THE MONROE KGRA

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ABSTRACT

A preliminary resource assessment of the Monroe KGRA estimated a maximum resource temperature of 120° C associated with the Sevier Fault. The fault is fed from a large watershed to the east. In drilling, the maximum bottom-hole temperature encountered was 81° C with a wellhead temperature of 165° F. The natural artesian flow was 16.4 liters per second. Well pumping at 390 liters per second reduced the water level in the well by 122 meters in 30 hours during which water seepages at the Monroe Mound were either greatly reduced or stopped entirely.

INTRODUCTION

Monroe City is a small central Utah community with a population of 2,000. It is located about 250 km south of Salt Lake City in the Sevier River Valley to the immediate west of the Sevier Fault. The fault rises to within 600 m of the town's eastern boundary. The Monroe KGRA is situated along this fault and is characterized by two large tufa mounds from which springs discharge up to 24 liters per second of warm water.

Mundorff (1970) described the hot springs of the area, furnished chemical data and flow estimates. He reported the dissolved solids concentration of the Monroe Springs discharge at 2,770 ppm with the major constituents being: Silica 54 ppm, Calcium 282, Sodium 562, Bicarbonate 354, Sulphate 898 and Chloride 630. Utilizing the Na-K-Ca geothermometer of Fournier and Truesdell (1973), W. T. Parry calculated the minimum geothermal reservoir temperatures (temperature of last wall rock equilibration) at the Monroe Mound and Red Hill Springs as 197° C and 193° C, respectively. Measured temperatures of the Monroe Mound and Red Hill Springs were 65° C and 76° C, respectively.

In the summer of 1977, the University of Utah (Ward, 1977) performed a comprehensive resource assessment of the Monroe KGRA under U. S. Dept. of Energy funding. This reservoir assessment indicated that a temperature of 120° C might be realized at a depth of 300 m. Recharge to the field is provided from drainage from the Sevier River Valley and a large watershed area to the east for which the Sevier Fault serves as a conduit.

This paper summarizes the exploration and resource assessment performed in the vicinity of the Monroe Mound.

SITE EXPLORATION

Geology. The hot springs and geothermal system are structurally controlled by the Sevier Fault which separates upthrown Tertiary volcanics to the east from Quaternary alluvium to the west; see Figure 1. Test hole lithologies indicate a sequence of sinter deposits in the shallow subsurface, underlain by altered Quaternary alluvium consisting primarily of quartz latite fragments derived from the volcanic range to the east, and more consolidated volcanic bedrock at the base.

A dip of 67° ± 3° from horizontal for the Sevier Fault zone was computed on the basis of the intersections with more consolidated volcanics, well geometries, and an assumed fault trend of north 10° west. This dip is shallower than that deduced from the geophysical modeling and may indicate step faulting. Temperatures observed in the test holes and the thermal gradient holes indicate a strong convective system rigorously confined along the fault zone.

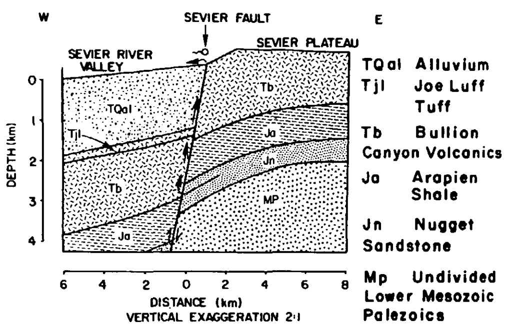

Figure 1. Generalized geologic cross section of the Sevier Fault near Monroe, Utah.

