Geothermal Resources Council, TRANSACTIONS Vol. 7, October 1983

ROOSEVELT HOT SPRINGS/HOT DRY ROCK PROSPECT AND EVALUATION OF THE ACORD 1-26 WELL

S. S. Shannon, Jr., F. Goff, J. C. Rowley, R. A. Pettitt, and F. D. Vuataz

Earth and Space Sciences Division
Los Alamos National Laboratory
Los Alamos, New Mexico 87545

ABSTRACT

Previous hot, dry rock (HDR) geothermal resource evaluation efforts have identified the Roosevelt Hot Springs KGRA as a prime HDR target. The size of the HDR resource is estimated to be at least eight times larger than the adjacent hydrothermal resource. Further research activites to evaluate this HDR resource have involved review of data from the Acord hot dry well, the seismic structure of the area, fluid geochemistry, and hydrology of a shallow aquifer. These recent results are summarized and the most likely HDR prospect area is identified.

INTRODUCTION

The Roosevelt Hot Springs KGRA and peripheral hot dry rock area occur on the western flank of the Mineral Mountains and the adjacent Milford Valley, west-central Utah (Fig. 1). Tectonically, the region is part of the Basin and Range province and displays high seismicity and high regional heat flow (Ward et al., 1978). Young igneous activity and local geology may explain the high thermal output in this region. A young igneous heat source is consistent with 0.01 Myr basaltic flows and cones in the area, and the 0.8-0.5 Myr rhyolitic domes, flows, and ash-flow tuffs along the crest of the Mineral Mountains. However, the volume of the silicic volcanics is small, the geophysical evidence for a shallow magma chamber is inconclusive and the known hydrothermal system is 5 km or so west of the axis of the rhyolitic volcanism. Also, a high temperature of 230°C was recorded at a depth of 3.855 km in Milford Valley in well Acord 1-26, a dry hole about 8 km west of the known hydrothermal system (Fig. 1). Hence, some high subsurface temperatures may be due to conductive effects of a high regional heat flux below thick accumulations of low conductivity Tertiary alluvium in the regional sedimentary basins.

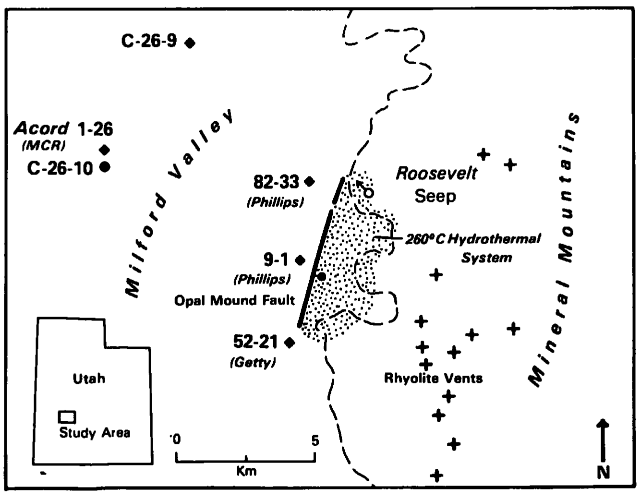

Fig. 1. Location map of the Roosevelt Hot Springs area and exploratory wells.

The known hydrothermal system is localized in a fractured graben east of the Opal Mound (Dome) Fault. The proposed HDR resource area is west of the Opal Mound Fault. Bottom-hole temperatures in four holes range from 200-300°C; and the thermal gradients range from 55-60°C/km (Fig. 1, Table 1). The depths of these hot dry rock holes range from 2 to 4 km; they all bottom in Precambrian gneiss and/or Tertiary monzonite. Similar crystalline rocks occur in the core of the Mineral Mountains and below the area having known hydrothermal resources. The massive monzonite is considered to be a more favorable reservoir rock for HDR than the banded gneiss because fracture control is likely to be simpler in more nearly isotropic rock.

Using simple calculations based on geologic and geophysical constraints, Goff and Decker (1983) estimated that there is about 17 x 10^{18} J of conductive heat in a 2.3 km deep, 27 km^3 volume of rock beneath the Roosevelt Hot springs-Milford

TABLE 1. DATA FROM SELECTED DEEP GEOTHERMAL WELLS IN ROOSEVELT HOT SPRINGS REGION, UTAH
(See Fig. 1 for locations.)

