PRELIMINARY

GEOTHERMAL EVALUATION AND ANALYSIS OF THE YUCCA MOUNTAIN REPOSITORY, NEVADA

FINAL REPORT
FOR THE PERIOD

JULY 1, 1989-DECEMBER 31, 1989

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I. INTRODUCTION

This is the final report on the geothermal analysis and evaluation for the proposed nuclear waste repository at Yucca Mountain, for the period July 1, 1989 to December 31, 1989.

The Yucca Mountain area is situated within a region which has been described by Sass et al. (1971) as the "Eureka Low". The heat-flow estimates in this area are reported to be lower than the average values typical of the Basin and Range province (40-63 mWm^{-2} versus 80-90 mWm^{-2}). Heat-flow values are derived by measuring the thermal conductivities of core (rock) samples taken from selected drillholes. Thermal profiles (gradients) are recorded from the same wells. Using these two variables, heat-flow estimates are calculated using a basic mathematical formula (i.e. q=KT, where q=heat-flow, K=thermal conductivity and T=temperature gradient).

Obviously, the accuracy and validity of such calculations are dependent upon a number of factors, including the conditions of the drillholes, when measurements were recorded and natural and physical parameters.

Thermal measurements taken within the Yucca Mountain region, to date, have been inconsistent and misleading. Temperature gradient data collected from drillholes within and outside of the proposed repository perimeter are subject to question for the following reasons: (1) The holes were not constructed properly with the annulus between access casing and borehole wall completely sealed off with grouting, and the holes filled with water. (2) Temperature measurements were made in some cases too soon after drilling, where equilibrium conditions had not been reached. (3) Many of the drillholes do not penetrate below the water table. Without these conditions being met, thermal logging can be attenuated by hydrologic disturbances within the geologic formations. Sass et al.(1988) affirms this by stating,

" The temperature data suggest that the thermal regimes of both the saturated (SZ) and unsaturated (UZ) zones are strongly influenced by a complex hydrologic regime in the saturated tuffs and underlying Paleozoic carbonate rocks...and...The quality of the presently available data set does not allow an unambiguous interpretation of heat-flow data from either the UZ or the SZ....For the UZ, this means reconfiguring the WT series of holes so that temperatures can be measured in water-filled pipes. For the SZ, access pipes must be grouted in to total depth to ensure that all hydrologic disturbances observed are in the formation, and not merely in the annulus between casing and borehole wall".

As an example, well UE25a-3, located approximately 10 km west of the repository site exhibits a heat-flow value of 130 mWm^{-2}, whereas UE25a-1 (11.5 km WSW of UE25a-3) indicates only 48 mWm^{-2}. These anomolies cannot be resolved without properly constructed drillholes, combined with appropriate thermal measuring techniques.

II. COMPUTER CONTOURED HEAT-FLOW MAPS

In 1982, Sass and Lachenbruch interpreted heat-flow data to extend the the southern boundary of the "Eureka Low", essentially bisecting the Nuclear Test Site (NTS) (Figure 1). However, in their 1988 report, Sass et al. qualified their prior action, stating that it could just as easily been interpreted (contoured) as an isolated thermal sink with then-exisiting data. The subjective nature of these interpretations leave much to doubt. Especially considering anomolies in the data taken in and adjacent to the proposed repository site.

To provide another interpretation of these data, DES has produced computer-generated, contour maps of the area, utilizing a graphics system designed by Golden Software. The program "Surfer" allows data points to be located by geographic coordinates (i.e. latitude and longitude). In this case, data represent heat-flow measurements in HFU (heat-flow units) for selected drillholes used by Sass et al. (1971,1988). A grid is produced which is used to develop a contour map. Three values are plotted: X,Y (coordinates) and Z (lines of equal values). The program is instructed to search out a prescribed radius from each plotted point, thus

