THREE-METER TEMPERATURE SURVEYS AT THREE SITES IN NEVADA AND UTAH

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3 June 1980

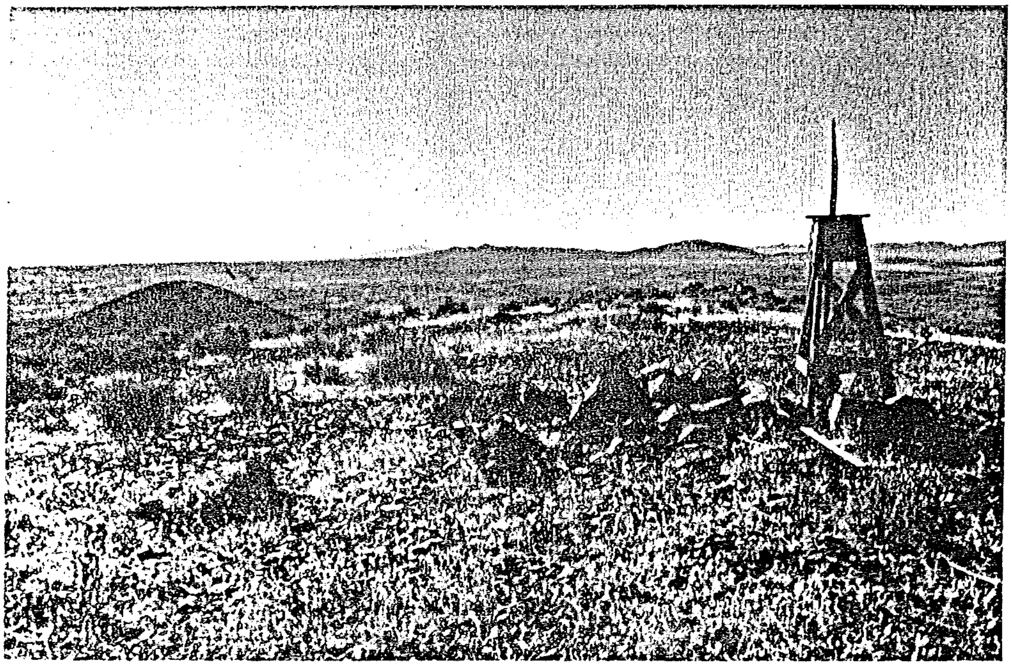


Plate I. Deeth, Nevada prospect from Hot Hole Triangulation Station on Twin Buttes.

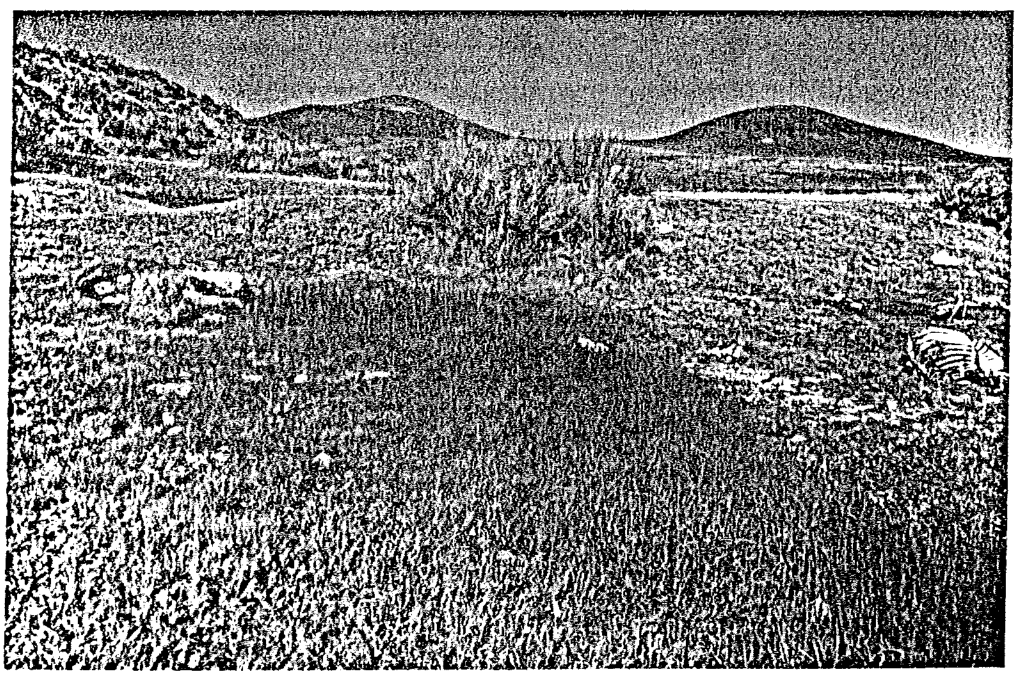


Plate II. Twin Buttes viewed from the Hot Spring on Mary's River.

Introduction

Numerous attempts have been made to extrapolate temperature patterns to depth using measurements in very shallow holes. The region from 0 to about 20 meters, is one in which diurnal and seasonal temperature waves as well as the low conductivity weathering severely perturb the normal temperature log. I refer to this zone as the "dermal zone". The diurnal wave normally dies out by one meter depth; the seasonal wave is the principal contributor to earth temperatures down to about 10 meters, where the geothermal gradiant begins to prevail. The seasonal wave is an exponentially declining function of the ambient surface temperature, always propogating downward while diminishing in amplitude. Figure 1 illustrates the nature of the pure seasonal wave (the diurnal is here omitted). In Figure 2 the seasonal is superimposed upon the geothermal gradient.

Most practitioners of shallow temperature surveys have relied upon measurements at a common depth (usually one or 2 meters). Some have tried to compute the seasonal wave from weather records in order to subtract it from a standard temperature log. The latter procedure is fraught with uncertainties of climate, and soil properties; while the former is very sensitive to variations in soil diffusivities, well locations, and elevations. Nevertheless, the common depth measurements conducted simultaneously (i.e., on one particular day) in uniform environments and soil regimes can yield qualitative thermal pattterns, reflective of deeper thermal anomalies. The method was demonstrated by AMAX Geothermal in two recent reports*; wherein correlation with 30-and 40-meter temperatures was clearly seen.

