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MEMORANDUM

November 14, 1984

TO: W. R. Holman
Marshall Reed

FROM: D. L. Nielson
J. N. Moore

SUBJECT: Review of the Niland Geothermal Project

At your request we reviewed the geoscience data from the Niland geothermal project in conjunction with the Geothermal Loan Guarantee Program. The purpose of our review was to identify any resource related obstacle to the production of 25 MW. This review was brought about by information received from the drilling of Britz #4 which proved to be cooler than other holes drilled in the field.

On Thursday, November 1, we met with Bill Smith of Republic Geothermal, Inc. (RGI) and Gordon Austin of the Ralph M. Parson's Company at the offices of RGI in Santa Fe Springs, California. They presented us with an overview of the project to date. We were given copies of a summary report which Smith was preparing following the completion of the Britz #4 well. This report integrates the data from previous holes with that received from Britz #4. We were told that Britz #4 was drilled on the eastern portion of the property at DOE's request to test the limits of the field. The well was completed at 9570 feet. Attempts to flow the well were unsuccessful. During the drilling, approximately 200 feet of casing had unscrewed and followed the bit down the hole. This section of casing became lodged at about 8000 feet, and was causing sufficient problems that the well was plugged back to 6500 feet in preparation for a side track. Due to the lower temperatures encountered in this hole, Fee #6 was spudded from the pad of Fee #5 and it will be directionally drilled to the west.

On November 2, we returned to RGI for half the day to gather more information. We then went to the campus of the University of California Riverside for discussions with Dr. Wilfred Elders and his colleagues. Since the time frame of the review was so short, we had to rely a great deal on what other people were telling us, and our conversations with Elders allowed us to verify conclusions presented to us by RGI and Parsons. In addition, in order to complete this review in the required time we had to focus on a few points. These were as follows.

1. Is there a thermal barrier between Britz #3 and #4?
2. Is the stratigraphic and structural picture reasonable?
3. What controls the production of the geothermal fluids?
4. What can the fluid chemistry tell us about the temperatures and the origin of the geothermal fluids?
5. Is the hydrothermal alteration consistent with the reservoir model?

These points are discussed in detail below.

Thermal Regime

The Niland Associates lease is located on the northeast side of the Salton Sea geothermal temperature anomaly. Regional data demonstrates that the isothermal surfaces are dipping to the east in this area. It was therefore expected that holes on the eastern portion of the lease would be cooler as a function of depth than holes on the western portion of the lease. Bottom hole temperatures measured seven hours after circulation stopped in Britz #4 reached 391°F and 411°F, ten hours after circulation. Since the hole was plugged, we can only estimate what the bottom hole temperature would have been had the hole had time to equilibrate. Figure 1 shows the temperature vs time at two points in Britz #3; both depths showed an increase of 121°F from shortly after circulation to equilibration three years later. Of course many factors will influence the amount and speed of temperature increase, but if we accept 120°F as a good estimate then Britz #4 should reach a bottom hole equilibration temperature of 510°F. This is about 30°F lower than is predicted by extrapolating the regional isotherms. From this we conclude that the isotherms are dipping to the east as predicted, but there are no major thermal barriers that will affect the success of the project. Wells in this area have to be deeper to intersect the producing horizons.

Stratigraphy and Structure

The subsurface stratigraphy of the area is principally interpreted through the use of electrical logs. We looked at RGI's picks and they appear to be reasonable. Elders intends to lithologically log these holes and correlate the data with the electric logs to form a stratigraphic framework, but that task is outside his present interest in nuclear waste analogs. Given the stratigraphic picture, the structural interpretations presented by RGI are also quite reasonable.

Production Controls

Production is apparently controlled by fracturing which crosses lithologic boundaries. The fracturing appears to be related to the degree of alteration, and is best detected by cycle skipping on borehole sonic logs.

