Geothermal Resources Council, TRANSACTIONS, Vol. 1 May 1977

DEDUCING PRODUCTION ZONES FROM WELL LOGS

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ABSTRACT

Normal well logging techniques in the Raft River wells have failed to give definitive information about the actual production zones. The most useful tool has been the temperature log under non-equilibrium conditions, both flowing and quasi-static. The use of injected cold water has been a powerful tool in developing these non-equilibrium logging situations that have pinpointed the production zones.

The three successful producing Raft River deep geothermal wells have created a considerable challenge in measurement and analysis technique in deducing the characteristics and locations of the production zones. The Raft River water production is definitely not the result of homogeneous rock permeability, but is dependent on the highly fractured zones within the formations. These formations can be characterized as tuffaceous siltstone, congolomerate and sandstone in the upper 4600 ft with a metamorphic (phyllite, schist and quartzite) zone resting on the quartz monzonite basement rock below.

Full suites of conventional oil well logs were taken on all the wells. To date, these logs have correlated reasonably well as indications of stratigraphic change, but have occasionally shown decisive changes at locations where drill cuttings have shown no such distinctive change. General correlation and detailed statistical correlations have been conducted[1] revealing the general usefulness of dual induction and natural gamma logs, and a relatively accurate correlation on bulk density and porosity from gamma ray and neutron scattering logs. Sonic logs, it had been hoped, would give a more definitive indication of fracture production areas, but such has not been the case. However, preliminary work by the USGS on an "acoustic televiewer" shows considerable promise.[2]

Porosity measurements from the few cores obtained correlate reasonably well with the neutron log deduced porosity. The average effective porosity inthe producing regions is approximately 15%. The "in situ" simulated permeability sample measurements, on the other hand, vary substantially from a few microdarcies in the non-fractured cores to several hundred millidarcies in one obviously fractured core. However, many fractures appear to be sealed or partly sealed by chemical deposition.

Borehole flow meters have been attempted by several organizations with general lack of success, the result of instrument failure in the 300°F environment. A flow meter would be one of the most useful qualitative tools, and eventual success in using one would be a most significant result.

Temperature logs are of interpretative value only under non-equilibrium conditions for deducing production zones. Thus, as production is first beginning to develop in the well, a temperature log could be most revealing. Such precise timing is not always possible. Once production is established temperature profiles are smoothed and reveal little. A method of restoring non-equilibrium conditions is to pressure inject cold water into the well and formations. It is probably a safe assumption that those formations that were producing the hot water will most readily accept the cold water, and later discharge it back into the well.

In making the most of such a technique, an additional advantage has been found by using a temperature tool that lies directly against the borehole wall. Such a tool can detect the temperature of fluid entering the bore hole more readily than a centralized tool. Laboratory experiments of a scale model, using similar Reynold's numbers as experienced in the actual bore hole, in fact, demonstrate that the temperature front persists several well diameters

(1) "Borehole Geophysics Evaluation of the Raft River Geothermal Reservoir, Idaho" J. K. Applegate, P. R. Donaldson, D. L. Hinkley and T. L. Wallace

(2) "Borehole Geophysics in Geothermal Wells--Problems and Progress" W. S. Keys, USGS 2nd Workshop Geothermal Reservoir Engineering Stanford University, Stanford, California

downstream along the bore hole wall. Whereas the centerline temperature is largely a mixed mean average, showing therefore negligible changes if one is dealing with producing zone temperatures not much different from the main stream temperatures.

Figure 1 shows the results of a series of temperature logs taken after extensive re-injection of cold water into the formation.

It seems safe to assume that the production zones will be the same zones that accept the cold water, later discharging it to the well bore when production is resumed. This flow coming out of formation has yielded the height of the production zones, and the thermal changes have given clues of the effective product of height and porosity.

