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**ASSESSMENT OF GEOTHERMAL RESOURCES
OF CALIENTE, NEVADA**

By
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March 1980

Work Performed Under Contract No. AC08-79NV10039

Nevada Bureau of Mines and Geology
University of Nevada, Reno
Reno, Nevada

U. S. DEPARTMENT OF ENERGY
Geothermal Energy

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RESOURCES OF CALIENTE, NEVADA

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ABSTRACT

An assessment of the geothermal resources of Caliente, Nevada was made to provide information on resource characteristics and to site 2 (two) 500 ft (152 m) test wells to confirm the resource. This report considers only the physical aspects of the resource and is part of a concerted effort to determine the feasibility of geothermal space heating on a city-wide basis.

The strategy used in the resource assessment employed a logical sequence of work elements that included 1) baseline data collection, 2) field investigations, 3) laboratory analyses and 4) data interpretation and synthesis. Airphoto interpretation indicated that a series of normal faults produced a stepped arrangement in the canyon walls on the west side of Meadow Valley Wash north of downtown Caliente. This area coincides with the area of known geothermal occurrences. Temperature measurements in existing wells indicate a rapid cooling of the geothermal waters as they mix with cold groundwater flows in Meadow Valley Wash. Soil mercury analyses range from 15 ppb to as high as 120 ppb. Trends in soil mercury content may indicate the presence of buried faults. Temperatures measured in 2-meter deep auger holes indicated temperatures as high as 40°C in an area north of the Lincoln County Medical Facility. Interpretation of chemical analyses, both major and minor, of waters collected from wells and streams in the area failed to conclusively show any mechanisms for the mixing of thermal and nonthermal waters.

The selection of sites for the 2 (two) 500 ft (152 m) reservoir confirmation wells was made using the results of temperature surveys, geologic structure and historic observations.

ACKNOWLEDGMENTS

The success of this investigation is due largely to the cooperation of the residents of Caliente. For their assistance in providing access to wells for measuring and sampling, the authors would like to thank Mr. Glen White, Mr. R. S. Van Kirk, Mr. and Mrs. Lloyd Van Kirk, Mr. and Mrs. Kevin Phillips, Mr. and Mrs. William Miller, and Mr. John Schaffer. In addition, Mr. Neldon Mathew, Superintendent of the Lincoln County School District, provided his personal services as a pilot, and the resulting photographs from the Air-survey helped to put the study into perspective. The authors wish to especially acknowledge Mr. Fergus Wallis and Mayor Keith Larson. This investigation was initiated by the efforts of these men, and the authors are extremely grateful for their support.

INTRODUCTION

In November, 1979 the Nevada Resource Assessment Team was asked to perform a preliminary geothermal resource assessment of Caliente, Nevada. The purpose of this investigation is to provide information on the resource extent and to site two (2) 500 foot (152 m) test wells to confirm the resource characteristics. This report considers only the physical aspects of the resources and is part of a concerted effort to determine the feasibility of geothermal space heating on a city-wide basis. Other agencies participating in the feasibility study are the Nevada Department of Energy and the Geoheat Utilization Center of the Oregon Institute of Technology.

The strategy used in the resource assessment employed a logical sequence of work elements that included; 1) baseline data collection, 2) field investigations, 3) laboratory analyses, and 4) data interpretation and synthesis. The individual tasks employed in the resource assessment included:

- 1) Collection of existing geologic and hydrologic data.
- 2) Airphoto interpretation to define structural controls.
- 3) Reconnaissance geologic observations.
- 4) Temperature measurements of existing water wells.
- 5) Collection and analyses of water samples from existing wells and surface waters and springs.
- 6) Two-meter temperature probe survey.
- 7) Collection of soil samples for mercury analysis.

Prior to the initiation of the field work phase of the program, existing airphotos of Caliente were examined. The photos included both black and white (scale 1:15,840) and color (scale 1:24,000) stereo pairs. Initial interpretation of the aerial photography indicated the presence of numerous normal faults which produce a stepped arrangement along the western side of Meadow Valley Wash north of the main part of town.

Field work in the Caliente area was performed during the period December 3 to December 8, 1979. A total of 12 man-days were expended during this phase of the program. Results of the major-minor element analyses were not available for interpretation until mid-February, and the results of samples submitted for isotopic analyses have not as yet been received. We will provide this information if it should in any way alter the conclusions and recommendations of this report.