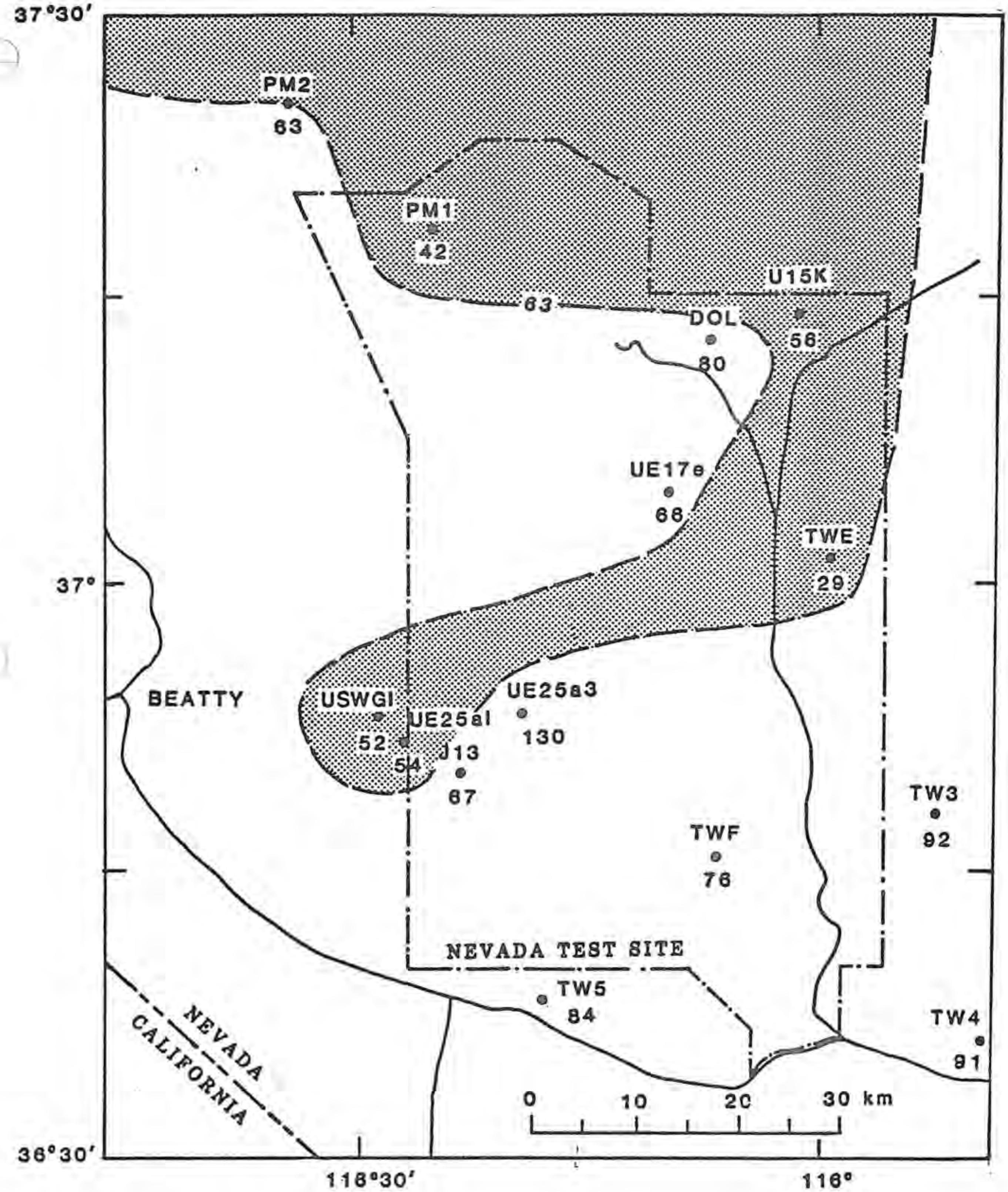


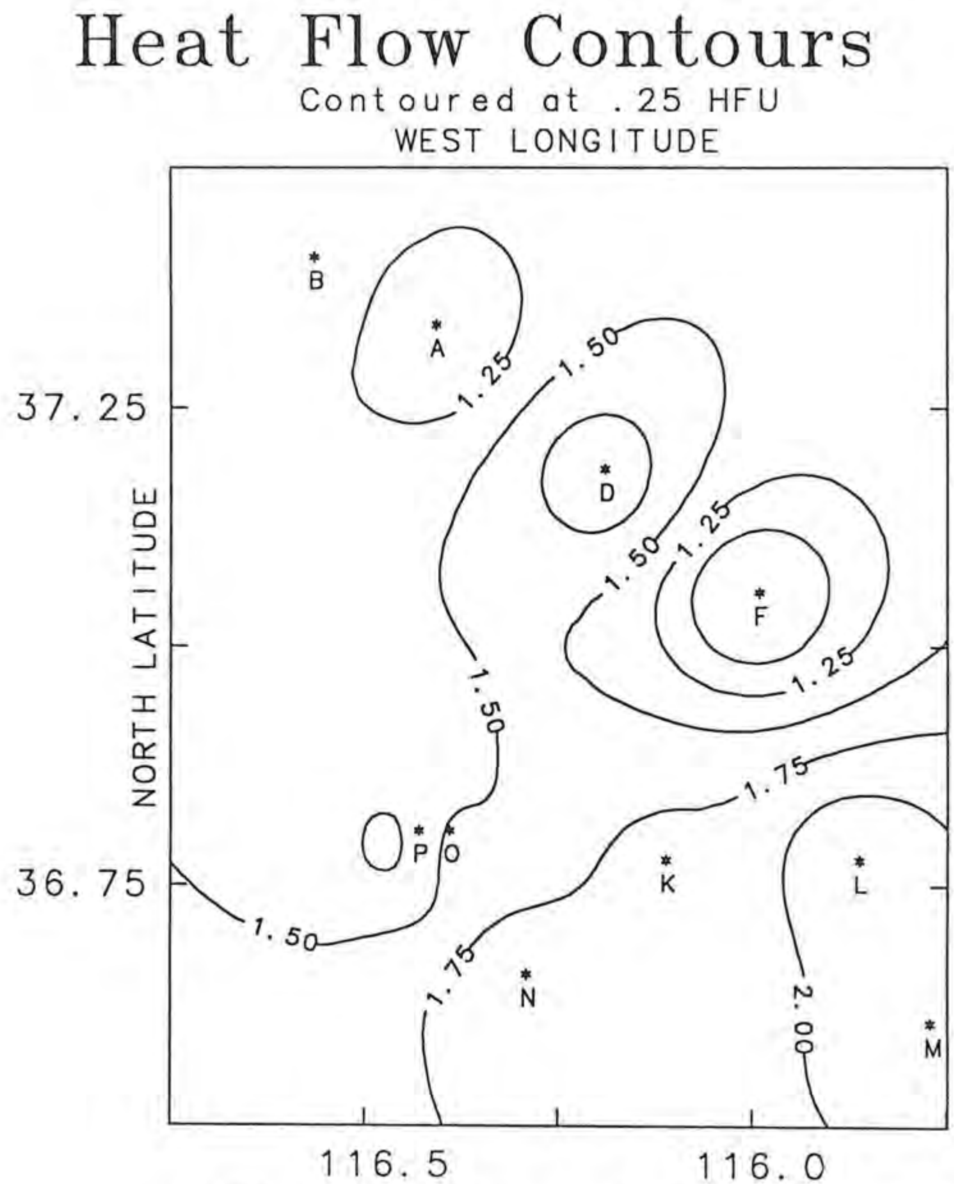
Figure 1. Configuration of 63 mW m^{-2} contour (1.5 heat-flow units) in the vicinity of the Nevada Test Site (from Sass and Lachenbruch, 1982). Stippled area has heat flow less than 63 mW m^{-2}.

