	55.4
95.0	19.153	59.4
100.0	19.937	156.8

LOCATION: ALTERATION 75 1A 27S 9W CBB HOLE NUMBER: UU 751A DATE MEASURED: 7/22/76

DEPTH	TEMPERATURE	GRADIENT
METERS	DEG C	DEG C/KM
10.0	26.283	.0
15.0	34.349	1613.2
20.0	40.036	1137.4
25.0	44.876	928.0
30.0	49.158	896.4
35.0	53.288	826.0
40.0	57.622	866.8
45.0	61.177	711.0
50.0	63.990	562.6
55.0	67.365	675.0
60.0	70.687	664.4
65.0	74.307	724.0
68.5	76.434	607.7

LOCAT	CION:	ALTE	RATI	ON 75	1 B
		275	9w 4	DDA	
HOLE	NUMBE	R: U	U 75	1B	
DATE	MEASU	JRED:	7/2	2/76	

DEPTH	TEMPERATURE	GRADIENT
METERS	DEG C	DEG C/KM
5.0	14.926	.0
10.0	18.065	627.8
15.0	21.878	762.6
20.0	25.194	663.2
25.0	28.354	632.0
30.0	31.719	673.0
35.0	35.043	664.8
40.0	37.561	503.6
45.0	40.288	545.4
50.0	42.688	480.0
55.0	44.676	397.6
60.0	47.008	466.4
65.0	49.088	416.0

	LOCATION: BOYLES 12RKGRA 26S 9W 27BBB HOLE NUMBER: UU 75 12 DATE MEASURED: 6/11/76	
DEPTH METERS	TEMPERATURE DEG C	GRADIENT DEG C/KM
5.0 10.0 15.0 20.0 25.0 30.0	16.072 19.622 21.794 24.981 28.579 29.861 30.922	.0 710.0 434.4 637.4 719.6 256.4 235.8

28.579 29.861 30.922 25.0 30.0 34.5

LOCATION: BOYLES 13 RKGRA 26S 9W 20 AC HOLE NUMBER: UU 75 13 DATE MEASURED: 11/8/75

DEPTH	TEMPERATURE	GRADIENT
METERS	DEG C	DEG C/KM
10.0	19.715	.0
20.0	25.496	578.1
30.0	30.489	499.3
40.0	34.301	381.2
43.0	36.742	813.7

		1
	LOCATION: BEARSKIN RKGRA	,
	275 ON DAD	
	HOLE NOMBER: 00 /3	
	DATE MEASURED: 8/20/76	
DEPTH	TEMPERATURE	GRADIENT
METERS	DEG C	DEG C/KM
10.0	8.088	.0
15.0	9.455	273.4
20.0	9.907	90.4
25.0	9.683	-44.8
30.0	9.074	-121.8
35.0	9.048	-5.2
40.0	8.834	-42.8
45.0	8.867	6.6
50.0	8.942	15.0
55.0	8 .99 8	11.2
60.0	9.077	15.8
65.0	9.084	1.4
70.0	9.217	26.6
75.0	9.331	22.8
80.0	9.351	4.0
85.0	9.462	22.2
90.0	9.496	6.8
95.0	9.629	26.6
100.0	9.797	33.6
110.0	10.137	34.0
115.0	10.176	7,8
120.0	10.113	-12.6
125.0	10.296	36.6
130.0	10.249	-9.4
135.0	10.459	42.0
	10.584	25.0
145.0	10.391	-38.6
150.0	10.459	13.6
155.0	10.823	72.8
156.0	10 999	176 0

LOCATION:	ALTERATION 7 27S 9W 54CAB	6 1A RKGRA
HOLE NUMBE	ER: UU 76 LA	

DEPTH	TEMPERATURE	GRADIENT
METERS	DEG C	DEG C/KM
5.0	30.028	.0
10.0	41.190	2232.8
15.0	57.022	3166.4
20.0	63.642	1324.0
25.0	69.025	1076.6
30.0	77.158	1626.6
35.0	84.082	1384.8
40.0	98.606	953.2
45.0	93.914	1013.2
50.0	97.362	689.6
55.0	101.100	747.6
60.0	105.584	896.8
63 .5	107.885	657.4

LOCATION: RKGRA TG-0

26S 9W 16BDC HOLE NUMBER: UU 76 160 DATE MEASURED: 8/30/76

DEPTH	TEMPERATURE	GRADIENT
METERS	DEG C	DEG C/KM
10.0	14.029	•0
15.0	15.124	219.0
20.0	15.405	56.2
25.0	15.757	70.4
30.0	16.164	81.4
35.0	16.501	67.4
40.0	16.839	67.6
45.0	17.234	79.0
50.0	17.502	53.6
55.0	17.674	34.4
60.0	18.012	67.6
65.0	18.210	39.6
70.0	18.432	44.4
75.0	18.750	63.6
77.5	18.967	86.8

١

.

LOCATI	ON:	BKGR	A TO	-1	
		265	9w	15	CBA
HOLE	NUMB	ER:	VU7E	5 TC	\$1
OATE	MEAS	URED	: 10	0/10	3176

DEPTH	TEMPERATURE	GRADIENT
METERS	DEG C	DEG C/KM
10.0	16.428	• 0
15.D	18.095	333.4
20.0	19.382	257.4
25.0	20.549	233.4
30.0	21.506	191.4
35.0	22.476	194.0
40.0	23.231	151.0
45.0	23.893	132.4
50.0	24.521	125.6
55.0	25.071	110.0
60.0	25.5B2	102.2

LOCAT	ION: BKGRA TG-2	
	265 9W 5CDB	
HOLE	NUMBER: UN76 TG2	
DATE	MEASURED: 11/6/76	
DEPTH	TEMPERATURE	GRADIENT
METERS	DEG C	DEG C/KM
5.0	15.877	• 0
10.0	14.619	-251.6
15.0	15.169	110.0
20.0	15.567	7 9. 6
25.0	15.902	67.0
30.0	16.259	71.4
35.0	16.679	84.0
40.0	17.066	77.4
45.0	17.389	64.6
50.0	17.690	60.2
55.0	17.955	53.0
60.0	18.195	48.0
65.0	18.426	46.2
67.5	18,580	61.6

. 4

LOCATI	ION: BKGRA TG-3	
	265 9W 19 DBC	
HOLE	NUMBER: U476 TG3	
DATE	MEASURED: 11/6/76	
оертн	TENPERATURE	GRADIENT
meters	deg c	DEG C/KM
5.0	17.946	• 0
20.0	18.391	89.0
15.0	24.383	398.4
20.0	22.441	411.6
25.0	24.223	356.4
30.0	26.143	384.0
35.0	28.078	387.0
40.0	29.447	273.8
45.0	30.770	264.6
50.0	32.031	252.2
55.0	32.994	192.6
60.D	33.887	178.6
65.0	34.691	160.8
70.0	35.305	123.0
15.0	35.601	59. 0
80.0	35.883	56.4
85.0	36.121	47.6
90.0	36.243	24.4
95.0	36.544	60.2
100.0	36.405	-27.8

LOCATIO	N: BKGRA T6-5 265: 9W 14 DAA	
HOLE N DATE	umber: UU76 TG5 Weasured: 10/10/76	
DEPTH METERS	TEMPERATURE DEG C	GRADIENT DEG C/KM
10.0 15.0 20.0 25.0 30.0 35.0 40.0 45.0	13.204 13.577 13.906 14.156 14.381 14.593 14.781 15.006 15.195	.0 74.6 65.8 50.0 45.0 42.4 37.6 45.0 35.8

LOCAT	ION: BKERA TG-6	
	265 9W 7CAA	
HOLE	NUMBER: 11176 TEC	
DATE	MEASURED: 11/6/76	
DEPTH	TEMPERATURE	GRADIENT
METERS	DEG C	
		DEG CZKM
5.0	14.273	. 0
19.0	14.275	• 0
15.0	14.847	9 9 9
20.0	15.436	117 e
25.0	16.913	205 4
30.0	17.828	293.4
35.0	18,108	185.0
40.0	19 774	56.0
45.0	10.227	23.2
50.0	19 402	46.8
55.0		46.8
60.0	10 • / 4 1.	5.8
65.0		22.8
70.0		33.8
75.0	19.149	29.0
80.0	19.255	21.2
85.0	19.348	18.6
90.0	19.489	28.2
95.0	19.712	44.6
97.5	19.952	48.0
11.0	19.983	12.4

LOCATI	ON: BKGRA SALT COVE	
	265 9W 25 DCA	
HOLE	NUBBER: UN 76	
DATE	MEASURED: 3/24/77	
DEPTH	TEMPERATURE	GRADIENT
METERS	deg c	DEG C/KM
10.0	10.908	• 0
15.0	10.989	16.2
20.0	11.188	39.8
25.0	11.492	60.8
30.0	11.742	50.0
35.0	11.596	-29.2
40.0	12.156	112.0
45.0	12.335	35.8
50.0	12.504	33.8
55.0	12.658	30.B
60.0	12.807	29.8
65.0	12.942	27.0
70.0	13.071	25.8
75.0	13.196	25.0
80.0	13.337	28.2
85.0	13.476	27.8
90.0	13.617	28.2
95.0	13.761	28.8
100.0	13.908	29.4
05.0	14、连方之	28.8
110.0	14.201	29.8
\$15.0	14.352	30.2
120.0	14.505	30.6
125.0	14.653	29.6
130.0	14.836	36.6
135.0	14.993	31.4
140.0	15.145	30.4
145.0	15.298	30.6
150.0	15.404	21.2

LOCATION: RANCH CANYON PPC 27S/9W-35 CAD HOLE NUMBER: EV 4113 DATE MEASURED: 8/12/75

DEPTH	TEMPERATURE	GRADIENT
METERS	DEG C	DEG C/KM
10.0	8.650 9.640	.0 99.0
30.0	9.770	13.0
36.0	9.890	20.0

LOCATION: RANCH CANYON PPC 27S/9W-35 DB HOLE NUMBER: EV 4115 DATE MEASURED: 8/12/75

TEMPERATURE DEG C	GRADIENT DEG C/KM
10.920	.0
11.240	132.0
11.700	46.0
11.820	12.0
11.910	9.0
11.980	7.0
12.140	16.0
	TEMPERATURE DEG C 10.920 11.240 11.700 11.820 11.910 11.980 12.140

LOCATION: MINERAL MTS - RADIO RD PPC 26S/8W-30 CDA HOLE NUMBER: Crater Knoll #2 DATE MEASURED: 8/15/75

DEPTH METERS	TEMPERATURE DEG C	GRADIENT DEG C/KM
10.0	8.010	.0
20.0	8.660	65.0
30.0	8.690	4.0
40.0	8.750	6.0
50.0	8.850	10.0
60.0	8.870	2.0
70.0	8.890	2.0
80.0	8.990	10.0
90.0	9.080	9.0

LOCATION: MINERAL MTS - PPC 27S/8W-6 AA HOLE NUMBER: Crater Knoll #3 DATE MEASURED: 8/15/75

EMPERATURE DEG C	GRADIENT DEG C/KM
9.230	.0
9.700	47.0
10.210	51.0
10.430	22.0
10.610	18.0
10.700	10.0
	EMPERATURE DEG C 9.230 9.700 10.210 10.430 10.610 10.700

LOCATION: NEGRO MAG WASH PPC 27S/9W-1 HOLE NUMBER: 21

TEMPERATURE DEG C	GRADIENT DEG C/KM
13.000	.0
15.600	260.0
17.300	170.0
17.550	125.0
	TEMPERATURE DEG C 13.000 15.600 17.300 17.550

LUCATION:	WATER WELL 42	
Caring to Aventity	ED. PUTINIES	
	UNET: 7/05/76	
DEPTE.	TEMPERATURE	GRADIEDT
IL TELS	DEG C	DEG CZKM
10.0	14.500	• 0
20.0	17.700	32 0.0
30.0	20.600	290.0
35.0	21.900	260.0
40.0	23.000	220.0
45.0	23.950	190.0
50.0	24.800	170.0
55.0	25.600	200.0
60.0	26.700	180.0
65.0	27.800	180.0
70.0	28.400	160.0
75.0	29.100	140.0
80.0	29.800	140.0
85.0	30.600	160.0
90.0	31.200	120.0
95.0	31.800	120.0
100.0	32.500	140.0
105.0	33.000	100.0
110.0	33.600	120.0
115.0	33,800	40.0

••••

-

wark with the second second
LOCATION: PHILLIPS WATER WELL 43 265/10W-25A HOLE NUMPER: PHILLIPS JATE TEASUPER: 6/30/76

DEPTH	TEAPERATURE	GRADIENT
AL FERS	0E6 C	DEG CZKM
5,0	14.200	• 0
15.0	17.100	290.0
20.8	18.400	560.0
25.0	19.500	220.0
30.0	21.000	300.0
35.0	22.400	280.0
40.0	23.600	240.0
45.0	24.600	200.0
50.0	25.600	240.0
55.0	27.200	280.0
69.0	27.900	140.0
65.0	28,900	200.0
70.0	29.400	100.0
75.0	30.000	120.0
80.0	30.600	120.0
85.0	30.600	• 0

LOCAT	1011: WATER WELL 44 265/941-360	
HOLE UN1E	NUMPER: PHILLIPS NEASUREY: 7/03/76	
ULPTH	TENPERATURE	GRADIENT
REFERS	DEG C	DEG CIKM
5.0	17.900	• 0
10.0	17.200	-140.0
15.0	19.100	380.0
20.0	20.700	320.0
25.0	21,500	160.0
30.0	24.200	540.0
35.0	26.200	400.0
40.0	28.600	480.0
45.0	29.300	140.0
50.0	31.800	500.0
55.0	34.900	620.0
		- - +

