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THE KEMP THERMAL ANOMALY: A NEWLY DISCOVERED GEOTHERMAL RESOURCE IN PUMPERNICKEL VALLEY, NEVADA.

Thomas Flynn, Dennis T. Trexler
Division of Earth Sciences, UNLV
255 Bell Street, Reno, Nevada 89503

Brian A. Koenig
Union Oil Company, Santa Rosa, California

Abstract

Geophysical, geochemical and shallow-depth drilling surveys were successfully employed in Pumpernickel Valley, Nevada, to identify a previously unrecognized geothermal resource. The study area, located within the "Battle Mountain Heat Flow High", contains many low-temperature (<100°C) geothermal occurrences and at least one moderate temperature (100-150°C) geothermal well. The newly recognized resource is not spatially associated with any known thermal manifestation, and was first identifed on the basis of a 2-m depth temperature-probe survey. Gravity data suggest the thermal anomaly originates from a fault located 1 -2 km (.6-1.2mi.) east of a prominent northeast-trending range-bounding fault. The maximum temperature measured was 70°C at a depth of approximately 100 m (300 ft.). The areal distribution of economically recoverable geothermal fluids associated with this discovery is probably limited to one km^2 or less. Direct temperature measurement techniques were judged to be the most useful in this study.

Introduction

In May, 1981, the Division of Earth Sciences began an assessment of low and moderate temperature geothermal occurrences in Carlin and Pumpernickel Valley, Nevada. (This work was funded by the U.S. Department of Energy, Division of Geothermal Energy, (DOE/DGE) under contract number DE-AC08-81NV10220). The exploration techniques employed in this investigation are based on previous DOE/DGE funded assessment programs that were completed in Carson-Eagle Valleys, Big Smoky Valley, Caliente, Hawthorne, and Paradise Valley, Nevada. The federally-funded geothermal assessment programs were established to expand the geothermal resource data base by characterizing known geothermal areas, evaluating exploration techniques, and possibly identifying new resources.

This paper presents the results of the Pumpernickel Valley assessment. Exploration techniques that provided direct temperature measurements, including 2-m depth temperature probe surveys, and 35-meter depth and 150-meter depth temperature gradient holes, were judged to be most useful in this study. Indirect exploration techniques, including water geochemistry and gravity surveys, provided additional supporting data.

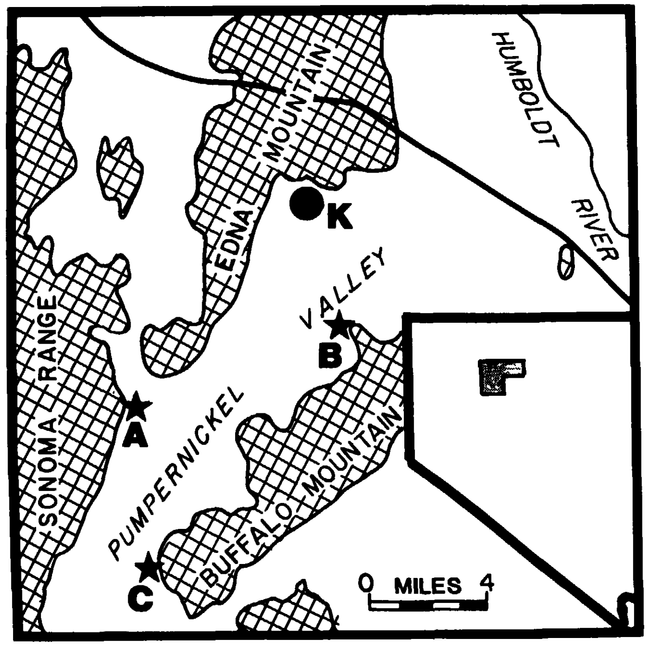

Figure 1. Location map of Pumpernickel Valley: A. Tipton Hot Springs; B. Brooks Hot Springs; C. Tipton-II Warm Spring; K. Kemp thermal anomaly.