creating contour lines of equal values. Geographic coordinates correspond to the boundaries in Figure 1.

Our maps do not coincide with Sass's observations. The 1971 data produced a 1.5 HFU ($63 mWm^{-2}$) contour which does extend through the NTS, however it doesn't register as an extension of the Eureka Low (Figure 2) . Furthermore, there is a 1.75 HFU contour running across the southern half of the NTS.

The 1988 data created even more interesting graphics (Figure 3). The 1.5 HFU line still extends through the NTS, though somewhat modified. But the major change is represented by the higher heat-flow contours surrounding well UE25a-3 (3.1 HFU).

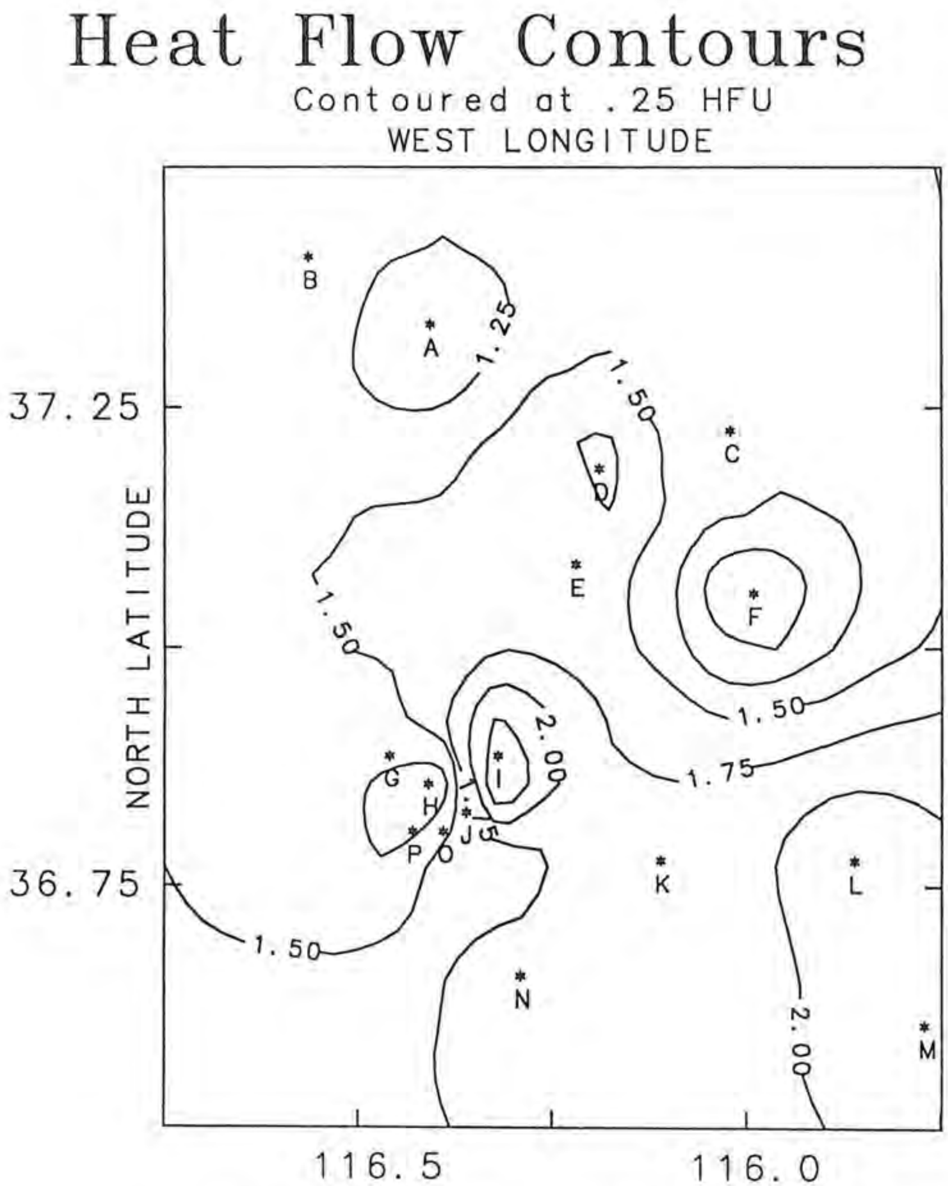
If all of this appears nebulous and confusing, then we have accomplished our objective- to substantiate that the quality of the heat-flow data is subject to question. Interpretations and analyses of the thermal regimes at Yucca Mountain, therefore, become vague and ambiguous, including any discussions on the geothermal resource potential. Consequently, DES proposed new methodologies and acquisition of additional data for the current project year (July 1, 1989 to June 30, 1990). Stringent budget restraints have curtailed this effort, and we have resorted to other approaches.