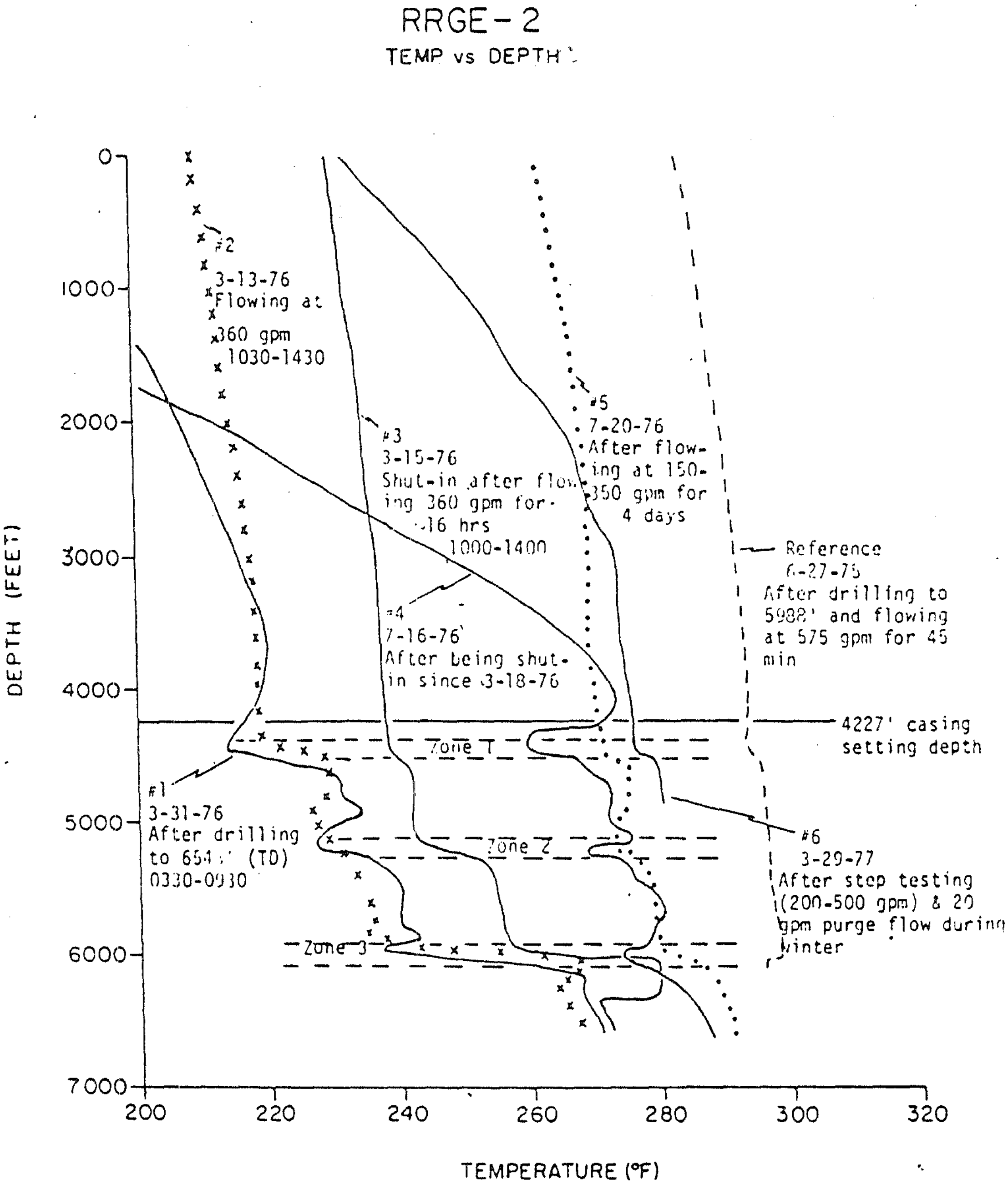

FIGURE 1

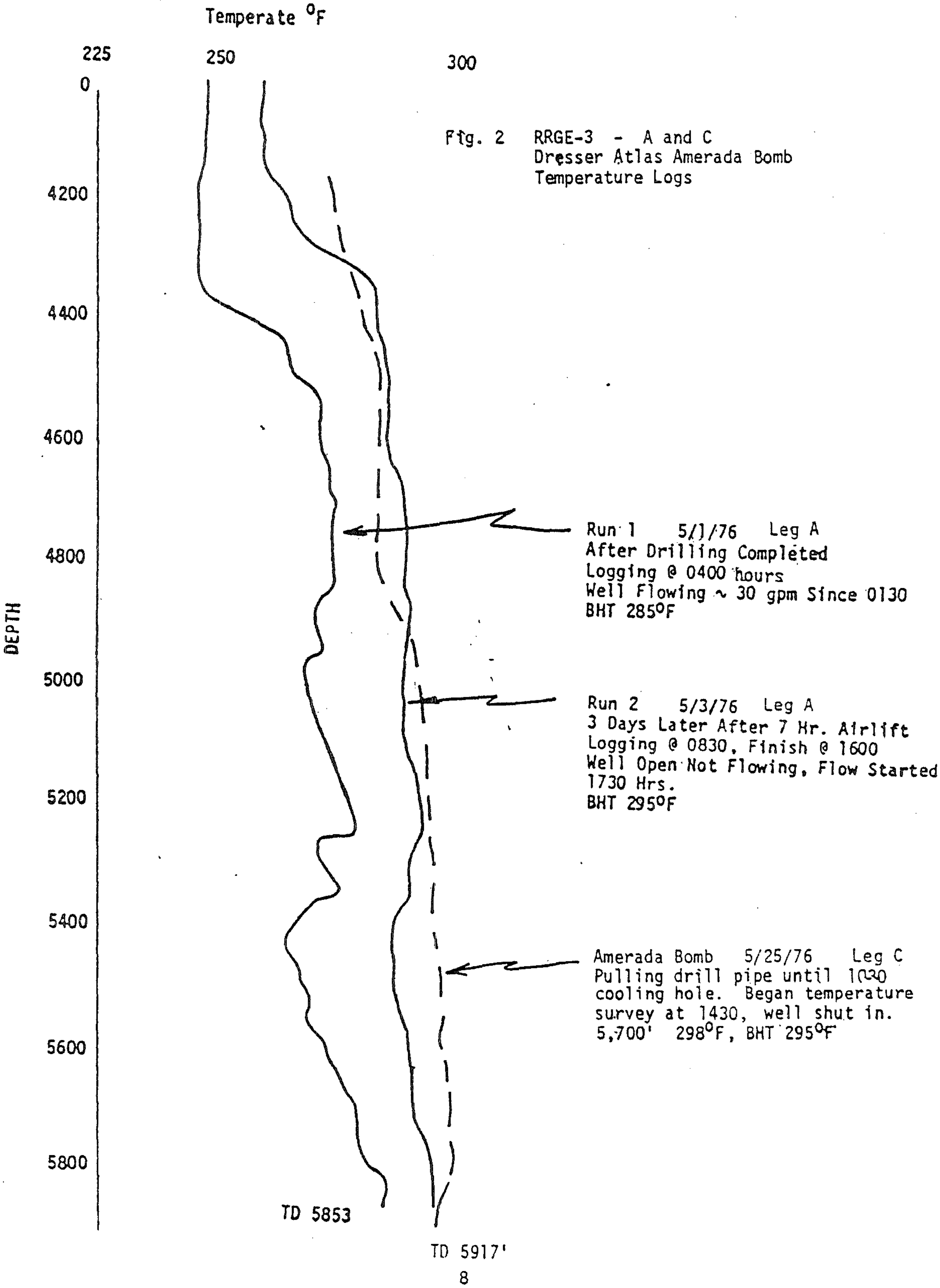

