Temperature data and drilling history of the Sandia National Laboratories well at Newberry caldera

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ABSTRACT

A new geothermal well drilled by Sandia National Laboratories in Newberry caldera reached temperatures in excess of 158° C at depths of 350 to 424 m. Artesian fluids entered the well between about 379 and 397 m at a rate of about 340 liters per minute (lpm). The temperature of the main fluid entry is probably in excess of 170° C. The temperature-depth profile of the Sandia well is similar in shape to the nearby Newberry 2 drill hole but reaches higher temperatures at equivalent depths. It is possible that the Sandia well, which is closer to the caldera ring-fault system than Newberry 2, intercepted some of the same hot-water aquifers that Newberry 2 encountered, but the Sandia well is closer to the source of the fluids.

INTRODUCTION

Sandia National Laboratories, Albuquerque, New Mexico, drilled well RDO-1 in Newberry caldera in September and October of 1983. The drilling began on September 16, 1983, and the hole was abandoned on October 20, 1983, as a result of casing problems. The well, which reached a depth of 424 m, was drilled about 457 m southeast of the U.S. Geological Survey (USGS) Newberry 2 drill hole (Figure 1).

The Oregon Department of Geology and Mineral Industries (DOGAMI) and Columbia Geoscience of Hillsboro, Oregon, assisted Sandia scientists with planning and logging the well. Edward A. Sammel of the USGS was also involved in the planning stages.

This report focuses on the temperature data obtained from the well. Lithologic data will be presented in later papers by Marshall Gannett of Columbia Geoscience, John Eichelberger of Sandia National Laboratories, and Terry E.C. Keith of the USGS, and the drilling history will be discussed by Sandia.

TEMPERATURE LOG ANALYSIS

General observations

The final temperature log of RDO-1 was taken on October 6, 1983, two days after mud circulation ceased (Figure 2, Table 1). The log is characterized by very low gradients in the upper part of the well and a very high gradient in the lower part. In the interval from 38 m to approximately 274 m, the hole is essentially isothermal, with a temperature of about 40° ±5° C. From 274 m to the last measurement at 350.5 m, the hole has a linear (conductive) gradient of 1,665° C/km. The temperature probe failed at a depth of 350.5 m, so the final log did not reach total depth.