WELL DATA

Well	HFU	Symbol
PM-1	1.0	A
PM-2	1.5	B
DOL	1.9	D
TWE	0.7	F
TWF	1.8	K
TW3	2.2	L
TW4	2.2	M
TW5	2.0	N
TW6	1.6	O
UE25b1	1.1	P

Figure 2. Heat-Flow Contours (From Sass et al. 1971)



WELL DATA

Well	HFU	Symbol
PM-1	1.0	A
PM-2	1.5	B
U15K	1.3	C
DOL	1.9	D
UE17e	1.6	E
TWE	0.7	F
USWG1	1.3	G
UE25a1	0.6	H
UE25a3	3.1	I
J13	1.6	J
TWF	1.8	K
TW3	2.2	L
TW4	2.2	M
TW5	2.0	N
TW6	1.6	O
UE25b1	1.1	P

Figure 3. Heat-Flow Contours (From Sass et al. 1988).

II. TEMPERATURE DATA

Within the east-central and south-central sections of Nevada, extensive petroleum exploration and development has occurred. Also, data from drillholes associated with AEC tests in Hot Creek Valley were available. Much of this activity is within the boundaries of the "Eureka Low". Wildcat exploration wells may be drilled to over 10,000 feet, and can provide temperature data from the deep Paleozoic carbonate units which underlie the "Eureka Low", and the proposed repository site.

DES has compiled temperature information from selected drillholes within and adjacent to the "Eureka Low". Sources have included Nevada State Department of Minerals, University of Nevada, Bureau of Mines and Geology, and Bureau of Land Management, Nevada State Office. We have also made personal contacts with the following oil companies and representatives: Makoil, Inc. Stanton, CA. Mr. Gregg Kozlowski, Apache Corporation, Denver, CO. Mr. Paul Noble, J.R. Bacon, Inc. Shelby, MT. Mr. Roy Brown, Pioneer Oil and Gas, Midvale, UT. Mr. Jason Blake and True Oil Co., Casper, WY. Mr. Lowell Lischer.

Well logs for hydrocarbon exploration list bottom hole temperatures (BHT) and total depths (TD). However, recorded temperatures may be subject to some of the same problems encountered in other exploratory drillholes (i.e. hydrologic perturbations and not allowing adequate time to equilibrate). Therefore, in interpreting this data, the actual values may not be accurate representations of actual temperatures. We can, however, analyze the relative differences in temperature from well to well, and between locations.

We have plotted temperature and depth data from petrochemical logs for Railroad Valley (Figure 4), Pine Valley (Figure 5) and AEC drillholes in Hot Creek Valley (Figure 6). For the Nevada Test Site (NTS), temperature and depth data were taken from Sass et al.(1988), and represent thermal data recorded expressly for determining temperature gradient profiles (Figure 7). The NTS information provides a control data set to be used as a comparison to the oil well and AEC data.

Depth and temperature data (X,Y coordinates) were plotted using a program called "Grapher", also designed by Golden Software. A best-fit line was drawn with a polynominal program option which produces best-fit lines from degrees zero to ten. A degree factor of two was utilized which resulted in an optimum residual sums-of-squares fit for each graph.

IV. DISCUSSION OF TEMPERATURE-DEPTH RELATIONSHIPS

At depths less than 8,000 feet the data fron Hot Creek Valley (Figure 8) and Railroad Valley (Figure 9) compare favorably. For depths greater than 8,000 feet, no data exist for Hot

RAILROAD VALLEY WELLS

Permit #	Well	Temp.(F)	Depth(Ft)
105	Nyala Unit #1	197	7780
265	Bullwhacker Spr. #1	222	9200
278	F-2-4-55 #1	146	5950
280	F-30-4-55 #1	146	8347
293	White Rvr.Valley #7	166	5000
310	Warm Spr. Fed. #10-14	201	9180
371	White Rvr. Unit #3	116	8700
374	Grant Canyon #2	160	6389
482	Lone Tree #1-14-43	127	4703
483	Lone Tree #2-23-23	125	4519
498	So. Grant Fed. #11-32	132	4681
506	Railroad JVP-1	158	6595
519	Abel Spr.Unit #41-4	185	5348
520	Hanks #1	128	4865
529	True-Bird Fed. #31-23	226	11912