Geology and Geothermal Occurrences

The Pumpernickel Valley study area covers approximately 500 km^2 (200 mi.^{2}) and is located in the southeast corner of Humboldt County and the northeast corner of Pershing County in north-central Nevada (fig. 1). Pumpernickel Valley trends predominantly northeast and is bounded by the Sonoma Range to the west, Edna Mountain along the northwest, Tobin Range to the south, and Buffalo Mountain on the southeast.

Rocks exposed in the mountains surrounding Pumpernickel Valley range in age from early Paleozoic to early Quaternary. Early Paleozoic rock types include both deep water off-shore and shallow water near-shore lithologies. The former is represented by the Ordovician Valmy Formation and includes chert, slate, argillite and greenstone; the latter is represented by quartzite of the Osgood Mountain Formation as well as interbedded shale and limestone of the Preble Formation. Both the Osgood Mountain and Preble Formations are Cambrian age. Chert, argillite, shale, and occasional greenstone of the Havallah sequence (Silberling and Roberts, 1962) represent the majority of late Paleozoic rocks found in the ranges surrounding the valley.

Granodiorites of Mesozoic age intrude the Paleozoic sediments and are extensively exposed in the ranges surrounding Pumpernickel Valley. Mafic rocks are observed in some areas between the granodiorites and sedimentary rocks. Limited exposures of Triassic age Koipato group rhyolitic lavas and tuffs are also present.

Tertiary age rocks are almost entirely welded to non-welded silicic ash-flow tuffs, air-fall tuffs and sedimentary rocks. Olivine-bearing basalt flows of Tertiary-Quaternary age crop out at the northern end of Pumpernickel Valley, and prominent exposures occur on Edna Mountain. These rocks represent the most recent volcanic activity in the study area. Alluvial deposits of Quaternary age include fans, playas, and stream gravels, silts and clays related to the Humboldt River.

Exposed faults in the area consist of thrust faults associated with the Permo-Triassic Golconda thrust, northeast trending high-angle normal faults related to Basin and Range style deformation and north-northwest oriented faults associated with the Oregon-Nevada lineament (Stewart and others, 1975). The latter faults have been mapped in Quaternary and Tertiary age basalts (Stewart and Carlson, 1976).

Thermal fluids are known to occur at several locations within the study area. At the Tipton Ranch along the west side of Pumpernickel Valley, several springs discharge thermal fluids from a prominent fault at 30 to 40 GPM with temperatures as high as 85°C. Steam and hot water (104°C) also issue from a 936-meter (3071 ft.) deep well drilled in the immediate vicinity of the former 85°C spring. A single spring (28°C) issues from rocks near the southwest end of Buffalo Mountain on the Pumpernickel Valley side. Brooks Hot Spring (35°C) is situated approximately along the contact between playa sediments and alluvium derived from the northeast end of Buffalo Mountain. There are no thermal springs in the immediate vicinity of the newly discovered thermal anomaly (located near the Kemp benchmark, black circle on fig. 1) although Sulfur Spring (18°C) discharges fluids that are compositionaly similar to Brooks Hot Spring fluids.

Two-Meter Depth Temperature Probe Survey

During October and November, 1981, approximately 100 holes were drilled to a depth of 2-m throughout Pumpernickel Valley. These holes were drilled along accessible roads at 1.6 km (1 mi.) intervals. Thermistor probes, encased in 1.9 cm (.75 in.) diameter PVC tubes were then emplanted and allowed to equilibrate for at least 24 hours. Measured temperatures were corrected for seasonal variations and elevation differences. This was accomplished by using control probes which were allowed to remain in place for the duration of the survey.

Corrected temperatures ranged from 17.5°C to 26°C. Background temperatures ranged from 18°C to 22°C and were affected principally by soil moisture content. Temperatures greater than 22°C were considered anomalous and were taregeted for further exploration. The corrected temperature at Kemp was 26°C.

Corrected temperatures of 23°C and 24°C occurred 1.6 km (1 mi.) north and 2.5 km (1.5 mi.) west, respectively, of Kemp.

Temperatures that were only slightly above background were recorded near Brooks Hot Spring 6.6 km (4 mi.) southeast of Kemp and Blossom Hot Pot 20 km (12 mi.) northeast of Kemp.

