in Symposium on Rock Mechanics, 17th U.S. Symposium on Rock Mechanics

4568

1976

THE EXPERIENCE OF GETTING WATER OUT OF THE RAFT RIVER GEOTHERMAL WELLS

J. F. Kunze, L. G. Miller, R. C. Stoker

IDAHO NATIONAL ENGINEERING LABORATORY
Idaho Falls, Idaho 83401

1.0 BACKGROUND AND SUMMARY

Beginning in January, 1975, deep drilling for geothermal water began in the Raft River Valley of south-central Idaho, 6 miles north of the Utah border. The Valley has tectonic features characteristic of both the Snake River Plain volcanic rift zones, with which it intersects, and the older sedimentary characteristics of the Salt Lake - Old Lake Bonneville formations. The Valley had a number of wells showing minor thermal anomalies, and two wells producing boiling water from depths of 400 ft, evidently drilled into faults along the west edge of the Valley near the Raft River Narrows region. All of these wells were originally drilled for agricultural irrigation purposes. The geochemistry of the wells predicts maximum reservoir temperatures of 140 to 150°C (284 to 302°F), too low to compete in the electric generating market using current practiced technology for converting heat to electricity.

The Idaho National Engineering Laboratory (INEL, a laboratory of the Energy Research and Development Administration) selected the area for a potential location to develop advanced technology to, hopefully, make such moderate temperature geothermal fluids more competitive in the electric generating and industrial direct heat use markets. The electric utility serving the area, the Raft River Rural Electric Cooperative, had interest in developing indigenous power sources for the future, and had a wide service territory (10,000 square miles in Idaho, Northwest Utah, and Northeast Nevada) which might well encompass other similar geothermal regions.

By the fall of 1974, the U.S. Geological Survey had completed an extensive set of geophysical measurements. They and INEL assessed the geothermal potential as not being outstanding, but being typical of a western valley setting. It was found that the formation might be tighter than average, however. The electrical resistivity had identified low resistivity regions at depth, and structural interpretations had been made through the active seismic and surface geological work. The Colorado School of Mines had conducted a four month micro-seismic survey. The region was extremely quiescent, with no correlated events greater than +.2 on the Richter scale during that period.

The average characteristics of the Valley made it more pertinent as the site for research and development work, since experience gained from it would be transferable to many other equivalent sites throughout the west. Therefore, spurred by an initial input of drilling funds from the State of Idaho, plans were initiated to begin drilling in January 1975, into an indicated low resistivity zone at depth, approximately 12 miles due south of Malta, Idaho, 4 miles West of Bridge. (Figure 1) The shortage of drill rigs (then was the peak of the post Arab Oil embargo drilling activity in the U.S.), the INEL engaged a sister facility, the Nevada Test Site, to do the drilling.

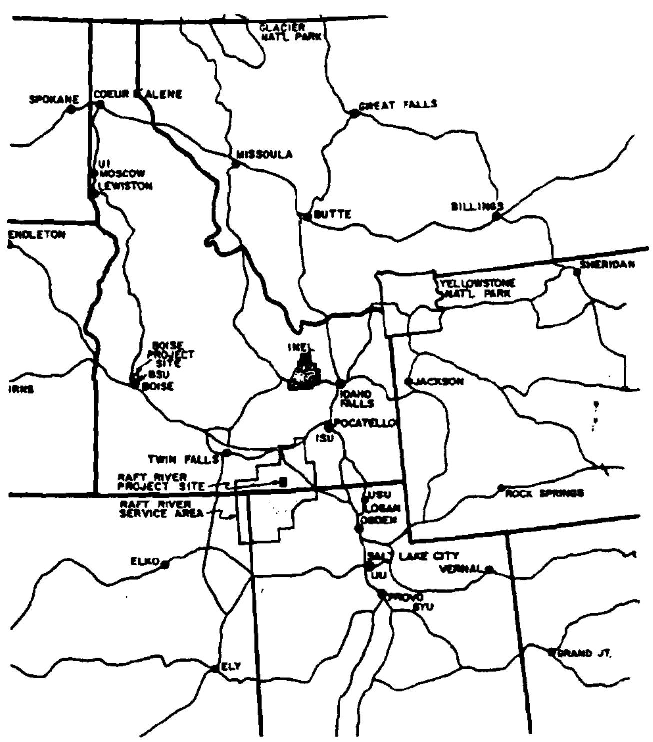


FIGURE 1

To date, three wells have been drilled, the most recent completed in June, 1976. All have produced water from a reservoir(s) at measured temperatures of 148 to 149°C, as predicted by geochemistry. Artesian flows have been in the range of 600 gallons per minute (38 liters/sec) or higher. Artesian well head pressures are typically 10 to 11 atmospheres with a hot water column, 7 or 8 atmospheres with a cool equilibrium water column.