No.	Name	Operator	Depth, m	BHT, °C	Formation at depth	Comment
1	Well 82-33	Phillips Pet.	--	--	Gneiss-Granite	Dry; data proprietary
2	Well 9-1[a]	Phillips Pet.	2049	227	Gneiss-Granite	Dry
3	Utah State 52-21[b]	Getty Oil	2281	202	Gneiss-Granite	Dry
4	Acord 1-26[b]	MCR Geothermal	3855	230	Gneiss-Granite	Dry; heat flow = 3.5 HFU

[a] Glenn et al. (1981)
[b] East (1981)

Valley area, if the average temperature of the mass is taken to be 265°C and if the area of the upper surface of the prism is 10 km^2. East (1981) conservatively estimates, however, that the prospectively valuable HDR prospect area in Milford Valley could be 160 km^2; therefore, some 250 x 10^{18} J of stored heat could exist below this region. East's data also imply that the area with HDR potential is about 8 times larger than that underlain by known hydrothermal resources.

The Roosevelt Hot Springs area has many characteristics that make near-term HDR development feasible. The subsurface temperatures are adequate for generation of electricity, and technology exists to drill and hydro-fracture the crystalline reservoir rocks. HDR-based electricity also could be channeled into existing power lines because a 20 MW(e) plant is under construction and a small wellhead generator has been in operation (Rasband, 1982). Environmental and civil issues should be favorable as the area is a remote desert.

The regional geology and geophysics (horst-graben structure, young igneous rocks, high heat flow, etc.) of this prospect resemble those of other localities in the Basin and Range. A successful HDR system in the Roosevelt area could therefore serve as a prototype for other installations in similar parts of the Great Basin.

DRILLING HISTORY OF ACORD 1-26 WELL

The Acord 1-26 well is dry and has a high bottom-hole temperature as well as an extremely high heat flow (Table 1). This well and the Phillips 9-1 well to the east (Glenn et al., 1981) are significant because they verify that a large HDR resource exists in the area.

The Acord well was spudded on March 30, 1979 and drilling proceeded largely without incident to the total depth of 3855 m (12,645 ft) on June 5, 1979. The rig consisted of a GB-800 EMSCO draw works, an IDECO Full View 40.5 m (133 ft) mast, powered by two D-379 Caterpillar engines. The present configuration of the well is shown in Fig. 2.

The average penetration rate through the predominately conglomerate and monzonite sequence in the lower section of the hole was 2.8 m/hr at a bit load of 9 to 11 t, at 40 to 60 rpm. The only problem occurred at 2813 m (9230 ft), where the drill pipe twisted off leaving 17 drill collars in the hole. These were retrieved, however, on the first fishing attempt. In general, the drilling progressed very smoothly, taking 68 days and averaging 56.7 m (186 ft) per day.

The initial mud mixture, to a depth of 2536 m (8320 ft), was bentonite and water. In the upper 2195 m (7200 ft) of the hole, mud losses were often 1.6 to 4.8 kl/hr, with mica and nut plug being added as lost-circulation materials. Below 2536 m (8320 ft), a Geo-Gel (sepiolite) mud was used. Throughout the drilling, the mud weight was kept between 1080 and 1100 g/l, at a viscosity of