Fig. 2 RRGE-3 - A and C
Dresser Atlas Amerada Bomb
Temperature Logs

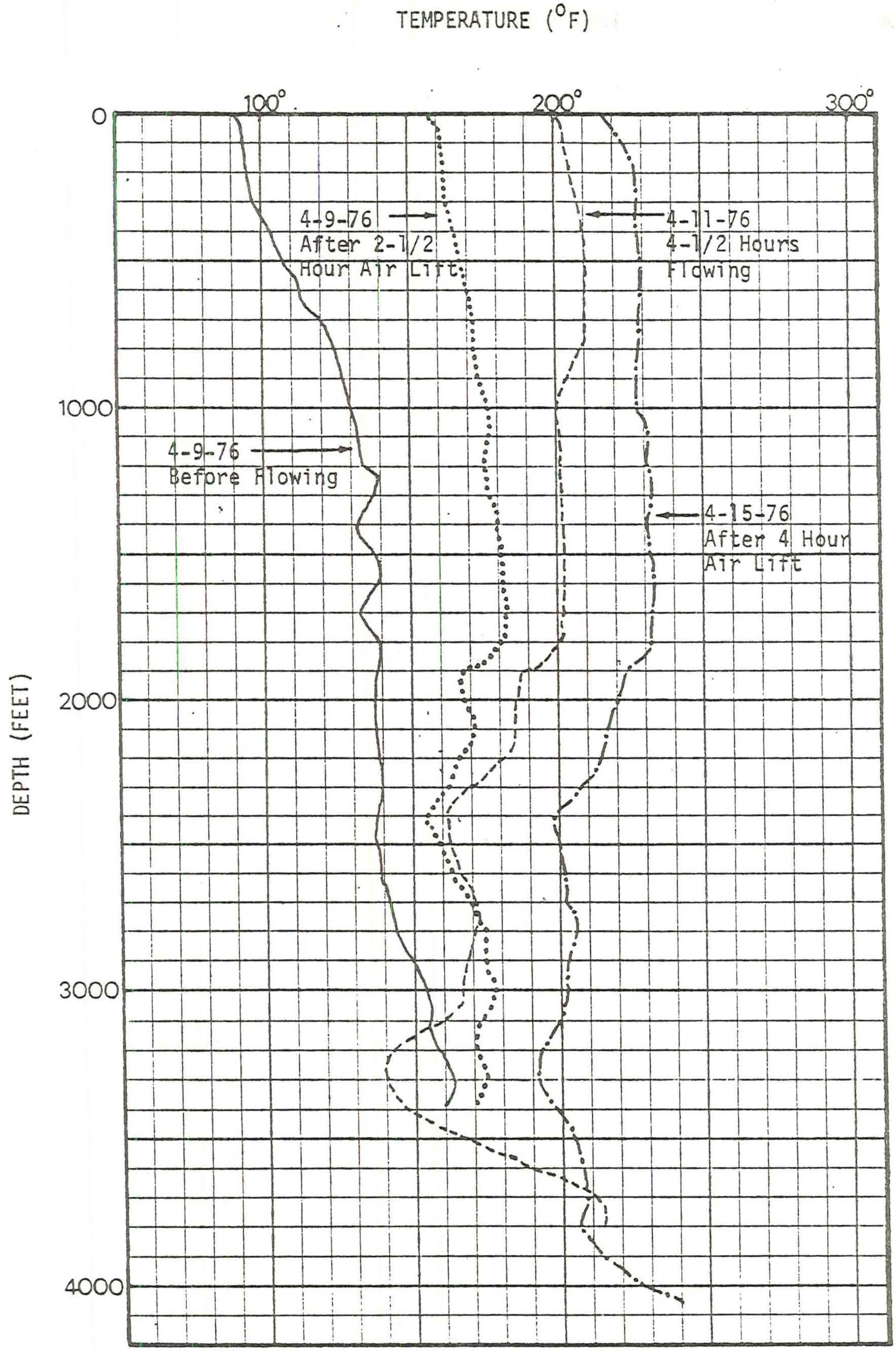

Fig. 9 Temperature profiles in RRGE-3 after completion to a depth of 4,237 ft.