Figure 4. Source: University of Nevada, Bureau of Mines and Geology

PINE VALLEY WELLS

PERMIT#	WELL	TEMP.(F)	DEPTH(FT)
121	Damele Bros.#2	102	3612
186	Nost I#1	224	9486
284	Blackburn #1	109	4893
301	Blackburn #2	135	5272
324	Blackburn #3	105	7955
333	Blackburn #4	240	8100
334	Blackburn #5	218	8059
335	Blackburn #6	218	7648
350	Blackburn #10	265	7645
356	Blackburn #12	225	8426
357	East Bailey Rnh. #1	248	9000
415	Big Pole Crk. #1-11	188	8217
425	E. Henderson Crk.#1	163	10977
442	Blackburn #14	248	7201
450	Blackburn #15	202	7567
458	Blackburn #16	224	7208
488	MaryKay Fed. #1	197	7505
491	Blackburn #17	238	7392
495	Foreland Pony Crk.#1-22	230	8505

Figure 5. Source: University of Nevada, Bureau of Mines and Geology

HOT CREEK VALLEY
DRILLHOLES

HOLE	TEMP.(F)	DEPTH(FT)
UC 3	156	4846
UC 3I1	150	4870
UC 3I2	105	2556
UC 3I3	110	3002
UC 4	168	5500
UC e11	147	4226
UC e17	194	7978
UC e18	195	6503
UC e20	201	6000
UC e21	185	6495
HTH #1	122	3700
HTH #5	188	6007
UC 1 P2-SR	143	3694

Figure 6. Source: University of California, Lawrence Livermore Lab.

NEVADA TEST SITE
DRILLHOLES

HOLE	TEMP.(F)	DEPTH(FT)
UE25a1	140	2477
UE25a4	71	492
UE25a7	77	886
UE25b1h	99	1193
UE25p1	129	5742
USW G1	141	1827
USW G2	124	4101
USW G3	110	4495
USW G4	97	2986
USW H1	142	5938
USW H3	108	3895
USW H4	104	3897
USW H5	104	3609
USW H6	128	3898
J 13	96	3346
VH 1	107	2221
VH 2	129	3937

Figure 7. From Sass et al. 1988.