LOCAT	IOP: WATER WELL 45	
401 E 1	2/3/9W-1/4	
0 ATT	(L/X /X / X / X / X / X / X / X / X / X /	
DEPTH	TELFERATURE	GRADIENT
METERS	DEG C	DEG CZKM
5.0	12.900	• 0
10.0	15,300	480.0
15.0	17.500	440.0
20.0	19.1 00	320.0
25.0	20.900	360.0
30.0	22.1 00	240.0
35.0	23.7 00	320.0
40.0	25.200	300.0
45.0	26.7 00	300.0
50.0	28.000	260.0
55.0	29.600	320.0
60.0	31.200	320.0
65.0	32.4 (0)	240.0
70.0	33.7 00	260.0
75.0	35.600	260.0
BO.0	36.4 00	280.0
85.9	37.900	300.0
90.0	39.2 00	260.0
95.0	40.2 00	200.0
100.0	41.600	280. 0
105.0	43.100	300.0
110.0	44. 400	560.0
115.0	45.600	240.0
120.0	47.000	280.0
	48.600	320.0
130.0	49.700	220.0
	51.000	260.0
145 0	32.000 53.400	260.0
150 0	55.4 00	220.0
155.0	374°•2009 56 000	280.0
160.0		240.0
165.0	59 500	560.0
170.0	60 - 6 00	140.0
175.0	61-200	CAU . U
180.0	61.800	120 0
185.0	61,900	20 0
	······································	£∪•U

LOCA	IION: RHS KGRA	
	275/10 <i>1</i> -23 CA	
HOLE	NUMBER: 5	
DATE	MEASURED: 9/03/75	
DEPTH	TEMPERATURE	GRADIENT
METERS	DEG C	DEG C/KM
10.0	14.480	•0
20.0	17,450	297.0
30.0	20.130	268.0
40.0	22.580	245.0
50.0	25,000	242.0
60.0	26,930	193.0
70.0	27 .6 50	72.0
80.0	28.390	74.0
90.0	28.960	57.0
100.0	29.590	63.0
110.0	30.100	51.0
120.0	30,550	45.0
130.0	31.100	55.0
140.0	31.520	42.0
150.0	32.180	66.0
151.5	32.210	20.0

LUCA	TION: RHS KGRA	
	275/9W-16 BB	
HULE	NUMPER: 7	
υλτε	MEASURED: 8/08/75	
DEPTH	TEMPERATURE	GRADIENT
METERS	DEG C	DEG C/KM
10.0	16.600	• 0
20.0	23.300	670.0
30.0	28.200	490.0
49.0	32,900	470.0
50.0	37.300	440.0
60.0	41.550	425.0
70.0	45.730	418.0
d0.0	49.800	407.0
90.0	5 3.9 00	410.0
100.0	57.780	388.0
110.0	61,450	367.0
120.0	65.300	385.0
130.0	68,840	354.0
140.0	72.300	346.0
145.0	74.000	340.0

LOCAT	10N: RHS KGRA 275/9%-10 AD	
HOLE. DATE	NUMPER: 8 PEASURED: 8/11/75	
DEPTH METERS	TEMPERATURE DEG C	GRADIENT DEG C/KM
10.0 20.0 30.0 40.0 50.0 50.0 50.0 70.0 80.0 90.0	24.620 37.470 49.320 60.170 69.580 78.120 84.080 89.650 95.400	0 1285.0 1185.0 1085.0 941.0 854.0 596.0 557.0 575.0

'n

LOCA	TION: RHS KGRA	
	27\$/9W-21 DD	
HOLE	NUMPER: 9	
DATE	MEASURED: 9/05/75	
OEDIH	TEMDEDATURE	GRADIENT
METERS		DEG CZKM
	520 0	
10.0	20.950	• 0
20.0	32.810	1186.0
23.0	34.000	396.7

~

LULA	TION: RHS KGRA	
	275/9W-15 ABD	
HOLE	NUMPER: TO	
DATE	MEASURED: 9/02/75	
DEPTH	TEMPERATURE	GRADIENT
METERS	DEG C	DEG C/KM
10.0	15.370	• 0
20.0	19.880	451.0
30.0	23.800	392.0
40.0	27.560	376.0
50.0	32,580	502.0
60.0	37.410	483.0
64.3	39.100	393.0

LOCA	TION: RHS KGRA	
	275/10W-10 DDD	
HOLE	NUMPER: 12	
DATE	MEASURED: 8/11/75	
DEPTH	TEMPERATURE	GRADIENT
METERS	DEG C	DEG C/KM
10.0	14.860	• 0
20.0	18.640	378.0
30.0	21.380	274.0
40.0	24.190	281.0
56.0	26.270	208.0
60.0	27.470	120.0
70.0	28,510	104.0
80.0	29.240	73.0
90.0	29,810	57.0
100.0	30.370	56.0
110.0	30.960	59.0
120.0	31.530	57.0
130.0	32.150	62.0
140.0	32 .73 0	58.0
150.0	33.180	45.0
160.0	33.770	59.0
170.0	34.320	55.0
180.0	34.840	52.0
190.0	35.320	48.0
290.0	35.860	54.0
203.0	35 .98 0	40.0

LOCA	TION: RHS KGRA	
	275/9W-7 CC	
HOLE	NUMBER: 14	
ΟΑΤΕ	MEASURED: NO DATE	
осрти	TEMPERATURE	GRADIENT
METERS	DEG C	DEG C/KM
10.0	15.250	• 0
20.0	17.900	265.0
30.0	20.500	260.0
40.0	23.100	260.0
50.0	25,100	200.0
60.0	26,900	180.0
7(1,1)	28.700	180.0
80.6	30,500	180.0
90.0	31,900	140.0
100.0	33.200	130.0
110.0	34.300	110.0
120.0	35,250	95.0
130.0	36.100	85.0
140.0	36.900	80.0
150.0	37.600	70.0
160.0	38.300	70.0
170.0	39.050	75.0
180.0	39 .85 0	80.0
190.0	40.650	80.0
195.0	41.000	70.0

275/9W-7D DD	
HOLE NUMBER: 15	
DATE MEASURED: NO DATE	
DEPTH TEMPERATURE	GRADIENT
METERS DEG C	DEG C/KM
10.0 15.040	• 0
20.0 18.100	306.0
30.0 20 .3 00	220.0
40.0 22.200	190.0
50.0 24.400	220.0
60.0 26.300	190.0
70.0 28.000	170.0
80.0 29.500	150.0
90.0 31.200	170.0
100.0 32.800	160.0
110.0 34.700	190.0
120.0 36.300	160.0
130.0 37.700	140.0
140.0 38.900	120.0
150.0 39.800	90.0
40.700	90.0
41.6 00	90.0
175.0 41. 9 00	60.0

LOCA	TION: RHS KGRA 275/9 W-4 AD	
HOLE	NUMBER: 17	
DATE	MEASURED: NO DATE	
DEPTH	TENPERATURE	GRADIENT
METERS	DEG C	DEG C/KM
10.0	17.600	.0
20.0	23.600	600.0
30.0	29.700	610.0
40.0	34.700	500.0
50.0	40.000	530.0
60.0	44.100	410.0
63.0	4 5 .000	300.0

•

LOCATION: RHS KGRA 27S/R9W-2 CAA HOLE NUMBER: 20 DATE MEASURED: 8/13/75

DEPTH METERS	TEMPERATURE DEG C	GRADIENT DEG C/KM
10 0	12 410	0
20.0	14.690	228.0
30.0	16.570	188.0
40.0	18.310	174.0
50.0	20.300	199.0
60.0	21.160	86.0
70.0	22.400	124.0
80.0	23.440	104.0
90.0	24.290	85.0
100.0	24.990	70.0
105.0	25.350	72.0
105.5		

LOCA	TION: RHS KGRA	
	265/9W-32 AA	
HOLE	NUMPER: 25	
DATE	MEASURED: 9/05/75	
DEPTH	TEMPERATURE	GRADIENT
METERS	DEG C	DEG C/KM
10.0	15.590	• 0
20.0	21.160	557.0
30.0	25.030	387.0
40.0	28.080	305.0
50.0	30,960	288.0
60.0	33,590	263.0
70.0	36,200	261.0
80.0	38,550	235.0
90.0	40.510	196.0
100.0	42.600	209.0
110.0	44.790	219.0
120.0	47.090	230.0
130.0	49.330	224.0
140.0	51.260	193.0
144.3	51.360	23.3



ч r

•

4

<u>.</u>

Figure 6

.

•



• •

•

۰ ،

. L

¢

LOCATION ALTERATION 75 1A 275 9W 3CBB HOLE NUMBER UU 751A DATE MEASURED 7/22/76

.

٢



۱ I

-

,

(

Figure 8

LOCATION ALTERATION 75 1B 27S 9W 4DDA HOLE NUMBER UU 75 1B DATE MEASURED 7/22/76

4

•



; I

•

.

Figure 9



ł

ť

1

•

Figure 10

-



* t

۰ **۱**

Figure 11

٠





•

4

+



1

.

Figure 14

1

*



4

*

.

٠



.

*



۰.

.

•



٠

Figure 18

۴

.

LOCATION

RKGRA TG 3

C 4



.

¥

4

¢

.



۰

LOCATION RKGRA TG-6



.

•

ĸ

.



TECHNICAL REPORT: VOLUME 77-3

•

Thermal Gradients and Heat Flow at Roosevelt Hot Springs

Energy Research and Development Administration

Contract EY-76-S-07-1601

W. R. Sill J. Bodell

TABLE OF CONTENTS

Abstract

1.0	Introduction
2.0	Thermal Gradients at Roosevelt Hot Springs
3.0	Heat Flow at Roosevelt Hot Springs 6
4.0	Conclusions
	References
	List of Figures
	Appendix A

Abstract

Thermal gradient and electrical resistivity surveys both outline anomalous zones along the system of faults that control the near surface flow at Roosevelt Hot Springs. The source of both anomalies is the circulation of thermal water, which gives rise to the high heat flow and the lowered resistivity due to the hot brine and the associated hydrothermal alteration.

The nature of the temperature profiles and the asymmetry of the thermal gradient profile across the system are suggestive of a leakage and mixing of thermal water with the regional groundwater flow to the west. This interpretation is consistent with the resisitivty data in which conductive regions to the west of the fault system have been interpreted in terms of brine-saturated sediments.

The maximum conductive heat flow over the anomaly is 40 HFT $(1.7W/m^2)$ and the total conductive heat loss is estimated at 2 MW. Heat flow in the Mineral Mountains, to the east of the near-surface thermal anomaly, is low or near average for the Basin and Range. Recharge may be taking place in this region.

1.0 Introduction

Thermal gradient data from 39 drill holes in the Roosevelt Hot Springs KGRA area are presented in this report. Fifteen of these holes were drilled under subcontract to the University of Utah, permission to log another ten holes was granted by Phillips Petroleum Company and the remaining fourteen holes were provided by other sources. The locations of most of the holes are shown in Figures 1 through 3, along with the locations of test and production holes. These figures also show the contoured average thermal gradient in three depth intervals; shallow (30-60m), intermediate (60-100m) and deep (>100m).

Figure 4 displays a plan view of the interpreted faults in the area. Comparison of Figures 1 and 4 shows that the region of highest thermal gradients is aligned along the Dome Fault and Fault 1. To the south the high thermal gradients are terminated by several east-west trending faults. To the north there is a bending of the contours resulting in a ridge aligned along fault 5, which trends to the north west.

In Figures 1 and 2 there are isolated highs in the north and south that are probably the result of the sparseness of data in the central region. Considerations of the probable thermal gradient in the early steam well (drilled by Dr. E. N. Davie), based on the depth of blowout, and the near surface temperatures in sulfur pits in the bottom of Negro Mag Wash (North of 54-3) would indicate that the 900°C/km should run further to the west in the southern portion and is probably continuous with the high in the north.

Comparison of Figure 1 with the contoured apparent resistivity (Figure 5) shows that the resistivity and thermal gradient patterns are highly correlated. Both exhibit contours aligned along the Dome fault and a bending to the northwest along Fault 5. The obvious cause of the correlation

is the hot water circulation along the faults which gives rise to both high thermal gradients and low resistivities due to the hot brine and the associated hydrothermal alteration.

With increasing depth (Figures 2 and 3) the thermal gradients decrease and the alignment along the faults is less clear. The smearing of the pattern is partly due to the lack of data at greater depths. The acquisition of deep thermal gradient data from small drill holes in regions of very high thermal gradients is hindered by fear of blowouts, among other things.
2.0 Thermal Gradients at Roosevelt Hot Springs

Figures 6 to 20 show the temperature vs depth curves for the holes drilled by the University of Utah. As can be seen in these figures, the thermal gradient in holes drilled in alluvium often decreases with depth, with the depth intervals used in Figures 1 to 3 being somewhat characteristic of the several regions of changing gradient. For example, hole UUTG6 (Figure 20) shows an abrupt change at 30m and hole UUTG3 (Figure 18) displays a more gradual transition with suggested breaks at 35m and 70m. Such changes in the thermal gradients can be caused by changes in thermal conductivity due to changes in the porosity, saturation and lithology among other things.

Gravity measurements over a wash in the alluvium (Crebs and Cook, 1976) indicate a porosity of about 25% in the near surface (25-50m). Some decrease in porosity with depth is to be expected due to the increase in load. A change in the porosity of saturated granite alluvium from 25% to 10% would give rise to a change in thermal conductivity (and gradient) of about 25%. The changes in thermal gradient caused by such variations in porosity are then rather modest.

On the other hand, changes in saturation, from dry to completely saturated, would give rise to changes in thermal conductivity by a factor of 2.0 to 2.5 for porosities in the range from 20 to 30%.

Changes in the thermal conductivity due to lithology changes depends on the thermal conductivity of the components. For example, changing the thermal conductivity of the solid components by a factor of 2 results in a 1.7 change in conductivity at a porosity of 25%. Changes in lithology from a granite alluvium to a quartz rich sand are possible in this area. Measurements made on sands from the Roosevelt KGRA give solid component conductivities in the range from 10 to 11 HCU and samples of granite alluvium give values in the range from 6 to 7 HCU. Therefore, such changes in lithology can be expected to give rise to rather substantial changes in gradient.

Considering the thermal gradients in hole UUTG6 (Figure 21) we see that the average gradient in the 20-30m interval is about 200° C/km and below this depth it averages about 30° C/km, a factor of about 7 change is slope. Thermal conductivity measurements on samples from this hole average about 4 HCU, at a saturated bulk density of 2.2g/cm³, with no consistent changes above and below the break in the slope. The water table in a nearby well (2.4km) at about the same elevation is 26m (Mower and Cordova, 1974). This is near the break in the thermal gradient. However, the change in thermal conductivity due to undersaturation would only be a factor of 2 to 2.5 which is well below the observed value.