Collection of Existing Geologic and Hydrologic Data and Airphoto Interpretation

Existing geologic information consisted of the Lincoln County Report: Nevada Bureau of Mines and Geology Bulletin 73 (Tschanz and Pampeyan, 1970). The geologic map that accompanies this report is at a scale of 1:250,000 (1 in. equals 4 miles) and unfortunately provided only a gross indication of the major lithologies and structural features.

More detailed information on the geologic structure was obtained from interpretation of stereographic airphoto coverage of the study area. Preliminary interpretation of both B&W and color Ektachrome airphotos revealed many normal faults offsetting younger volcanic rocks (Tertiary) from older carbonates (Paleozoic) and Prospect Mountain quartzite. A small outlier of younger carbonate rocks rest in thrust contact with the quartzite in the Antelope Canyon area. The eastern contact of this thrust plate is a normal fault which juxtaposes the carbonates above the thrust fault with the Tertiary volcanic rocks. The thrust plate is dragged downward along the westernmost normal fault and produces a prominent (resistant) breccia zone on both the north and south sides of Antelope Canyon.

In addition to interpretation of existing airphotos the field geologists (Mr. Trexler and Mr. Flynn) flew an aerial reconnaissance over the area with Mr. Neldon Mathew, Superintendent of Lincoln County Schools on the morning of

December 6. This overflight provided information that supported earlier air-photo interpretations and substantiated observations made on the ground during the previous 2 1/2 days of field work.

Existing water well data from cold wells were collected from the files of the State Engineer. Information on geothermal wells and springs in the area were available from previous work funded by U.S. DOE (Trexler and others, 1979) and the Nevada Bureau of Mines and Geology Bulletin 91 (Garside and Schilling, 1979).

Reconnaissance Geologic Observations

A geologic field reconnaissance was performed along the western edge of Meadow Valley Wash from Antelope Canyon, on the north, to the prominent bluff west of the confluence of Meadow Valley Wash and Clover Creek (figure 1). This reconnaissance was undertaken to locate slickensides along fault planes. Orientation of slickensides can be used to determine the relative direction of movement of the rock units on either side of the fault plane.

During this reconnaissance several fissures in outcrops were noted to have warm air emanating from them. The fissures, from which air was issuing had dark halos of moss growing around the opening due to condensation of moisture on the cold rock surfaces. Figure 2 shows an outcrop 200 meters (200 yds.) north of the County Hospital along the western edge of Meadow Valley Wash. The dark fissures to the right of the power pole (arrow) are those from which warm air with temperatures as high as 32°C (90°F) is emanating. The white blotches of the rock face are caliche (CaCO₃) deposits. Figure 3 is a closer view of one of the fissures which has hot air evolving from it. Note the dark halo caused by moss around the opening and geologic hammer for scale.

Although some slickensides were located, no measurements were taken because it appeared the rocks were not in place.

Figure 1. Oblique Air Photo of Caliente, Nevada Looking North-northeast.
A = Antelope Valley B = County Hospital C = Meadow Valley Wash
D = Clover Creek

Figure 2. Photograph of the West Side of Meadow Valley Wash Showing Outcrop that Contains Fissures (arrow).

Figure 3. Close-up View of Fissure Which Emanates Warm Air. Note Geologic Pick for Scale.

Temperature Measurements of Existing Wells and Springs

Temperature measurements were made by two methods. In accessible wells, a down hole temperature was recorded using a cable and digital readout. In wells that were being used, and inaccessible for down hole measurements, the well was pumped for a period of time to insure that water from the bottom was circulated to the outflow which was measured. Results of the temperature measurements are given in Table 1 and the location of measurement sites is presented in Figure 4.

The warmest temperature recorded in the Caliente area was from location No. 2, figure 1, Agua Caliente Trailer Park. The temperature measured at this site was 67°C (153°F). Water from this well is used to heat mobile homes and trailers. As the geothermal fluids migrate southward (following the direction of groundwater flow in Meadow Valley Wash) they become cooler, probably by dilution with shallow groundwater. At the Lincoln County Medical Facility (location No. 3c), the maximum recorded temperature is 48.6°C (120°F). As the geothermal water travels further south, temperatures of only 42.8°C (109°F) are recorded in shallow wells (less than 150 ft) in the vicinity of locations 5-8 and 10, figure 4.