Because of uncertainties in soil diffusivities affecting the rate of propogation and amplitude of the seasonal wave, and the variability of weather cycles, we decided to sample at multiple depths in order to measure a significant segment of the seasonal curve. By so doing one is able to compute diffusivities, and, hence, conductivities, as well as fit to known or model weather cycles. Furthermore, one can select common depth points for comparison, that fall on stable portions of the temperature curve. To do this seven thermistors were installed at 1/4-meter spacing between 1.5 and 3 meters in 1/2" PVC pipe and sealed in a resin core. This thermistor "tree" could then be installed in pre-drilled 3-meter holes, containing a sleeve of a 3/4" PVC pipe. Wires from each thermistor lead to a plug at the surface, so that the resistance of each thermistor (corresponding to its temperature value) could be read through a 10-position switch, using a precision ohmmeter.

At the time of logging, soil samples are taken by hammering a section

*"Temperature Surveys in 2-meter holes can be effective", 5 June 1978: and "Three-meter vs. forty-meter temperatures in Dixie Valley, Nevada", 23 August 1979.

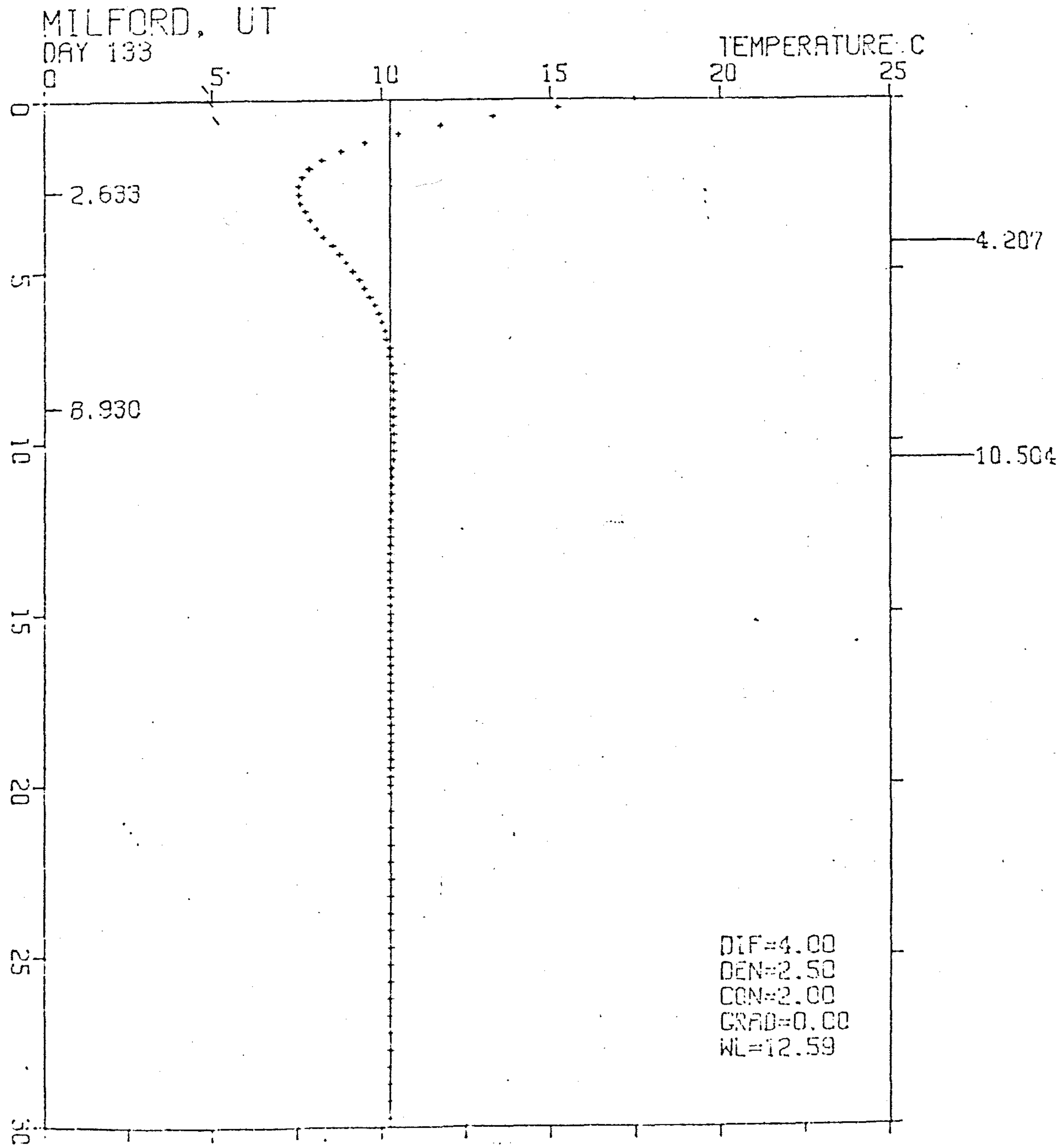


Figure 1. Theoretical seasonal log for Day 133 corresponding to a winter low occurring on 11 January and a diffusivity of 4.0.