One possible explanation of the strong change in gradient is a leakage of thermal water into the groundwater flow to the west. Some leakage of thermal water is indicated by the chemical analysis of the seep west of Salt Cove, which has a cool temperature (25°C) but a Na-K-Ca temperature of 241°C (Parry et. al., 1976). For a uniform mixing of thermal water into the groundwater in a region of constant thermal conductivity, the thermal gradient should decrease smoothly with depth in the mixing zone. The two gradient regions in UUTG6 may result from a combination of effects due to the presence of the water table and mixing. On the other hand, the thermal gradient in hole UUTG3 (3km to the south) shows a more gradual change, with no sharp break at the water table (50m). The overall change in slope between the top and bottom of this hole is about a factor of 8, which seems too large to be explained by the effects of saturation alone.

In holes UU751A and UU751B, just to the west of the dome fault, the water tables were located at about 35m and 40m respectively, which are also the locations of the alluvium altered bedrock interface. In both cases the thermal gradients do not show an abrupt change at the water table.

However, there is gradual increase in thermal gradient above these depths (20% to 40%), perhaps due to gradual changes in the saturation.

Figure 21 shows a series of temperature profiles on a west-east line across the southern part of the system (the letter designation runs from West-A to East-I). The thermal gradients and the 10m depth temperatures increase as the Dome Fault is approached from the west (A to G) and the two eastern holes (H & I) show decreasing temperatures and gradients.

The five westernmost holes (AA to D) show a decreasing gradient with depth, as did the western holes to the north(UUTG6 and UUTG3) discussed previously. The two westernmost holes 5(AA) and 12(A) have a thermal gradient in the deeper part near 50°C/km, which is near normal for a thermal gradient in the alluvium. The water table is about 40m in this region (Mower and Cordova, 1974) and both curves show changes in slope (15 to 30%) at this depth, which could be due to changes in saturation. There is a change in slope to a near constant slope region at a depth of about 60m. The change in average gradient above and below this depth is a factor of 1.5 to 3. The lithologic log on a nearby water well notes a change in lithology at this point, from sands containing numerous "igneous" fragments (up to 30%) to sands free of such material. Considering the average abundance of such material, it would be difficult to account for the changes in slope by the change in lithology. Once again a possible explanation for the change in slope could be leakage of thermal waters to the west and mixing with the groundwater. With respect to this, it is interesting to note that the thermal gradients at depth in the westernmost holes are near normal and that the gradient in the easternmost hole is constant with depth although slightly above normal. More conclusive evidence for leakage mixing of thermal waters would be the presence of gradient reversals which have not been observed to date.

3.0 Heat Flow at Roosevelt Hot Springs

Thermal conductivity measurements on a limited number of alluvial samples, indicates an average value of 4 HCU (1 HCU - mcal/cm S°C - 0.418 W/m°k). Maximum conductive heat fluxes are then in the neighborhood of 40 HFU (1 HFU = μ cal/cm²S = 41.8 mW/m²). The total integrated conductive heat loss over the anomaly (6.5 km in length) is about 10⁷cal/S or 2MW.

Figure 22 is a west to east thermal gradient profile for two depth intervals, 30-60m and 60-100m. Based on a *conductive* heat flow model, these profiles indicate an equivalent line source at 1.0 to 1.5km depth. Also shown on the figure, as a dashed line, is the theoretical thermal gradient profile for a line source, scaled to the 30-60m data. From this it is easy to see that the observed curve is asymmetrical, with smaller gradients in the east and larger to the west. This asymmetry is also observed in the deeper (60-100m) gradients. The observed asymmetry is compatable with the leakage of thermal water to the west, as discussed in the previous section, but source configuration in a conductive model could also produce such asymmetry.

Several core holes were also drilled in the granite of the Mineral Range so that samples could be measured for thermal conductivity and heat flow values calculated. Figure 13 shows the temperature profile in one such hole (UU76SC) located in Salt Cove on the west side of the Mineral Range, about 3 km east of the center of the thermal gradient-resistivity anomaly. The thermal gradient is quite uniform at an average value of 29°C/km below a depth of 50m. The average thermal conductivity in this region is 6.6 HCU (16 samples) giving a heat flow of 1.92 HFU.

Another hole (UU76BS) was drilled in the central part of the Mineral Range just to the north of Bearskin Mountain, the temperature profile from the last log (Figure 14) still shows some drilling disturbances, but the smoothed thermal gradient in the 80 to 150m interval is 17° C/km. The thermal gradient in a Phillips Petroleum Company hole, 1.5 km to the north (Figure 1) is similar (16° C/km) indicating that this is maybe representative of the area. The average thermal conductivity in this hole in the above depth interval is 7.65 HCU (11 samples) giving a heat flow of 1.28 HFU.

Two kilometers to the east of this hole, the hole at Ryans Ranch (UU75RR, Figure 11) has thermal gradient of 19.9° C/km (50 to 80 m) and the average thermal conductivity of several samples is 7.1 HCU, resulting in a heat flux of 1.41 HFU.

Roy et al. (1968) report a heat flow of 2.22 HFU for a location on the west side of Milford valley, just about due west of Roosevelt Hot Springs. None of the above calculated heat flow values are large for the Basin and Range, in fact the measurements in the central part of the range seem somewhat low. However, none of the measurements have been corrected for topographic effects, which should be largest for the locations north of Bearskin and at Ryans Ranch.

If the Mineral Mountains and the area to the east are regions of significant recharge, then the downward movements of cool water may contribute to the low thermal gradient and heat flow.

4.0 Conclusions

Thermal gradients and electrical resistivity data at Roosevelt Hot Springs both outline the same anomalous region along the system of faults which control the near surface circulation. Depending on the circumstances, these techniques may provide complementary or redundant information.

The character of the thermal gradients to the west of the fault system suggest that thermal waters are mixing with the ground water flow to the west. If so, this should be reflected in the water chemistry. Parry et al. (1976) show several anomalous Na-Ca-K temperatures to the northwest of Roosevelt Hot Springs but no data was available from wells in the immediate vicinity of the thermal gradient holes.

Heat flow values in the alluvium reach a maximum of about 40 HFU, and the estimated total conductive heat loss from the shallow part of the system is about 2MW. Heat flow values and thermal gradients in the Mineral Range are not high for the Basin and Range, and in fact several of the values seem low.

REFERENCES

- Crebs, T. J. and K. L. Cook, 1976; Gravity and ground magnetic surveys of the central Mineral Mountains, Utah, Volume 6, Grant GI-43741, National Science Foundation.
- Mower, R. W. and R.M. Cordova, 1974; Water resources of the Milford area, Utah, with emphasis on groundwater, State of Utah, Department of Natural Resources Technical Pub. No. 43.
- Parry, W. T., N. L. Benson and C. D. Miller, 1976; Geochemistry and hydrothermal alteration at selected Utah hot springs, volume 3, Grant GI-43741 National Science Foundation.
- Roy, R. F., E. R. Decker, D. D. Blackwell and F. Birch, 1968; Heat flow in the United States, J. Geophys. Res., 73,5207-5221.

LIST OF FIGURES

Thermal gradient Contour map, depth interval 30-60 meters, also Fig. 1 shown are the locations of test and production wells. Thermal gradient contour map, depth interval 60-100 meters. Fig. 2 Thermal gradient contour map, depth greater than 100 meters. Fig. 3 Fig. 4 Interpreted Fracture map. Fig. 5 Apparent resistivity contour map, first separation, 300 meter dipole-dipole. Fig. 6 Temperature profile hole UU75-12 11 п H Fig. 7 0075-13 " 11 u Fig. 8 UU75-1A 11 11 Ħ Fig. 9 UU75-1B н Fig. 10 11 11 UU75-BCC Fig.]] H 11 н UU75-RR 11 H п Fig. 12 UU76-1A н 11 H Fig. 13 UU76-SC н Fig. 14 11 н UU76-BS 11 н Fig. 15 11 UU76-TG0 Fig. 16 H 11 н UU76-TG1 н It 11 Fig. 17 UU76-TG2 11 Fig. 18 н 11 UU76-TG3 11 IF 11 Fig. 19 UU76-TG5 п 11 11 UU76-TG6 Fig. 20

Fig. 21 Temperature Profiles for a series of holes along an east-west line at approximately 2200N.

Fig. 22 Thermal gradients at two depth intervals (30-60m and 60-100m) along an east-west line at approximately 2200N. APPENDIX A

Temperature Logs

.

LOCATION: RYANS RANCH LOCATION: RYANS RANCH 275 8W 4DCD HOLE NUMBER: UU 75 DATE MEASURED: 11/6/76

DEPTH	TEMPERATURE	GRADIENT
METERS	DE6 C	DEG C/KM
5.0	9.894	• 0
10.0	8.803	-218.2
15.1	9.716	182.6
24.0	9.8 58	28.4
845.0	9.000	-171.6
30.0	9,007	1.4
さら・ じ	9.170	32.6
40.0	9.280	22.0
45.0	9.370	18.0
50.0	9.391	4.2
55+0	9,492	20.2
60.0	9.569	15.4
er5 • 0	9.681	22.4
73.0	9.781	20.0
75.1	9.886	21.0
行()・()	9.987	20.2
6.5.6	10.116	25.8
90.0	10.292	35.2
25.0	10.381	17.8
100-0	10.492	22.2

•

11 m 11 - 41

n Stan

1. 1. 1. 1.

. ;

LOCATION:	BIG	CEDI	IR COVE
	27S	8W	14 DDC
HOLE NUM	BER:	ר טט	15
DATE MEA	SURED	: 9/	22/75

Depth	TEMPERATURE	GRADIENT
NETERS	dec c	DEG C/KN
5.0	16.769	• 0
10.0	12.978	-758.2
1 1 • 1	13.421	88.6
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	13.543	24.4
2 · • U	13.973	86.0
5-) . ()	14.427	90.8
55.0	14.693	53.2
4.1.1	15.073	76.0
• 5 • A	15.520	90.6
19 J • 10	15.957	86.2
sty 🖕 fa	16.437	96.0
50 • C	16.754	63.4
55 • 0	17.132	75.6
71.11	17.081	69.8
7.5.1	17,905	84.8
). (.	18.380	75.0
1	18.579	59.8
·	18.658	55.4
- > • (-	19.153	59.4
100.0	19.937	155.8

.

13

 ~ 10

LOCATION: ALTERATION 75 IA	
275 9W 3CLB	
HOLE NUMBER: UU 751A	
DATE MEASURED: 7/22/76	
DEPTH TEMPERATURE	GRADIENT
METERS DEG C	DEG C/KM
	-
10.0 26.283	• 0
15.0 34.349	1613.2
80.0 40.036	1137.4
25.0 44.676	928.0
30.0 49.158	896.4
15.0 53.288	826.0
ио. 0 57.622	866.8
45.0 61.177	711.0
50.0 63.990	562.6
55.0 67.365	675.0
60.0 70.687	664.4
65 0 74.307	724.0
ZQ.5 76.434	607.7

¥

. Mj

GRADIENT
DEG C/KM
.0
627.8
762.6
663 .2
632.0
673.0
664 .8
503.6
545.4
480.0
397.6
466.4
416.0

.

٠

•

arganisnig st Ardi Sand P

 $\boldsymbol{y}_{i}, \ \boldsymbol{y}_{i}$

 $p(t_{i})$

LOCATION: BOYLES 12RKGRA

265 9W 27 BBB HOLE NUMBER: UU 75 12 DATE MEASURED: 6/11/76

DEPTH	TEMPERATURE	GRADIENT
METERS	deg c	DEG C/KM
5.0	16.072	• 0
10.0	19.622	710.0
15.0	21.794	434.4
20.0	24.981	637.4
25.0	28.579	719.6
30.0	29.061	255.4
34.5	30.922	235.8

11 18

no desidents to a day of the

#

5 199 5

LOCATI HOLE DATE	ON: BOYLES 13 RKGRA 26S-9W-20 A ^C NUMBER: UU-75-13 MEASURED: 11/8/75	
DEPTH	temperature	G RADIENT
METERS	Deg C	DE G C/ KM
10.0	19.715	0
20.0	25.496	578.1
30.0	30.489	499.3
40.0	34.301	381.2
43.0	36.742	813.7

•

с. ₁. так жили 1. 1. 1. 1. 2. 2.

-

17

LOCATION: BEARSKIN RKGRA 275 8W 8 BAB HOLE NUMBER: UU 75 DATE MEASURED: 8/20/76

DEPTH	TEMPERATURE	GRADIENT
METERS	deg c	DEG C/KM
	8.08A	• 0
	9,455	273.4
	9,907	90.4
20.0	9.683	-44.8
20.0	9.07#	-121.8
	9.048	-5.2
59.0	B 834	-42.8
40.0	B 847	6.6
45.0	0,007	15.0
50.0	8.746	11.2
55.0	8.778	15.0
60.0	9.077	1.4
65.0	y.084	26.6
10-0	y. 41 /	22.8
15.0	7.JJI 2 351	4.0
20.0	9.462	22.2
89.0	9.496	6.8
90.0	9.629	26.6
0.01	9.797	33.6
110.0	10.137	34.0
115.0	10,176	7.8
120.0	10.113	-12.6
125.0	10.296	36.6
130.0	10.249	-9.4
135.0	19.459	42.0
140.0	10.584	25.0
145.0	10.391	-38.6
150.0	10.459	13.6
155.0	10.823	72.8
156.0	10.999	176.0

LOCATION: ALTERATION 76-1A RKGRA 275 9W 34 CAB NELL NUMBER: UU 76-1A DATE MEASURED: 6/ /76

DEPTH	TEMPERATURE	GRADIENT
METERS	deg c	DEG C/KM
5.0	30.026	• 0
10.0	41.194	2232.6
15.0	57.022	3166.4
20.0	63.642	1324.0
25.0	69.025	1076.6
30.0	77.158	1626.6
35.0	84.082	1384.8
40.0	98.843	953.2
45.0	93.914	1013.2
50.0	97.362	689.6
55.0	101.100	747.6
60.0	105.584	896.8
63.5	107.885	657.4

LOCATION:	RKGRA TG-1	
HOLE NUME DATE MEAS	265 9N 15 CBA BER: UU76 TG1 SURED: 10/10/76	
depth	TEMPERATURE	GRADIENT
meters	deg c	DEG C/KN
10.0	16.428	•0
15.0	18.095	333.4
20.0	19.382	257.4
25.0	20.549	233.4
30.0	21.506	191.4
35.0	22.476	194.0
40.0	23.231	151.0
45.0	23.893	132.4
50.0	24.521	125.6
55.0	25.071	110.0
60.0	25.582	102.2

