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A REVIEW AND ANALYSIS OF GEOTHERMAL EXPLORATORY DRILLING RESULTS IN THE NORTHERN BASIN AND RANGE GEOLOGIC PROVINCE OF THE USA FROM 1974 THROUGH 1981

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ABSTRACT

The northern Basin and Range Geologic Province of the western USA has been widely recognized as a highly prospective area for high temperature geothermal reservoirs. Yet only six apparent discoveries resulted from the drilling of 53 geothermal wildcat wells in this area from 1974 through 1981. This relatively low success rate can be partly attributed to the difficulty of developing accurate geological and geophysical models in this area prior to drilling. However, it may also indicate that large high temperature geothermal reservoirs may be less common in this area than thought previously.

INTRODUCTION

The northern Basin and Range Province of the western United States was recognized in the 1960's as having a high potential for geothermal energy development. This recognition was based on the presence of numerous hot springs, abnormally high regional geothermal gradients, geophysical indications of an anomalous thinning of the earth's crust and, in some localities, recent silicic volcanism. Prior to the leasing of federal lands for geothermal development, which commenced in 1974, drilling at several geothermal prospects had produced encouraging results including one confirmed discovery having a temperature in excess of 390°F. This early drilling activity has been reviewed by Koenig (1970). The U. S. Geological Survey as recently as 1978 estimated the geothermal potential of the northern Basin and Range Province exceeded that of any other geologic province in the U. S. as well as the combined proven and indicated potentials of both The Geysers and the Imperial Valley of California.

This paper reviews the results of the exploratory drilling which has taken place since 1974 for geothermal reservoirs with temperatures greater than 350°F, estimates the average exploration cost per discovery, and presents some conclusions concerning the relatively low exploration success rate compared to earlier expectations. The following types of wells have been excluded from these statistics: (1) wells intended for non-electric uses, (2) wells designed as re-injection wells, (3) all wells at the Raft River Low Temperature Demonstration Project. In this paper the year in which a well is reported is based on the date when drilling operations were terminated.

DEFINITIONS

In discussions of geothermal drilling, confusion usually arises concerning the distinctions between the terms "geothermal well", "geothermal observation well", and "temperature gradient hole". In common usage, the term "geothermal well" refers to a well which is designed to intersect and produce fluids from a known or suspected geothermal reservoir. The term "observation well" usually denotes either a dry hole which is being used for long term monitoring of subsurface temperatures and pressures or a slim hole designed to intersect and test, but not produce, a potential reservoir. Observation wells are normally drilled with oil field rotary rigs and include complete formation evaluation programs. The term "temperature gradient hole (or well)" denotes a relatively shallow slim hole with minimal casing which is intended to monitor temperatures above a suspected reservoir. Temperature gradient holes are usually drilled to depths of less than 3,000 ft by water well type rotary rigs at a fraction of the cost of an observation well. To avoid biasing the statistics pertaining to geothermal well drilling with the inclusion of hundreds of temperature gradient holes, all slim holes having depths of less than 3,000 ft are classified as temperature gradient holes and excluded from this paper.

Definitions are also needed in a discussion of geothermal drilling concerning the distinction between exploratory wells and development wells. In common oil field usage, an exploratory well is usually defined as a well drilled more than one mile from the closest well producing from either the formation to be tested or a deeper formation. The term "wildcat well" is often used interchangeably with the term "exploratory well". However, the term "wildcat well" usually carries the connotation of a particularly high risk exploratory well drilled in an unproven area. In order to highlight the statistics pertaining to the drilling of unproven thermal gradient anomalies, the term "geothermal wildcat well" is defined in this paper to include all production scale wells and observation wells drilled more than three miles from the closest successful geothermal well. The term "non-wildcat well" as used herein includes all development wells, confirmation wells, step-out wells and those exploratory wells drilled less than three miles from the closest successful well.