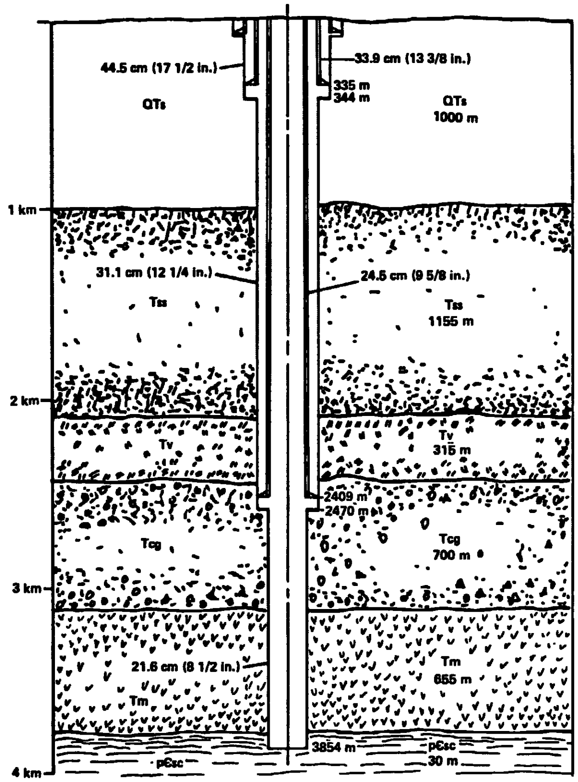

Fig. 2. Section showing well configuration and lithology of the Acord 1-26 well. Symbols similar to Fig. 3.

34 to 38 poise. Casing data for the well are summarized in Table 2. Both the 33.9 cm and 24.5 cm casing strings were cemented full length, from the casing shoe to the ground surface. The cement slurry was composed of Class G cement, containing 40% silica flour and 1:1 perlite.

Four temperature logs that were run in the well during April and May, 1979, were used to calculate the conductive heat flow of 3.5 HFU (East, 1981). Both temperature and differential temperature logs show a constant and essentially featureless gradient except for a few minor perturbations in the upper part of the monzonite section between 3170 and 3489 m (10,400 and 11,450 ft). The caliper log indicates a fairly smooth borehole, with a possible slight enlargement occurring from 3162 to 3165 m (10,374 to 10,384 ft). The gamma ray/neutron log indicates zones of high gamma ray intensity at 3216 m, 3277 m, 3414 m, 3454 m, 3600 m, 3679 to 3694 m, and 3746 to 3847 m (10,551 ft, 10,751 ft, 11,201 ft, 11,332

TABLE 2. CASING DATA FROM THE ACORD 1-26 WELL

Casing Size cm (in.)	Weight kg/m (lbs/ft)	Type	Thread	Length m (ft)	Set Depth m (ft)
33.9 (13-3/8)	81 (54.5)	K-55	Buttress	335 (1100)	335 (1100)
24.5 (9-5/8)	70 (47.0)	N-80	"	397 (1300)	
	70 (43.5)	N-80	"	465 (1526)	
	60 (40.0)	L-80	"	770 (2524)	
	60 (40.0)	K-55	"	779 (2554)	2411 (7904)

ft, 11,942 ft, 12,070 to 12,119 ft, and 12,290 to 12,621 ft), which may be caused by increased amounts of potassium at those depths when monzonitic dikes or sills were injected into the Precambrian country rock, or by the sealing of old fractures with uraniferous materials. However, the neutron log shows that these zones have little or no porosity. The density log gives density values ranging from 2.55 to 2.80 gm/cm^3, with zones of 2.5 from 3383 to 3414 m (11,099 to 11,201 ft), and 2.4 to 2.5 from 3571 to 3603 m (11,716 to 11,821 ft), which represent healed fractures or a change in lithology.

GEOPHYSICS OF ACORD 1-26 WELL

The bottom hole temperature of the Acord 1-26 well at 3855m is 230°C yielding an average temperature gradient of 60°C/km. The calculated heat flow by Group Seven, Inc. is about 3.5 HFU using thermal conductivity measurements on cuttings.

Three seismic lines were run in the general area to determine basement structure. Interpreted lithologies were tied into the stratigraphy of the Acord well. Fig 3, an E-W profile about 2 km south of the Acord well indicates a horst and graben type basement structure of large fault blocks bounded by high-angle normal faults, as expected for the Basin and Range province. The projected position of the Acord well (shown by arrow in Fig. 3 shows a large block of presumably

projected position of the Acord well (shown by arrow in Fig. 3 shows a large block of presumably
intact basement rock suitable for HDR use, but at a relatively great depth. Because depth to crystalline rocks and distance to the localized heat source at Roosevelt Hot Springs decrease to the east, drilling costs and development problems might also decrease if HDR systems were constructed in shallower crystalline rocks between Roosevelt Hot Springs and the Acord site.