LOCAT	ION: RKGRA TG-O
	265 9W 16 BDC
HOLE	NUMBER: UU76 TOD
UAIC	MERSURED: 8/30/70

VEPIN	I CINPERA IURE	GRADIENI
METERS	deg c	DEG C/KM
10.0	14.029	• 0
15.0	15.124	219.0
20.0	15.405	56.2
25.0	15.757	70.4
30.0	16.164	81.4
35.0	16.501	67.4
40.0	16.839	67.6
45.0	17.234	79.0
50.0	17.502	53.6
55.0	17.674	34.4
60.0	18.012	67.6
65.0	18.210	39.6
70.0	18.432	44.4
75.0	18.750	63.6
77.5	18.967	86.8
	÷	

LOCATION:	RKGRA TG-2	
HOLE MUMB	ER: UU76 TG2	
DATE MEAS	URED: 11/6/76	
DEPTH	TEMPERATURE	GRADIENT
meters	deg c	DEG C/KM
5.0	15.877	.0
10.0	14.619	-251.6
15.0	15.169	110.0
20.0	15.567	7 9.6
25.0	15.902	67.0
30.0	16.259	71.4
35.0	16.679	84.0
40.0	17.968	77.4
45.0	17.389	64.6
50.0	17.690	60.2
55.0	17.955	53.0
60.0	18.195	48.0
65.0	18.426	46.2
67.0	18.580	61.6

LOCATION:	RKGRA TG-3
	265 9W 19 DGC
HOLE NUM	BER: UU76 T63
DATE MEA	sured: 11/6/76

DEPTH	TEMPERATURE	GRADIENT
meters	olg c	DEG C/KM
5.0	17.946	.0
10.1	15.391	89. 0
1 3 • C	20.383	398.4
219 • F	28.441	411.6
ال والي	24.223	356.4
59.0	26.143	384.0
ن ز ر	28.078	387.0
40.4	29.147	273.8
45 1 × 6 1	38.770	264. 6
51) • (1	32.031	252.2
55.1	32.994	192.6
.10 · t.	33.987	178.6
. S. A	34.691	160.8
71).1	35.306	123.0
13.0	35.601	59. 0
8 i 🖕 .	35.883	56.4
13.) · · · ·	36.121	47.6
1993 • C	.36.243	24.4
13 · 1)	36.544	60.2
100.0	36.405	-27. 8

LOCATION	RKGRA TG-5	
	265 9N 14 DAA	
HOLE NUM	BER: UUT6 TG5	
date me	ASURED: 10/15/76	
DEPTH	TEMPERATURE	GRADIENT
METERS	deg c	DEG C/KM
10.0	13.204	.0
15.0	13.577	74.6
20.0	13.906	65.8
25.0	14.156	50.0
30.0	14.381	45.0
35.0	14.593	42.4
40-0	14.781	37.6
45.0	15.006	45. 0
50.0	15.195	35.8

LOCATION:	RKGRA TG-6
	265 9N 7CAA
HOLE NUM	BER: UU76 TG6
DATE MEAS	SURED: 11/6/76

DEPTH	TEMPERATURE	GRADIENT
meters	deg c	DEG C/KM
5.0	14.273	• 0
1 11 . 11	14.275	• 4
14.00	14.847	114.4
11.19	15.436	117.8
c. D • C	16.913	295.4
30.0	17.829	183.0
34.1	18.108	56.0
1	18.924	23.2
14 June 1	18.458	46.8
14. a. a. 24	18.692	46.8
14 N . N	18.721	5.8
1. 1. II	15.835	22.8
12 D + U	19.004	33.8
10. • 1	18.149	29.0
1. 1. 1.	19.256	21.2
	19.348	18.6
24 . 44	19.449	28.2
1. n. e. (19.712	44.6
95.0	19.952	48.0
97.5	19.983	12.4
	•	

LOCATION:	RKGRA SALT COVE	
HOLE NUM	265 9W 25 UCA BER: UU 76	
DATE MEAS	SURED: 6/24/77	
DENTU	TAMOROATIE	GPANTEAT
METERS	DEG C	DEG C/KM
10.0	10.908	•0
12-0	10.689	16.2
	11.188	39.8
<u></u> w k	11.492	60.8
(1) • t	11.742	50.0
5°5 • C	11.596	-29. 2
r . 3 • 5	12.150	112.0
1. ') . 1	12.335	35.8
1943 . .	12.904	33.8
J 3	12.658	30.8
(,1), f.	12.607	29.8
05+C	12.942	27.0
76.0	13.071	25.8
73. • X	13.186	25.0
	13.337	28.2
	13.476	27.8
49.1	13.617	28.2
\$25 • G	13.761	28.8
106.1	13.908	29.4
1 (5+)	14.452	28.8
110.	14.201	29.8
111 · 1	14.352	30.2
1211.0	14.505	30.6
125.0	14.653	29.6
130.9	14.936	36.6
2	14.993	31.4
1:0.	15.145	30.4
145.0	15.298	30.6
150.0	15.404	21.2

LOCATION: RANCH CANYON PPC 27S/9W-35 CAD HOLE NUMBER: EV 4113 DATE MEASURED: 8/12/75

TEMPERATURE DEG C	GRADIENT DEG C/KM	
8.650	.0	
9.640	99.0	
9.770	13.0	
9.890	20.0	
	TEMPERATURE DEG C 9.640 9.770 9.890	

LOCATION: RANCH CANYON PPC 27S/9W-35 DB HOLE NUMBER: EV 4115 DATE MEASURED: 8/12/75

DEPTH METERS	TEMPERATURE DEG C	GRADIENT DEG C/KM
10.0	10.920	.0
20.0	11.240	132.0
30.0	11.700	46.0
40.0	11.820	12.0
50.0	11.910	9.0
60.0	11.980	7.0
70.0	12.140	16.0

LOCATION: MINERAL MTS - RADIO RD PPC 26S/8W-30 CDA HOLE NUMBER: Crater Knoll #2 DATE MEASURED: 8/15/75

DEPTH METERS	TEMPERATURE DEG C	GRADIENT DEG C/KM
10.0	8.010	.0
20.0	8.660	65.0
30.0	8.690	4.0
40.0	8.750	6.0
50.0	8.850	10.0
60.0	8.870	2.0
70.0	8.890	2.0
80.0	8.990	10.0
90.0	9.080	9.0

LOCATION: MINERAL MTS - PPC 27S/8W-6 AA HOLE NUMBER: Crater Knoll #3 DATE MEASURED: 8/15/75

TEMPERATURE DEG C	GRADIENT DEG C/KM	
9.230	.0	
9.700	47.0	
10.210	51.0	
10.430	22.0	
10.610	18.0	
10.700	10.0	
	TEMPERATURE DEG C 9.230 9.700 10.210 10.430 10.610 10.700	

LOCATION: NEGRO MAG WASH PPC 27S/9W-1 HOLE NUMBER: 21

DEPTH	TEMPERATURE	GRADIENT	
METERS	DEG C	DEG C/KM	
10.0	13.000	.0	
20.0	15.600	260.0	
30.0	17.300	170.0	
32.0	17.550	125.0	

LOCATION:	WATER WELL HZ	
1101 - 111000	215/10N-120	
HOLE NUM	SEK: PRILLIFS	
DATE MEAS	UKED: //US/16	
DEPTH	TEMPERATURE	GRADIENT
METERS	DEG C	deg c/km
10.0	14.500	• 0
20.0	17.700	320.0
30.0	20.600	290.0
35.0	21.900	260.0
40.0	23.000	220.0
45.0	23.950	190.0
50.6	24.800	170.0
55.6	25.500	200.0
0.2 · Ú	26.700	180.0
05.0	27.600	180.0
70.0	28.400	160.0
75.0	29.100	140.0
39 • J	29.500	140.0
85.	30.600	160.0
90 . 0	31.200	120.0
90.0	31.300	i 20.0
100.0	32.500	140.0
105.0	33.000	100.0
110.0	33.800	120.0
115.0	23.800	40.0

LOCATION: PHILLIPS WATER WELL #3 265/10W-25A HOLE NUMBER: PHILLIPS DATE MEASURED: 6/30/76

TEMPERATURE	GRADIENT
deg c	deg c/km
£4.800	.0
17.100	290.0
18.400	260.0
19.500	220.0
21.600	300.0
22.400	280.0
23.600	240.0
24.600	200.0
25.800	240.0
27.200	280.0
27.900	140.0
28.900	200.0
29.400	100.0
30.000	120.0
30.600	120.0
30.800	.0
	TEMPERATURE DEG C 14.800 17.100 18.400 19.500 21.600 23.600 24.600 25.800 27.200 27.200 27.900 28.900 29.400 30.600 30.600 30.800

LOCATION	1: WATER WELL #4 285/9W-3. C.	
HOLE NUM	BER: PHILLIPS	
date mea	SURED: 7/03/76	
DEPTH	TEMPERATURE	GRADIENT
METERS	deg c	DEG C/KM
5.0	17.900	• 0
10.0	17.200	-140.0
15.0	19.100	380.0
20.0	20.700	320.0
25.0	21.500	160.0
30.0	24.200	540.0
35.0	26.200	400.0
40.0	28.600	48 0.0
45.0	29.300	140.0
50,0	31.800	500.0
55.0	34.900	620.0