Resistivity Survey. The major purpose of the survey was twofold, first to map the trace of the Sevier Fault which serves as the focus and the conduit for the hydrothermal fluids and second to map the near surface expression of the hydrothermal system in the vicinity of Monroe Mound - Red Hill Springs and its probable extent. The survey consisted of 21 line-km of 100m dipole-dipole mapping on short east-west lines (1 to 2 km

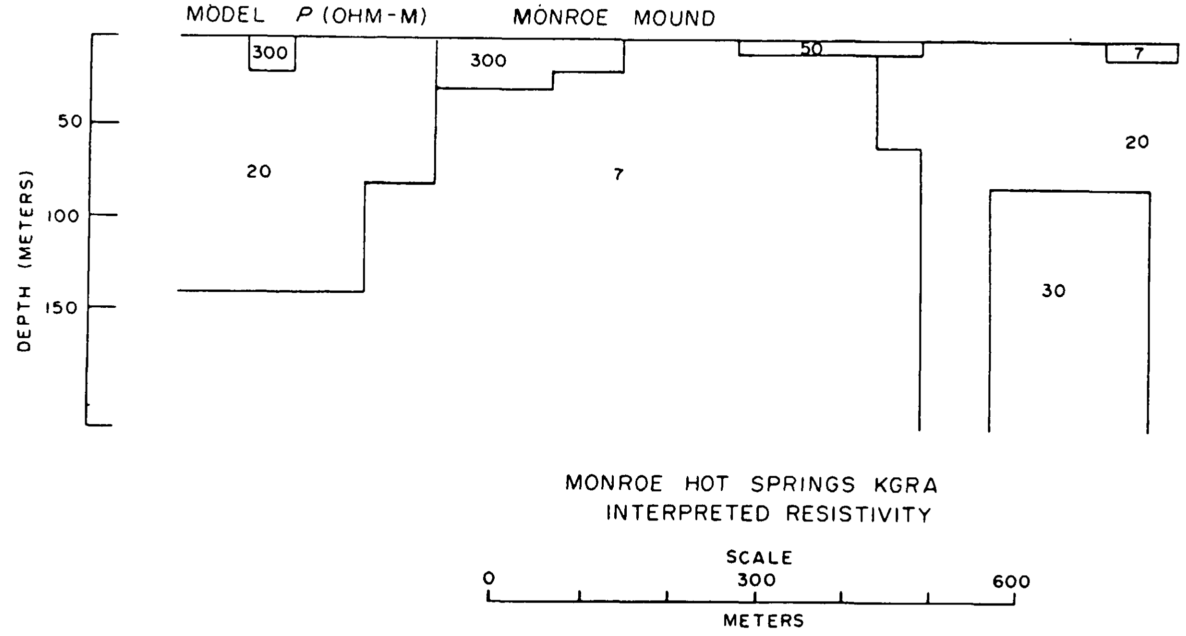

Figure 2. Two dimensional resistivity model across the Monroe Mound.

in length) spaced at 300m intervals through the hot springs area and 1 km intervals on the peripheral of the hot springs area. The resistivity contour map outlines a resistivity zone (<300Ωm) which represents the trace of the Sevier Fault. Within this zone is an area of low resistivity (<10Ωm) which represents the near surface extent of the hotter portions of the convective hydrothermal system, and follows the trend of hydrothermal springs in the Monroe Mound-Red Hill area. A northwest trend of low resistive values away from the Monroe Mound-Red Hill Springs may be assumed to be evidence of brine leaking northwestward from the convective hydrothermal system along the trend. This is demonstrated in the two dimensional model of Line M77-14 (Figure 2) across the Monroe Mound which indicates a surficial cover of resistive alluvium underlain by a low resistive brine-saturated alluvium. The model also indicates the extent of the convective hydrothermal system.

Thermal Gradient Measurements. Eight thermal gradient and test holes were drilled by the Univ. of Utah, seven in the vicinity of the Monroe Mound (Figure 3). Temperature profiles in the thermal gradient and test holes are shown in Figure 4. The data have been projected on a line perpendicular to the Sevier Fault. This projection allowed construction of the temperature profile across the Monroe geothermal field (Figure 5). This profile reveals the extent and characteristics of the temperature field. Even the bottom of these holes were undoubtedly located in the zone of mixing of deeper, hotter hydrothermal waters and surface water derived from the mountains to the east.

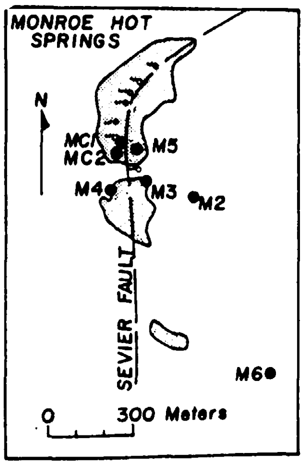

Figure 3. Thermal gradient and test holes.