SUMMARY OF DRILLING ACTIVITY

A total of 82 geothermal wells satisfying the above criteria were drilled in the northern Basin and Range Province between the beginning of 1974 and the end of 1981. Of this total, 53 satisfy the definition of geothermal wildcat wells and 29 fall into the classification of non-wildcat wells. The locations of the wildcat wells drilled during this period and the resulting apparent discoveries are shown in Figure 1. Most of these wells were operated by major and independent oil companies which drilled 44 of the wildcat wells and 26 of the non-wildcat wells. The remaining wells were operated by independent geothermal companies, mining companies and a government laboratory.

The 53 wildcat wells resulted in six apparent discoveries for an apparent wildcat success ratio of 11.3%. Of the six apparent discoveries, only one, the Roosevelt geothermal field in southwestern Utah, is currently undergoing development for a commercial electric power plant. In addition, an announcement is expected soon concerning a pilot plant at the site of the only confirmed geothermal discovery made in the Basin and Range Province prior to 1974, the Beowawe field in north central Nevada. If one or more of the remaining five apparent discoveries should turn out to be unsuitable for development, the wildcat success ratio will decrease correspondingly. On the other hand, reworking of some of the existing dry wildcat wells could result in one or more additional discoveries and a proportionate increase in the apparent wildcat success ratio. Of the 29 wells classified as non-wildcats, 19 were apparently successful for an apparent non-wildcat success ratio of 65.5%.

The 53 wildcat wells were drilled at 35 separate prospects. Twenty-three of these prospects were tested with only one well, eight were tested with two wells, and four were tested with three or more wildcat wells. All of the discoveries during this period were made on either the first or second well. The apparent prospect success ratio, based on six apparent discoveries out of 35 drilled prospects during this period is 17.1%.

The average depth and number of wildcat and non-wildcat wells drilled annually from 1974 through 1981 are shown in Figure 2. With the exception of the year 1979, drilling activity was relatively constant from 1974 through 1981 with an average of nine wells per year consisting of six wildcats and three non-wildcats. 1979 was a record year for geothermal drilling in the northern Basin and Range Province with the drilling of 13 wildcat wells and six non-wildcats. This peak in activity was caused partly by the drilling of seven DOE supported wells during 1979. As this paper is being written, it appears 1982 will see the drilling of about two or three wildcats and six non-wildcats in this region, reversing the wildcat to non-wildcat ratio of previous years.

The average depth of both wildcat and non-wildcat wells drilled from 1974 through 1978 was relatively constant at about 5,600 ft. Although each year saw the drilling of one or more wells to depths of more than 7,000 ft a trend toward the drilling of deeper wells did not occur until after the discovery in late-1978 of a geothermal reservoir at a depth of more than 7,000 ft in the Dixie Valley area of northwestern Neveda. This trend towards deeper wildcat drilling was offset in 1979 by several relatively shallow wells. However in 1980 and 1981 the trend became more apparent as the average depth of wildcat wells increased to 7,642 ft. None of the relatively deep wildcat wells drilled following the Dixie Valley discovery are reported to have been successful. In fact, the two apparent discoveries made during this period both occurred at depths of less than 3,100 ft. The average depth of all successful geothermal wildcat wells drilled in the northern Basin and Range Province from 1974 through 1981 was a relatively shallow 3,382 ft.

