TEC-1

TEMPERATURE SURVEYS
IN 2-METER HOLES
CAN BE EFFECTIVE

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INTER-OFFICE MEMORANDUM

SUBJECT: Temperature Surveys in 2-Meter Holes Can Be Effective DATE June 5, 1978

TO: R. A. Barker, W. M. Dolan, H. J. Olson, F. Dellechaie, J. Roth, J. E. Deymonaz

FROM: A. L. Lange

Shallow temperature surveys (one and two meter probes) have been used for many years to map near-surface groundwater patterns. Attempts using the method have been made also to map geothermal anomalies, in the hope that the cost of drilling deeper gradient holes could be avoided and the procurement of permits circumvented. Thus far, I have seen no clearly documented demonstrations that the resulting thermal anomalies duplicated the patterns obtained from deeper measurements with fidelity. Probably the evidence was there, but because the practitioners did not make both sets of measurements simultaneously and at the identical sites, ambiguities and discrepancies resulted. This memorandum demonstrates that shallow temperatuare measurements at AMAX' McCoy prospect in Nevada, delineate the temperature anomalies resulting from the 30-meter data sufficiently well to warrant the use of 2-meter surveys for both reconnaissance as well as detailing work.

The problem

Figure 1 depicts the temperature regime in the upper 30 m in a setting of homogeneous material. The temperature log is made up of three components: A) the geothermal gradient, shown as a constant with depth (but normally decreasing with deeper increasing thermal conductivities): B) the seasonal wave--a sinusoidal oscillation attenuating with depth. Here the previous winter low and summer high can be identified; C) the diurnal wave--a similar damped oscillation that in alluvium disappears beyond detection at one meter (two meters in rock). For practical purposes we may disregard the diurnal wave at 2 m. Because the rate of penetration and wavelength of the seasonal wave increase as a function of conductivity and density, one should attempt to place all holes in a similar material such as alluvium. The seasonal wave progresses downward rapidly enough that temperature changes from one day to the next can be easily measured with a probe accurate to .01 degree. Surveys logged over more than one or two days will not yield satisfactory results, unless careful referencing is made in common holes.