LOCATION:	WARER	WELL #5
	275/	9W-17A
HOLE NUMBE	FR: PH	illips
DATE MEASI	DRED:	7/02/76

5.0 12.900 $.0$ 10.0 15.300 480.0 15.0 17.500 440.0 20.0 19.100 320.0 25.0 20.900 360.0 30.0 22.100 240.0 35.0 23.700 320.0 40.0 25.200 300.0 45.0 26.700 300.0 55.0 29.600 320.0 55.0 29.600 320.0 55.0 29.600 320.0 55.0 29.600 320.0 55.0 29.600 320.0 55.0 29.600 320.0 55.0 29.600 320.0 55.0 29.600 320.0 60.0 31.200 260.0 75.0 35.600 260.0 30.0 39.200 260.0 90.0 39.200 260.0 90.0 43.100 300.0 90.0 45.600 240.0 100.0 41.600 280.0 100.0 45.600 240.0 120.0 47.000 280.0 120.0 47.000 280.0 120.0 47.000 280.0 125.0 48.600 320.0 130.0 49.700 220.0 135.0 51.000 260.0 140.0 52.600 280.0 150.0 54.600 280.0 150.0 56.000 240.0	KM
10.0 15.300 480.0 15.0 17.500 440.0 20.0 19.100 320.0 25.0 20.900 360.0 30.0 22.100 240.0 35.0 23.700 320.0 40.0 25.200 300.0 45.0 26.700 300.0 55.0 29.600 320.0 55.0 29.600 320.0 55.0 29.600 320.0 55.0 29.600 320.0 55.0 29.600 320.0 55.0 29.600 320.0 55.0 29.600 320.0 55.0 29.600 320.0 55.0 29.600 320.0 55.0 35.600 260.0 75.0 35.600 260.0 30.0 39.200 260.0 90.0 39.200 260.0 90.0 39.200 260.0 95.0 40.200 200.0 100.0 45.600 280.0 120.0 45.600 240.0 120.0 49.700 220.0 135.0 51.000 260.0 140.0 52.606 260.0 140.0 52.606 260.0 140.0 52.600 280.0 150.0 54.600 280.0 150.0 54.600 280.0	
15.6 17.500 440.6 20.0 19.100 320.6 25.0 20.900 360.6 30.0 22.100 240.6 35.0 23.700 320.6 40.0 25.200 300.6 45.0 26.700 300.6 50.0 26.700 300.6 50.0 26.700 300.6 50.0 26.700 320.6 50.0 29.600 320.6 50.0 29.600 320.6 50.0 29.600 320.6 50.0 31.200 320.6 50.0 32.400 240.6 70.0 35.600 260.6 40.0 36.400 280.6 35.6 37.900 300.6 90.0 39.200 260.6 95.0 40.200 200.6 105.0 45.600 280.6 120.0 47.000 280.6 120.0 47.000 280.6 120.0 49.700 220.6 135.6 51.000 260.6 145.0 53.406 220.6 145.0 53.406 220.6 145.0 54.600 280.6 145.0 54.600 280.6 145.0 54.600 280.6 145.0 54.600 280.6 145.0 54.600 280.6 145.0 54.600 280.6 145.0 54.600 280.6	
20.019.100 320.0 25.0 20.900 360.0 30.0 22.100 240.0 35.0 23.700 320.0 40.0 25.200 300.0 45.0 26.700 300.0 50.0 26.000 260.0 55.0 29.600 320.0 55.0 29.600 320.0 55.0 29.600 320.0 55.0 29.600 320.0 55.0 29.600 320.0 55.0 29.600 320.0 50.0 31.200 260.0 75.0 35.600 260.0 80.0 36.400 280.0 85.0 37.900 300.0 90.0 39.200 260.0 95.0 40.200 200.0 100.0 41.600 280.0 105.0 45.600 240.0 120.0 47.000 280.0 120.0 49.700 220.0 130.0 49.700 220.0 135.0 51.000 260.0 140.0 52.600 260.0 145.0 53.400 220.0 150.0 56.000 240.0	
25.0 20.900 360.0 30.0 22.100 240.0 35.0 23.700 320.0 40.0 25.200 300.0 40.0 25.200 300.0 40.0 25.200 300.0 40.0 26.700 300.0 50.0 26.700 300.0 55.0 29.600 320.0 55.0 29.600 320.0 55.0 29.600 320.0 55.0 29.600 320.0 50.0 31.200 220.0 50.0 35.600 260.0 75.0 35.600 260.0 85.0 37.900 300.0 90.0 39.200 260.0 90.0 39.200 260.0 90.0 41.600 280.0 100.0 41.600 280.0 100.0 45.600 240.0 120.0 47.000 280.0 120.0 49.700 220.0 130.0 49.700 220.0 135.0 51.000 260.0 140.0 52.600 260.0 145.0 53.406 220.0 150.0 56.000 240.0	I
30.0 22.100 240.0 35.0 23.700 320.0 40.0 25.200 300.0 45.0 26.700 300.0 50.0 28.000 260.0 55.0 29.600 320.0 60.0 31.200 320.0 60.0 31.200 320.0 60.0 31.200 320.0 60.0 31.200 320.0 60.0 31.200 320.0 60.0 31.200 260.0 75.0 35.600 260.0 85.0 37.900 300.0 85.0 37.900 300.0 90.0 39.200 260.0 95.0 40.200 200.0 100.0 41.600 280.0 105.0 45.600 240.0 120.0 47.000 280.0 120.0 47.000 220.0 130.0 49.700 220.0 135.0 51.000 260.0 140.0 52.600 260.0 145.0 53.400 220.0 150.0 56.000 240.0 150.0 56.000 240.0 150.0 56.000 240.0 150.0 56.000 240.0 150.0 56.000 240.0 150.0 56.000 240.0	İ
35.0 23.700 320.0 40.0 25.200 300.0 45.6 26.700 300.0 50.0 28.000 260.0 55.0 29.600 320.0 60.0 31.200 320.0 60.0 31.200 320.0 60.0 31.200 320.0 60.0 31.200 320.0 60.0 31.200 320.0 60.0 31.200 320.0 60.0 32.400 240.0 75.0 35.600 260.0 85.0 37.900 300.0 90.0 39.200 260.0 95.0 40.200 200.0 100.0 41.600 280.0 105.0 45.600 240.0 115.0 45.600 240.0 120.0 47.000 280.0 120.0 49.700 220.0 130.0 49.700 220.0 135.0 51.000 260.0 140.0 52.600 260.0 145.0 53.400 220.0 150.0 56.000 240.0 150.0 56.000 240.0	ł
40.0 25.200 300.0 50.0 26.700 300.0 50.0 28.000 260.0 55.0 29.600 320.0 60.0 31.200 320.0 65.0 32.400 240.0 70.0 33.700 260.0 75.0 35.600 260.0 80.0 36.400 280.0 85.6 37.900 300.0 90.0 39.200 260.0 90.0 41.600 280.0 100.0 41.600 280.0 105.0 45.600 240.0 120.0 47.000 280.0 125.0 48.600 320.0 125.0 51.000 260.0 140.0 52.600 260.0 145.0 53.400 220.0 150.0 54.600 280.0 150.0 54.600 280.0 150.0 54.600 280.0 150.0 54.600 280.0	I
45.6 26.700 300.6 50.0 28.000 260.6 55.0 29.600 320.6 60.0 31.200 320.6 60.0 31.200 320.6 60.0 31.200 320.6 60.0 32.400 240.6 75.0 35.600 260.6 80.0 36.400 280.6 85.6 37.900 300.6 90.0 39.200 260.6 95.0 40.200 200.6 105.0 43.100 300.6 105.0 45.600 240.6 120.0 47.000 280.6 125.0 48.600 320.6 125.0 48.600 320.6 140.0 52.606 260.6 145.0 53.406 220.6 150.0 54.600 280.6 150.0 54.600 280.6	t
50.0 26.000 260.0 55.0 29.600 320.0 50.0 31.200 320.0 50.0 31.200 320.0 50.0 32.400 240.0 70.0 33.700 260.0 75.0 35.600 260.0 80.0 36.400 280.0 85.0 37.900 300.0 90.0 39.200 260.0 90.0 39.200 260.0 90.0 41.600 280.0 105.0 43.100 300.0 110.0 47.000 280.0 120.0 47.000 280.0 125.0 48.600 320.0 130.0 49.700 220.0 135.0 51.000 260.0 140.0 52.600 260.0 145.0 53.400 220.0 150.0 54.600 280.0 150.0 54.600 280.0 150.0 54.600 280.0	ł
55.0 29.600 320.0 60.0 31.200 320.0 $a5.0$ 32.400 249.0 70.0 33.700 260.0 75.0 35.600 260.0 $a0.0$ 36.400 280.0 $a5.0$ 37.900 300.0 90.0 39.200 260.0 95.0 40.200 200.0 100.0 41.600 280.0 105.0 45.600 260.0 115.0 45.600 240.0 120.0 47.000 280.0 125.0 48.600 320.0 130.0 49.700 220.0 135.0 51.000 260.0 145.0 53.400 220.0 150.0 54.600 280.0 150.0 54.600 280.0 150.0 54.600 280.0	i
60.0 31.200 320.0 05.0 32.400 240.0 70.0 33.700 260.0 75.0 35.600 260.0 80.0 36.400 280.0 85.0 37.900 300.0 90.0 39.200 260.0 90.0 39.200 260.0 90.0 39.200 260.0 90.0 40.200 200.0 100.0 41.600 280.0 105.0 45.600 240.0 115.0 45.600 240.0 125.0 48.600 320.0 130.0 49.700 220.0 135.0 51.000 260.0 140.0 52.600 260.0 145.0 53.408 220.0 150.0 54.600 280.0 155.0 54.600 280.0	;
a5.0 52.400 240.4 70.0 33.700 260.4 75.0 35.600 260.4 $a0.0$ 36.400 280.4 $a5.0$ 37.900 300.4 90.0 39.200 260.4 90.0 39.200 260.4 90.0 39.200 260.4 90.0 39.200 260.4 90.0 41.600 280.4 90.0 41.600 280.4 100.0 41.600 280.4 105.0 45.600 240.4 105.0 45.600 240.4 120.0 47.000 280.4 120.0 47.000 280.4 125.0 48.600 320.4 130.0 49.700 220.4 130.0 51.000 260.4 140.0 52.600 260.4 145.0 53.400 220.4 150.0 54.600 280.4 150.0 56.000 240.4	ţ
70.0 33.700 260.4 75.6 35.600 260.0 80.0 36.400 280.0 85.6 37.900 300.0 90.0 39.200 260.0 95.0 40.200 200.0 105.0 43.100 300.0 105.0 43.100 300.0 110.0 44.400 260.0 115.0 45.600 240.0 120.0 47.000 280.0 125.0 48.600 320.0 130.0 49.700 220.0 135.0 51.000 260.0 144.0 52.600 260.0 145.0 53.400 220.0 150.0 54.600 280.0 155.0 56.000 240.0]
75.0 35.600 260.4 30.0 36.400 280.4 85.0 37.900 300.4 90.0 39.200 260.4 90.0 39.200 260.4 95.0 40.200 200.4 100.0 41.600 280.4 105.0 43.100 300.4 105.0 45.600 240.4 120.0 47.000 280.4 120.0 47.000 280.4 125.0 48.600 320.4 130.0 49.700 220.4 135.0 51.000 260.4 140.0 52.600 260.4 145.0 53.400 220.4 150.0 54.600 280.4 150.0 54.600 280.4 150.0 54.600 280.4	1
30.0 36.400 280.3 85.6 37.900 300.0 90.0 39.200 260.0 95.0 40.200 200.0 100.0 41.600 280.0 105.0 43.100 300.0 110.0 44.400 260.0 115.0 45.600 240.0 120.0 47.000 280.0 125.0 48.600 320.0 130.0 49.700 220.0 135.0 51.000 260.0 140.0 52.600 260.0 145.0 53.400 220.0 150.0 54.600 280.0 155.0 56.000 240.0)
85.0 37.900 300.1 90.0 39.200 260.1 95.0 40.200 200.1 100.0 41.600 280.1 105.0 43.100 300.1 105.0 43.100 300.1 110.0 44.400 260.1 115.0 45.600 240.1 120.0 47.000 280.1 125.0 48.600 320.1 130.0 49.700 $220.135.0$ 135.0 51.000 $260.145.0$ 145.0 53.400 $220.150.0$ 150.0 54.600 $280.155.0$ 155.0 56.000 $240.160.00$)
90.0 39.200 $260.$ 95.0 40.200 $200.$ 100.0 41.600 $280.$ 105.0 43.100 $300.$ 110.0 44.400 $260.$ 115.0 45.600 $240.$ 120.0 47.000 $280.$ 125.0 48.600 $320.$ 130.0 49.700 $220.$ 135.0 51.000 $260.$ 140.0 52.600 $220.$ 150.0 54.600 $280.$ 155.0 56.000 $240.$)
95.0 40.200 $200.$ 100.0 41.600 280.1 105.0 43.100 $300.$ 110.0 44.400 $260.$ 115.0 45.600 $240.$ 120.0 47.000 $280.$ 125.0 48.600 $320.$ 130.0 49.700 $220.$ 135.0 51.000 $260.$ 140.0 52.600 $260.$ 145.0 53.408 $220.$ 150.0 56.000 $240.$)
100.0 41.600 $280.$ 105.0 43.100 $300.$ 110.0 44.400 $260.$ 115.0 45.600 $240.$ 120.0 47.000 $280.$ 125.0 48.600 $320.$ 130.0 49.700 $220.$ 135.0 51.000 $260.$ 140.0 52.600 $260.$ 145.0 53.408 $220.$ 150.0 56.000 $240.$)
105.0 43.100 $300.$ 110.0 44.400 $260.$ 115.0 45.600 $240.$ 120.0 47.000 $280.$ 120.0 47.000 $280.$ 125.0 48.600 $320.$ 130.0 49.700 $220.$ 135.0 51.000 $260.$ 140.0 52.600 $260.$ 145.0 53.400 $220.$ 150.0 56.000 $240.$)
110.0 44.400 $260.$ 115.0 45.600 $240.$ 120.0 47.000 $280.$ 125.0 48.600 $320.$ 130.0 49.700 $220.$ 135.0 51.000 $260.$ 140.0 52.600 $260.$ 145.0 53.400 $220.$ 150.0 54.600 $280.$ 155.0 56.000 $240.$	3
115.0 45.600 240. 120.0 47.000 280. 125.0 48.600 320. 130.0 49.700 220. 135.0 51.000 260. 140.0 52.600 260. 145.0 53.400 220. 150.0 56.000 280. 155.0 56.000 240.)
120.0 47.000 280. 125.0 48.600 320. 130.0 49.700 220. 135.0 51.000 260. 140.0 52.600 260. 145.0 53.400 220. 150.0 54.600 280. 155.0 56.000 240.	J
125.6 48.600 $320.$ 130.0 49.700 $220.$ 135.0 51.000 $260.$ 140.0 52.600 $260.$ 145.0 53.400 $220.$ 150.0 54.600 $280.$ 155.0 56.000 $240.$)
130.0 49.700 220. 135.0 51.000 260. 140.0 52.600 260. 145.0 53.400 220. 150.0 54.600 280. 155.0 56.000 240.	J
135.6 51.000 260. 140.0 52.600 260. 145.0 53.400 220. 150.0 54.600 280. 155.0 56.000 240.) n
140.0 52.000 260. 145.0 53.408 220. 150.0 54.600 280. 155.0 56.000 240.	J
145.0 55.400 220. 150.0 54.600 280. 155.0 56.000 240.	ן ר
150.0 54.600 280. 155.0 56.000 240. 160.0 56.000 56.000) N
	ן ר
	ן ר
165 6 KO 500 300.	, ו
170 0 40 600 220.	, ì
175.0 61-200 120.	, 1
180.0 61.800 120.	, 1
185.0 61.900 20.	Ĵ

LOCA	IION: RHS KGRA	
	275/10W-23 CA	
HOLE	NUMBER: 5	
DATE	MEASURED: 9/03/75	
DEPTH	TEMPERATURE	GRADIENT
METERS	DEG C	DEG C/KM
10.0	14.480	• 0
20.0	17.450	297.0
30.0	20.130	268.0
40.0	22.580	245.0
50.0	25,000	242.0
60.0	26,930	193.0
70.0	27.6 50	72.0
80.0	28.390	74.0
90.0	28.960	57.0
100.0	2 9.590	63.0
110.0	30.100	51.0
120.0	30.550	45.0
130.0	31.100	55.0
140.0	31.520	42.0
150.0	32.180	66.0
151.5	32.210	20.0

LUCA	TION: RHS KGRA	
	275/9W-16 BB	
HULE	NUMBER: 7	
DATE	MEASURED: 3/08/75	
DEPTH	TEMPERATURE	GRADIENT
METERS	DEG C	DEG C/KM
10.0	16.600	•0
20.0	23.300	670.0
30.0	28.200	490.0
40.0	32,900	470.0
50.0	37.300	440.0
60.0	41.550	425.0
70.0	45,730	418.0
0.06	49.800	407.0
90.0	53,900	410.0
100.0	57.780	388.0
110.0	61.450	367.0
120.0	65.300	385.0
130.0	68.840	354.0
140.0	72.300	346.0
145.0	74.000	340.0

LOCA	TION: RHS KGRA	
	275/9N-16 AD	
HOLE	NUMBER: 8	
DATE	MEASURED: 8/11/75	
DEPTH	TEMPERATURE	GRADIENT
METERS	. DEG C	DEG C/KM
10.0	24.620	• 0
20.0	37.470	1285.0
30.0	49.320	1185.0
4.).(60.170	1085.0
50.0	69.580	941.0
00.0	78.120	854.0
70.0	84.080	596.0
80.0	B9.65 0	557.0
90.0	95.400	575.0
LOCA	TION: RHS KGRA	
--------	----------------------	----------
	27 5/9W-21 DD	
HOLE	HUMPER: 9	
DATE	MEASURED: 9/05/75	
0	TENTOPINATION	
UEPTH	TEMPERATURE	GRADIENT
METERS	DEG C	DEG C/KM
10.0	20.950	• 0
20.6	32,810	1186-0
23.0	34 000	306 7
20.0	J 4 • 0 0 0	390.1

•••

LOCA	TION: RHS KGRA	
	27 5/9W-15 ABD	
HOLE	NUMPER: 10	
DATE	MEASURED: 9/02/75	
DEPTH	TEMPERATURE	GRADIENT
METERS	DEG C	DEG C/KM
10.0	15.370	• 0
20.0	19.880	451.0
30.0	23.800	392.0
40.0	27.560	376.0
50.0	32.580	502.0
60.0	37.410	483.0
64.3	39.100	393.0

LOCA	TION: RHS KGRA	
	275/10W-10 DDD	
HOLE	NUMBER: 12	
DATE	MEASURED: 8/11/75	
DEPTH	TEMPERATURE	GRADIENT
METERS	DEG C	DEG C/KM
10.0	14,860	•0
20.0	18,640	378.0
30.0	21 .3 80	274.0
40.0	24.190	281.0
50.0	26.270	208.0
60.0	27.470	120.0
70.0	28,510	104.0
80.0	29 .2 40	73.0
90.0	29 .8 10	57.0
100.0	30 .37 0	56.0
110.0	30 .96 0	59.0
120.0	31.530	57.0
130.0	32,150	62.0
140.0	32.730	58.0
150.0	33.180	45.0
160.0	33.770	59.0
170.0	34.320	55.0
189.0	34.840	52.0
190.0	35.320	48.0
200.0	35.860	54.0
203.0	3 5.98 0	40.0
	-	