GEOCHEMISTRY AND HYDROLOGY OF SHALLOW AQUIFERS

A 50MW(e) power plant, fed by heat extracted from HDR geothermal systems, is presently envisioned to require about 2000 lpm of cold circulating water to make up operating losses (H. Murphy, Los Alamos National Laboratory, oral commun., 1982). Although the Roosevelt area is essentially a desert, several stock wells are drilled into the Quaternary fill around the Acord area and many large irrigation wells draw water for agriculture around the Milford area to the south.

A study of the chemistry of shallow aquifers in the Acord area (F. Vuataz and F. Goff, Los Alamos National Laboratory, unpub. data, 1982) shows that some local wells (i.e., (C-26-10)26) are highly mineralized, resembling in their ratios of Na, Li, and B to Cl, the chemistry of water from the deep hydrothermal system represented by

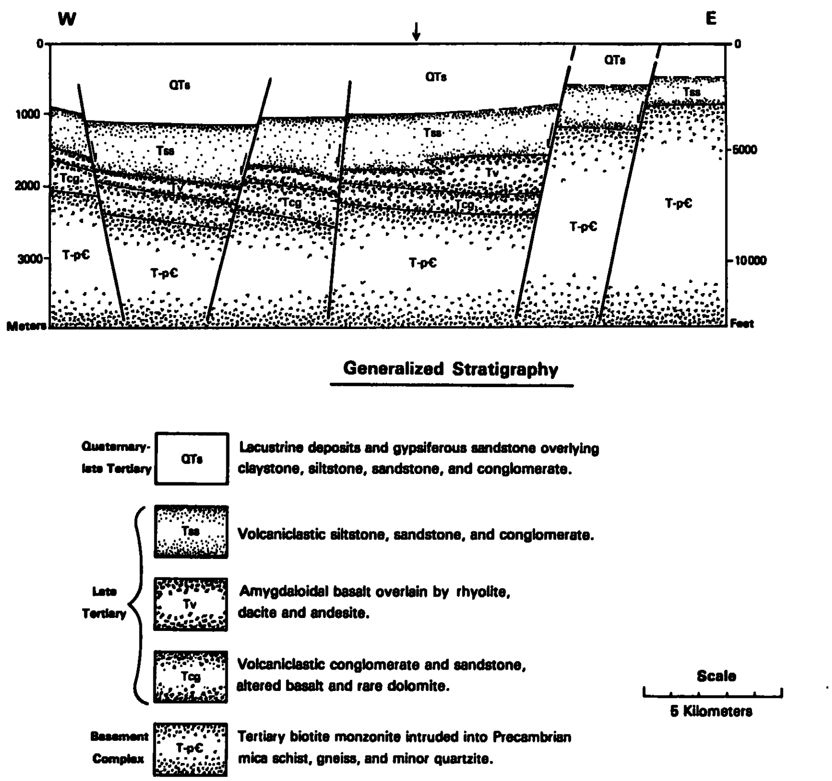

Fig. 3. Generalized stratigraphy of an E-W section through the Milford Valley. The projected position of the Acord 1-26 well is indicated by the arrow.

the Roosevelt Seep (Table 3). The chemistry of these stock wells is significantly more mineralized than water in the Milford area to the south, and because of their high B, it is unlikely that shallow aquifers in the Acord area could be used for commercial irrigation. On the other hand, the mineralized well waters may be suitable for HDR heat extraction which can tolerate mineralization up to 3000 TDS or more. Thus, these well waters are being geochemically evaluated to see how they will behave under high temperature conditions.

Another factor to consider is the storage capacity of the shallow aquifers and their ability to produce water. Two wells located about 4.5 km north of (C-26-9)18 produce roughly 4000 lpm suggesting that at least locally the shallow aquifers are capable of significant production. During April 1983, Los Alamos conducted small scale pump tests of the (C-26-9)18 well. Although hydrologic evaluation is not complete (F. Vuataz, Los Alamos National Laboratory, unpub. data, 1983), this 8-in. well is capable of over 800 lpm with steady state conditions reached in only a few hours; draw down is roughly 8m in granitic alluvial fan gravels. It would seem that a large well could be designed to produce the 2000 lpm necessary for a large scale HDR power plant.