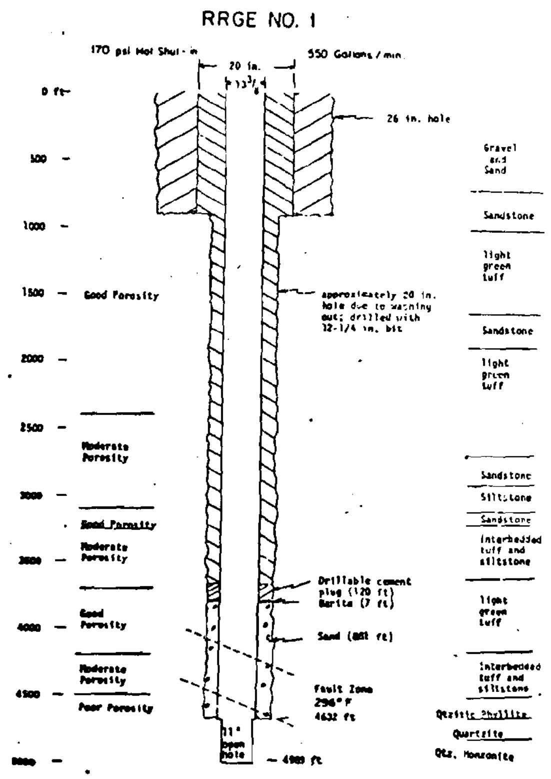
2.0 DRILLING PROGRAM

Because of the experimental nature of the program, the drilling plans were designed to try unusual or non-standard techniques that would maximize the ability to detect and extract the geothermal waters. Such drilling techniques may not necessarily be the optimum techniques developed for oil and gas drilling.

2.1 RRGE #1

The first well, RRGE #1, was drilled with water as the drilling fluid, to avoid blocking fractures and to make it easier for geothermal fluid to find its way up the well bore because of the reduced weight of the column above it. (Note, in all cases, surface casing was drilled and set with mud, to stabilize the hole, to 1300 to 1800 ft depths.) It is fortunate this choice was made, for by 4500 ft depth neither the drilling fluid returns nor downhole logging had given an indication of a producer, though the downhole temperature was high. It required 12 hours of static hole conditions before some artesian flow developed at the surface. Once the hole (barefoot below 900 ft) was developed, it could not be killed with cold water, presenting a difficult problem for the installation of production casing. Figure 2 shows the cross section of this well when finally completed.

FIGURE 2



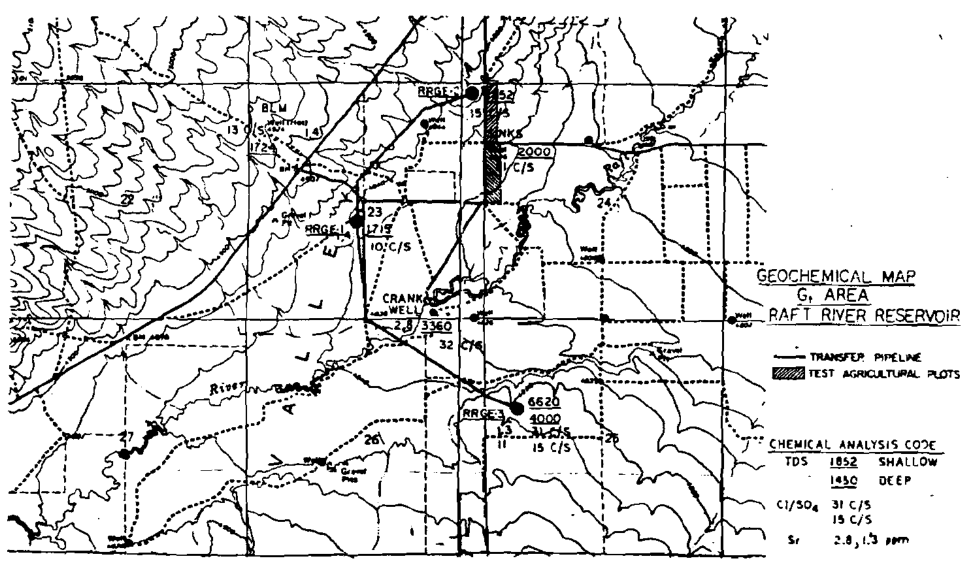
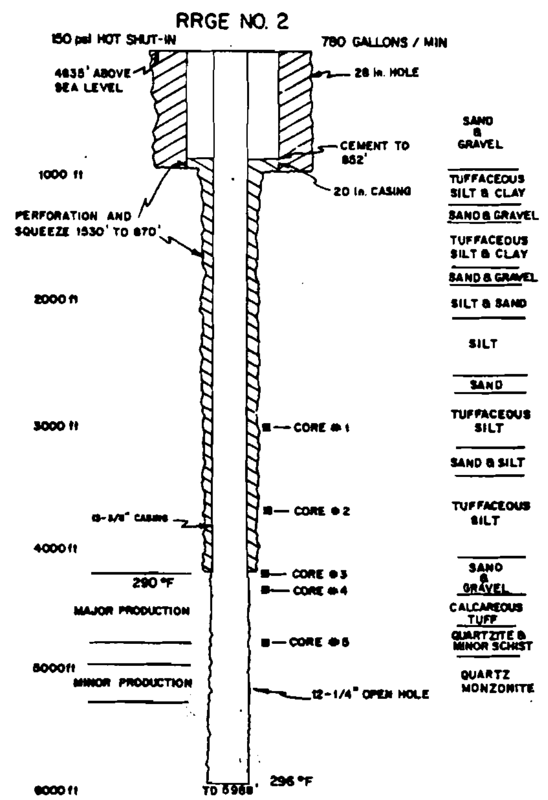