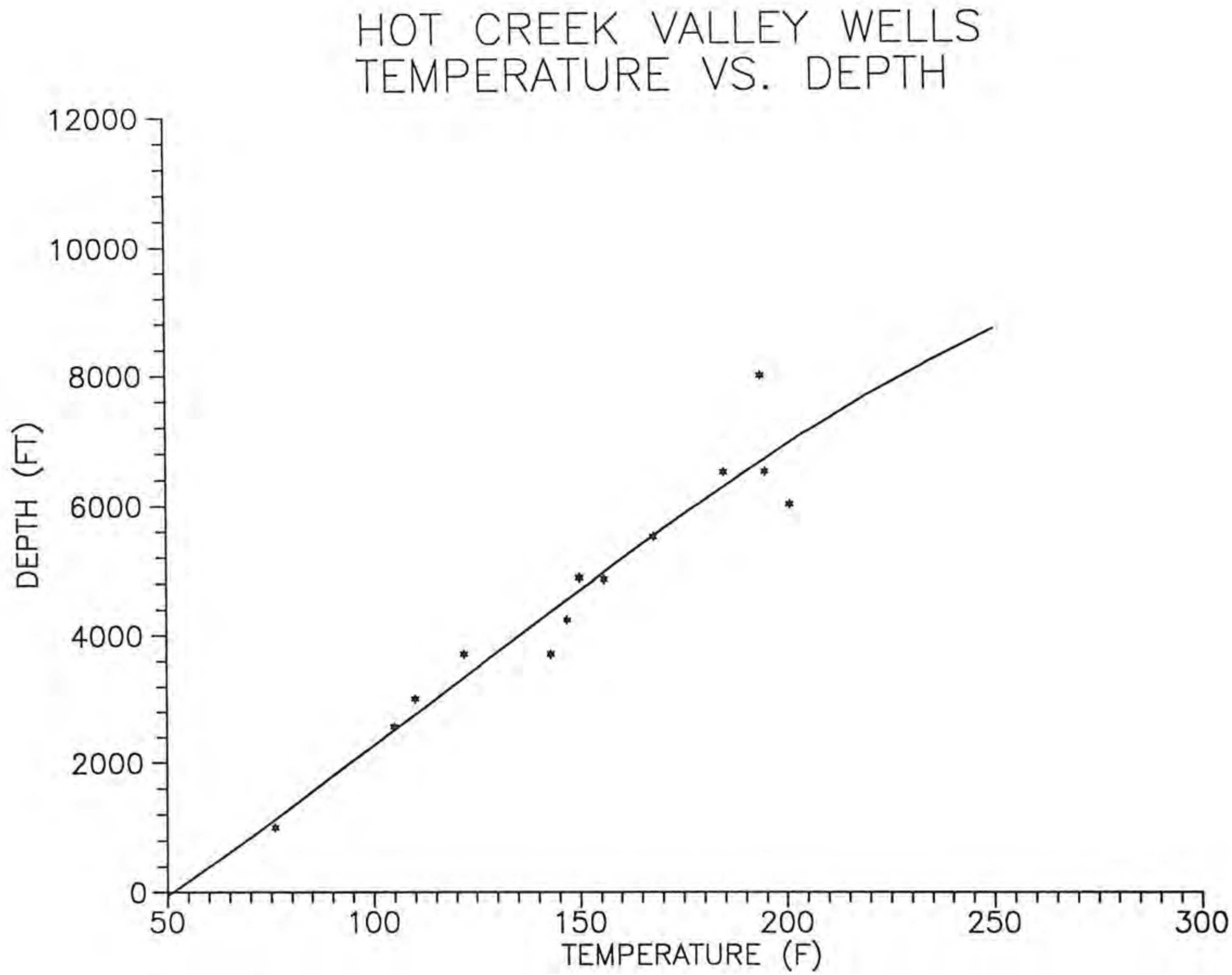

HOT CREEK VALLEY WELLS
TEMPERATURE VS. DEPTH
DEPTH (FT)
12000
10000
8000
6000
4000
2000
0
50
100
150
200
250
300
TEMPERATURE (F)

Figure 8.

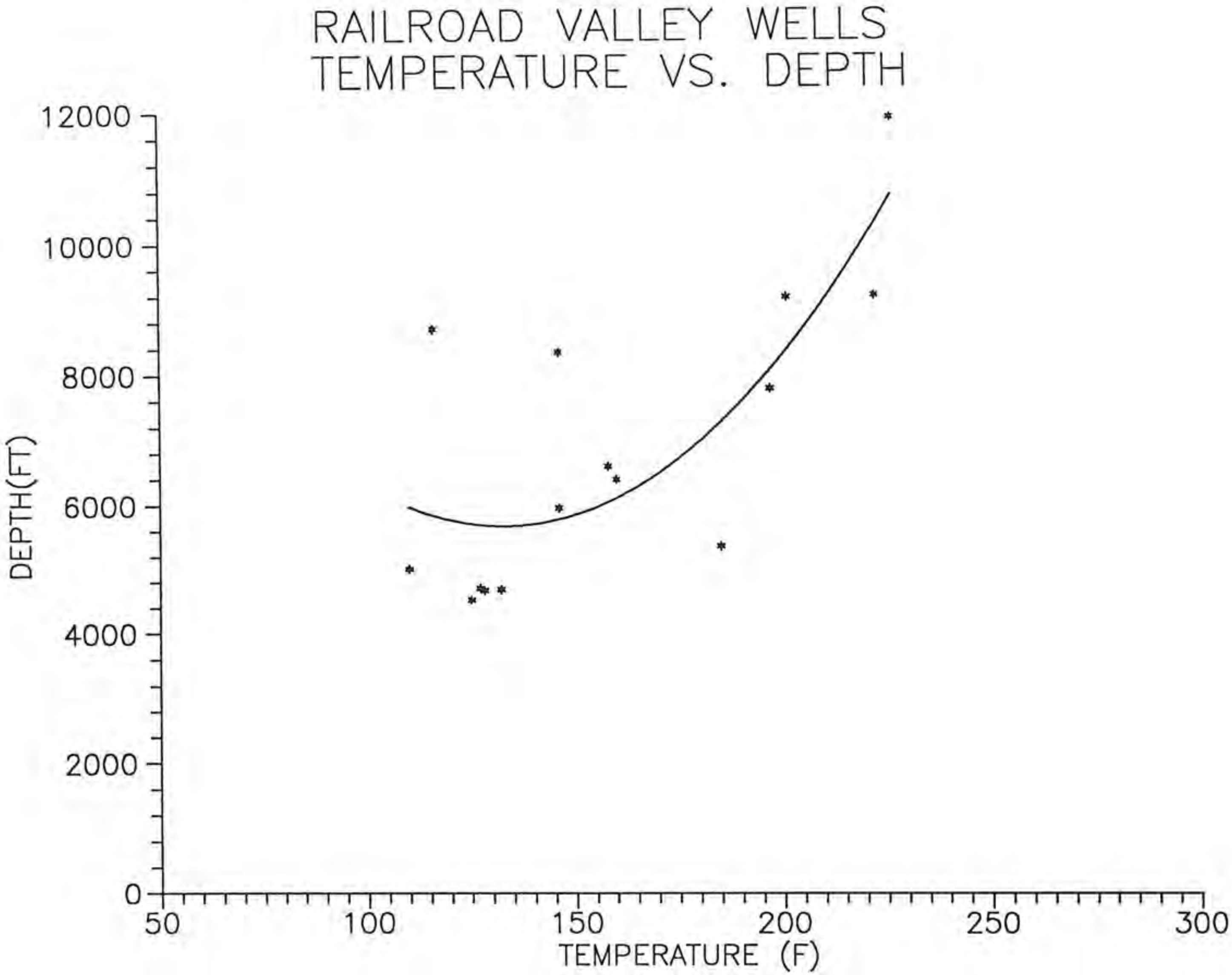

RAILROAD VALLEY WELLS
TEMPERATURE VS. DEPTH
DEPTH(FT)
0
2000
4000
6000
8000
10000
12000
50
100
150
200
250
300
TEMPERATURE (F)

Figure 9.