CONCLUSIONS

It can be inferred from seismic data that there are large faulted blocks of crystalline rock at depth which can be penetrated for hot, dry rock reservoir development. From drilling records and geophysical logs, the rock within these blocks appears to be especially tight and dry. The best location for a new hot, dry rock well would be east of Acord 1-26 and west of Phillips 9-1. In this intervening area, the depth to crystalline rock is shallow, but the rocks are still impermeable and very hot. It also appears that abundant circulating water occurs in shallow alluvium above this preferred zone that is not desirable for agricultural use. A hydrofracture and pumping test in a large block of underlying basement would be extremely valuable. The fracture gradient, instantaneous shut-in pressure (ISIP) and fracture density could be determined, and various tools and fracturing techniques could be tested in a different HDR regime (as compared to the only United State HDR test site at Fenton Hill, New Mexico).

The Acord 1-26 well has already been drilled and cased, and could furnish valuable data (as discussed above) at relatively small additional cost. Because of its high temperature gradient and extremely low permeability, the Acord 1-26 well is a prime candidate for near-term HDR experimental work. The BHST of the well at 230°C, a gradient of 60°C/km, and the contact with crystalline rock at 3170 m (10,400 ft) indicate that deepening the well by another kilometer (3048 ft) should be considered for HDR use.

TABLE 3. PARTIAL CHEMICAL ANALYSES (mg/l) OF SELECTED GROUND WATERS OF THE ROOSEVELT HOT SPRINGS GEOTHERMAL REGION, UTAH

Name	T(°C)	K(μS/cm)	pH	Na	K	Ca	Li	HCO_3	SO_4	Cl	B	SiO_2
Roosevelt Seep	26	10400	6.17	1800	280	101	18.2	292	127	3160	28.1	160
(C-26-9)18	18.6	6320	6.70	860	66	300	8.5	890	14.8	1600	14.4	73
(C-26-10)26	16.3	7760	6.97	920	42	380	9.1	387	7.1	2330	19.9	81
Milford Well #1	23.3	418	8.24	60	2	14	0.04	160	53.5	18	0.05	30

ACKNOWLEDGMENTS

Access to the Acord 1-26 well and related data was made possible through the MCR Geothermal Corp. and their interest and generosity in sharing this information is greatly appreciated. Dr. J. Jacobson and Jordon McNay of MCR Geothermal Corp. were especially helpful and we benefitted from their comments and suggestions. Seismic interpretation of Fig. 3 is adapted from T. L. Davis. The aid, encouragement, and cooperation of the Phillips Petroleum Co., Geothermal Division Staff, and especially Dr. R. Lenzer is gratefully acknowledged.

This study is a part of the Los Alamos HDR Resource Assessment and was supported by the U.S. Department of Energy, Division of Geothermal Energy and Hydropower Technology.

REFERENCES

East, J., 1981, Hot Dry Rock Geothermal Potential of Roosevelt Hot Springs Area: Review of Data and Recommendations, Los Alamos National Laboratory Informal Report LA-8751-HDR, 45 p.

Glenn, W. E., Hulen, J. B., and Nielson, D. L., 1980, A Comprehensive Study of Los Alamos National Laboratory Well C/T-2, Roosevelt Hot Springs KGRA, Utah, and Applications to Geothermal Well Logging, Los Alamos National Laboratory Informal Report LA-8686-MS, 175 p.

Goff, F., and Decker, E. R., 1983, Candidate Sites for Future Hot Dry Rock Development in the United States, Jour. Volcan. Geother. Research, v. 15, p. 187-221.

Rasband, L., 1982, Wellhead Geothermal Development Activities, Roosevelt Hot Springs Geothermal Reservoir, Proceedings of EPRI 6th Annual Geothermal Conference and Workshop, June 28 - July 1, 1982, p. 2-1 - 2-2.

Shannon, S. S., Jr., Pettitt, R., Rowley, J., Goff, F., and Jacobson, J. J., 1983, Acord 1-26 Hot Dry Well, Roosevelt Hot Springs Hot Dry Rock Prospect, Utah, Los Alamos National Laboratory Informal Report (in press).

Ward, S. H., Parry, W. T., Nash, W. P., Sill, W. R., Cook, K. L., Smith, R. B., Chapman, D. S., Brown, F. H., Whelan, J. A., and Bowman, J. R., 1978, A Summary of the Geology, Geochemistry and Geophysics of the Roosevelt Hot Springs Thermal Area, Utah. Geophysics, v. 43, p. 1515-1542.