35-Meter Temperature Gradient Holes

Four drill sites were selected for 35 m temperature gradient holes on the basis of results obtained in the 2-meter depth temperature probe survey. An additional site was selected in an area where no other subsurface data were available. The holes were drilled with a small, rotary mud rig. Return mud temperatures were monitored continuously and cuttings were collected at 3 m (10 ft.) intervals. The holes were blind-cased with 5 cm (2 in.) diameter, water-filled PVC pipe, backfilled and allowed to equilibrate for three weeks. Lithologic logs for these holes consist of various ratios of gravel, sand, silt, and clay layers. No bedrock was encountered.

Temperature gradients were calculated from temperatures measured at 3 m (10 ft.) intervals in the equilibrated well bores. Gradients for the bottom 10 m (30 ft.) ranged from 25°C/km to a high of 600°C/km at Kemp. Gradients of 100°C/km and 220°C/km were measured at 2-m probe sites with corrected temperatures of 22°C and 19.4°C respectively.

Bottom hole temperatures for four of the wells ranged from 12°C to 20°C. At Kemp, the bottom hole temperature was 50°C.

65-145 Meter Depth Temperature Gradient Holes

Five holes, ranging in depth from 65 m (220 ft.) to 145 m (480 ft.) were drilled in the area surrounding the Kemp thermal anomaly during April and May, 1982. The objectives of this drilling program were to determine resource characteristics such as temperature and depth, to identify possible structural or stratigraphic controls, and to ascertain the areal extent of the resource.

The holes were drilled with a Gardner-Denver rotary rig with both mud and air drilling capabilities. Return mud temperatures were continuously monitored and drill chip samples were collected at 6 m (20 ft.) intervals. The holes were then blind-cased with 5 cm (2 in.) diameter water filled steel pipe and backfilled.

Temperature-depth profile measurements were completed after allowing approximately three weeks for equilibration. Lithologic logs constructed from drill chip samples indicate that alluvial material ranging in thickness from 90 to 110 m (200-350 ft.) overlies bedrock consisting of Paleozoic sedimentary rocks and Mesozoic igneous and volcanic rocks. Figure 2 illustrates the temperature-depth profile and lithologic log for the 110 m (360 ft.) hole drilled at Kemp. The diagram shows a constant gradient of 600°C/km to a depth of approximately 67 m (220 ft.). The well is isothermal to approximately 100 m (350 ft.) with a slight temperature reversal at the bottom where bedrock was encountered.

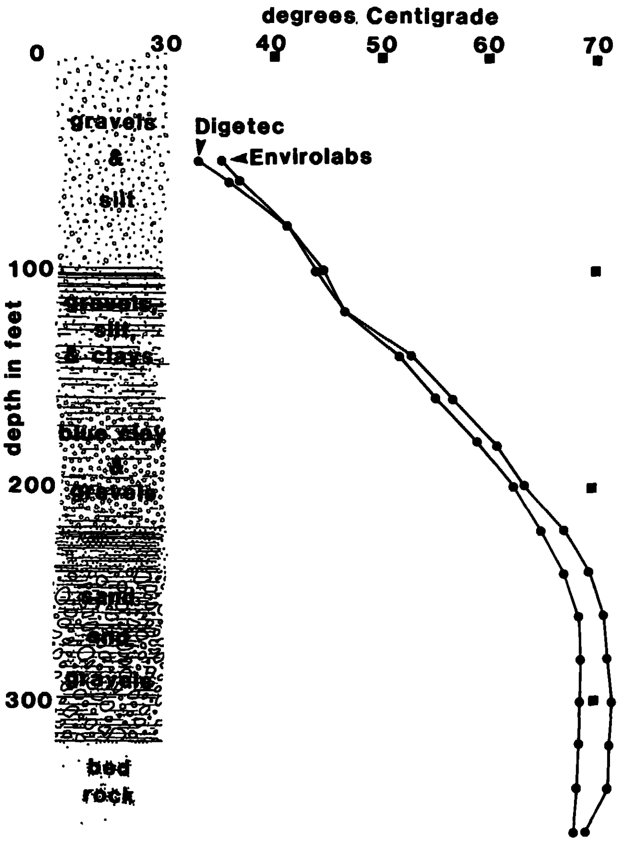

Figure 2. Lithologic log and temperature depth profile for Kemp 110 m (360 ft.) temperature gradient hole.