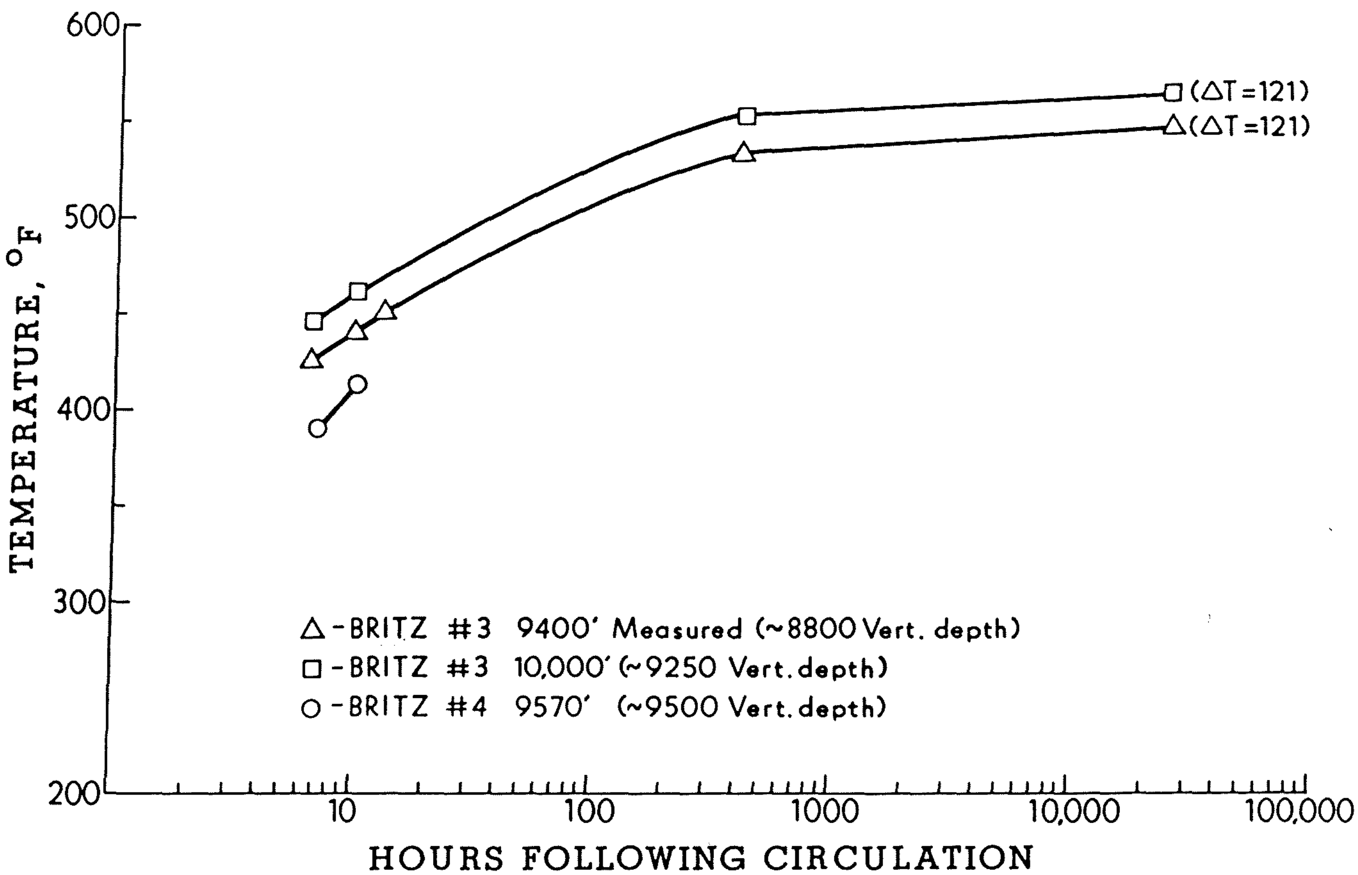
600
500
400
300
200
TEMPERATURE, °F
(ΔT=121)
(ΔT=121)
△-BRITZ #3 9400' Measured (~8800 Vert. depth)
□-BRITZ #3 10,000' (~9250 Vert. depth)
○-BRITZ #4 9570' (~9500 Vert. depth)
10
100
1000
10,000
100,000
HOURS FOLLOWING CIRCULATION

FIGURE 1

Britz #4 was only about 100 feet into this zone of fracturing when drilling stopped.