Creek Valley, and temperature as a function of depth for Railroad Valley wells is spurious with values ranging from 110°F to approximately 225° at similar depths.

In comparing Hot Creek Valley and Railroad Valley data, temperatures for Hot Creek Valley are 15 to 25°F higher for similar depths. Again, it must be stressed that the quality of the Railroad Valley data is questionable. Between 6,000 and 7,000 feet, temperatures range from 145 to 160°F in Railroad Valley, whereas similar readings were made at depths between 4,000 and 5,000 feet in the Hot Creek Valley wells.

Data from an area outside the "Eureka Low", represented by the Pine Valley graph (Figure 10) indicate consistently higher temperatures for depths between 7,000 and 9,000 feet when compared to the other data sets, which ostensibly are located within the "Eureka Low". However, similar temperatures at a depth of 9,600 feet can be observed in both the Railroad and Pine Valley data sets.

The data generated for the NTS wells (Figure 11) are similar to the Pine and Railroad Valley temperatures for depths to 6,000 feet. At intermediate depths, between 2,000 and 5,000 feet, the NTS data show lower readings for comparable depths when compared to data from Hot Creek Valley.

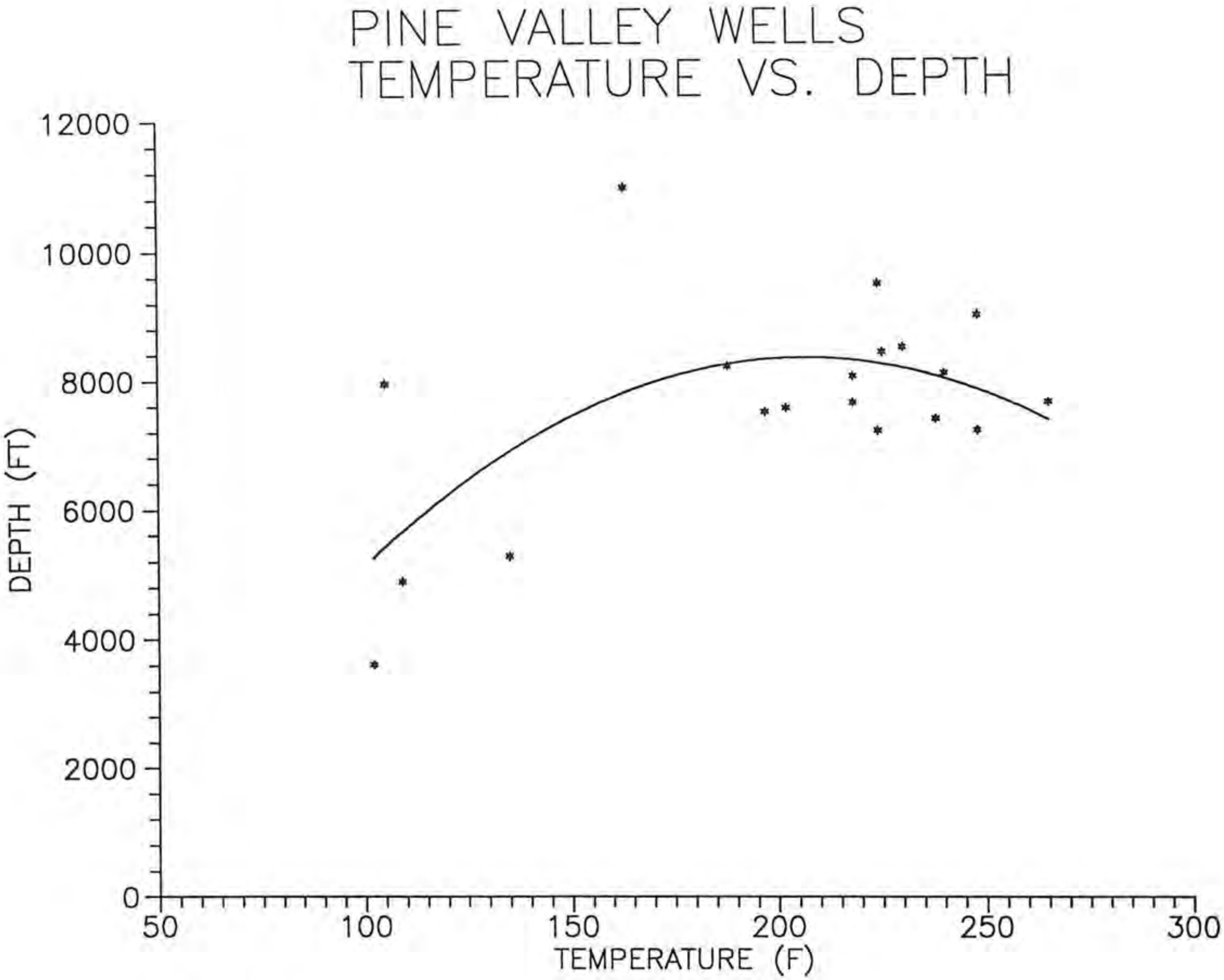

PINE VALLEY WELLS
TEMPERATURE VS. DEPTH
DEPTH (FT)
12000
10000
8000
6000
4000
2000
0
50
100
150
200
250
300
TEMPERATURE (F)

Figure 10.