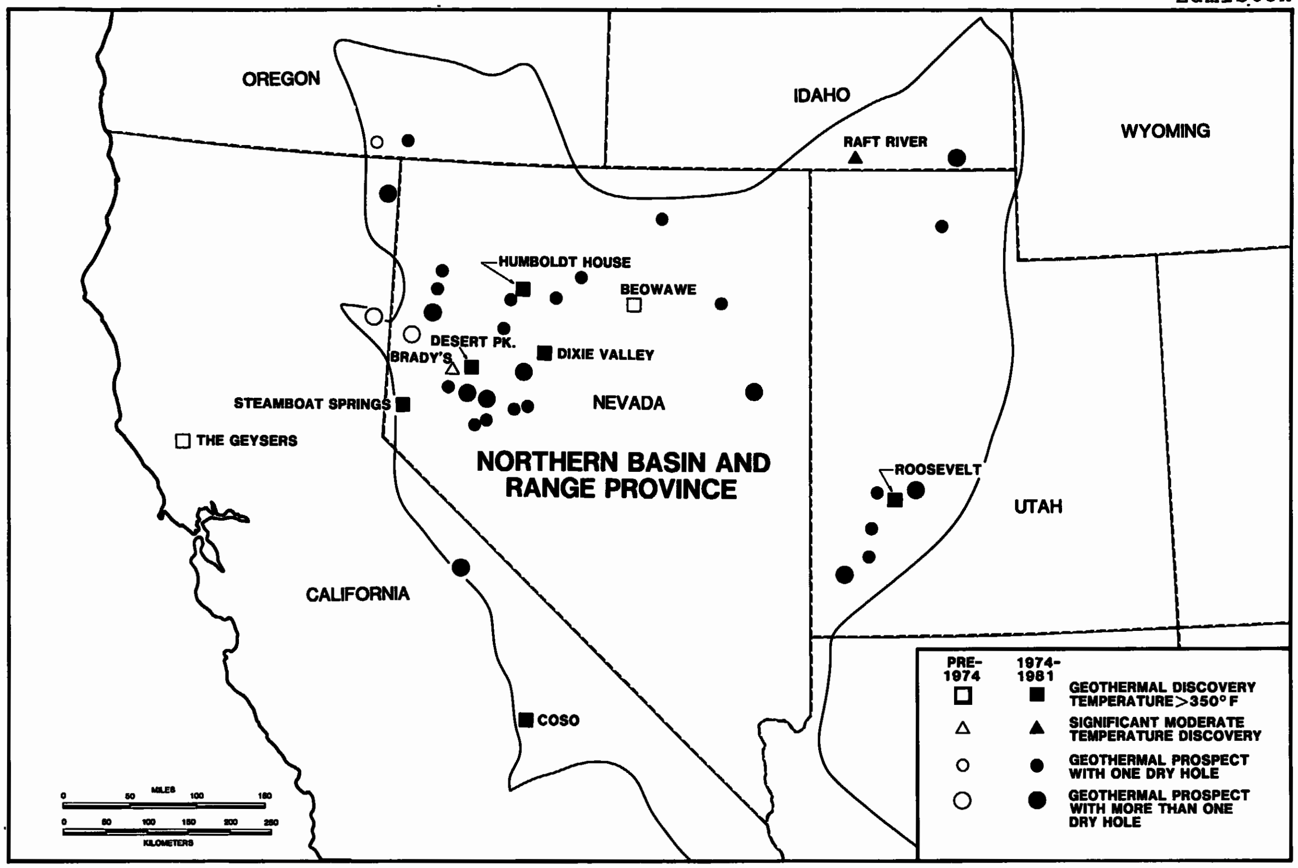

Figure 1. Map showing the location of geothermal discoveries and unsuccessful geothermal wildcat wells in the northern Basin and Range Province.

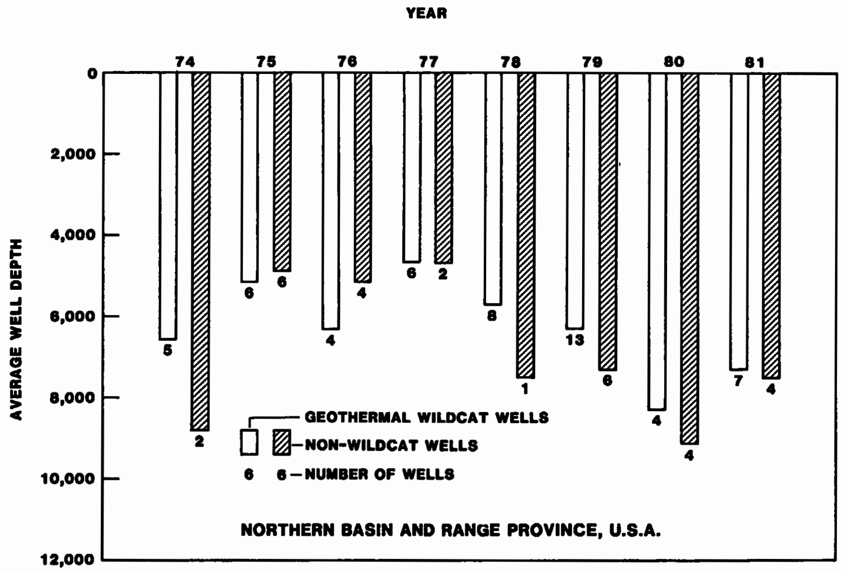

Figure 2. Average depth and number of geothermal wildcat and non-wildcat wells drilled in the northern Basin and Range Province from 1974 through 1981.