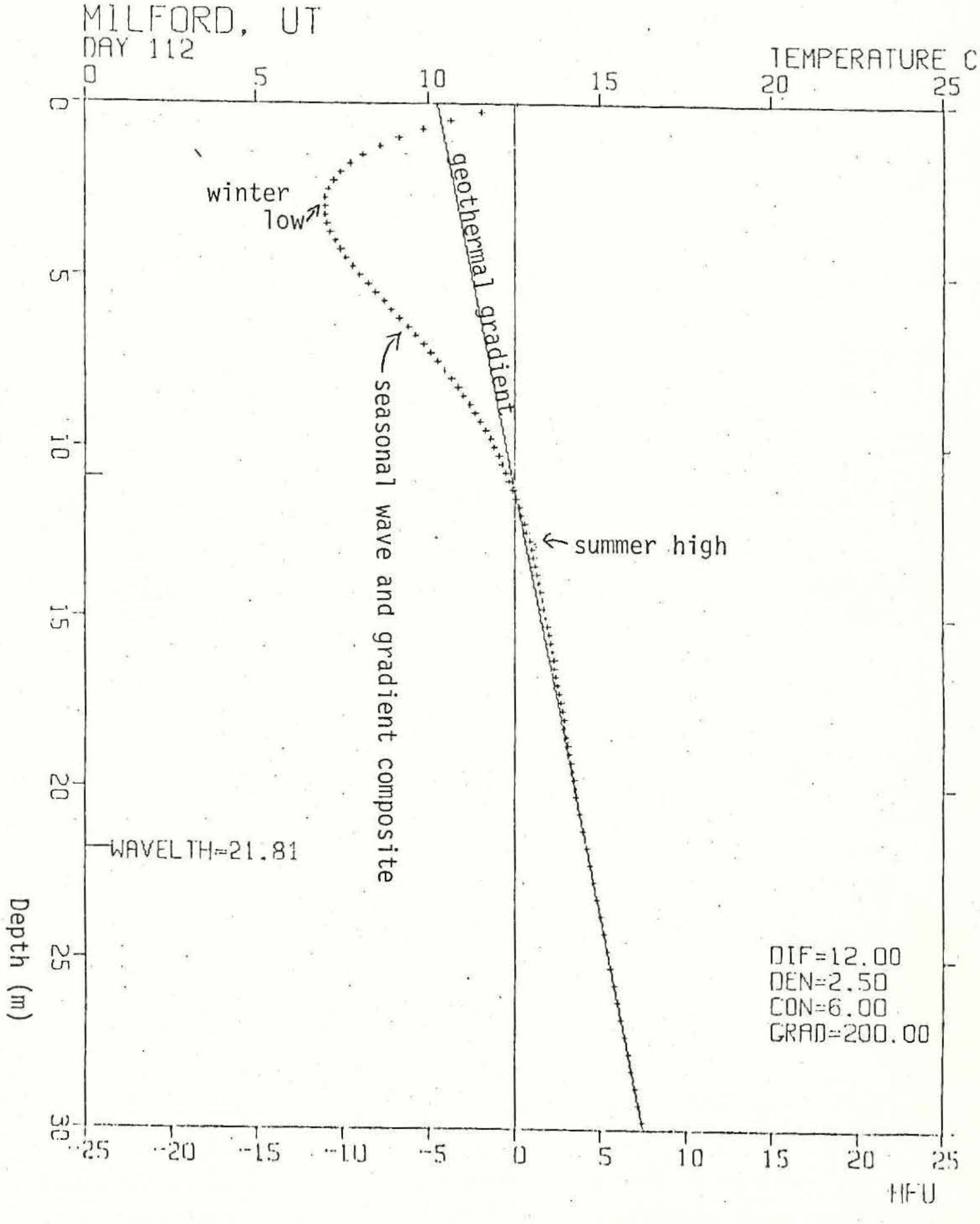


Figure 1. Thermal log (+) consisting of the seasonal wave superimposed on a geothermal gradient of 200°C/km, in a medium having a thermal conductivity of 6 units. The diurnal wave is not shown, but would be confined to the upper 1 meter of the log.

Mr. Len LeSchack of LeSchack Associates performed two surveys at 2-meter depth for ERDA--at Long Valley, and Coso Hot Springs, California. Each survey consisted of nearly 100 stations, but to his discredit he did not tie his stations to the previous 30 m holes of Lachenbruch and Combs, respectively. I have scrutinized his results at Coso using the unprejudiced, disinterested computer. These exhibits are on file in a special Coso folio in our drafting room. LeSchack claimed success for his experiment at Coso on the basis that 1) Thermal anomalies depicted from late September measurements conform quite well to those from early February (demonstrating not so much the efficacy of the method but rather the reliability of his tools). 2) The 2m thermal pattern agrees roughly with that obtained from the 30 m measurements and provides considerably more detail. His maps reveal that the unsuccessful production test was drilled on the flanks of the thermal high rather than on its apex (due to the paucity of 30 m holes).

When my computer compared the 2 m measurements with those from 30 m for the locations only at the deeper wells, the agreement was only fair; LeSchack did not place his stations at the wells; furthermore, he applied an adiabatic lapse-rate correction (temperature decrease with increased altitude) for his 2 m data but not for Combs' 30 m data (both are affected equally). Compounding the problem, Combs' temperature information as provided to us, was "obscure".

Two-meter surveys cannot be done haphazardly and with lack of understanding of the equations governing the temperatures in the ground, and their perturbing effects. My review of LeSchack's work convinces me that he missed his opportunity to prove this method; that, without any additional effort, he could have produced a convincing demonstration of the technique.

The McCoy experiment

On the one day of 22 April 1978, Pilkington, Edgerton and I logged 15 drill holes at the McCoy property in Nevada. All but one were approximately 38 m holes drilled by us; the exception was a 150 m windmill well. The holes were logged in water-filled PVC pipe, commencing just below water level (usually around 2 meters or somewhat below). In most cases, measurements were made at 1/2 meter intervals to 10 meter, 1 meter intervals to 20, and 2 meter intervals to the bottom. Because of the detailed logging on a common day, it was possible to compare shallow temperatures to those obtained at 30 m. Not enough stations contained 2-meter readings, so that 3 and 4 meter samples were employed instead.