FIGURE 3

2.2 RRGE #2

The second well, RRGE #2, was drilled 4000 ft to the northeast and offset about 700 feet further away (downdip) from the Bridge Fault. Because of the difficulty in casing RRGE #1, this hole was planned for drilling with mud until the resource was encountered. After casing, drilling continued with water. The lithology was compared with RRGE #1 during drilling, and showed an offset of 500 feet lower at #2. No resource was detected prior to casing, but shortly after drilling out with water, geothermal flow was noted. Figure 3 shows the location of the well, and Figure 4 shows a cross section.

FIGURE 4



2.3 RRGE #3

The third well, about 7000 ft southeast of the other two, was drilled with water and rather thoroughly tested on the way down until it appeared the resource of the desired temperature had just been entered. Casing was then installed (before the well became too difficult to handle) and drilling proceeded into the resource again with water. However, the well was initially a poor (<100 gal/min) producer from depth.

Had the well been a successful producer, it had been planned to dig several side channels at depths below the casing, each at a 10° to 15° angle away. Calculations had indicated that up to 50% increase in flow might be expected if the second channel could be 300 to 400 ft separated from the first in the main producing zone. It was decided, nevertheless, to try the technique on this poor producer. Shortly after beginning the second channel (from 4500 ft depth), the well began to produce significant artesian pressures. Yet a third channel was drilled, and after completion the well developed artesian flows of 800 gpm (51 liters/sec) initially. Flow was 350 gpm when steam flashing choked the flow in the well bore.

Figure 5 shows a cross section of this well, and Figure 6 the paths that the three channels took, shown on a horizontal projection.