The Hot Springs Motel well (location No. 4) is located along an escarpment which may represent a fault, and has temperatures of 45°C (113°F). This well is shallow (16 ft) and may represent water that has risen by convection along a fault at the base of the bluff on the east of Meadow Valley Wash. An alternative explanation for temperatures that are slightly higher at the motel vs. locations No. 5-8 and 10 is that the amount of mixing with cold groundwater is less because the well at the Hot Spring Motel (location No. 4) is peripheral to the main groundwater flow in Meadow Valley Wash.

Table 1. Measured Temperatures of Wells and Springs

Map Location Number		Temperature °C	Sample Number
1	Cane Spring (Indian Cove)	12.0	CW-1X
2	Agua Caliente Trailer Park	67.0	CW-2X
3	Lincoln County Medical Facility		
	a. production well		
	b. reinjection well	29.2	CW-3X
	c. abandoned well	48.6	CW-4X
4	Hot Spring Motel Well	45.0	CW-5X
5	L. Van Kirk Well (a)	42.8	CW-8X
6	L. Van Kirk Well (b)	42.8	
7	R. S. Van Kirk Well	42.8	
8	K. Phillips Well	42.0	CW-10X
9	Church of Latter Day Saints Well	24.0	CW-11X
10	Miller Well	39.7	CW-12X
11	City well at park	15.0	CW-9X

FIGURE 4
LOCATION OF MEASURED WELLS

WELL AND NUMBER

CALIENTE
LINCOLN COUNTY
NEVADA
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NEVADA STATE HIGHWAY DEPARTMENT
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Two-meter Temperature Probe Survey

To identify near surface temperature anomalies a temperature probe survey was employed. The technique consisted of drilling 3 1/2 inch diameter holes to a depth of 2 meters (6.5 ft) and implanting a thermister probe encased in 3/4 inch PVC tubing. Drilling was performed with a gasoline powered drive and 2 sections of 4-foot long, 3 1/2 inch diameter continuous auger with a fish-tail bit. In areas of difficult drilling, such as Antelope Canyon, where 2-meter depths could not be obtained 1.5 meter probe holes were used. The decrease in depth of penetration was taken into consideration when comparing temperature data from holes that reached the 2 m depth. The locations of the 2-meter probe holes and the resulting isotherms are presented in figure 5.

Temperatures recorded in the 2-meter deep probe holes ranged from 9°C (54°F) at probe site T-17 (located .75 north of T-15, fig. 5) to 40°C (104°F) at probe site T-19. A comparison of the two-meter probe survey with the water well temperature survey reveals three interesting facts; 1) the area containing the highest well temperature (location No. 2, figure 1) is outside of the 30°C contour, 2) the near surface temperatures decrease to the south, much like the well temperature data, 3) minimum temperatures recorded in the two-meter probe survey are found in the southern part of the city.

Temperatures recorded in the two-meter probe survey tend to mimic those measured in wells. The southward shift of isotherms recorded by the 2-meter probe may represent the influence of near surface groundwater. If large quantities of cold groundwater in the near surface are present in Meadow Valley Wash the southward shift would be expected.

Temperature probe holes were placed in Antelope Canyon. Although 2-meter depths were not attained, temperatures of 28°C (82°F) were measured in probe holes of 1.5 meters depth. There are no well data available for Antelope Canyon and inferences about the relationship between near surface temperatures and well

FIGURE 5
2 meter Temperature Probe Survey
Isotherm Configuration.

T-23 ⊗ Measurement site

—25— Contours in °C

CALIENTE
LINCOLN COUNTY
NEVADA

1978

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 FEDERAL HIGHWAY ADMINISTRATION

temperatures cannot be made. However such high temperatures at depths of 1.5 meters (4 ft) may indicate a high temperature geothermal resource at depth.