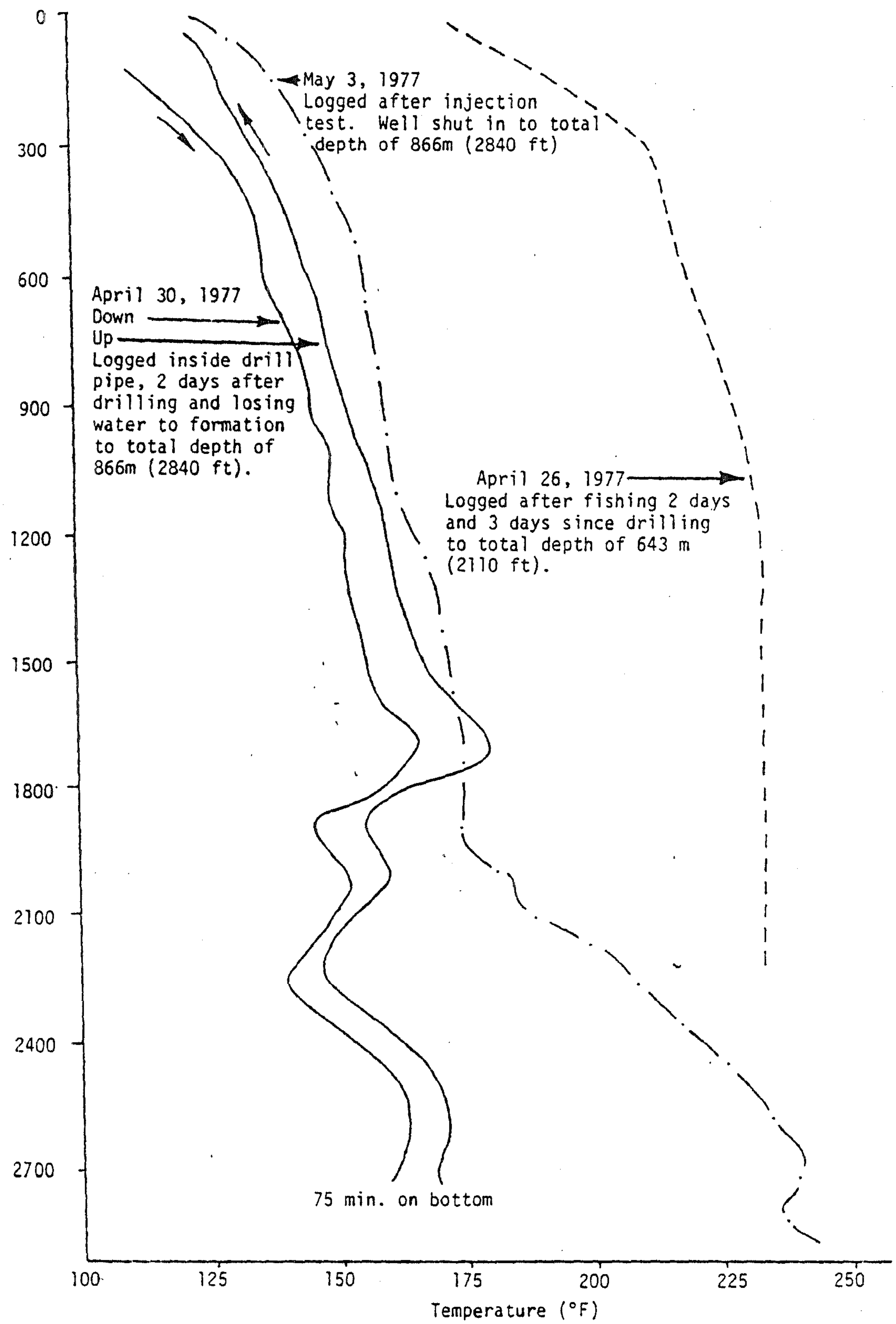

Fig. 2 RRGI-4 temperature logs

Temperature vs Depth