Fluid Chemistry

The chemistry of the hydrothermal fluids has been examined in detail by Don Michels of RGI. Fee #1 and #5 produce hypersaline brines characterized by a total dissolved solids (TDS) content of approximately 250,000 ppm. In contrast, the fluid discharged from Britz #3 is less saline, having a TDS content of 138,000 ppm.

Michels has suggested that this moderately saline water does not represent an independent fluid type but is instead a mixture of the hypersaline brine with a second, less saline fluid. His calculations indicate that this second fluid must have a TDS near 70,000 ppm. Furthermore, it can be shown that the lower salinity fluid must be less dense, and therefore lie above the hypersaline brines.

The presence of two fluids with different salinities is supported by fluid inclusion data from Fee #1. Low salinity fluid inclusions occur in paleoaquifers at depths of 6000 and 10,000 feet, whereas inclusions containing hypersaline brines occur at a depth of about 9000 feet. Heating measurements indicate that the high salinity fluids had a temperature of 572°C, whereas the lower salinity brines occurring at 10,000 feet had a temperature of about 563°C. These data are generally consistent with the present temperatures and indicate that the boundary between the brines has not remained stationary with time.

Britz #4 produced a fluid slightly less saline than the fluid from Britz #3. This fluid has a TDS content of approximately 80,000 ppm. Although the fluid was contaminated with drilling mud, the relatively high metal contents suggest that the fluid is a mixture of the hypersaline brine and lower salinity fluids. The hypersaline fluid may have entered the well near its base where the sonic logs indicate an increase in fracturing. The presence of hypersaline brine in Britz #4 argues that the poor productivity of this well is more a reflection of its failure to intersect permeable fractures than to any fundamental changes in the reservoir. Drilling to deeper depths appears to be warranted in this area of the field.

Hydrothermal Alteration

The hydrothermal mineralogy of the Niland wells is being studied by scientists at the University of California at Riverside. The mineralogy of Fee #1 and #5 and Britz #3 have been established from X-ray analysis of the cuttings and by some thin section work. Chlorite is the dominant hydrothermal mineral in the wells first occurring in quantities greater than 5% at 4000 feet in Fee #1 and at 6000 feet in Britz #3. All of the production in Fee #1 and Britz #3 occurs at least several thousand feet beneath the top of the chlorite zone. At these metamorphic grades, permeability will probably be controlled by fractures.

Chlorite typically marks the onset of high temperature alteration in the Imperial Valley, becoming abundant only at temperatures above about 180°C. The top of the chlorite zone in the two wells thus defines a south-eastward dipping surface that appears to be generally formable with the present temperature distributions in the wells. The hydrothermal mineralogy of the Niland wells differs in two respects from the more "usual" alteration assemblages which characterize the high temperature fields of the Imperial Valley. Despite the relatively high temperatures at Niland, epidote and base metal sulfides are absent from the altered rocks. The lack of epidote may reflect relatively high CO_2 contents in the reservoir; the reason for the absence of sulfides (other than pyrite) is less clear.

Conclusions

The results of our review were reported at a meeting in the offices of BGI in Berkeley on November 3. These conclusions were also phoned to Marshall Reed following our meeting.

Our review found that the results of Britz #4 do not change the resource model for the Niland field. The resource was known to have been deeper in the vicinity of Britz #4 and its failure to encounter significant fluid production results from the relatively shallow depth of the well. Evidence shows that had the hole been allowed to come to equilibrium, temperatures would be in line with those previously predicted.