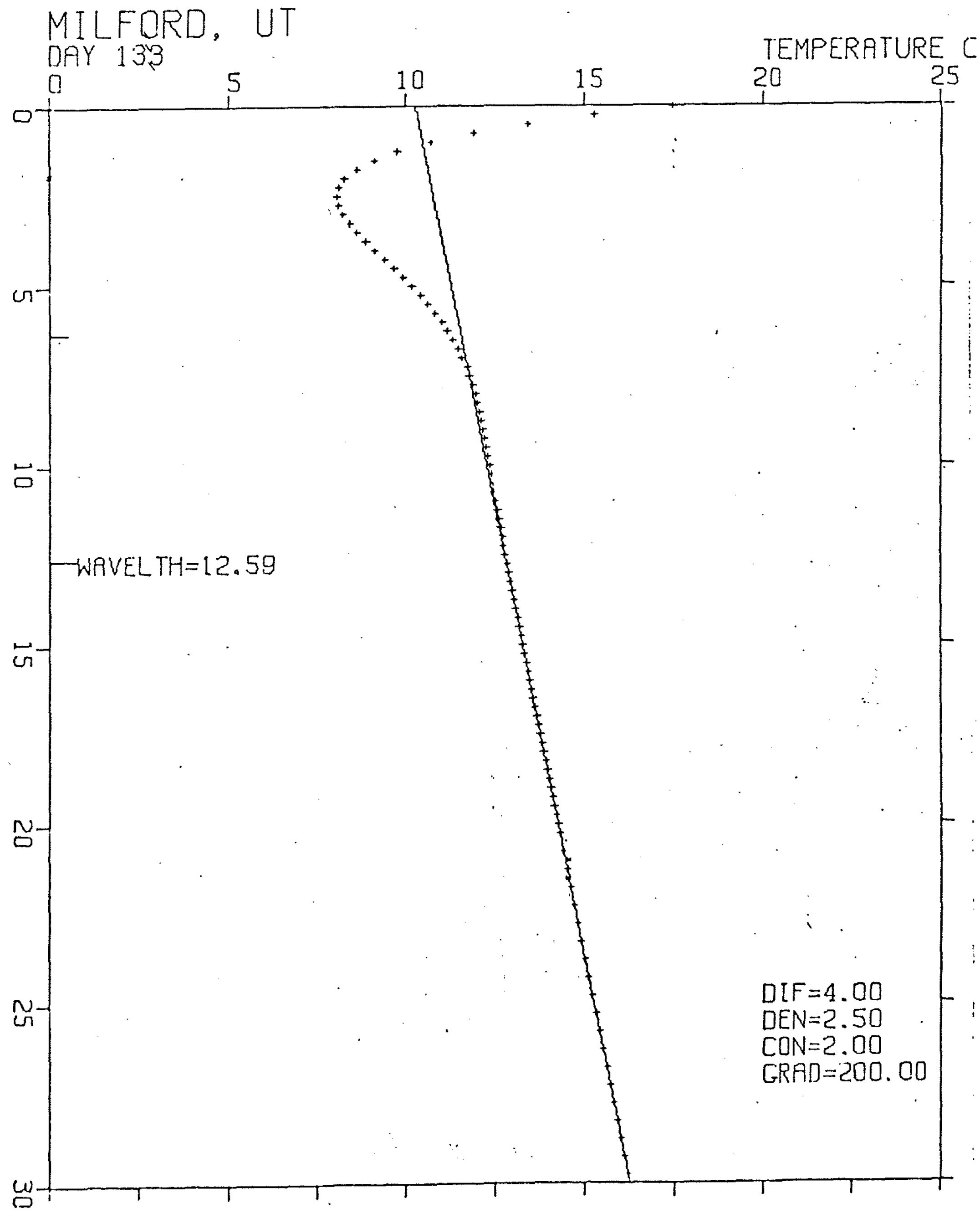


Figure 2. The seasonal log of Figure 1 superimposed on a geothermal gradient of 200°C/km.

of pipe into the ground and are then weighed on a triple-beam balance to compute density. This quantity in conjunction with a determination of mean diffusivity, from the measured depth of the extremum, permits the calculation of soil conductivity. This quantity will prove valuable in future attempts to compute heatflow.

During May 1980 three such dermal surveys were conducted utilizing pre-drilled ten-foot holes. Despite the loss of some critical holes during the months intervening between drilling and logging, each survey revealed a thermal pattern from which subsequent deeper drilling might be planned. In addition engineering problems were encountered that must be surmounted in subsequent systems.