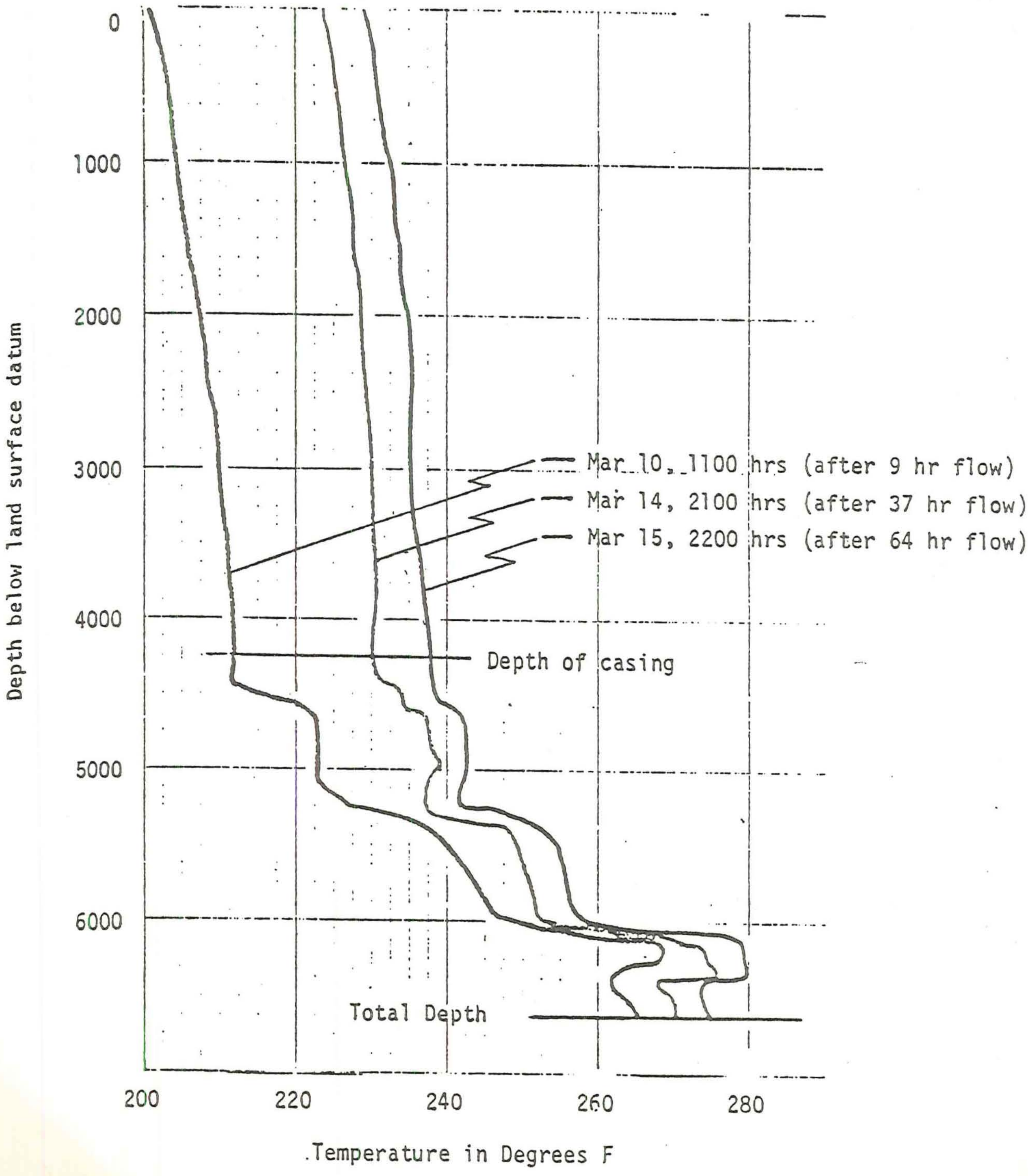

Fig. 4 Raft River Geothermal Exploratory Well No. 2