FIGURE 5

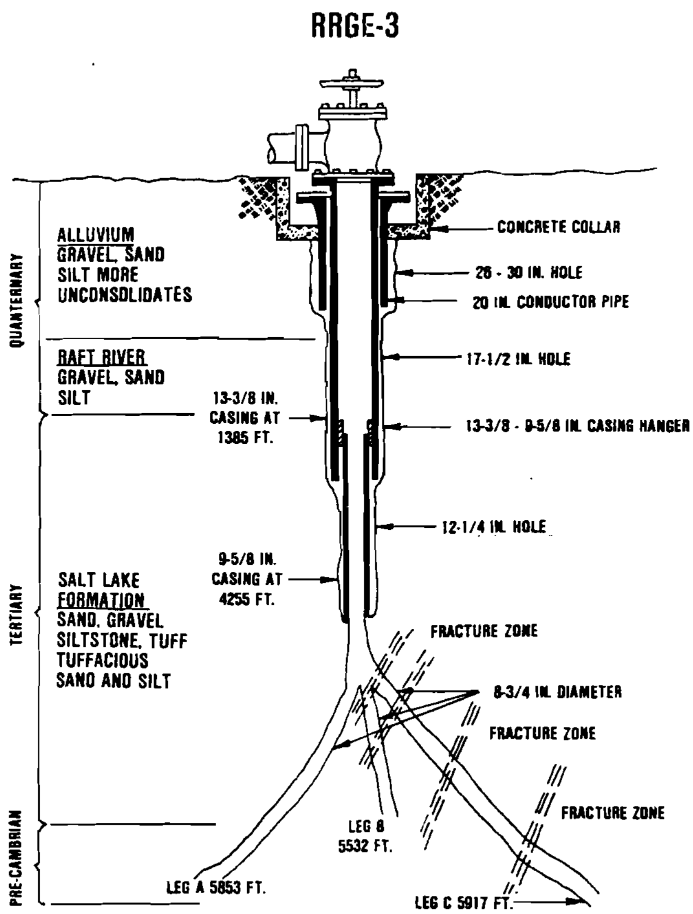
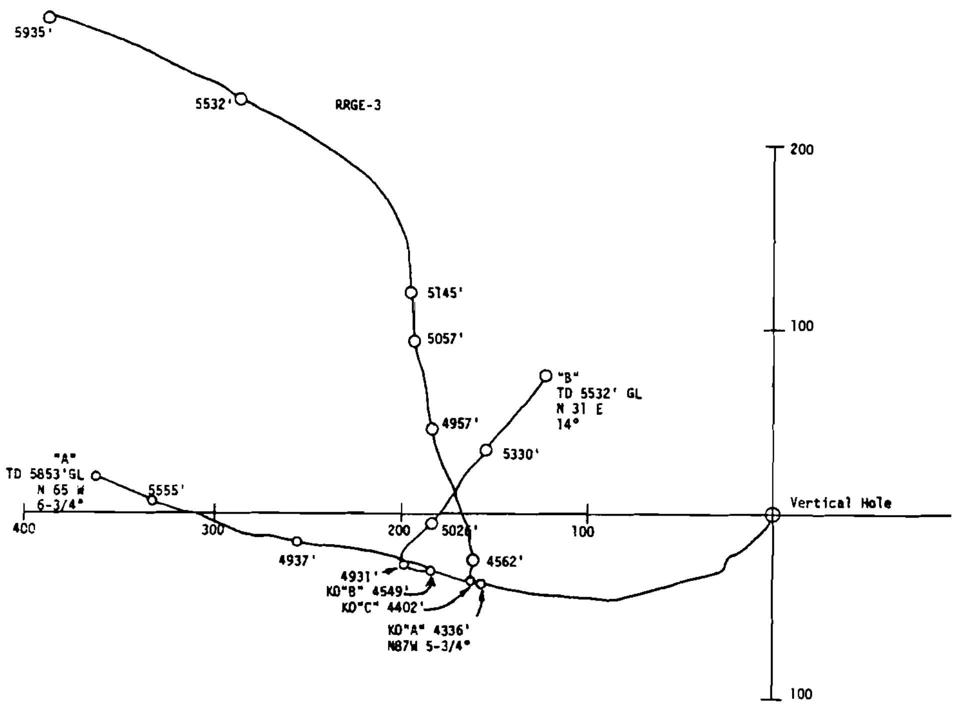


FIGURE 6



3.0 LOGGING, CORING, AND RESERVOIR ANALYSIS

A full complement of the standard logs was taken on each well. Though neutron and sonic logs give some clue (after-the-fact) of where the production zones might be, there is still no reliable correlation to use such logs to indicate producing regions prior to running production casing. (In the case of fracture permeability, the well must be left barefoot or slotted casing installed.) Perhaps the main difficulty is that to date it is not positively known where the producing zones are. Flow meters from a number of organizations have failed to work in the down hole environment. Re-injection of cold water into formation has, where done, given clues from resulting temperature logs where the formation is taking water. These might correspond to the producing zones.

A number of simulated in situ permeability measurements were taken on the cores withdraw. The results varied by several orders of magnitude, even from samples a foot apart. This further supports the contention that the production is from fractures and not from homogeneous permeability.

Well down-hole pressure response has been measured, both in the producing wells and in the other two wells, for several combinations of the producing well. From the data, the product of permeability and reservoir thickness has been calculated, where definitive results were obtained. One such case is the response from flowing well #2, and these are summarized in Table 1. The two wells seem definitely to be located within the same reservoir. This reservoir appears to be extensive, since it exhibits twice daily tidal effects. (Figure 7)