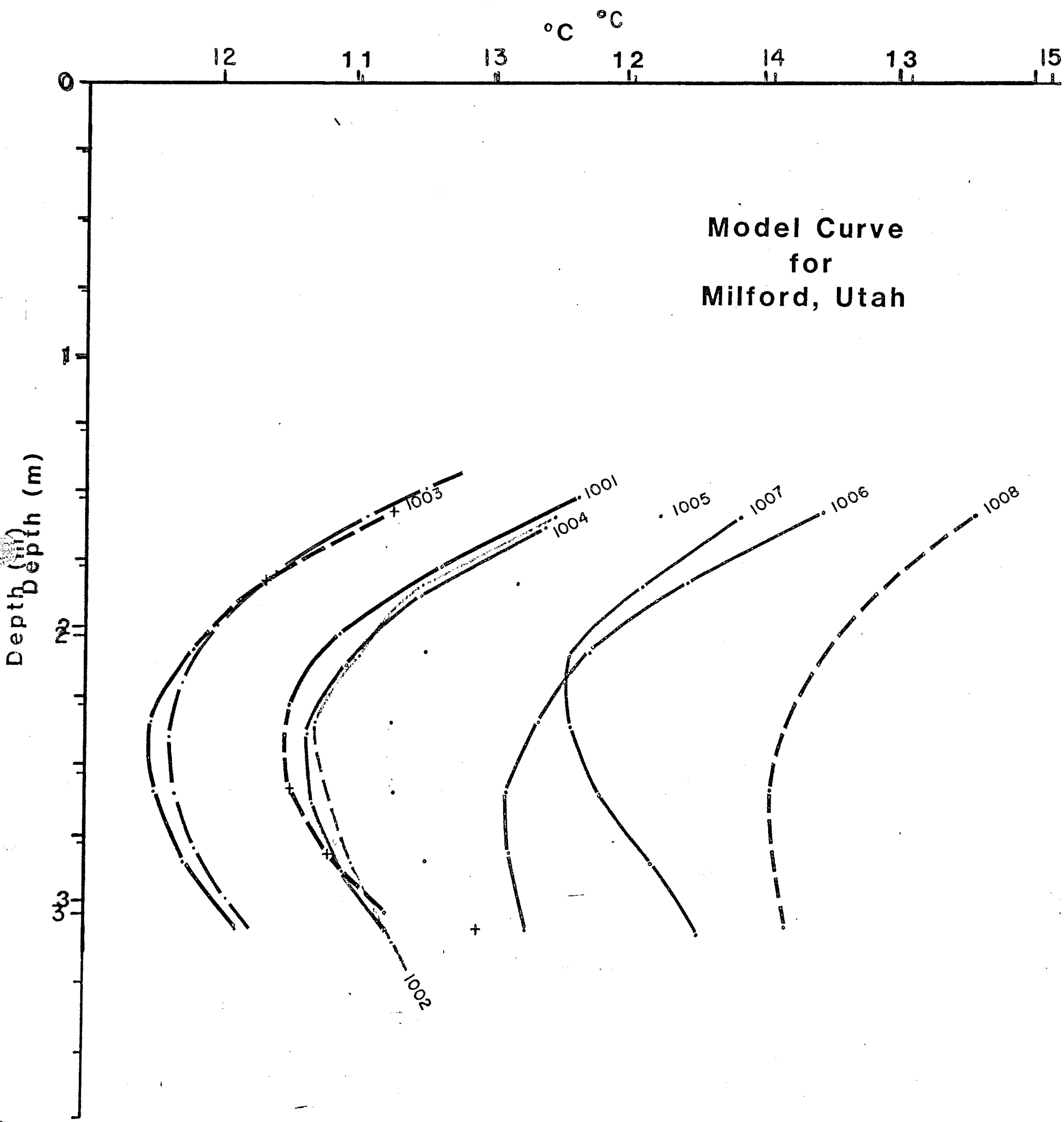
McCoy survey

A previous report depicted the correlation of 2, and 3 meter temperatures at gradient well sites with 30-and 40-meter temperature patterns at the McCoy, Nevada prospect. The experiment demonstrated that the McCoy thermal anomaly would have been easily detected and outlined by a dermal survey. The current survey extends a thermal profile from the thermal anomaly westward through Hole in the Wall and into Dixie Valley. Eight 3m holes survived the winter; unfortunately none of these were situated adjacent to a deep hole.

The thermistor trees were installed on 10 May and logged on 12 May. Figure 3 reproduces the resulting logs for the 8 trees. Note that the winter's low has penetrated to about 2.25 meters in each case, corresponding to a diffusivity of 3.41. A model curve based on this value and the 1977 winter temperature record at Milford, Utah is shown as an overlay for comparison. The lateral shift of the curves is due both to local heat flow variations as well as to the differing mean annual temperature values at each station, resulting from elevation differences. Individual distortions of the curves result from a) soil changes, and b) superimposed temperature gradients. The effect of a high gradient is to steepen the lower segment of the curve and to displace the minimum upwards.

Because temperature varies least in the region of the extremum, common-depth levels of 2.0, 2.25 and 2.5 meters were selected for profiling. The resulting pattern appears in Figure 4. Here the 2.25m measurements (solid blue curve) are taken to be most reliable. Adjusting this curve for altitude (adapting a 10^{0}/km vertical lapse rate) yeilds the blue dashed curve. The 30m temperatures, from the nearest deep wells are plotted in brown (altitude adjusted dashed). The dip in the 30m profile can only be inferred from the dermal profiles, since no deep hole was present there. Had there been one, I am confident that the dip would have been observed.

Figure Thermal logs for the eight holes along Hole in the Wall wash, McCoy, Nevada.
Overlay: Model curve, typical of 13 May for a diffusivity of 3.41, corresponding to the value determined in Hole 1004.