Because data are more easily compared in profile that in contour form, I selected a well-to-well circuit around the property and plotted the wells on a line (Figure 2). These well locations appear in Figure 4. The lowermost curve shows temperatures as logged at 3 meters. Successive curves correspond to temperatures at 4, 10, 20 and 30 meters respectively. Figure 3 depicts, for the same circuit, the deepest gradient of each well and corresponding heatflow determinations from estimated conductivities.

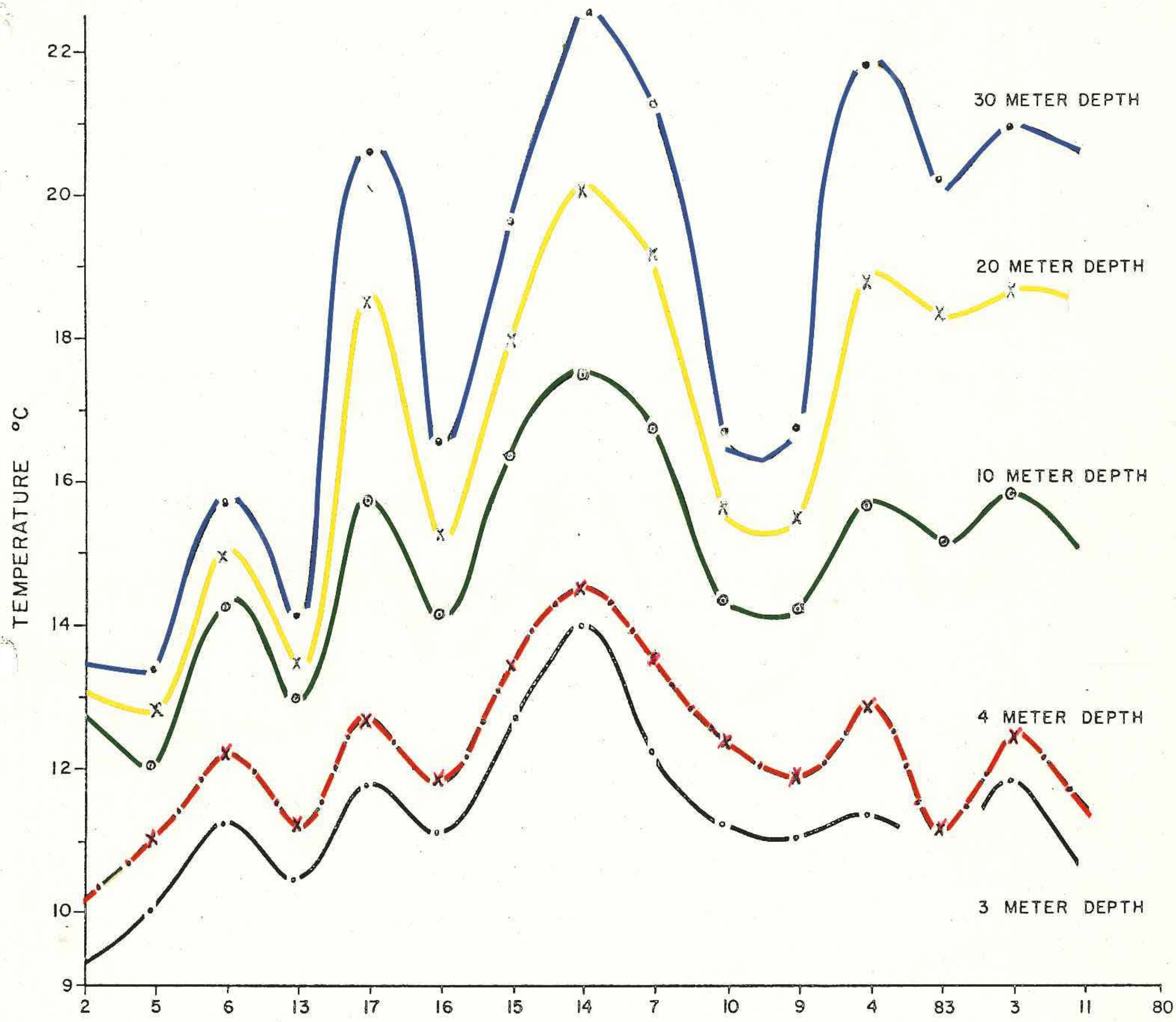


Figure 2. Temperatures at five different depths in each of the McCoy wells indicated. The deeper curves are essentially amplified versions of the shallow curves.