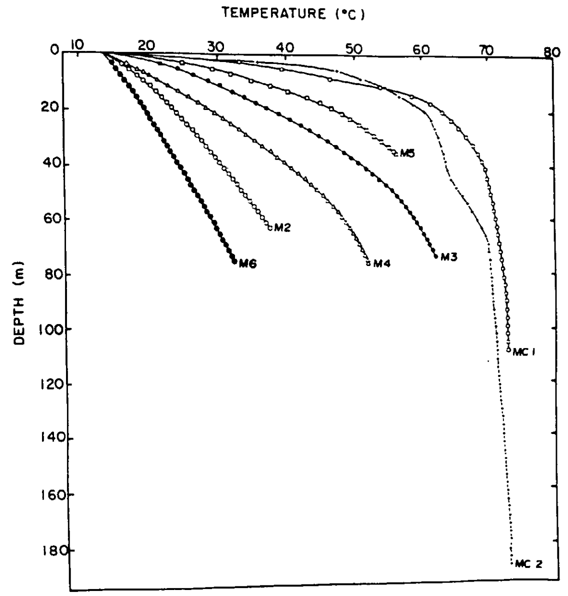

Figure 4. Temperature profiles in thermal gradient and test holes.

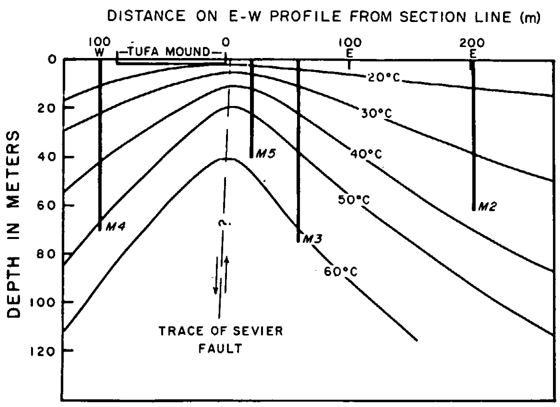

Figure 5. Thermal gradient profile across the Monroe Mound.

Geochemistry. The chemical analysis of the water is:

Calcium	224 ppm
Magnesium	33
Sodium	558
Potassium	57
Silica	44
Sulphate	750
Chloride	750
Bicarbonate	435
TDS	2700
pH	6.6

CO_2 concentration was 0.3 percent by weight.

Summary of Exploration. The geophysical survey identifies the Sevier Fault as the source of the geothermal water. Since this is a major north-south fault and because it appears to be fed from a large watershed to the east where rainfall exceeds 38 cm, an adequate reservoir with an adequate recharge was believed to exist. The chemically estimated mixing model maximum temperature was 120° C.

Drilling in excess of 300 m was recommended for developing the reservoir for direct heat application.

PRODUCTION TEST WELL

Penetration of fractures within the fault, thereby inducing production was the principal goal of the production test drilling. The well was designed and located on the basis of the geometry inferred from the test hole drilling to intersect the volcanic bedrock at 275-335 meters. It was felt that production from the 335 meter level and below offered the advantages of good artesian flow due to increased driving potential with depth. In addition, it was expected that production from this level would minimize any influence of surface hydrologic conditions.

Drilling proceeded as planned until a hard formation was intersected at approximately 210 meters. The chips from this hard zone primarily consisted of limestone with some quartz distributed within the matrix. This was interpreted as a possible locustrine formation resulting from ancient ponding against the fault. Hard drilling persisted to 400 meters although a number of clay stringers were intersected. A significant increase in the fraction of volcanic rock in the returned chips was noted from about 320 meters.

The well was cleaned at 400 meters and logged. Artesian flow was steady at 5.36 liters per second with a shut-in well head pressure of 159 kPa. In view of the disappointing artesian flow (compared with the flow obtained from fractures at 238 meters in MC2) it was decided to drill on to 457 meters in the hope of finding a good producing fracture in the volcanics. The well was completed at 457 meters as shown in Figure 6.