McCoy Thermistor Profiles

12 MAY, 1980

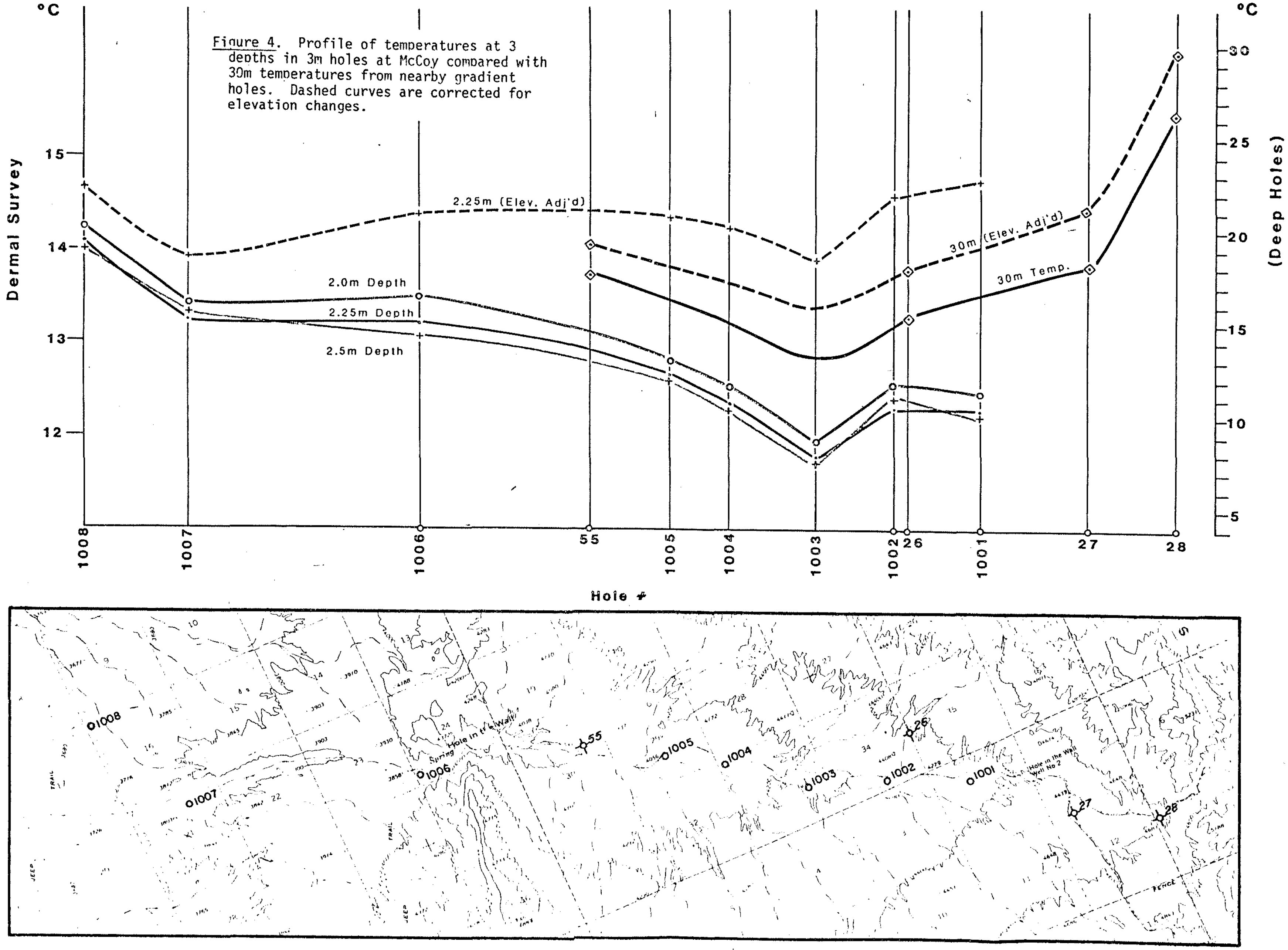


Figure 4. Profile of temperatures at 3 depths in 3m holes at McCoy compared with 30m temperatures from nearby gradient holes. Dashed curves are corrected for elevation changes.

Thus, coming off the flank of the thermal anomaly, temperatures reach a low at Well 1003, beyond which, westward, they rise slightly. Near the wash below Hole in the Wall, the temperature is depressed; on a terrace away from the wash, temperatures increase. Possibly the profile might have appeared quite different, if the holes could have been placed a kilometer or more distant from the wash.

Deeth survey

During 1979 a self-potential survey encountered a large (>800m) negative SP anomaly across intrusive rocks of Twin Buttes, near Deeth, Nevada. Several hot springs discharge along the Mary's River to the east leading us to suspect that the SP anomaly might be related to temperature. In the absence of deep temperature holes in the vicinity, an array of 3m holes was drilled. Eleven were found useable and thermistor trees installed on 11 May. Logging was done on 13 May, resulting in the curves of Figure 5. Only a crooked profile can be constructed from the available wells, as shown in Figure 6. Four depths-2.,2.25, 2.5 and 3.-were plotted; again, the extremum fell most commonly near the 2.25m level and hence it is the most reliable. Only one hole (1004) occurred at a deeper temperature hole (gradient 68°/km). The original SP anomaly, taken along the projected profile is shown for comparison. Evidently, elevated temperatures occur at the Buttes, and to some extent near the river at Hole 1010.

