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THE USE OF SHALLOW AND DEEP TEMPERATURE GRADIENTS IN GEOTHERMAL EXPLORATION IN NORTHWESTERN NEVADA USING THE DESERT PEAK THERMAL ANOMALY AS A MODEL

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The Desert Peak thermal anomaly is located about 50 miles east of Reno, Nevada. It was discovered while drilling temperature-gradient holes near Brady's Hot Springs. This anomaly covers about 100 square miles, making it the largest known thermal anomaly in Nevada. It has a complex outline as it is a composite feature over at least two apparently separate thermal systems. The internal structure is also complex and intense with temperature gradients of from 30 to 60°F/100 feet being common in the heart of the anomaly. Fifty-four temperature-gradient holes deeper than 180 feet have been drilled by Phillips Petroleum to define this anomaly.

The Desert Peak thermal anomaly, along with the Steamboat thermal anomaly, are unique among the larger thermal anomalies in western Nevada in that they are centered on horsts. All other presently known northwestern Nevada thermal anomalies are centered within the basins or along range-front faults. In spite of this unique feature the Desert Peak area has many thermal similarities with such northwestern Nevada geothermal prospects as Humboldt House, Soda Lake, Steamboat, and San Emidio. At the present time Desert Peak can be used as a possible model for these areas.

During the early stages of temperature-gradient drilling at Desert Peak most of the holes were drilled to a depth of 500 feet, however, as the drilling progressed it became apparent that the temperature profiles usually showed no significant changes between depths of 300 and 500 feet. Therefore, with a few exceptions, the last 43 temperature-gradient holes were limited to about 300 feet in depth. In hindsight, had all the temperature-gradient holes been limited to a depth of 200 feet the results of the exploration program would not have changed. An isothermal map at a depth of 200 feet shows an anomaly identical to the temperature-gradient map. In fact, the 100-foot-depth isothermal map also quite accurately outlines this intense anomaly. The Desert Peak thermal anomaly is so intense that for exploration purposes heat flow calculations offer no advantages over simple temperature gradients.

Much additional shallow temperature-gradient work in the basins and low-relief ranges of western Nevada suggests that shallow temperature-gradient holes need not exceed 200 to 300 feet in depth for preliminary exploration purposes.

Well 29-1 was the first deep test at Desert Peak and is located in the heart of the thermal anomaly where the shallow temperature gradients exceed 25°F/100 feet. The location is also within a large roving dipole and magnetotelluric anomaly with resistivities reported to be less than 5 ohmmeters to depths of several thousand feet. The temperature profile of well 29-1 shows a temperature gradient reversal at a depth of 700 feet and an estimated bottomhole temperature of 330°F at 7660 feet. This reversal is believed to be caused by a subhorizontal thermal aquifer which became active about 3000 years ago (Blackwell 1975).

Well 29-1 did not intersect a reservoir, clearly proving that the aquifer extended beyond any reservoir boundaries. Well 29-1 clearly demonstrates that the near-surface temperature gradients and electrical methods are unreliable when located over unexpected shallow thermal aquifers.

It was decided that drilling slim holes, which will be referred to as strat. tests, from 1000 to 2000 feet deep would be the best, cheapest, and possibly the only way to "see" through this aquifer.

To date, eight strat. tests ranging in depth from 1293 to 2000 feet have been drilled at Desert Peak. The temperature profiles in these holes are highly variable and have been extremely valuable in understanding the hydrogeology and geology of the area. With these strat. tests it is possible to construct a temperature cross section which removes the near-surface effects of the thermal aquifer and clearly shows where deep tests should be located. Based on this information wells B21-1 and B21-2 were drilled. Both are producers.

The strat. tests have shown at least three near-surface thermal aquifers to be present within the thermal anomaly. The tops of these aquifers range in depth from 200 to 900 feet, the thickness of the aquifers varies from a few feet to 1000 feet, and the temperature ranges from 108 to 300°F. With this information it is clear that the shallow temperature data over much of the anomaly is controlled by the aquifer temperature and depth, not by proximity to a deep reservoir Generally temperature gradients in excess of 15°F/100 feet at Desert Peak indicate that a shallow thermal aquifer is controlling the near-surface thermal gradient.

Recent deeper drilling at the Humboldt House, Soda Lake, San Emidio, and Steamboat thermal anomalies shows that similar thermal aquifers are common in northwestern Nevada. These complications, which often occur below a depth of 500 feet, mean that heat flow values will be as misleading as simple temperature gradients in properly locating deep wells. Experience to date in these other northwestern Nevada geothermal areas suggests that areally extensive shallow temperature gradients in excess of 10 or 15°F/100 feet should be interpreted as a warning that shallow thermal aquifers are probably present. Electrical methods in these other areas also appear to give misleading and suspect results, especially when there is much water-saturated clay at or near the surface.

Comparison of the two producing wells, B21-1 and B21-2, with nearby strat. tests demonstrates that the temperature gradients measured beneath the aquifers may be accurately extrapolated to reservoir temperatures. However, geological complications do not presently allow prediction of the depth to the reservoir. Well B21-2 proves that these shallow thermal aquifers can overlie the reservoir.

Projecting all the strat. test bottom-hole gradients suggests that an area of four square miles is underlain by 400°F temperatures at a depth of 4000 feet or less, and an area of about 10 square miles is underlain by 400°F temperatures at a depth of 5000 feet or less. This data also shows the deep thermal anomaly to be offset about two miles northeast of the heart of the near-surface thermal anomaly.

In conclusion:

1) Temperature-gradient holes need not be deeper than 200 to 300 feet to outline the Desert Peak thermal anomaly. This also appears to be the case for most of northwestern Nevada when the holes are located in basins or horsts of low relief.

2) The presence of subhorizontal thermal aquifers at Desert Peak and other areas in northwestern Nevada make locating deep and expensive geothermal tests on shallow temperature-gradient data very risky. Electrical techniques and/or the present methods of interpreting electrical data do not appear to be capable of recognizing these aquifers. Experience to date suggests that these aquifers are often misinterpreted as being reservoirs at greater depths, especially when highly conductive material is present at or near the surface.

3) At Desert Peak and other intense thermal anomalies in northwestern Nevada, heat flow determinations offer no advantage over simple thermal gradients for exploration purposes.

4) Slim-hole strat. tests from 1000 to 2000 feet deep offer the best and cheapest means to "see" through these aquifers and to properly locate deep geothermal tests.

5) At Desert Peak it is possible to accurately project the depth to reservoir temperatures based on strat. test information obtained below the thermal aquifers. However, additional complications make it difficult to predict the depth to the actual reservoir.

6) At Desert Peak the heart of the deep thermal anomaly lies about two miles northeast of the heart of the shallow thermal anomaly.

7) The technique of using shallow temperature-gradient holes to outline thermal anomalies and strat. tests to locate deep geothermal tests within the anomalies appears to work well in northwestern Nevada. In other provinces, such as the Snake River Plain in Idaho or the Franciscan terrain in California, other exploration tools and techniques appear to be required.

References:

Blackwell, D. D., 1975, Interpretation of geothermal data from Desert Peak 29-1, Churchill County, Nevada. Confidential report for Phillips Petroleum Company, 19 pp.