Temperature logs in the production well after completion (see Figure 7) indicate a slight warming at the bottom of the well when flowing artesian at 10 liters per second compared to the shut-in condition. This is attributed to the diversion of warmer water, which would normally flow up the fault zone, into the bottom of the well where the local pressure is reduced below the surrounding reservoir conditions.

The abrupt change in temperature at 305 and 390 meters in the flowing temperature log probably indicates an influx of water into the wellbore at the top and bottom of the slotted liner.

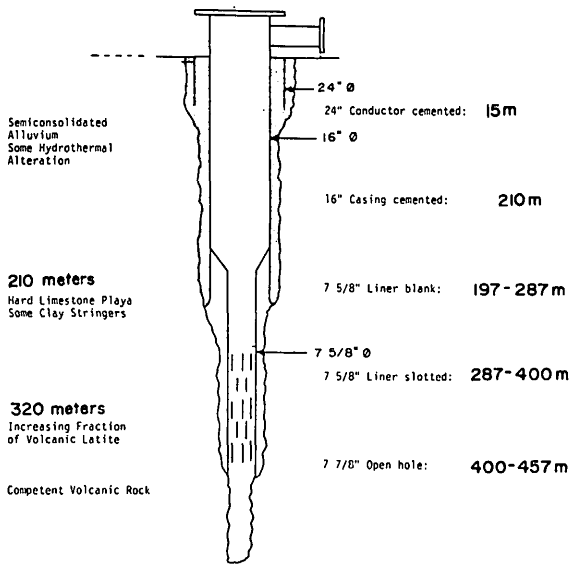

Figure 6. Production Test Well MC3

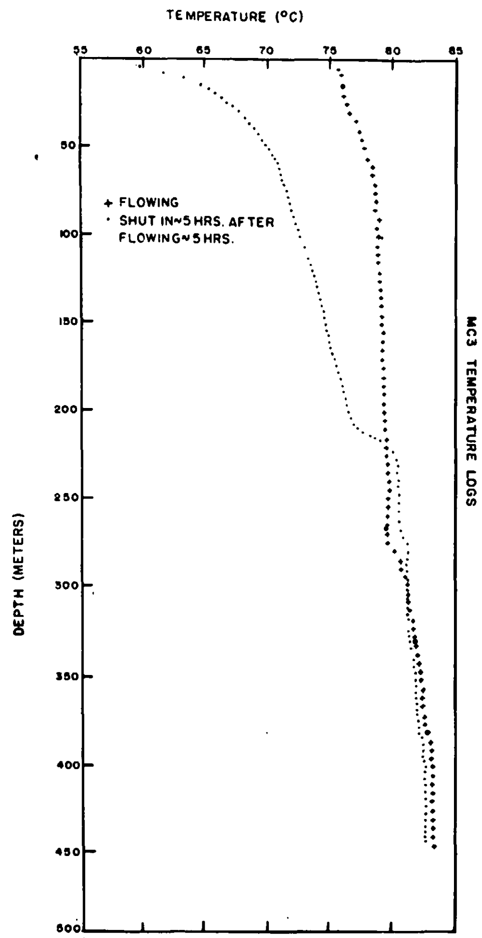

Figure 7. Temperature profiles in production well (MC3).

WELL TESTS

Results of a 70-hour drawdown test during which the well was pumped at 20.5 liters per second are shown in Figure 8. The two monitor wells MC1 and MC2 are 50 meters and 110 meters from the production well, respectively. Computed storage coefficients indicate that confinement increases with depth. This result is consistent with the presence of a discharging hot spring zone. Simple Theis (1935) type curve analysis of the data gives transmissivities of 2.5 m^2/hr and 1.7 m^2/hr for MC1 and MC2, respectively.

The large initial drawdown in the production well is due in part to formation damage near the wellbore. The leveling off in drawdown after approximately 12 minutes indicates the presence of a high permeability or recharge zone, perhaps a water carrying fracture, at between 12 and 20 meters from the wellbore.