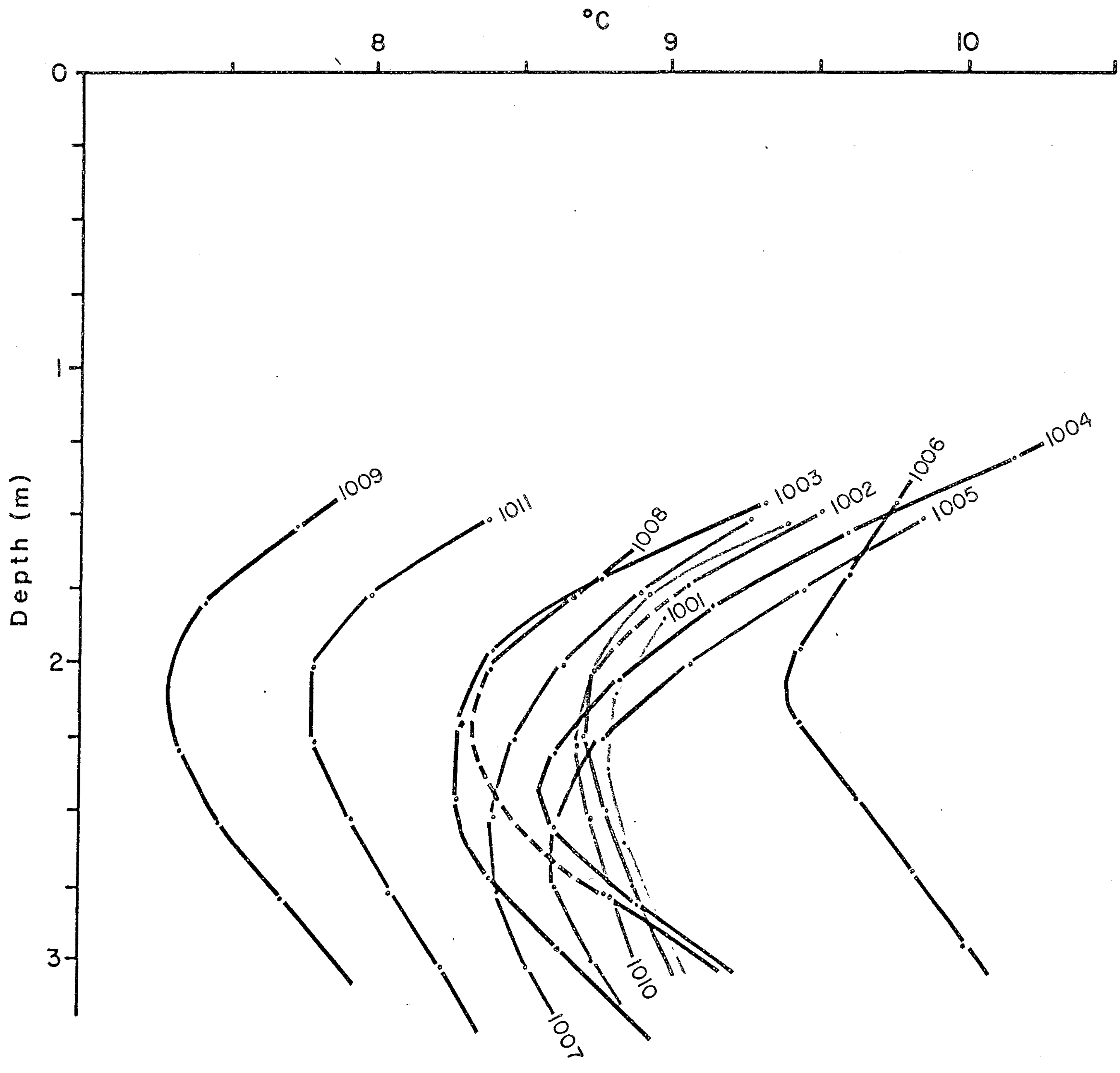
Topaz survey

John Deymonaz encountered warm water in a well (Fera No. 38) on the east pediment of the Dugway Range in Juab County, Utah. Eight 3m holes were drilled in the vicinity and on 14 May thermistors were installed. Logging was done on the following day with the resulting curves of Figure 7. Again, levels of 2.0, 2.25 and 2.5 meters were found to be the most stable and their temperature profiles are plotted along two lines (Figure 8). The thermal anomaly is evidently delimited on the east by a fault parallel to the range front. Its northern, southern and western extent remain undetermined. Addition dermal measurements are needed in order to fully determine the extent of this feature.

Engineering problems

Altogether 30 thermistor trees were constructed. About 15% of the individual thermistors have thus far failed to perform to specifications. In a few cases, they read consistently off and can be corrected; but in most cases they simply continue drifting in resistance or cycling over a range corresponding to several degrees of temperature. Sometimes the problem clears up in one thermistor and starts up in a different one. I tentatively attribute this effect to water leakage at the wire junction inside the pipe, since we observed that the trees tended to absorb water

Figure 5. Thermal logs from eleven 3m holes at Twin Buttes near Deeth, Nevada.



Deeth Thermistor Profiles

13, May 1980

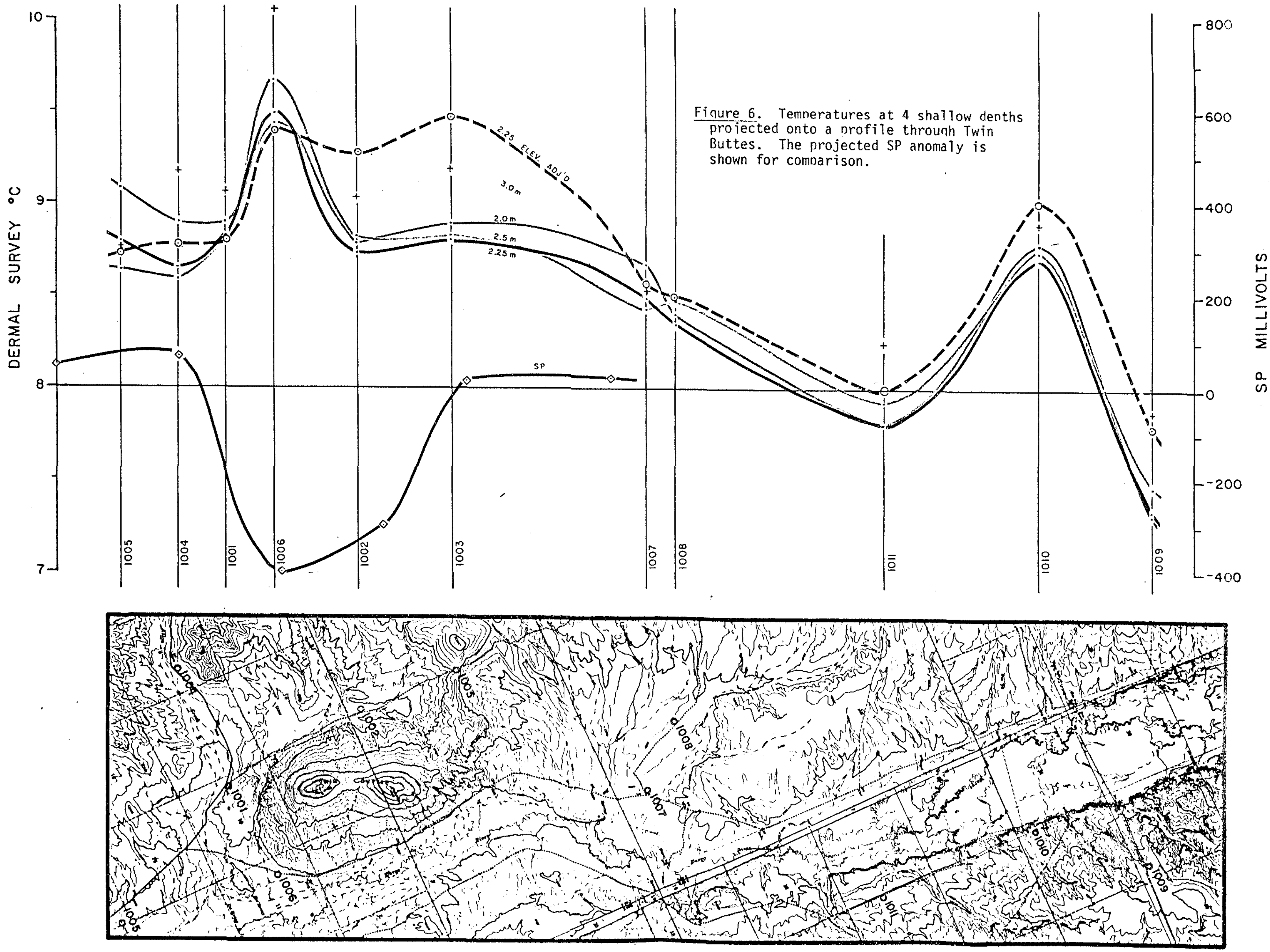


Figure 6. Temperatures at 4 shallow depths projected onto a profile through Twin Buttes. The projected SP anomaly is shown for comparison.

during tests in ice baths and in a stream. Stress due to flexing of the pipe may also be a factor. Subsequent trees will require carefully sealed connections and fully waterproofed pipe.