FIGURE

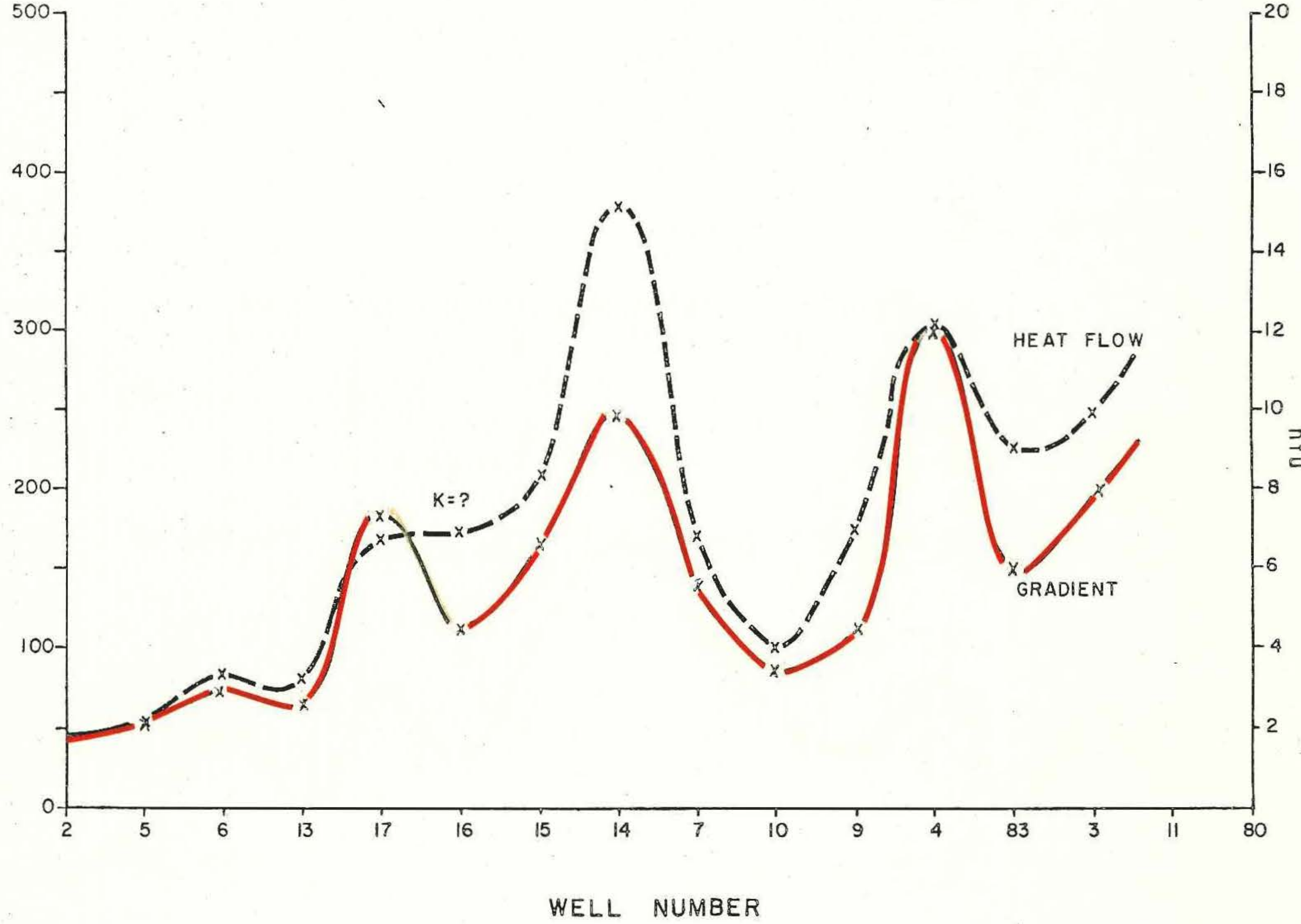


Figure 3. Temperature gradients in the deepest part of the McCoy wells and corresponding heatflow values computed from estimated conductivities.