The well was surged in an effort to increase the well efficiency. The results of a subsequent drawdown test in which the well was pumped at 38 liters per second for 30 hours are shown in Figure 9. Apparent transmissivities of 2.3 m^2/hr and 1.5 m^2/hr in MC1 and MC2 are consistent with results from the previous test. The drawdown results from the production well, however, do not indicate a strong recharge zone.

The complicated geometry of the aquifer obviously precludes the use of the simple Theis analysis. The two shallow monitor wells MC1 and MC2 probably exhibit the characteristics of the alluvium in the shallow subsurface. The production well draws both from storage in the alluvium and directly from the brecciated fault zone which carries water to the surface.

SUMMARY

The following conclusions are based on the exploration and test program reported.

1. The Monroe Mound/Red-Hill Springs thermal anomaly as defined by resistivity and heat flow surveys is a moderate temperature system rigorously confined to the Sevier Fault Zone. An apparent structural discontinuity in the Sevier Fault provides the plumbing for forced convective discharge of deep circulating water to the surface. The lack of Pleistocene and Quaternary volcanism in the area suggests that the system is in a thermally stable condition supported by the high regional heat flow common to the Basin and Range Province.

2. Temperatures of 82° C (maximum) have been observed at the bottom of the existing well as compared to the maximum temperature of 120° C estimated based on a chemical mixing model. Recent geothermometry interpretations listed in "Assessment of Geothermal Resources of the United States - 1978", Geological Survey Circular 790, suggests that the Monroe Mound/ Red Hill Springs maximum source temperature is between 79° C (chalcedony geothermometry) and

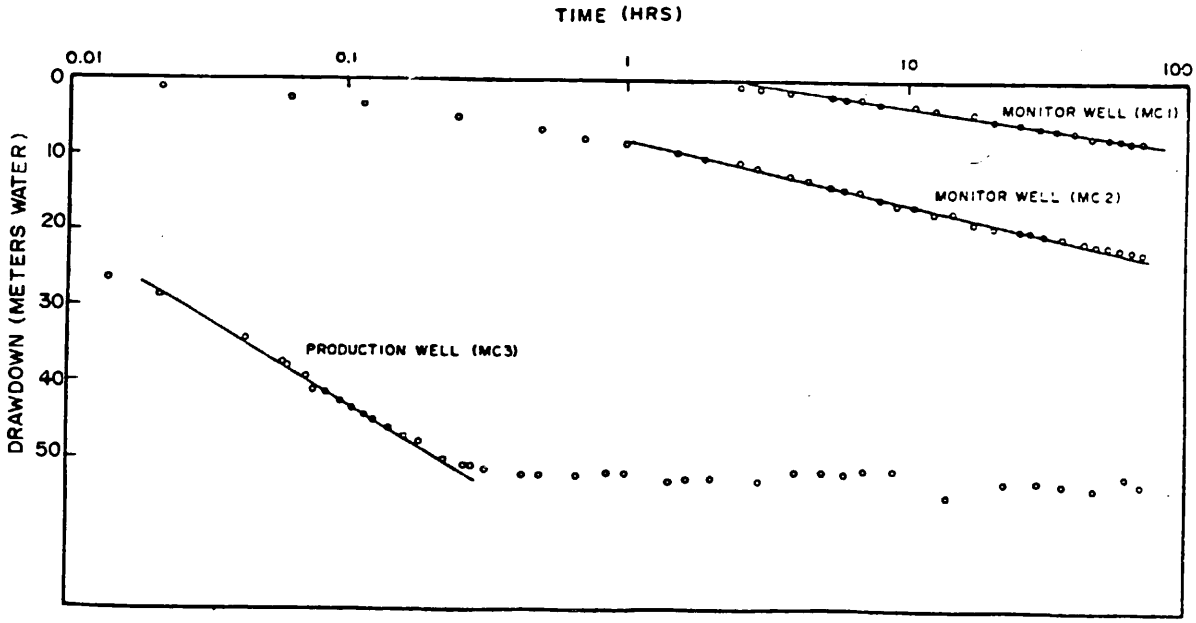

Figure 8. Drawdown data for 70-hour pump test.