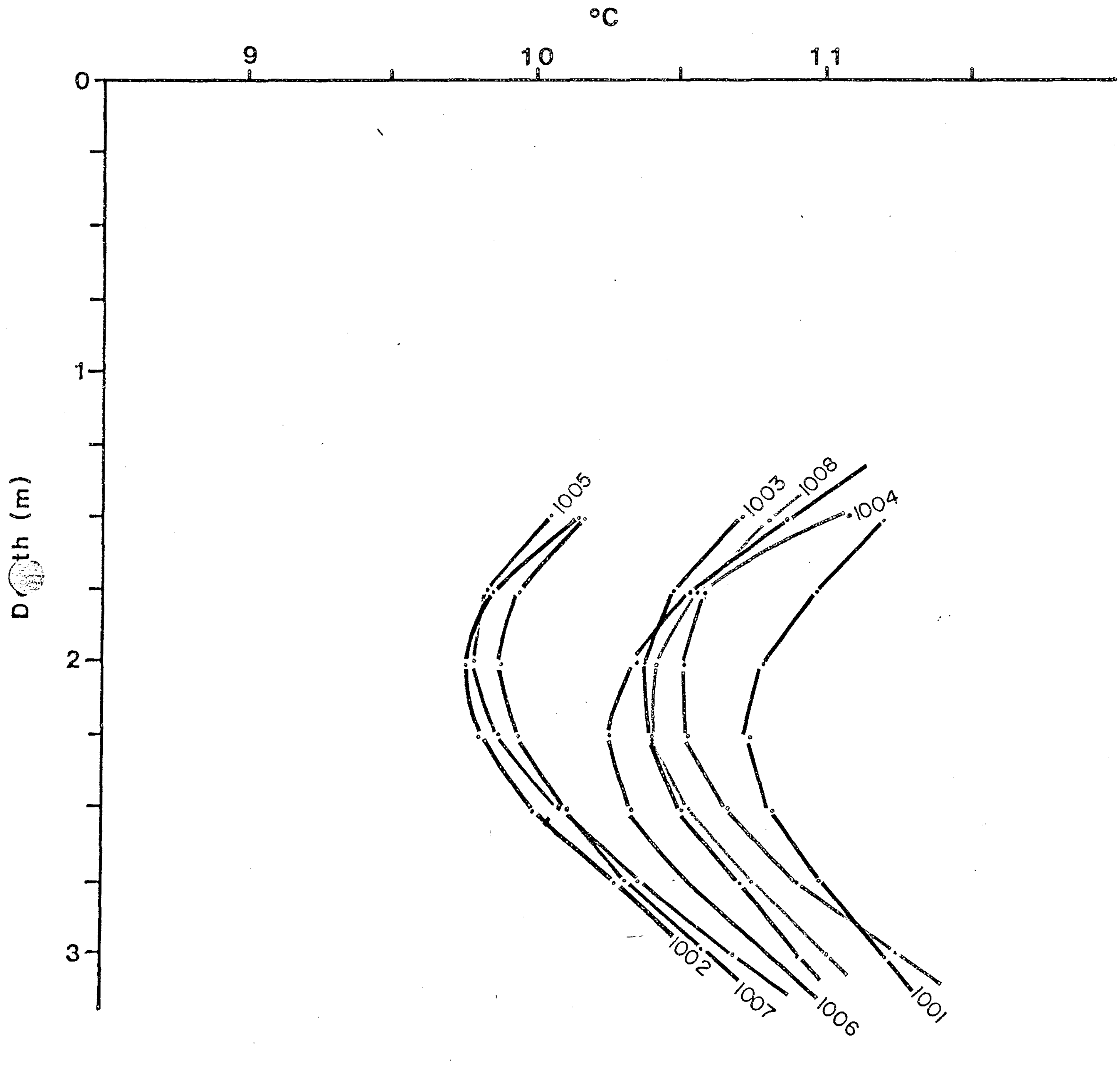
Minor problems resulted from unprotected plugs above the ground, usually correctable by cleaning and drying. In the future, waterproof plugs will be employed.

Outlook for the method:

The existing technique appears to be functioning adequately, and is producing clearly identifiable thermal anomalies. Thus far I have not attempted to quantify the results in terms of downhole temperatures, gradients or heatflow determinations. In principle, these extrapolations are contained in the data; they remain to be extracted. During the summer's reconnaissance work, now going on, I shall be experimenting in this direction, with the objective of ultimately computing heatflow at each station. I believe that the chances are good for doing this as a routine calculation in the field and to the accuracy of heatflows based on conductivities from cuttings or estimates in deep holes.

My helpers in the system development are Chris Tower, Bill Huntsman, John Deymonaz, John Petros and Mark Avery. My thanks for their patience and persverence.

Figu 7. Thermal logs from eight 3 ıoles on the east flank of the Dugway Range, Utah (Topaz).