The zone of constant temperature is coincident with a 30 m (100 ft.) thick section of sandy gravels that lies above the sandstone bedrock and sandy blue clay. The highest temperature recorded in the Kemp well was 70°C at a depth of 76 m (250 ft.).

Temperature gradients in the other wells were significantly lower. PVTG-2, drilled 1.6 km (1 mi.) west of the Kemp well, had a gradient of 3.2°C/km. Several cold water aquifers were encountered in this hole. The gradients in the other holes ranged from 29°C/km to 32°C/km; these gradients are typical for the Battle Mountain Heat Flow High. Lithologic logs for these wells were similar to the Kemp well with the exception of the blue clay layer, which was unique to Kemp.

Gravity Survey

Proprietary gravity data from southern Pumpernickel Valley were combined with the results of a 200-station gravity survey in northern Pumpernickel Valley to construct a complete Bouguer gravity map of the entire study area. A regional gravity survey (Erwin, 1974) was available and both data sets were formatted into digitized 40 x 50 matrices that covered the entire study area. After subtracting the regional effects, a three-dimensional computer-generated graphical representation of the residual gravity was produced (fig. 3).

The view in this diagram is to the southwest with an elevation of 30° above the zero-plane horizon. This figure roughly corresponds to the basement topography and prominent features such as the Buffalo Mountain Gravity high (BM) and Pumpernickel Valley gravity low (PV) can be readily distinguished. The Kemp thermal anomaly (K) is coincident with a gravity low, which may be interpreted as an alluvial-filled asymmetric graben. The resolution of this diagram and lack of additional data in the Kemp area do not permit an exact interpretation of the small-scale structures responsible for control of the thermal fluids.

Aqueous Geochemistry

There are no surface manifestations of thermal fluids in the Kemp area. Thermal fluids were not recognized during drilling, but they are probably present in the sands and gravels that lie between bedrock and the thick layer of blue clay in the 110 m (360 ft.) hole at Kemp. Sulfur Spring, located 1.6 km (1 mi.) northeast of Kemp, discharges 18°C waters from a prominent northeast-trending fault scarp. Kerr (1940) described a hot spring with well-developed tufa deposits in the Sulfur Springs area. There are no well-developed tufa deposits at Sulfur Spring, but a fossil hot spring deposit, consisting of globular and botryoidal travertine, was discovered approximately 1.6 km (1 mi.) northeast of Sulfur Spring. The spring deposits are located in a brecciated fault zone, approximately 30 m (100 ft.) wide, in the Pumpernickel formation. The deposits suggest that fluids discharged at the surface, but it is impossible to deduce the temperature of those fluids.

Silica geothermometers for Sulfur Spring indicate an equilibrium temperature of 112°C, and magnesium-corrected cation geothermometers suggest equilibrium temperastures of 106°C. The bulk chemical composition of Sulfur Spring is similar to thermal fluids at Blossom Hot Pot (58°C), which is located 20 km (12 mi.) to the northeast. Sulfur Spring is also somewhat similar to Brooks Hot Spring (35°C), which is located 6.6 km (4 mi.) to the east. All three springs are chemically similar to Humboldt River waters.

Conclusions

Direct temperature measurement techniques were successfully employed in Pumpernickel Valley, Nevada, to locate a geothermal resource that is not associated with any surface thermal manifestations. The resource was originally identified during a 2-m depth temperature probe survey and later confirmed by 35 and 110 m (120 and 360 ft.) temperature gradient holes. Lithologic logs and temperature-depth measurements indicate that thermal fluids are present in a 30 m (100 ft.) thick layer of sand and gravels that overlies bedrock of Paleozoic sedimentary rocks. Thermal fluids do not appear at the surface and are probably trapped beneath a thick layer of blue clay.

A gravity low associated with the thermal anomaly suggests the presence of a buried fault, located 1-2 km (.6-1.2 mi.) east of a prominent northeast trending range bounding fault. The buried fault has no surface expression and is a likely source for rising thermal fluids.