FIGURE 3

The curves of Figure 2 show the following:

1) The 3 and 4-meter data reproduce clearly the ups and downs of the deeper data.

2) The oscillations of the shallow curves are "amplified" in the deeper curves. This phenomenon is exactly what one would expect, since temperatures increase faster with higher gradients. In practice the 30 meter curve could be extrapolated from the shallow data by means of an algorithm that would compute this amplification as a function of temperature measured and change of surface temperature with elevation (ignored here). Residual differences can be attributed to the change of conductivity with depth and lithology variation. Despite the perturbing factors, it is evident that had the wells at McCoy been drilled no deeper than 3 or 4 meters the thermal variations would have been reasonably mapped.

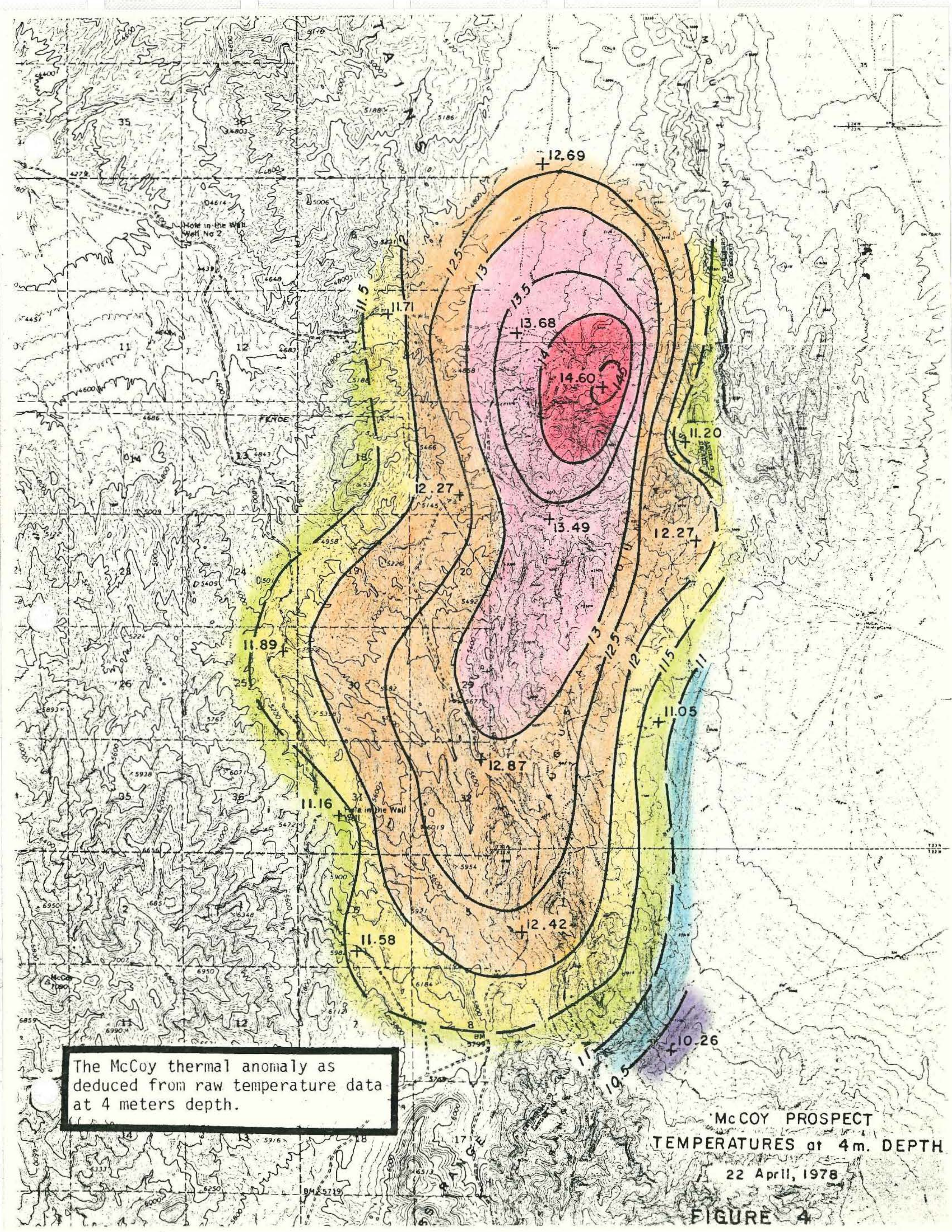
Contour views of the data are drawn in Figures 4 and 5, for these 15 wells only. The form of the thermal anomaly is clearly evident in the 4-meter map--even the minor bulge on the east side appears. The dimple in the SW corner of the 4 m map is probably the result of a faulty measurement at the windmill, where the shallow readings had to be made within the air column.