Topaz Thermistor Profile

15, May 1980

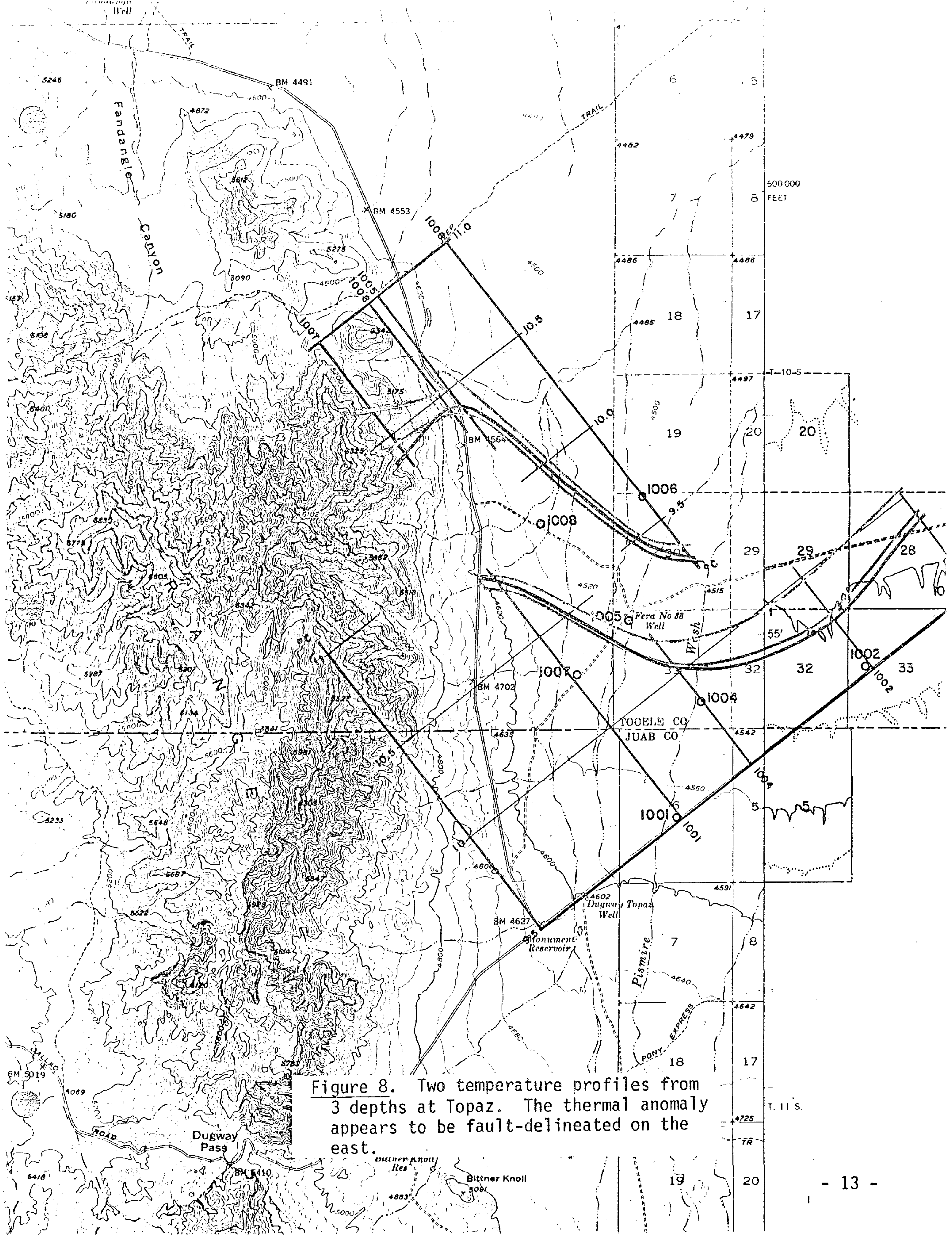


Figure 8. Two temperature profiles from 3 depths at Topaz. The thermal anomaly appears to be fault-delineated on the east.

TEMPERATURE SURVEY - McCOY

Backward probe 66-8 to 2070' - used all cable on probe to reach 2070' -

250 m (815') - annulus in saturated water vapor
450-455 m (1467'-1483' - water entry
475 m (1550') - 100.3^{o} C - maximum temp - rolls over and assumes neg gradient to bottom of hole - readings taken 30 seconds after reaching depth to 250 m - reading steady enough after 250 m and taken immediately

25 m	24.67^{o}
50 m	35.20
75 m	43.37
100 m	50.02
125 m	57.41
150 m	64.02
175 m	71.11
200 m	79.15
225 m	83.85
250 m	94.55
275 m	95.01
300 m	95.18
325 m	95.18
350 m	95.22
375 m	95.27
400 m	95.31
425 m	95.35
450 m	98.52
475 m	100.30
500 m	99.60
525 m	98.36
550 m	96.28
575 m	94.30
600 m	92.23
625 m	91.06
635 m	90.30

Additional readings from 435 m - 465 m

435 m	95.40^{o}
442 m	97.45
455 m	99.24
460 m	99.56
465 m	100.00

2340
Hole 66-8
12-Mar-80

Tx			°C
1389	.867-.483	.384	88.59
1404	.866-.483	.383	88.48
1419	.866-.482	.384	88.59
1434	.867-.483	.384	88.59
1449	.867-.483	.384	88.59
1464	.867-.483	.384	88.59
1479	.867-.483	.384	88.59
1494	.867-.483	.384	88.59
15.09	.867-.483	.384	88.59
1524	.867-.483	.384	88.59
1539	.866-.483	.383	88.48
15.54	.866-.484	.382	88.37
1569	.866-.484	.382	88.37
1584	.865-.484	.381	88.26
1599	.865-.484	.381	88.26
1614	.865-.484	.381	88.26
1629	.864-.484	.380	88.15

Depth.			°C
2300	.858-.485	.373	87.37
2250	.855-.485	.370	87.03
2200	.858-.485	.373	87.37
2150	.859-.485	.374	87.48
2100	.863-.485	.378	87.92
2050	.869-.486	.383	88.48
2000	.893-.486	.407	91.15
1950	.907-.485	.422	92.82

MRTS.	°C
214	101.1
212	100.0
214	101.1
215	101.7

2340 To @ 11:20 AM. 11-MAR
12:~~50~~ 15 P AM STOP CIRC S = 90min.
10:29 AM 12-MAR ON BOTTOM.
14:30 P.O.H.