Collection and Analyses of Water Samples

Water samples were collected from all sites listed on Table 1, except from location No. 3a, which was obstructed by piping and not capable of being pumped. In addition surface water samples were collected in Meadow Valley Wash opposite Antelope Canyon and in Clover Creek, near the Nevada State Girls Training Center. Quantitative chemical analyses were performed for 18 elements, pH and conductivity. Isotopic analyses are being performed to identify the delta values for deuterium and oxygen 18; at the time of preparation of this report the results are not yet available. The results of the chemical analyses are presented in Table 2 and sample locations are shown in Figure 4.

The subsequent discussion of the results of chemical analyses is presented in two parts. The first reports on the analyses for major chemical constituents such as; calcium, magnesium, potassium, sodium, silica, nitrate and nitrite, fluorine, chlorine, sulfate and bicarbonate-carbonate. The next part deals with the interpretation of minor and trace element analyses.

Major Chemical Constituents

The major chemical constituents for both thermal and non-thermal water in the Caliente area do not vary over a wide range. Table 2 lists both physical and chemical data for all waters. Table 3 shows the average chemical composition for thermal and non-thermal waters. These data are also illustrated in Figure 6. With the exception of silica, and to a lesser extent calcium and chloride, the differences in the chemical compositions are not significant.

Figure 7 is a Piper plot for all the water samples collected in Caliente. There is no clear distinction between hot and cold waters. A weak grouping may be apparent for those waters taken from north (II) of Clover Creek and those

Table 2.

Chemical analyses of water from sampled sites: Caliente study area.

Sample Name	Sample Number	T°C	pH	SC µmhos	B ppm	Ca ppm	Mg ppm	K ppm	Na ppm	Li ppb	Cl ⁻ ppm	NO ₃ /NO ₂ ppm	SiO ₂ ppm	SO ₄ ppm	CO ₃ /HCO ₃ ppm	F ⁻ ppm	As ⁺⁴ ppb	Ba ppm	Fe ⁺² ppm	Rb ppb	Cs ppb	Sr ppm
Crane Spring	CW1X	12	7.63	732	2.37	55.4	12.5	9.08	69.2	46.3	55.6	7.54	67.8	53.7	228	1.38	22.1	<0.1	<0.01	26.5	7.9	0.11
Wallis well (pumped) 88 ft	CW2X	67	7.71	414	0.321	33.1	4.69	15.4	39.5	187	7.97	7.10	103	33.2	191	1.55	15.4	0.08	<0.01	48	12.8	0.17
Hospital reinjection well 35 ft	CW3X	29.2	7.54	617	0.238	39.7	6.37	35.5	69.7	262	9.31	2.70	151	31.7	323	2.48	<5	0.16	1.29	30.4	6.4	0.09
Hospital old well 50 ft	CW4X	48.6	7.75	476	0.216	37.9	6.59	17.1	45.7	172	15.3	19.7	103	37.2	186	1.38	6.2	0.08	0.034	42	6.1	0.18
Hot Springs Motel well 16 ft	CW5X	45	7.96	504	.311	35.1	6.88	22.1	50.1	191	30.5	3.81	142	29.9	199	1.43	6.9	0.04	<0.01	42.3	5.3	0.06
Clover Valley Wash	CW6X	12	7.74	758	0.180	77.3	13.9	6.36	48.3	41.8	19	2.83	53.7	18.7	371	1.61	87.1	<0.1	<0.01	2.3	7.3	0.14
Meadow Valley Wash	CW7X	5	7.85	990	0.258	58.1	24.9	15.4	94.6	93.6	59.1	0.308	58.6	66.2	387	2.04	85.7	<0.1	<0.01	11	6.4	0.17
Llyod Van Kirk well 115 ft	CW8X	42.8	8.07	462	1.83	25.3	6.41	23	54.1	20.2	13.4	0.447	114	19.1	231	1.74	52.2	<0.1	0.055	8.3	6.5	0.08
Caliente City well Dixon/ McKinley	CW9X	15	7.77	398	0.288	53.3	6.59	4.59	27.6	26.8	12.5	2.26	47.1	5.56	232	1.68	12.4	<0.1	<0.01	3.8	5.1	0.12
K. Phillips well 120 ft	CW10X	42	7.75	482	0.112	29.6	8.02	18.4	49.5	161	17.3	2.66	113	30.8	209	1.43	13.9	<0.1	0.028	12.8	4.9	0.07
LDS well	CW11X	24	7.59	813	0.309	53.2	16.1	20.2	68.7	205	23.2	2.50	94.8	53.7	337	1.43	88.6	<0.1	<0.01	16.8	6.2	0.25
Miller well 120 ft	CW12X	39.7	7.75	554	0.394	45.5	8.25	16.4	46.9	196	19.5	<0.01	113	43.6	254	1.38	18.0	<0.1	0.049	18.1	4.9	0.15