Why does the 30 m pattern appear so much sharper than the shallow one? Because of the "amplification" effect described above. When the continuation algorithm is applied to the shallow data, its thermal anomaly will appear equally sharp.

Procedures to be followed in practice

The results shown for the 3- and 4-meter surveys apply equally well to two-meter sampling; hence, drilling to this depth could be accomplished by a small rig mounted on a pickup. All holes should be made in alluvium whereever feasible, to keep the drilling easy and minimize conductivity corrections. All sites should be in flat places away from severe topography and with common solar exposure, but elevation changes are not a problem. About 30 to 40 holes might be drilled in a day.

Immediately following drilling, a calibrated thermistor is inserted at exactly 2 meters in the hole. The sensor might be mounted inside a slender pipe, in contact with a bottom seal, with the pipe filled with sand or other filler, and the remainder of the hole backfilled. The pipe is than left in the ground with a wire or plug at the surface for making the reading. After several days of equilibration, the thermistor is ready to be logged. Only one reading need be taken at each site; although a vertical string of buried thermistors at occasional stations could be logged for the purpose of computing conductivites of the near surface material. The pipe and thermistor are extracted at the end of the survey and may be reused.



The McCoy thermal anomaly as deduced from raw temperature data at 4 meters depth.

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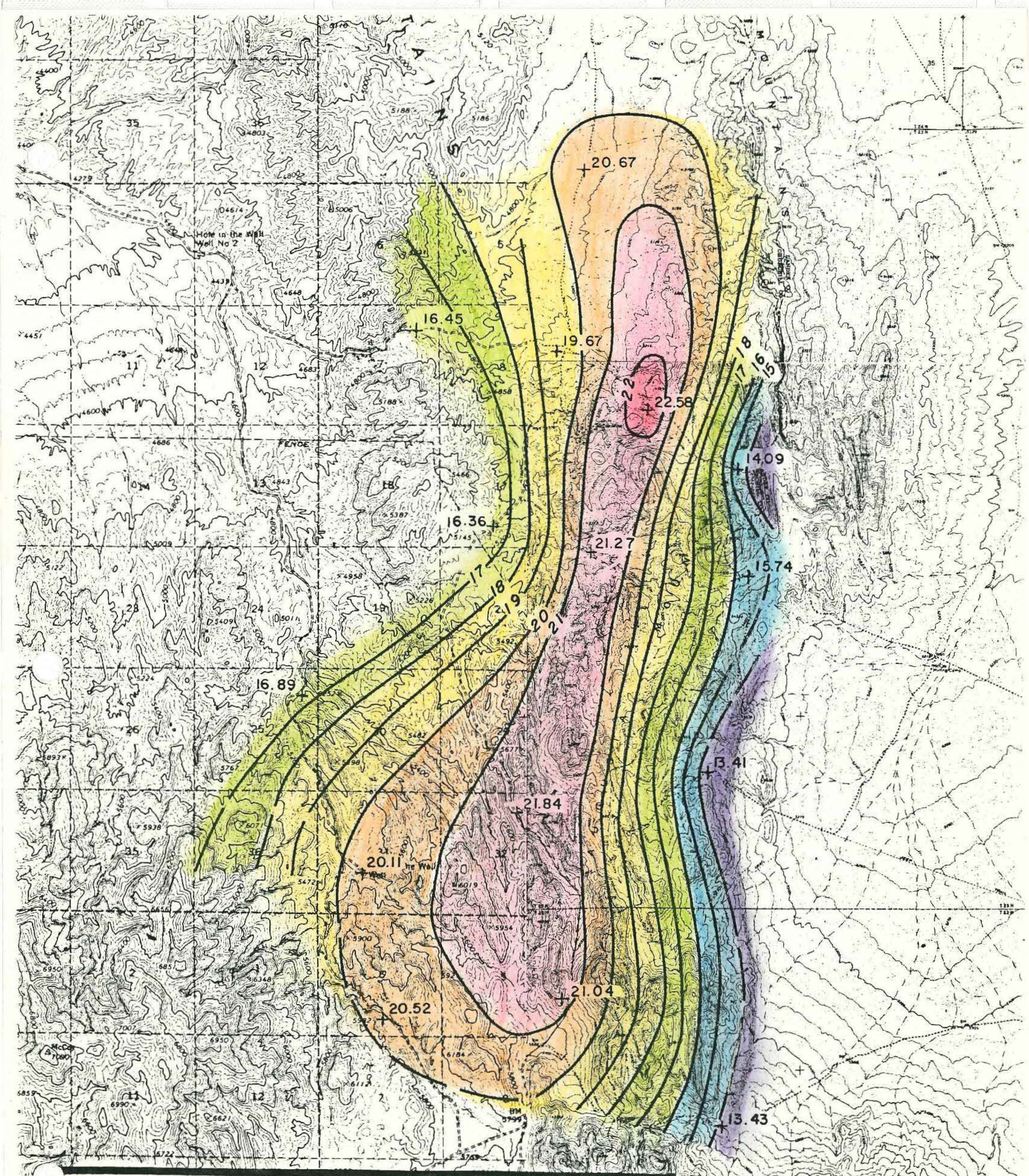
22 April, 1978

FIGURE 4



The McCoy thermal anomaly as deduced from 30 meter temperatures. The enhancement of the anomaly compared with the preceeding 4-meter pattern is due to exaggeration of the higher temperatures at depth under the influence of the increased geothermal gradients.