LOCA	TION: RHS KGRA	
	275/9W-7 CC	
HOLE	NUMBER: 14	
UATE	MEASURED: NO DATE	
DEPTH	TEMPERATURE	GRADIENT
METERS	DEG C	DEG C/KM
10.0	15.250	.0
20.0	17.900	265.0
30.0	20.500	260.0
40.0	23.100	260.0
50.0	25,100	200.0
60.0	26.900	180.0
70.0	28.700	180.0
80.0	30.500	180.0
90.0	31.900	140.0
100.0	33.200	130.0
110.0	34.300	110.0
120.0	35.250	95.0
130.0	36.100	85.0
140.0	36.9 00	80.0
150.0	37.600	70.0
160.0	38.300	70.0
170.0	39.050	75.0
180.0	39.850	80.0
190.0	40.650	80.0
195.0	41.000	70.0

LUCA	TION: RHS KGRA	
	275/9W-7D DD	
HULE	NUMBER: 15	
DATE	MEASURED: NO DATE	
DEPTH	TEMPERATURE	GRADIENT
METERS	DEG C	DEG C/KM
10.0	15.040	• 0
20.0	18.100	306.0
30.0	20.300	220.0
40.0	22.200	190.0
50.0	24.400	220.0
60.0	26.300	190.0
70.0	28.000	170.0
80.0	29.5 00	150.0
90.0	31.200	170.0
100.0	32.800	160.0
110.0	34.700	190.0
120.0	36.300	160.0
130.0	37.700	140.0
140.0	38,900	120.0
150.0	39.800	90.0
160.0	40.700	90.0
170.0	41.600	90.0
175.0	41,900	60.0

LOCA	TION: RHS KGRA	
	275/9W-4 AD	
HOLE	NUMBER: 17	
UATE	MEASURED: NO DATE	
рертн	TEMPERATURE	GRADIENT
METERS	DEG C	DEG C/KM
10.0	17.600	• 0
20.0	23.600	600.0
30.0	29.700	610.0
40.0	34.700	500.0
50.0	40.000	530.0
60.0	44.100	410.0
63.0	45.000	300.0

LOCATION: RHS KGRA 27S/R9W-2 CAA HOLE NUMBER: 20 DATE MEASURED: 8/13/75

DEPTH METERS	TEMPERATURE DEG C	GRADIENT DEG C/KM
10.0	12.410	.0
20.0	14.690	228.0
30.0	16.570	188.0
40.0	18.310	174.0
50.0	20.300	199.0
60.0	21.160	86.0
70.0	22.400	124.0
80.0	23.440	104.0
90.0	24.290	85.0
100.0	24.990	70.0
105.0	25.350	72.0
105.5		

LOCA	TION: RHS KGRA	
	265/9%-32 AA	
HOLE	NUMPER: 25	
DATE	MEASURED: 9705775	
DEPTH	TEMPERATURE	GRADIENT
METERS	DEG C	DEG C/KM
10.0	15.590	• 0
20.0	21.160	557.0
30.0	25.030	387.0
40.0	28.080	305.0
50.0	3 0.960	288.0
60.0	33.590	263.0
70.0	36.200	261.0
80.0	38.550	235.0
90.0	40.510	196.0
100.0	42.600	209.0
110.0	44.790	219.0
120.0	47.090	230.0
130.0	49,330	224.0
140.0	51.260	193.0
144.3	51.360	23.3



Figure 6

ı

,



ı,

٠

۲

.5

Figure 7

ī

,

LOCATION ALTERATION 75 1A 275 9W 3CBB HOLE NUMBER UU 751A DATE MEASURED 7/22/76

ł

. •



1

a

1

٠

Figure 8

LOCATION ALTERATION 75 1B 27S 9W 4DDA HOLE NUMBER UU 75 1B DATE MEASURED 7/22/76



•

ъ

3

.

Figure 9

.

ļ.



1

.

.

Figure 10

1

,



4

٠

Figure 11

.

,





٠

×

5

÷



Figure 14

,

.



3

۲

.

"

×



.

×

×

4

,



A

×



Figure 18

4



é.

4

4

.

÷



.



4

Figure 21

,

ć



٠

Figure 22

24

* (

DEPARTMENT OF GEOLOGY AND GEOPHYSICS



7

UNIVERSITY OF UTAH SALT LAKE CITY, UTAH 84112

TECHNICAL REPORT: VOLUME 77-3

Thermal Gradients and Heat Flow at Roosevelt Hot Springs

Energy Research and Development Administration

Contract EY-76-S-07-1601

W. R. Sill J. Bodell

TABLE OF CONTENTS

Abstract

1.0	Introduction	
2.0	Thermal Gradients at Roosevelt Hot Springs	•
3.0	Heat Flow at Roosevelt Hot Springs 6	;
4.0	Conclusions	}
	References)
	List of Figures)
	Appendix A	

Abstract

Thermal gradient and electrical resistivity surveys both outline anomalous zones along the system of faults that control the near surface flow at Roosevelt Hot Springs. The source of both anomalies is the circulation of thermal water, which gives rise to the high heat flow and the lowered resistivity due to the hot brine and the associated hydrothermal alteration.

The nature of the temperature profiles and the asymmetry of the thermal gradient profile across the system are suggestive of a leakage and mixing of thermal water with the regional groundwater flow to the west. This interpretation is consistent with the resisitivty data in which conductive regions to the west of the fault system have been interpreted in terms of brine-saturated sediments.

The maximum conductive heat flow over the anomaly is 40 HFT $(1.7W/m^2)$ and the total conductive heat loss is estimated at 2 MW. Heat flow in the Mineral Mountains, to the east of the near-surface thermal anomaly, is low or near average for the Basin and Range. Recharge may be taking place in this region.

1.0 Introduction

Thermal gradient data from 39 drill holes in the Roosevelt Hot Springs KGRA area are presented in this report. Fifteen of these holes were drilled under subcontract to the University of Utah, permission to log another ten holes was granted by Phillips Petroleum Company and the remaining fourteen holes were provided by other sources. The locations of most of the holes are shown in Figures 1 through 3, along with the locations of test and production holes. These figures also show the contoured average thermal gradient in three depth intervals; shallow (30-60m), intermediate (60-100m) and deep (>100m).

Figure 4 displays a plan view of the interpreted faults in the area. Comparison of Figures 1 and 4 shows that the region of highest thermal gradients is aligned along the Dome Fault and Fault 1. To the south the high thermal gradients are terminated by several east-west trending faults. To the north there is a bending of the contours resulting in a ridge aligned along fault 5, which trends to the north west.

In Figures 1 and 2 there are isolated highs in the north and south that are probably the result of the sparseness of data in the central region. Considerations of the probable thermal gradient in the early steam well (drilled by Dr. E. N. Davie), based on the depth of blowout, and the near surface temperatures in sulfur pits in the bottom of Negro Mag Wash (North of 54-3) would indicate that the 900°C/km should run further to the west in the southern portion and is probably continuous with the high in the north.

Comparison of Figure 1 with the contoured apparent resistivity (Figure 5) shows that the resistivity and thermal gradient patterns are highly correlated. Both exhibit contours aligned along the Dome fault and a bending to the northwest along Fault 5. The obvious cause of the correlation

is the hot water circulation along the faults which gives rise to both high thermal gradients and low resistivities due to the hot brine and the associated hydrothermal alteration.

With increasing depth (Figures 2 and 3) the thermal gradients decrease and the alignment along the faults is less clear. The smearing of the pattern is partly due to the lack of data at greater depths. The acquisition of deep thermal gradient data from small drill holes in regions of very high thermal gradients is hindered by fear of blowouts, among other things.

2.0 Thermal Gradients at Roosevelt Hot Springs

Figures 6 to 20 show the temperature vs depth curves for the holes drilled by the University of Utah. As can be seen in these figures, the thermal gradient in holes drilled in alluvium often decreases with depth, with the depth intervals used in Figures 1 to 3 being somewhat characteristic of the several regions of changing gradient. For example, hole UUTG6 (Figure 20) shows an abrupt change at 30m and hole UUTG3 (Figure 18) displays a more gradual transition with suggested breaks at 35m and 70m. Such changes in the thermal gradients can be caused by changes in thermal conductivity due to changes in the porosity, saturation and lithology among other things.

Gravity measurements over a wash in the alluvium (Crebs and Cook, 1976) indicate a porosity of about 25% in the near surface (25-50m). Some decrease in porosity with depth is to be expected due to the increase in load. A change in the porosity of saturated granite alluvium from 25% to 10% would give rise to a change in thermal conductivity (and gradient) of about 25%. The changes in thermal gradient caused by such variations in porosity are then rather modest.

On the other hand, changes in saturation, from dry to completely saturated, would give rise to changes in thermal conductivity by a factor of 2.0 to 2.5 for porosities in the range from 20 to 30%.

Changes in the thermal conductivity due to lithology changes depends on the thermal conductivity of the components. For example, changing the thermal conductivity of the solid components by a factor of 2 results in a 1.7 change in conductivity at a porosity of 25%. Changes in lithology from a granite alluvium to a quartz rich sand are possible in this area. Measurements made on sands from the Roosevelt KGRA give solid component conductivities in the range from 10 to 11 HCU and samples of granite alluvium give

values in the range from 6 to 7 HCU. Therefore, such changes in lithology can be expected to give rise to rather substantial changes in gradient.

Considering the thermal gradients in hole UUTG6 (Figure 21) we see that the average gradient in the 20-30m interval is about 200° C/km and below this depth it averages about 30° C/km, a factor of about 7 change is slope. Thermal conductivity measurements on samples from this hole average about 4 HCU, at a saturated bulk density of $2.2g/\text{cm}^3$, with no consistent changes above and below the break in the slope. The water table in a nearby well (2.4km) at about the same elevation is 26m (Mower and Cordova, 1974). This is near the break in the thermal gradient. However, the change in thermal conductivity due to undersaturation would only be a factor of 2 to 2.5 which is well below the observed value.

One possible explanation of the strong change in gradient is a leakage of thermal water into the groundwater flow to the west. Some leakage of thermal water is indicated by the chemical analysis of the seep west of Salt Cove, which has a cool temperature (25°C) but a Na-K-Ca temperature of 241°C (Parry et. al., 1976). For a uniform mixing of thermal water into the groundwater in a region of constant thermal conductivity, the thermal gradient should decrease smoothly with depth in the mixing zone. The two gradient regions in UUTG6 may result from a combination of effects due to the presence of the water table and mixing. On the other hand, the thermal gradient in hole UUTG3 (3km to the south) shows a more gradual change, with no sharp break at the water table (50m). The overall change in slope between the top and bottom of this hole is about a factor of 8, which seems too large to be explained by the effects of saturation alone.

In holes UU751A and UU751B, just to the west of the dome fault, the water tables were located at about 35m and 40m respectively, which are also the locations of the alluvium altered bedrock interface. In both cases the thermal gradients do not show an abrupt change at the water table.

However, there is gradual increase in thermal gradient above these depths (20% to 40%), perhaps due to gradual changes in the saturation.

Figure 21 shows a series of temperature profiles on a west-east line across the southern part of the system (the letter designation runs from West-A to East-I). The thermal gradients and the 10m depth temperatures increase as the Dome Fault is approached from the west (A to G) and the two eastern holes (H & I) show decreasing temperatures and gradients.

The five westernmost holes (AA to D) show a decreasing gradient with depth, as did the western holes to the north(UUTG6 and UUTG3) discussed previously. The two westernmost holes 5(AA) and 12(A) have a thermal gradient in the deeper part near 50°C/km, which is near normal for a thermal gradient in the alluvium. The water table is about 40m in this region (Mower and Cordova, 1974) and both curves show changes in slope (15 to 30%) at this depth, which could be due to changes in saturation. There is a change in slope to a near constant slope region at a depth of about 60m. The change in average gradient above and below this depth is a factor of 1.5 to 3. The lithologic log on a nearby water well notes a change in lithology at this point, from sands containing numerous "igneous" fragments (up to 30%) to sands free of such material. Considering the average abundance of such material, it would be difficult to account for the changes in slope by the change in lithology. Once again a possible explanation for the change in slope could be leakage of thermal waters to the west and mixing with the groundwater. With respect to this, it is interesting to note that the thermal gradients at depth in the westernmost holes are near normal and that the gradient in the easternmost hole is constant with depth although slightly above normal. More conclusive evidence for leakage mixing of thermal waters would be the presence of gradient reversals which have not been observed to date.

3.0 Heat Flow at Roosevelt Hot Springs

Thermal conductivity measurements on a limited number of alluvial samples, indicates an average value of 4 HCU (1 HCU - mcal/cm S°C - 0.418 W/m°k). Maximum conductive heat fluxes are then in the neighborhood of 40 HFU (1 HFU = μ cal/cm²S = 41.8 mW/m²). The total integrated conductive heat loss over the anomaly (6.5 km in length) is about 10⁷ cal/S or 2MW.

Figure 22 is a west to east thermal gradient profile for two depth intervals, 30-60m and 60-100m. Based on a *conductive* heat flow model, these profiles indicate an equivalent line source at 1.0 to 1.5km depth. Also shown on the figure, as a dashed line, is the theoretical thermal gradient profile for a line source, scaled to the 30-60m data. From this it is easy to see that the observed curve is asymmetrical, with smaller gradients in the east and larger to the west. This asymmetry is also observed in the deeper (60-100m) gradients. The observed asymmetry is compatable with the leakage of thermal water to the west, as discussed in the previous section, but source configuration in a conductive model could also produce such asymmetry.

Several core holes were also drilled in the granite of the Mineral Range so that samples could be measured for thermal conductivity and heat flow values calculated. Figure 13 shows the temperature profile in one such hole (UU76SC) located in Salt Cove on the west side of the Mineral Range, about 3 km east of the center of the thermal gradient-resistivity anomaly. The thermal gradient is quite uniform at an average value of 29°C/km below a depth of 50m. The average thermal conductivity in this region is 6.6 HCU (16 samples) giving a heat flow of 1.92 HFU.