In 1977, the DOE initiated the DOE-Industry Coupled Program which eventually resulted in DOE bottom hole contributions to 15 new wells and the purchase of data from eight existing wells. These data are described by Glenn et al (1982). Of the 15 new DOE supported wells, ten fit the classification of wildcat wells. None of these wildcat wells and only one of the five non-wildcat wells, a step-out well at the Beowawe field, appear to have been successful. The DOE program may have encouraged the drilling of a few particularly high risk wells thereby lowering the success ratios in this region.

ANALYSIS AND CONCLUSIONS

The relatively low geothermal wildcat success ratio of 11.3%, while comparable to current oil and gas figures, is disappointing since some of the unsuccessful geothermal wildcats were drilled on highly rated prospects having hot springs for which the U. S. Geological Survey (1979) and private industry had estimated high subsurface temperatures and inferred large reservoir volumes. Combining this success ratio with the overall average wildcat depth from 1974 to 1981 of 6,212 ft and a current estimated dry hole drilling cost for this area of $200 per ft, the cumulative dry hole cost per discovery (at current prices) is estimated to be about $11 million.

In addition, for each prospect drilled, about $750,000 is typically spent on leasing, temperature gradient holes, and geophysics on that prospect and an additional $750,000 is spent on reconnaissance surveys and other prospects which never reach the drilling stage. Since the industry as a whole is currently making one discovery for every six prospects drilled, total non-drilling exploration costs amount to about $9 million per discovery bringing the total cost per discovery to about $20 million. This number can be slightly reduced by drilling observation wells in those areas where long casing strings are not required. It can be shown that an exploration cost per discovery of $20 million is not excessive in comparison to oil and gas exploration costs if the resulting discovery is promptly developed and is capable of producing at least 50 MW of electricity for 20 years.

The most commonly stated reason for the relatively low geothermal wildcat success rate in this region is the lack of a geophysical technique capable of locating geothermal reservoirs at depths of more than a few thousand feet with reasonable precision and reliability. The relatively shallow depth of most geothermal discoveries and the poor success rate for wildcat wells deeper than 5,000 ft support this argument. Conventional and high resolution seismic reflection surveys have been conducted at some prospects. These surveys have produced good coverage of the Tertiary basins but data quality deteriorates near the margins of the basins where most geothermal drilling takes place. Our limited understanding of the geology of geothermal reservoirs is also commonly cited as a reason for the low success rate in this particular province.

While there is truth in both of these arguments it should also be recognized that our starting hypothesis of numerous large geothermal reservoirs associated with the hot springs in the northern Basin and Range Province may be in error. Drilling results to date seem to indicate that, except in the vicinity of a few centers of recent silicic volcanism, geothermal reservoirs are generally smaller and lower in temperature than thought previously. It also appears that most hot springs are not points of leakage from large reservoirs. These observations do not mean that new discoveries will not be made. However, they do suggest that in the future companies may be more cautious in the selection and evaluation of geothermal prospects in this region.

REFERENCES

Glenn, W. E., Ross, H. P., and Atwood, J. W., 1982, Review of well logging in the Basin and Range Known Geothermal Resource Areas: Jour. of Pet. Tech., V. 34, p. 1104-1118.

Koenig, J. B., 1970, Geothermal exploration in the Western United States: U. N. Symp. on Dev. and Util. of Geothermal Resources, Pisa, Italy.

U. S. Geological Survey, 1979, Assessment of Geothermal Resources of the United States - 1978: USGS Circular 790