Earlier temperature logs utilizing Sandia's thermocouple

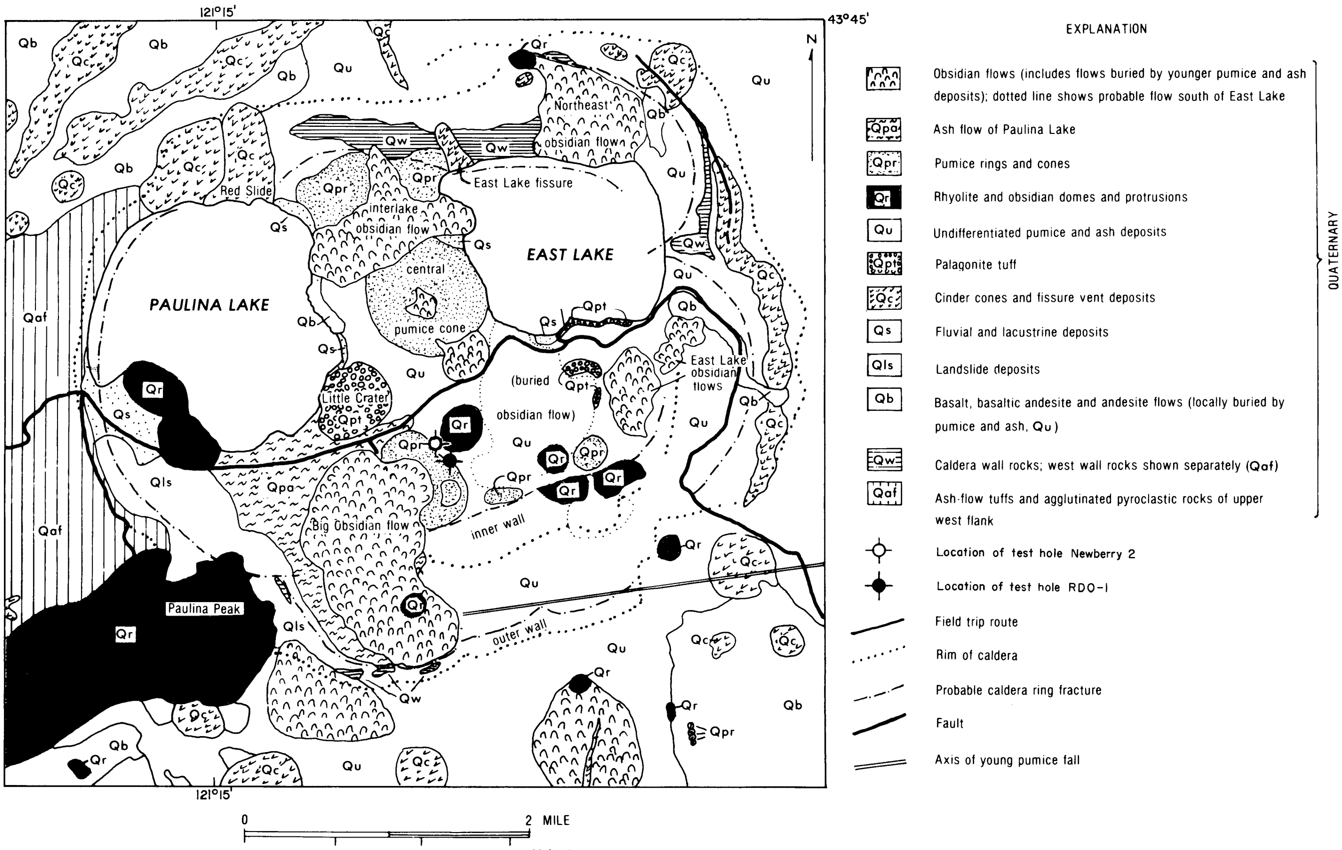

Figure 1. Locations of USGS well Newberry 2 and Sandia National Laboratories well RDO-1. Geologic map is from MacLeod and Sammel (1982).