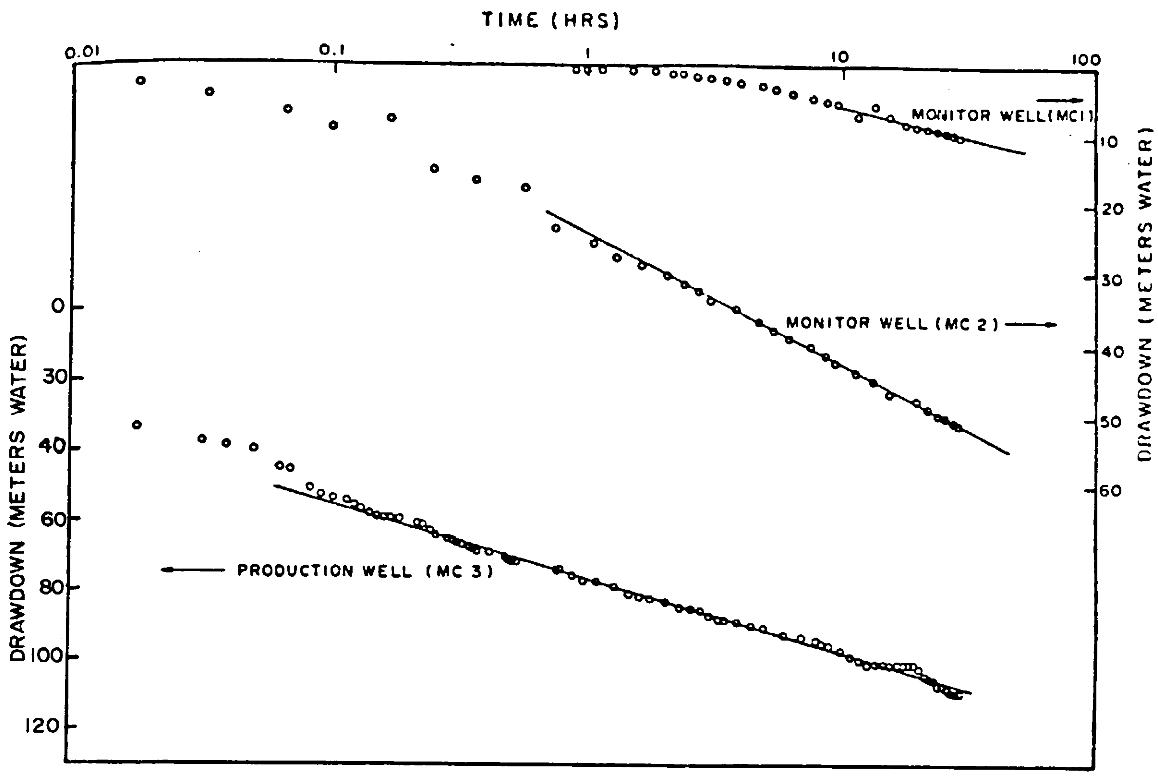

Figure 9. Drawdown data for 30-hour pump test.

114° C (Na-K-Co, Mg - corrected geothermometry) with the most likely reservoir temperature of 109° C (quartz conductive geothermometry).

3. Natural flow from behind the slotted liner (287 to 400 meters) and the open hole section (400 to 457 meters) resulted in a 16.4 liters per second artesian flow. This rate compares with the 12 liters per second at 48° C to 70° C natural seepage at the Monroe Mound. The data suggests that the well is not in direct communication with a natural, hot water conduit but does indicate hot water diversion into the well. The drawdown in the monitor wells and the flow reduction in the nearby springs suggests that water is supplied to the well from a limited, near surface aquifer. Breaks in the drawdown data can be interpreted as evidence of the existence of a water carrying fracture at between 12 and 20 meters from the wellbore. However, the non-uniform flow over the 170 meters of open hole and slotted liner, as evidenced by the localized low temperature water influx at the 287 meters level, occludes a detailed physical interpretation of the drawdown data. Well tests on an isolated, lower portion of the well is needed to further investigate the existence of a nearby natural, hot-water conduit.

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