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TEMPERATURES at 30 m. DEPTH
22 April, 1978

FIGURE 5

A reconnaissance survey performed in this way would require confirmation by several conventional gradient holes, but not very many. Additional shallow holes could be programmed at any time to help define anomalies.

Costs

Using a truck mounted auger or drill, a two-man crew might produce 30 or more holes per day. Allowing $500 per day for the crew, the cost runs to $17 per hole. If the siting of the holes, installation of the pipe and the subsequent logging are performed by AMAX personnel, no extra costs would be entailed. The thermistor cost should be on the order of $10 apiece; the pipe cost would be much less. Meters are on hand already. I have no information at this time on the type of drill required or its cost. In essence, following the purchase of the equipment, a 100-hole survey should entail somewhat less than $2000. plus normal field operation costs for one or two AMAX persons. In a direct comparison, these costs per hole are about 1/40th that of the 40m-hole survey previously done at McCoy.

Recommendations:

I recommend that the necessary drill and thermistors be acquired to conduct 2-meter temperature surveys. Any new suitable target area could then be reconnoitered at a station density of one per section, and presently held properties could be extended or refined. Resulting thermal patterns should then be confirmed by a limited number of conventional gradient holes. Where further definition is required, additional 2-meter holes can be installed. Measurements may be made within one week of drilling, or any time thereafter, and the resulting thermal map is constructed in the field from the raw data. Appropriate corrections can then be applied to continue the shallow data to depth; however, I do not believe that the anomalies of interest would substantially change by the refining process.

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Attach.