Another hole (UU76BS) was drilled in the central part of the Mineral Range just to the north of Bearskin Mountain, the temperature profile from the last log (Figure 14) still shows some drilling disturbances, but the smoothed thermal gradient in the 80 to 150m interval is 17° C/km. The thermal gradient in a Phillips Petroleum Company hole, 1.5 km to the north (Figure 1) is similar (16° C/km) indicating that this is maybe representative of the area. The average thermal conductivity in this hole in the above depth interval is 7.65 HCU (11 samples) giving a heat flow of 1.28 HFU.

Two kilometers to the east of this hole, the hole at Ryans Ranch (UU75RR, Figure 11) has thermal gradient of $19.9^{\circ}C/km$ (50 to 80 m) and the average thermal conductivity of several samples is 7.1 HCU, resulting in a heat flux of 1.41 HFU.

Roy et al. (1968) report a heat flow of 2.22 HFU for a location on the west side of Milford valley, just about due west of Roosevelt Hot Springs. None of the above calculated heat flow values are large for the Basin and Range, in fact the measurements in the central part of the range seem somewhat low. However, none of the measurements have been corrected for topographic effects, which should be largest for the locations north of Bearskin and at Ryans Ranch.

If the Mineral Mountains and the area to the east are regions of significant recharge, then the downward movements of cool water may contribute to the low thermal gradient and heat flow.
4.0 Conclusions

Thermal gradients and electrical resistivity data at Roosevelt Hot Springs both outline the same anomalous region along the system of faults which control the near surface circulation. Depending on the circumstances, these techniques may provide complementary or redundant information.

The character of the thermal gradients to the west of the fault system suggest that thermal waters are mixing with the ground water flow to the west. If so, this should be reflected in the water chemistry. Parry et al. (1976) show several anomalous Na-Ca-K temperatures to the northwest of Roosevelt Hot Springs but no data was available from wells in the immediate vicinity of the thermal gradient holes.

Heat flow values in the alluvium reach a maximum of about 40 HFU, and the estimated total conductive heat loss from the shallow part of the system is about 2MW. Heat flow values and thermal gradients in the Mineral Range are not high for the Basin and Range, and in fact several of the values seem low.

REFERENCES

- Crebs, T. J. and K. L. Cook, 1976; Gravity and ground magnetic surveys of the central Mineral Mountains, Utah, Volume 6, Grant GI-43741, National Science Foundation.
- Mower, R. W. and R.M. Cordova, 1974; Water resources of the Milford area, Utah, with emphasis on groundwater, State of Utah, Department of Natural Resources Technical Pub. No. 43.
- Parry, W. T., N. L. Benson and C. D. Miller, 1976; Geochemistry and hydrothermal alteration at selected Utah hot springs, volume 3, Grant GI-43741 National Science Foundation.
- Roy, R. F., E. R. Decker, D. D. Blackwell and F. Birch, 1968; Heat flow in the United States, J. Geophys. Res., 73,5207-5221.

LIST OF FIGURES

Fig.	1	Thermal gradie	nt Con	tour	map, depth interval 30-60 meters, also
		shown are the	locatio	ons (of test and production wells.
Fig.	2	Thermal gradie	nt con	tour	map, depth interval 60-100 meters.
Fig.	3	Thermal gradie	nt con	tour	map, depth greater than 100 meters.
Fig.	4	Interpreted Fr	acture	map	
Fig.	5	Apparent resis	tivity	con	tour map, first separation, 300 meter
		dipole-dipole.			
Fig.	6	Temperature pr	ofile	hole	UU75-12
Fig.	7	u	11	**	UU75-13
Fig.	8	11	11	n	UU75-1A
Fig.	9	11	¥1	11	UU75-1B
Fig.	10	0	ŧI	н	UU75-BCC
Fig.	11	u	u	11	UU75-RR
Fig.	12	53	u	H	UU76-1A
Fig.	13	II	68		UU76-SC
Fig.	14	11	14	11	UU76-BS
Fig.	15	11		11	UU76-TG0
Fig.	16	41	0	11	UU76-TG1
Fig.	17	н	u	IJ	UU76-TG2
Fig.	18	п	**	11	UU76-TG3
Fig.	19	11	11	11	UU76-TG5
Fig.	20	ш	1¢	11	UU76-TG6

Fig. 21 Temperature Profiles for a series of holes along an east-west line at approximately 2200N.

Fig. 22 Thermal gradients at two depth intervals (30-60m and 60-100m) along an east-west line at approximately 2200N.

:

APPENDIX A

.

Temperature Logs

LOCATION: RYANS RANCH LOCATION: RYANS RANCH 275 BW 4DCD HOLE NUMBER: UU 75 DATE MEASURED: 11/6/76

NEDTH	TEMPERATURE	GRADIEN
METERS	DE6 C	DEG C/KM
5.0	9.894	• 0
	6.803	-218.2
1.0000	9.716	182.6
	9.858	28.4
23740 115.10	9.000	-171.6
2)•0 3.0 -6	9.007	1.4
	9.170	32.6
0.0.0	9.280	22.0
40.0	9.370	18.0
50.0	9,391	4.2
55.0	9.492	20.2
50.0	9.569	15.4
u5.0	9.601	22.4
1.0	9.781	20.0
745 - 12	9.888	21.0
80.0	9.987	20.2
1. 4 4i	10.116	25.8
	10.292	35.2
Ω(F ● U) (3)(L = Ω)	10.381	17.8
100.0	10.492	22.2
100+6		

.

1

a Sinte

in and and a

1. Stanta

LOCATION: BIG CEDAR COVE 275 8W 14 DDC HOLE NUMBER: UU 75 DATE MEASURED: 9/22/75

DEPTH	TEMPERATURE	GRADIENT
NETERS	deg c	DEG C/KM
5.0	16.769	• 0
10.0	12.978	-758.2
4 3 • ¹⁷	13.421	88.6
1 a a 19	13.543	24.4
2 · • 11	13.973	86.0
(j.) • (t	14.427	90.8
35.0	14.693	53.2
43.4	15.073	76.0
• 7 • 6	15.520	90 .6
· · 문 • 나	15.957	86.2
:) • (i	16.437	96.0
5 d • D	16.754	63.4
55 • 0	17.132	75.6
7.0.0	17.081	69.8
7.5.0	17.905	84.8
). E.	18.380	75.0
5 🖡 🖞	18.579	59.8
1. . (*	18.858	55.4
• > • (-	19.153	59.4
100.0	19.937	156.8

LOCATION:	ALTERATION 75 1A	
	275 9W 3CLB	
HOLE NUM	2ER - U(1 7514	
hATE MEAS		
UNIC INCAS	SONED. 1722/16	
DEPTH	TEMPERATURE	GRADIENT
METERS	DEG C	DEG CIKM
	2-0 0	
10.0	26.283	•0
15.0	34.349	1613.2
20.0	40.036	1137.4
25.0	44.676	928.0
30.0	49.158	896.4
35.0	53.288	826 0
40.0	57 622	644 0
15 0		000.0
42.0	61.17	/11.0
50.0	63.990	562. 6
55.0	67.365	675. 0
60.0	70.687	664.4
65.0	74.307	724.0
68.5	76 434	607 7

ź,

LOCATION;	ALTERATION 75 1B	
	275 9W 40DA	
HOLE NUM	3ER: UU 75 1B	
DATE MEAS	Sured: 7/22/76	
DEPTH	TEMPERATURE	GRADIENT
METERS	deg c	DEG C/KM
5.0	14.926	.0
10.0	18.065	627.8
15.0	21.878	762.6
20.0	25.194	663.2
25.0	28.354	632.0
30.0	31.719	673.0
35.0	35.043	664.8
40.0	37.561	503.6
45.0	40.288	545.4
50.0	42.688	480.0
55.0	44.676	397.6
60.0	47.008	466.4
65.0	49.088	416.0
	-	

.

14 M 1

and games

u - 10

 $\{e_{i}\}_{i\in I}$

See. 34

. 44

LOCATION	: BOYLES IZRKGRA	
	265 9W 27 BBB	
HOLE NU	MBER: UU 75 12	
DATE NE	ASURED: 6/11/76	
DEPTH	TEMPERATURE	GRADIENT
METERS	deg c	DEG C/KM
5.0	16.072	• 0
10.0	19.622	710.0
15.0	21.794	434.4
20.0	24.981	637.4
25.0	28.579	719.6
30.0	29.061	256.4
34.5	30.922	235.8
-		

ĩ

9 N

1

HOLE DATE	ION: BOYLES 13 RKGRA 265-9W-20 AC NUMBER: UU-75-13 MEASURED: 11/8/75	
DEPTH	temperature	G RAD IENT
METERS	deg c	DEG C/KM
10.0	19.715	.0
20.0	25.496	578.1
30.0	30.489	499.3
40.0	34.301	381.2
43.0	36.742	813.7

۰.

ł.

;

.

> atara N S. A.

an ha

ngaringa Syri Ngari

State State State

LOCATION:	BEARSK	IN RKGRA
	275 80	B BAB
HOLE NUM	BER: UU	75
DATE MEAS	sured: e	3/20/76

DEPTH	TEMPERATURE	GRADIENT
METERS	deg c	DEG C/KM
	A 084	• 0
	9 4 5 5	273.4
19.0	5 9n7	
20.0	9 693	-44.8
25.0	9.005	-121 B
50.0	9.074	-16.1+0
55.0	9.048	
40.0	8.834	=42.8
45.0	8.867	6.6
50.0	8.942	15+0
55.0	B.998	11.2
60.0	9.077	15.8
65.0	9.084	1.4
70.0	9.217	26.6
75.0	9.331	22.8
80.0	9.351	4.0
85.0	9.462	55.5
90.0	9.496	6.8
95.0	9.629	26.6
100.0	9.797	33.6
110.0	10.137	34.0
115.0	10.176	7.8
120.0	10.113	-12.6
125.0	10.296	36.6
130.0	10.249	-9.4
135.0	10.459	42.0
140.0	10.584	25.0
145.0	10.391	-38.6
150.0	10.459	13.6
155.0	10.823	72.8
156.0	10.999	176.0

LOCATION: ALTERATION 76-1A RKGRA 275 9W 34 CAB NELL NUMBER: UU 76-1A DATE MEASURED: 6/ /76

ł

DEPTH	TEMPERATURE	GRADIENT
METERS	deg c	deg c/km
5.0	30.026	• 0
10-0	41.194	2232.8
15.0	57.022	3166.4
20.0	63.642	1324.0
25.0	69.025	1076.6
30.0	77.158	1626.6
35.0	84.082	1384.8
40.0	98.843	953.2
45.0	93.914	1013.2
50.0	97.362	689.6
55.0	101.100	747.6
60.0	105.584	896.8
63.5	107.885	657.4

LOCATION:	RKGRA TG-1	
HOLE NUM DATE MEAS	265 91 13 CDA BER: UU76 TG1 SURED: 10/10/76	
DEPTH	TEMPERATURE	GRADIENT
METERS	deg c	DEG C/KN
10.0	16.428	.0
15.0	18.095	333.4
20.0	19.382	257.4
25.0	20.549	2 53 • 4
30.0	21.506	191.4
35.0	22.476	194.0
40.0	23.231	151.0
115.0	23.893	132.4
43.0	24,521	125.6
	05 071	110.0
60.0	25.582	102.2

LOCATI	ON: RKGRA TG-2	
	265 9¥ 500B	
HOLE	MUMBER: WU76 TG2	
DATE	MEASURED: L1/6/70	5

Depth	TEMPERATURE	GRADIENT
meters	deg c	DEG C/KM
5.0	15.877	.0
10.0	14.619	-251.6
15.0	15.169	110.0
20.0	15.567	79.6
25.0	15.902	67.0
30.0	16.259	71.4
35.0	16.679	84.0
40.0	17.868	77.4
45.0	17.389	64.6
50.0	17.690	60.2
55.0	17.955	53.0
60.0	18.195	48.0
65.0	18.426	46.2
67.0	18.580	61.6

ł

LOCATION:	RKGRA	TG-3
	265 9	W 19 DGC
HOLE NUM	BER: U	J76 T63
DATE MEA	sured:	11/6/76

(DPTH	TEMPERATURE	GRADIENI
METERS	DLG C	DEG C/KM
Б.О	17.946	.0
	15.391	99. 0
	20.383	398.4
20.15	28.441	411.6
	24.223	356.4
	26.143	384.0
1919 • 11 5 5 5 19	28.078	387.0
	29.147	273. 8
	38.770	264.6
13 () • () • 1 •	32.031	252.2
	32.994	192.6
	33.887	178.6
()() ● () /: S	34.691	160.8
20.1	35.306	123.0
15.1	35.601	59.0
	35.883	56.4
35.0	36.121	47.6
1441 × 3	36.243	24.4
-913 • 1)	36.544	60.2
100.0	36.405	-27.8

LOCATION	RKGRA TG-5	
HOLE NUN	1BER: UU76 TG5	
date me	ASURED: 10/15/76	
DEPTH	TEMPERATURE	GRADIENT
METERS	deg c	DEG C/KM
10.0	13.204	•0
15.0	13.577	74.6
20.0	13.906	65.8
25.0	14.154	50.0
30.0	14.381	45.0
35.0	14.593	42.4
40.0	14.781	37.6
45.0	15.006	45.0
50.0	15.195	35.8

LOCATION:	PLS ON TCAA	
HALT BUNG	050 · 11176 TG6	
HOLE NUM	100 = 100 = 100	
Unte hero		
OFDTH	TEMPERATURE	GRADIENT
METERS	deg c	DEG C/KM
5.0	14.273	• 0
	14.275	•4
	14.847	114.4
271.41	15.436	117.8
2.13.4.1	16.913	295.4
30.0	17.829	183.0
500 C	18.108	56.0
	18.924	23.2
••••••••••••••••••••••••••••••••••••••	18.458	46.8
4 ja 4 ja 11 ja 11	18.692	46.8
110 e	18.721	5.8
1 1 • •	15.935	22.8
	19.004	33.8
0.3 • 0 2 5 • 0	18.149	29.0
•	19.256	21.2
	19.348	18.6
2 C • 1	19.449	28.2
27 • 1 	19.712	44.6
	19,952	48.0
47.5	19.983	12.4

LOCATION:	rkgra salt cove
	265 9N 25 DCA
HOLE NUM	BER: UU 76
DATE MEAS	SURED: 6/24/77