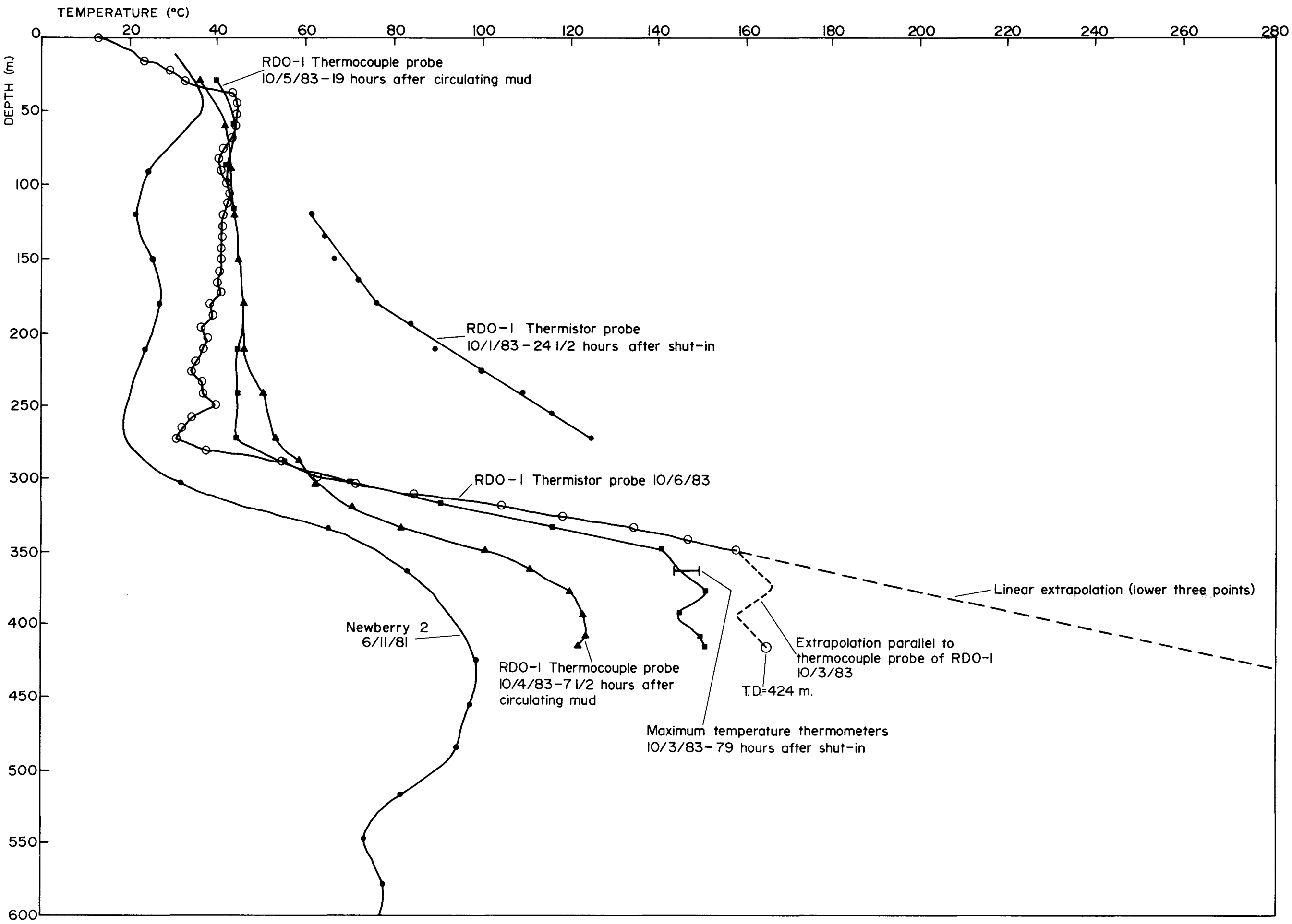

Figure 2. Temperature-depth profiles run at various times during and after drilling the RDO-1 drill hole compared to the profile of the Newberry 2 drill hole at equivalent depths. Thermocouple logs were run by Sandia National Laboratories. The thermistor probe was provided by David D. Blackwell, Southern Methodist University. The first thermistor log was run by Marshall Gannett of Columbia Geoscience; the final log was run by Gerald L. Black of the Oregon Department of Geology and Mineral Industries.

probe indicate that the temperature profile below about 351 m has a very low, irregular gradient, which probably reverses near the bottom of the hole. The earlier logs also show considerable cooling in the lower part of the well as a result of mud circulation. It is probable that the hole was not in complete thermal equilibrium when the final log was completed.

Detailed log analysis

0-38 m: In this interval, the gradient is 770° C/km. It represents conductive heat flow between the surface and a warm aquifer at 38 m. Nearby water wells indicate that the volcaniclastic rocks from 12 to 38 m are saturated. The conductive gradient indicates that there is probably neither rapid lateral nor vertical ground-water flow in this interval.

38-67 m: A warm aquifer (44.5° C) causes this isothermal section of the profile.

Negative inflection at 84, 183, 198, 239, and 274 m: All of these negative inflections (Figure 2) occur in the portion of the hole which has been cased off (casing was set to 305.7 m), so it is unlikely that they are the result of disturbances caused by the injection of drilling fluid into permeable zones in the formation. Mud was circulated in the hole shortly before the temperature log of 10/4/83 was run. As can be seen in Figure 2, the upper portion of the hole was roughly isothermal at a temperature just over 40° C, 19 hours after mud circulation ceased, although the wide separation of data points could allow short wave length temperature inflections to go unnoticed. On the final log of 10/6/83 (Figure 2), the upper portion of the hole had apparently cooled (the DOGAMI thermistor probe and the Sandia thermocouple were not calibrated against one another), and several negative temperature inflections are present. The inflection at 84 m correlates with a pumiceous layer and probably represents a relatively cool aquifer. The inflections at 183, 198, 239, and 274 m do not correlate with lithologic changes. All occur in a portion of the hole composed of uniform basaltic lapilli tuff (Marshall Gannett, personal communication, 1983). The inflections at 183 and 198 m are minor and may be of no significance, or they may represent very small, slightly cool aquifers. The inflections at 239 and 274 m are of higher amplitude than those of 183 and 198 m. They flank what is probably a small, warm aquifer at 250 m. The minimum at 274 m correlates precisely with a cool aquifer in the nearby Newberry 2 drill hole (MacLeod and Sammel, 1982). The convex shape of the temperature-depth curve above and below the temperature minimum indicates that the hole is not yet in equilibrium at that point. Projection of the linear segments just above and below the convex segments indicates that the temperature should eventually stabilize at about the same temperature as observed in Newberry 2.

111-274 m: The overall gradient, except for one interval from 121 to 175 m which is essentially isothermal at a temperature of 41.5° C, is −69.8° C/km. This overall negative gradient, which reaches a minimum temperature of 31.4° C at 274 m, indicates the influence of a cold aquifer at 274 m.

274-350.5 m: The smooth linear gradient of 1,665° C/km in this interval is representative of conductive heat flow through relatively impermeable rocks. These rocks consist predominantly of the fine clay-rich volcanic sediments and devitrified tuffs which are incompetent and incapable of sustaining open fractures for fluid movement (Marshall Gannett, personal communication, 1983).

350.5-424 m (total depth): The last temperature probe did not cover this interval because of failure of the cable and loss of the probe at 350.5 m.

The log of 10/4/83 turns isothermal at approximately 375 m. The hot aquifer occurs between 379 and 397 m (Marshall Gannett, personal communication, 1983). The log of 10/5/83 turns isothermal at approximately 350 m. The difference between the two logs results from intraborehole upflow caused by the overpressured hot aquifer. The negative inflection at approximately 380 m may result from the injection of drilling mud into the hot aquifer. Approximately 80 barrels of fluid were pumped back into the thermal aquifer about two days before this log was run (Marshall Gannett, personal communication, 1983).