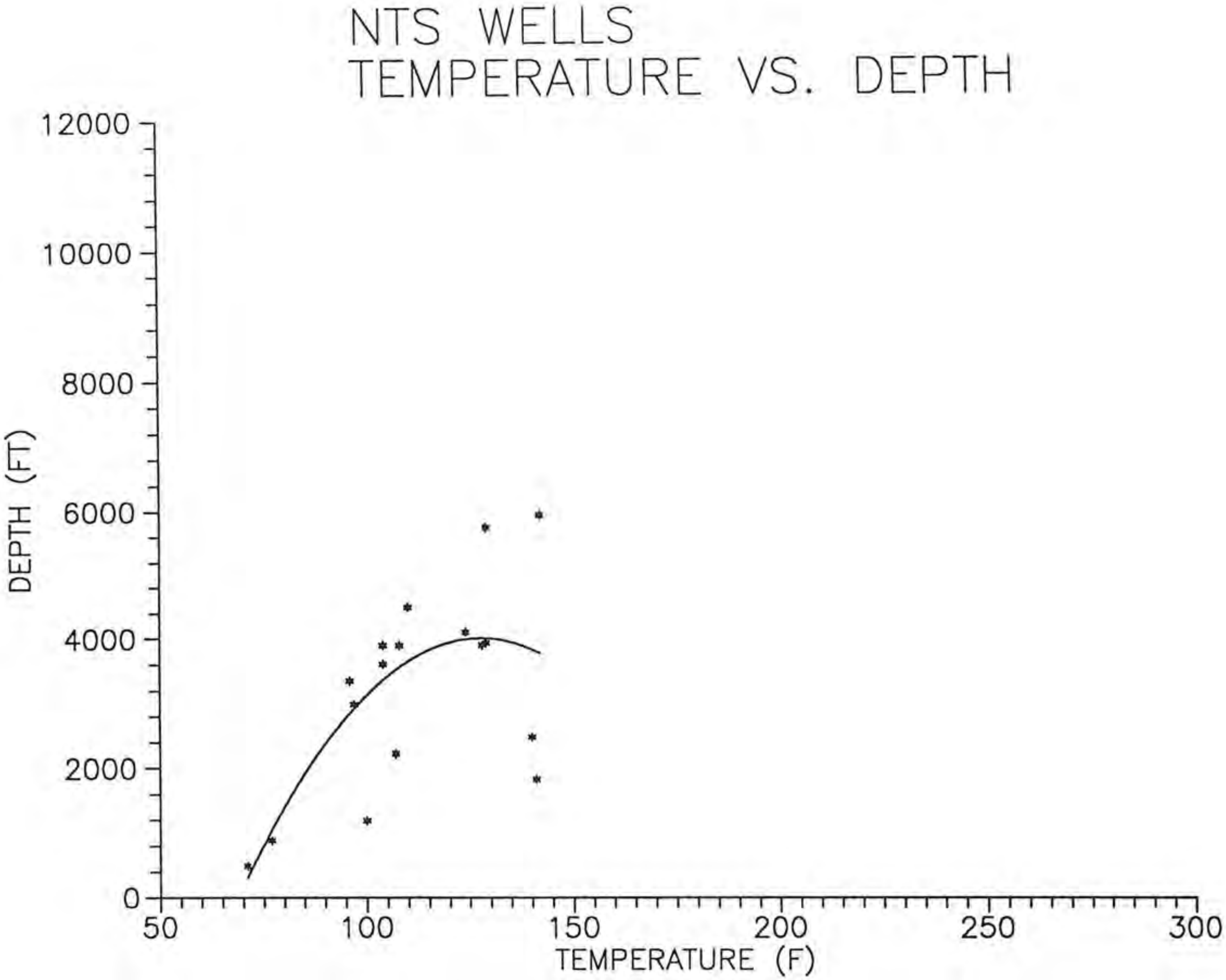

NTS WELLS
TEMPERATURE VS. DEPTH
DEPTH (FT)
0
2000
4000
6000
8000
10000
12000
50
100
150
200
250
300
TEMPERATURE (F)

Figure 11.

The only significant fact that can be summarized concerning the data from the three areas within the "Eureka Low" is a wide variability in the temperature-depth relationships. The fact that wells from Hot Creek Valley are consistently hotter for comparable depths to 7,000 feet, may be important. Below 7,000 feet, the data set for Pine Valley (outside the "Eureka Low") inddicate higher temperatures when compared to Railroad Valley.

In summary, the data suggest that no distinction can be made between data from sites within the "Eureka Low" for depths less than 5,000 feet. It is curious that the Hot Creek data (Figure 8), which is located within the boundary of the "Eureka Low", has comparable temperatures at shallower depths to the data from Pine Valley(outside of the boundary).

The data tend to suggest that the western boundary of the "Eureka Low", in the vicinity of Hot Creek Valley, may require reevaluation based on the temperature-depth information presented here.

V. REFERENCES

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