Figure 4 is a cross-sectional representation of structural and stratigraphic controls at the Kemp thermal anomaly.

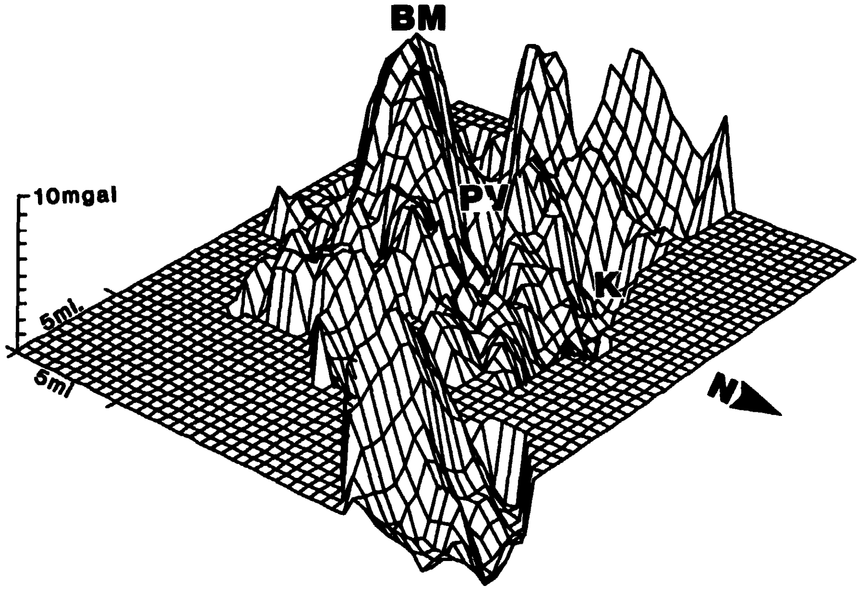

Figure 3. Three-dimensional computer-generated residual gravity map of Pumpernickel Valley: BM, Buffalo Mountain; PV, Pumpernickel Valley; K, Kemp (NCAR plot).

The diagram shows thermal fluids, rising along a buried fault zone, are channelled away from the surface by an impermeable layer of blue clay and are restricted to flow along the top of the bedrock. The ultimate destination of these fluids is unknown.

Temperature gradients for holes drilled 1-2 km north and west of Kemp ranged from 3.2°C/km to 32°C/km; the gradient at Kemp was 600°C/km. These data suggest that the resource is less than one km^2 in areal extent.

Direct temperature measurement techniques were judged to be the most effective for both resource identification and definition. Indirect methods were useful in the preparation of a structural model.

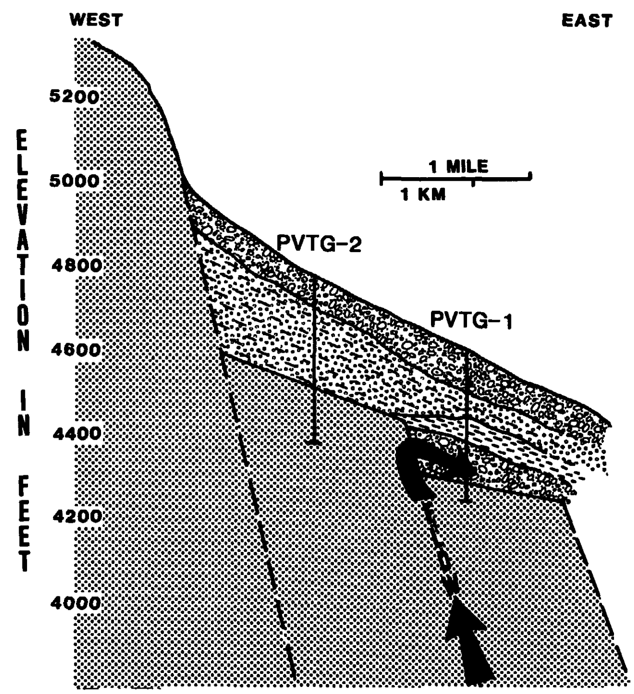

Figure 4. Possible stratigraphic and structural model through the Kemp thermal anomaly.

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