DEPTH	TEMPERATURE	GRADIENT
meters	deg c	deg c/km
10-0	10.908	• 0
15-0	10.689	16.2
1.13 . 1	11.188	39.8
2° 3° • 4	11.492	60.8
<u>7</u> .3.4	11.742	50. 0
313 • 1	11.596	-29.2
rit . t.	12.150	112.0
· · ·) • · ·	12.335	35.8
1949 • C	12.904	33.8
13 + J	12.658	30.8
$G_{\bullet} = E_{\bullet}$	12.607	29.8
<u>ت ، د ت</u>	12.942	27.0
71:.1	13.071	25.8
75	13.186	25. 0
14 J 🖝 6	13.337	28.2
5. 5 • 4	13.476	27.8
91.1	13.617	28.2
945 • (r	13.761	28.8
1.15.	13.908	29.4
1.259+2	14.452	28.8
	14.201	29.8
a a North	14.352	30.2
120.0	14.505	30.6
12340	14.653	29.6
1.50.41	14.836	36.6
2 (1995 - 1	19.993	31.4
	12.145	30.4
175.0	15.298	30.6
120.0	15.404	21.2

\$

LOCATION: RANCH CANYON PPC 27S/9W-35 CAD HOLE NUMBER: EV 4113 DATE MEASURED: 8/12/75

TEMPERATURE DEG C	GRADIENT DEG C/KM
8.650	.0
9.640	99.0
9.770	13.0
9.890	20.0
	TEMPERATURE DEG C 9.640 9.770 9.890

1

,

LOCATION: RANCH CANYON PPC 27S/9W-35 DB HOLE NUMBER: EV 4115 DATE MEASURED: 8/12/75

GRADIENT DEG C/KM
.0
132.0
46.0
12.0
9.0
7.0
16.0

LOCATION: MINERAL MTS - RADIO RD PPC 26S/8W-30 CDA HOLE NUMBER: Crater Knoll #2 DATE MEASURED: 8/15/75

DEPTH METERS	TEMPERATURE DEG C	GRADIENT DEG C/KM
10.0	8.010	.0
20.0	8.660	65.0
30.0	8.690	4.0
40.0	8.750	6.0
50.0	8.850	10.0
60.0	8.870	2.0
70.0	8.890	2.0
80.0	8.990	10.0
90.0	9.080	9.0

LOCATION: MINERAL MTS - PPC 27S/8W-6 AA HOLE NUMBER: Crater Knoll #3 DATE MEASURED: 8/15/75

TEMPERATURE DEG C	GRADIENT DEG C/KM
9.230	.0
9.700	47.0
10.210	51.0
10.430	22.0
10.610	18.0
10.700	10.0
	TEMPERATURE DEG C 9.230 9.700 10.210 10.430 10.610 10.700

LOCATION: NEGRO MAG WASH PPC 27S/9W-1 HOLE NUMBER: 21

DEPTH	TEMPERATURE	GRADIENT
METERS	DEG C	DEG C/KM
10.0	13.000	.0
20.0	15.600	260.0
30.0	17.300	170.0
32.0	17.550	125.0

LOCATION:	NATER WELL H2 275/10W-12B	
HALE NUMBER	PHILLIPS	
DATE MEASU	RED: 7/05/76	
DEPTH	TEMPERATURE	GRADIENT
METERS	deg c	DEG C/KM
10.0	14.500	• 0
20.0	17.700	320.0
30.0	20.600	290.0
35.0	21.900	260.0
40.0	23.000	220.0
45.0	23.950	190.0
50.0	24.800	170.0
55.0	25.500	200.0
60.0	26.700	180.0
65.0	27.600	180.0
70.0	28.400	160.0
75.0	29.100	140.0
80.0	29.500	140.0
85.0	30.600	160.0
91.0 91.0	31.200	120.0
95.0	31.300	120.0
100.0	12.500	140.0
105.0	33.000	100.0
110.0	33.800	120.0
115.0	23.800	40.0

LOCATION: PHILLIPS WATER WELL #3 265/10W-25A HOLE NUMBER: PHILLIPS DATE MEASURED: 6/30/76

DEPTH	TEMPERATURE	GRADIENT
METERS	deg c	deg c/km
5,0	14.800	.0
10.0	17.100	290.0
20.0	18.400	260.0
25.0	19.500	220.0
30.0	21.600	300.0
35.0	22.400	280.0
40.0	23.600	240.0
45.0	24.600	200.0
50.0	25.800	240.0
55.0	27.200	280.0
60.0	27.900	140.0
65.0	28.900	200.0
70.0	29.400	100.0
75.0	30.000	120.0
80.0	30.600	120.0
85. 0	30.800	• 0

HOLE NUMP	ER: PHILLIPS	
DATE MEAS	URED: 7/03/76	
DEPTH	TEMPERATURE	GRADIENT
METERS	deg c	DEG C/KM
5.0	17.900	• 0
10.0	17.200	-140.0
15.0	19.100	380. 0
20.0	20.700	320.0
25.0	21.500	160.0
30.0	24.200	540.0
35.0	26.200	400.0
40.0	28.600	48 0.0
45.0	29.300	140.0
50.0	31.800	500.0
55.0	34.900	620.0

LOCATION: WATER WELL #4

LOCATION:	WARER	WELL #5
	275/	9W-17A
HOLE NUMBE	R: PH	ILLIPS
DATE MEASI	vred:	7/02/76

depth Meters	DEG C	DEG C/KM
5.0	12.900	• 0
10.0	15.300	480.0
15.0	17.500	440.0
20.0	19.100	320.0
25.0	20.900	360.0
30.0	22.100	240.0
35.0	23.700	320.0
40.0	25.200	300.0
45.6	26.700	300.0
5∂•0	28.000	260.0
55.0	29.600	320.0
60 . 0	31.200	320.0
05.0	52.400	240.0
70.0	33.700	260.0
75.C	35.600	260.0
0.06	36.400	280.0
85.0	37.900	300.0
9 J • 0	39.200	260.0
95.0	40.200	200.0
100.0	41.600	280.0
105.0	43.100	300.0
110.0	44.400	260.0
115.0	45.600	240.0
120.0	47.000	280.0
125.0	48.600	320.0
130.0	49.700	220.0
135.0	51.000	260.0
140.0	52.680	260.0
145.0	53.400	220.0
150.0	54.600	280.0
155.0	56.000	240.0
160.0	50.800	560.0
170 0	20 600	140+0 230 n
175.0	61 200	120 0
180.0	61.800	120.0
185.0	61,900	20.0

LOCA	IION: RHS KGRA	
	275/10W-23 CA	
HOLE	NUMBER: 5	
DATE	MEASURED: 9/03/75	
NEDTH	TEMPERATURE	GRADIENT
METERS	DEG C	DEG C/KM
10.0	14,480	• 0
20.0	17.450	297.0
	20,130	268.0
40.0	22.580	245.0
50.0	25.000	242.0
60.0	26,930	193.0
70.0	27.650	72.0
0.0 0.0	28,390	74.0
00.0	28,960	57.0
100.0	29.590	63.0
110.0	30.100	51.0
120.0	30,550	45.0
130.0	31.100	55.0
140.0	31.520	42.0
150.0	32.180	66.0
151.5	32.210	20.0
~~~~		

LUCA	TION: RHS K	GRA	
	275/	9W-16 BB	
HULE	NUMBER: 7		
υΛΤΕ	MEASURED:	8/08/75	
рертн	TE	MPERATURE	GRADIENT
METERS		DEG C	DEG C/KM
10.0		16.600	• 0
20.0		23.300	670.0
30.0		28.200	490.0
40.0		32,900	470.0
50.0		37.300	440.0
60.0		41.550	425.0
70.0		45.730	418.0
40.0		49.800	407.0
90.0		53,900	410.0
100.0		57.780	388.0
110.0		61.450	367.0
120.0		65.300	385.0
130.0		68.840	354.0
140.0		72.300	346.0
145.0		74.000	340.0

LOCA	TION: RHS KGRA	
	275/9W-16 AD	
HOLE	NUMBER: 8	
DATE	MEASURED: 8/11/75	
DEPTH	TEMPERATURE	GRADIENT
METERS	DEG C	DEG C/KM
10.0	24.620	• 0
20.0	<b>37.</b> 470	1285.0
30.0	49.320	1185.0
4.).0	60.170	1085.0
50.0	69.580	941.0
<b>60.0</b>	78.120	854.0
70.0	84.080	596.0
80.0	89.650	557.0
90.0	95.400	575.0

LOCA	TION: RHS KGRA	
	275/9W-21 DD	
HOLE	NUMPER: 9	
DATE	MEASURED: 9/05/75	
θεριμ	TEMPERATURE	GRADIENT
METERS	DEG C	DEG C/KM
10.0	20.950	• 0
20.0	32.810	1186.0
23.0	34.000	396.7

LUCA	TION: RHS KGRA	
HOLE	273794-13 ADD NUMPER: 10 NEASURED: 9702775	
DEPTH	TEMPERATURE	GRADIENT
METERS	DEG C	DEG C/KM
10.0	15.370	.0
20.0	19.880	451.0
30.0	23.800	392.0
40.0	27.560	376.0
50.0	32.580	502.0
60.0	37.410	483.0
64.3	39.100	393.0

LOCA	TION: RHS KGRA	
	275/10W-10 DDD	
HOLE	NUMBER: 12	
DATE	MEASURED: 8/11/75	
DEPTH	TEMPERATURE	GRADIENT
METERS	DEG C	DEG C/KM
10.0	14.860	• 0
20.0	18.640	378.0
<b>3</b> 0.0	21 <b>.3</b> 80	274.0
40.0	24.190	281.0
56.0	26.270	208.0
60.0	27.470	120.0
70.0	28.510	104.0
80.0	29 <b>.2</b> 40	73.0
90.0	29.810	57.0
100.0	30 <b>.37</b> 0	56.0
110.0	30 <b>.96</b> 0	59.0
120.0	31,530	57.0
130.0	32.150	62.0
140.0	32.730	58.0
150.0	33,180	45.0
160.0	33.770	59.0
170.0	34.320	55.0
189.0	34.840	52.0
<b>190.</b> 0	35.320	48.0
200.0	3 <b>5.86</b> 0	54.0
203.0	35.980	40.0

LOCA.	TION: RHS KGRA	
	275/9W-7 CC	
HOLE	NUMBER: 14	
υΛΤΕ	MEASURED: NO DATE	
DEPTH	TEMPERATURE	GRADIENT
METERS	DEG C	DEG C/KM
10.0	15,250	• 0
20.0	17.900	265.0
30.0	20.500	260.0
40.0	23.100	260.0
50.0	25.100	200.0
60.0	26,900	180.0
7U.U	28.700	180.0
80.0	30.500	180.0
90.0	31.900	140.0
100.0	33.200	130.0
110.0	34.300	110.0
120.0	35.250	95.0
130.0	36.100	85.0
140.0	36.900	80.0
150.0	37.600	70.0
160.0	38.300	70.0
170.0	39.050	75.0
180.0	39.850	80.0
190.0	40.650	80.0
195.0	41.000	70.0

ION: RHS KG	RA	
275/	9₩-7D DD	
NUMBER: 15		
MEASURED:	NO DATE	
ŤE	MPERATURE	GRADIENT
	DEG C	DEG C/KM
	15.040	• 0
	18.100	306.0
	20.300	220.0
	22.200	190.0
	24.400	220.0
	26.300	190.0
	28.000	170.0
	29.500	150.0
	31.200	170.0
	32.800	160.0
	34.700	190.0
	36.300	160.0
	37.700	140.0
	38.900	120.0
-	39.800	90.0
	40.700	90.0
	41.600	90.0
	41.900	60.0
	ION: RHS KG 275/ NUMBER: 15 MEASURED: TE	ION: RHS KGRA 275/9W-7D DD NUMRER: 15 MEASURED: NO DATE TEMPERATURE DEG C 15.040 18.100 20.300 22.200 24.400 26.300 28.000 29.500 31.200 32.800 34.700 36.300 37.700 38.900 39.800 40.700 41.600 41.900

LOCA	TION: RHS KGRA	
	275/9W-4 AD	
HOLE	NUMBER: 17	
UATE	MEASURED: NO DATE	
рертн	TEMPERATURE	GRADIENT
METERS	DEG C	DEG C/KM
10.0	17.600	• 0
20.0	23,600	600.0
30.0	29.700	610.0
40.0	34.700	500.0
50.0	40.000	530.0
60.0	44.100	410.0
63.0	45.000	300.0

ı

.
## LOCATION: RHS KGRA 27S/R9W-2 CAA HOLE NUMBER: 20 DATE MEASURED: 8/13/75

DEPTH METERS	TEMPERATURE DEG C	GRADIENT DEG C/KM
10.0	12 410	٥
10.0	12.410	0.0
20.0	14.690	228.0
30.0	16.570	188.0
40.0	18.310	174.0
50.0	20.300	199.0
60.0	21.160	86.0
70.0	22.400	124.0
80.0	23.440	104.0
90.0	24.290	85.0
100.0	24.990	70.0
105.0	25.350	72.0
105.5		

1

LUCA	TION: RHS KGRA	
	265/91-32 AA	
HOLE	NUMPER: 25	
DATE	MEASURED: 9/05/75	
DEPTH	TEMPERATURE	GRADIENT
METERS	DEG C	DEG C/KM
10.0	15,590	• 0
20.0	21.160	557.0
30.0	25.030	387.0
40.0	28.080	305.0
50.0	30,960	288.0
60.0	33.590	263.0
70.0	36.200	261.0
80.0	38,550	235.0
90.0	40.510	196.0
100.0	42.600	209.0
110.0	44.790	219.0
120.0	47,090	230.0
130.0	49.330	224.0
140.0	51.260	193.0
144.3	51.360	23.3



- ,

.

.



;

,

LOCATION ALTERATION 75 1A 275 9W 3CBB HOLE NUMBER UU 751A DATE MEASURED 7/22/76

t



.

,

,

.



τ

.



,

•





.

LOCATION ALTERATION 76-1A RKGRA 27S 9W 34 CA HOLE NUMBER UU 76-1A DATE MEASURED 8/ /76



.

,

.

4



.

,



.

.

.





· · · ·

÷





LOCATION

RKGRA TG-2

-

-



,

.

LOCATION

RKGRA TG 3





.

.



-

Figure 21



٤,