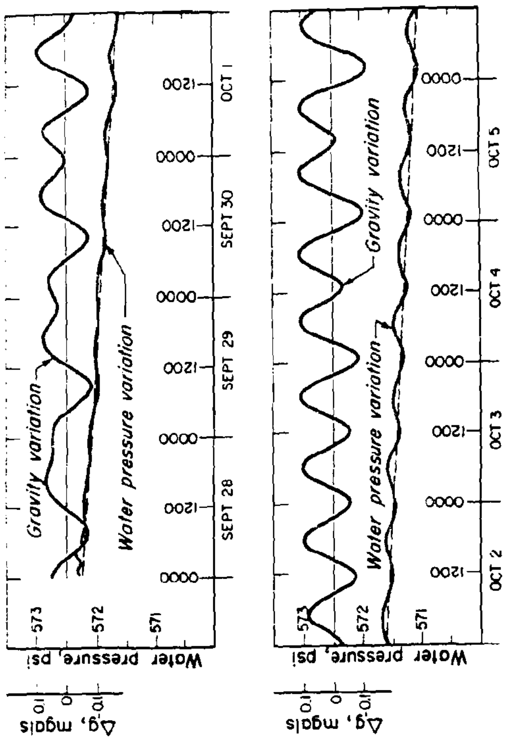
TABLE 1

Results from Flowing RRGE-2 and Measuring Pressure in RRGE-1

	Preliminary Test Sept. 14 to Sept. 17, 1975		Long Duration Test Sept. 20 to Oct. 16, 1975	
	Theis Curve Matching Procedure	Asymptotic Solu. (Jacob's Method)	Theis Curve Matching Procedure	Asymptotic Solu. (Jacob's Method)
kH, md feet	2.25×10^5	2.22×10^5	2.28×10^5	2.28×10^5
ØCH, ft/psi (Porosity x Compressibility x Thickness)	5.74×10^{-4}	5.39×10^{-4}	1.19×10^{-3}	9.38×10^{-4}
Transmissibility gpd/ft at 296°F	2.37×10^4	2.34×10^4	2.41×10^4	2.37×10^4
Storage Coefficient S	2.31×10^{-4}	2.16×10^{-4}	4.78×10^{-4}	3.77×10^{-4}

FIGURE 7

EFFECT OF LUNAR ATTRACTION ON WATER PRESSURE IN GEOTHERMAL RESERVOIR, RAFT RIVER VALLEY, IDAHO



On the other hand, well #3 appears to not be communicating readily with the other two. It also exhibits notably different chemistry than the first two. RRGE #1 and #2 have 2000 ppm dissolved solids, while RRGE #3 has nearly twice this amount.

4.0 TECHNIQUE SUMMARY

The Raft River producing formation itself is tight (low permeability) except for fractures, which are the key to getting adequate production from its wells. To the extent this area is typical of western valleys, the experience in discovering and extracting the resource is instructive. Since one never knows in advance where the resource is, drilling it with water is essential. Though drill stem testing should overcome the effects of a mud column, the test involved dangers of hole collapse and may be testing a region of no fractures (as occurred in RRGE #2 on a test of a 100 ft column just above the region that first started producing). The advantage of a light density column of drilling fluid, whether water or aerated water, should not be underestimated in allowing the geothermal fluid to enter the hole during drilling.

The variable nature of the distribution of fractures makes it appropriate to consider multiple channeling below the production casing. Each such directionally drilled channel adds only 10 to 15% to the total well cost, and can mean the difference between a successful producer and a failure. Such channels can also provide an increment to total flow in a homogeneous formation exceeding the incremental cost increase.

To date, logging methods during drilling are inadequate to tell where the resource is. The expense is usually prohibitive of maintaining a drill rig over the well while it is tested adequately prior to a decision on casing the well or drilling further. For this reason, a light drilling fluid that will not even temporarily block the fractures is important. Multiple channeling, in the case of Raft River was undertaken in a relatively consolidated region, and the use of only water did not involve problems of hole stability.

The producing zones in the wells have been inferred indirectly from temperature profiles taken after the re-injection of cool water. Further attempts at use of flow meters will be made. Currently, the following conclusions about the individual wells producing zones can be drawn:

- #1 Various producing zones from 3700 to 4600 ft. No production below 4600 to T.D. at 5000 ft; this latter 400 ft being quartzite and quartz monzonite.
- #2 Principal producing zones at 4400, 4900, 5200, 5800, and 5900 ft. Essentially no production below. The principal production appears to be at 4400 and 4900 ft, before reaching quartz monzonite.
- #3 Production from 4500, 4900, 5300 and 5400 ft depths, most of these are fractured zones in the Pre-cambrian.

Re-injection experience with the wells shows almost a direct comparison with the production flow and pressure data, i.e. 400 psi pressure to re-inject 1200 gpm to 1500 gpm typically. None of the three wells were designed specifically for re-injection. Current preference is that such a well should consider regions of good permeability not only in the main producing reservoir but somewhat above it in the mixing zones where already lower temperature water exists. Reduced pumping costs for re-injection are a major emphasis for future efforts.