By projecting the gradient from the thermocouple log of 10/5/79 onto the bottom of the thermistor profile of 10/6/83, a highly speculative bottom-hole temperature of 158°-166° C is predicted. However, in view of the amount of fluid pumped back into the formation, it is likely that the bottom-hole temperature is in excess of 170° C.

POSSIBLE RELATIONSHIP OF RDO-1 TO NEWBERRY 2

The absolute temperatures in the RDO-1 hole are higher than the nearby Newberry 2 well, but the thermal profiles of the two wells are very similar (Figure 2). This similarity implies that components of common aquifers were encountered in both holes. The fluids in Newberry 2 may be cooler than those in RDO-1 as a result of conductive cooling and mixing with cool meteoric water. RDO-1 may therefore be closer to the source of the upwelling thermal waters which have migrated laterally to the Newberry 2 well. RDO-1 is also closer to the caldera ring fault system than Newberry 2. While it is only speculation, a possible interpretation is that thermal water is convecting up the nearby ring faults and spreading out laterally along permeable layers within the caldera. If this is the case, then similar lateral circulation may be occurring from the ring faults into permeable layers outside of the caldera as well.

CONCLUSIONS

Drill hole RDO-1, drilled to 424 m by Sandia National Laboratories, intercepted a moderate-temperature hydrothermal system at shallow depth in Newberry caldera. Between about 379 and about 397 m, fluids in excess of 158° C produced artesian flow at 340 lpm. Although not reliably measured, the temperature at the fluid entry was probably in excess of 170° C.

Temperatures, although not fully recovered from drilling effects, clearly show that the temperature-depth profile of RDO-1 is very similar to, but much hotter than, that of the nearby Newberry 2 hole drilled by the USGS. The RDO-1 hole may be closer to the source of the shallow thermal water encountered in Newberry 2. Closer proximity of RDO-1 to thermal fluids possibly upwelling in a caldera ring-fracture system may be the cause of the differences in temperature between the two wells.

Table 1. *Temperature-depth log of the Sandia well in Newberry caldera, taken 10-6-83, approximately two days after circulating mud. Total depth of well=1,390 ft; depth logged=1,150 ft*

Depth (ft)	Temp. ° C	Depth (ft)	Temp. ° C
0	14.43	600	39.15
25	20.08	625	39.60
50	23.68	650	36.93
75	29.47	675	38.19
100	33.10	700	37.15
125	43.78	725	35.84
150	44.67	750	34.38
175	44.58	775	36.82
200	44.36	800	37.51
225	43.87	825	40.13
250	41.64	850	35.08
275	40.38	875	32.20
300	41.23	900	31.40
325	42.26	925	38.06
350	42.79	950	55.39
375	42.47	975	63.22
400	41.74	1000	71.78
425	41.64	1025	85.04
450	41.35	1050	104.92
475	41.17	1075	118.78
500	41.38	1100	134.70
525	40.98	1125	147.58
550	40.53	1150	158.27
575	41.28		

REFERENCES CITED

MacLeod, N.S., and Sammel, E.A., 1982, Newberry volcano, Oregon: A Cascade Range geothermal prospect: Oregon Department of Geology and Mineral Industries, Oregon Geology, v. 44, no. 11, p. 123-131.

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Unique state map produced by OSU

Oregon State University researchers at the Environmental Remote Sensing Applications Laboratory (ERSAL) have produced this map of Oregon called the Oregon Landsat Mosaic. It combines satellite pictures of Oregon in a conventional map format with standard map information such as roads, towns, and county boundaries, and Oregon is the first state for which a map of these pictures has been prepared.

The Oregon Landsat Mosaic is a composite of 74 different satellite photographs, the most detailed satellite imagery of Oregon available through 1982—that of Landsat-3 RBV (Landsat is the name of the satellite, and this one is the third in a series launched by NASA in 1978; RBV designates the camera system as "Return Beam Vidicon").

Landsat-3 has been taking pictures from a circular orbit at an altitude of 920 km (570 mi). The orbit is synchronized with the rotation of the earth and also sun-synchronous, so that the satellite covers areas repeatedly, on a regular schedule, and at approximately the same time of day (in this case, 10:05 a.m. PST). Since clouds often cover the state and block the satellite's view, the pictures chosen for the mosaic are mostly summertime photos taken in 1978, 1979, and 1980.

Portions of the RBV pictures were composed for the mosaic by matching them to the 1:500,000 base map of Oregon produced by the U.S. Geological Survey. The resolution quality of the pictures is better than 40 m (43 yds).

The resulting Oregon Landsat Mosaic measures 42 by 53 in. and is available in a black-and-white and a three-color version. A 1,000-word text of technical information about the satellite system and the mosaic is included in the side margin. The three-color version is sold by the Oregon Department of Geology and Mineral Industries in Portland. See the listing under "Miscellaneous Publications" on the last page of this issue. □

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