Table 3
Average Composition of Constituents for Thermal and Nonthermal Waters

	Non-thermal waters 4 samples temperatures 5°-15°C	Thermal waters 8 samples temperatures 24°-67°C
Ca	61	37.4
Mg	14.5	7.9
K	8.9	21.0
Na	60	53.0
SiO ₂	57	116.7
NO ₃ /NO ₂	3	4.9
F	1.5	1.6
Cl	36.5	17.1
SO ₄	36	35
HCO ₃ /CO ₃	304.5	241.3

from the south (I). This distinction in chemical similarity may be partially geographical since some samples in Group II are non-thermal.

Table 4 shows the results of two chemical analyses of the water from the Agua Caliente Trailer Park well. The well water samples were taken and analyzed over a year apart by two different laboratories. The fact that the data are nearly identical indicates the geothermal system is geochemically consistent over a period of time.

Table 4
Analyses from Agua Caliente Trailer Park Well, Temperature 67°C

	T°C	pH	SC μmohs	HCO ₃ ⁻ ppm	Cl ⁻ ppm	SO ₄ ⁻ ppm	F ⁻ ppm	Na ppm	K ppm	Ca ppm	Mg ppm	SiO ₂ ppm
Nov. 1978	67	7.2	400	200	8	30	1.4	39.2	14.3	34	4.8	106
Dec. 1979	67	7.7	414	191	7.9	33.2	1.5	39.5	15.4	33.1	4.7	103

Figure 6. Comparison of Average Chemical Composition for Thermal and Non-thermal Waters in Caliente.

Sample Number	Temperature °C	Sample Number	Temperature °C
1	12	7	5
2	67	8	43
3	29	9	15
4	48	10	42
5	45	11	24
6	12	12	40

Figure 7. Piper Plot of All Water Samples Collected.

Several different mixing models were unsuccessfully attempted for waters in the Caliente area. The chemical composition of waters at location No. 1 which is located several miles north of the town were considered to be background. These chemical constituents were summed with the chemical constituents from two other samples (No. 6 or 9 and 3 or 8). The results of these mixtures of different waters were compared to the composition of thermal waters from location numbers 2 or 10. The method indicated that the hypothesis for mixing was valid for only 50 percent of the major dissolved species.

Thermal waters do show a significantly greater amount of dissolved silica. The use of chemical geothermometers for these waters is considered imprudent, however, because the thermal waters are not significantly different in chemical composition from the non-thermal waters and the probability of mixing is very high, this rules out the use of any geothermometers which are based on the premise of non-mixing of thermal and non-thermal water.

In conclusion, the thermal waters in Caliente 1) appear to be derived from the shallow, non-thermal waters, 2) do not vary chemically over time 3) cannot be used to estimate reservoir temperatures, 4) and will not be used to aid in the drill-site selection process.

Interpretation of Minor and Trace Elements

Minor and trace element analyses for the Caliente waters included boron, arsenic, barium, iron, rubidium, cesium, and strontium. The results of the analyses are listed in Table 2. The values for both barium and iron were too low to plot and will not be given any further consideration.

The values for the remaining elements were plotted against temperature (figures 8A, B, C, D and E). Numbers on figures 8A-E correspond to sample numbers on Table 1. In Figures B, C, and E, no trends can be seen, and the values are consistently low for waters over the entire temperature range. The

Figure 8D and 8E. Plots of Minor Element Compositions as a Function of Temperature.

Figure 8A-8C. Plots of Minor Element Compositions as a Function of Temperature.

one exception is the boron value for sample number one, which was collected 2.2 miles (3.6 km) north of Caliente.

The rubidium values (figure 8A) appear to increase with increasing temperatures, but these values are too variable in the 30-50°C temperature range to be useful in a quantitative temperature estimate. The spread certainly precludes the use of rubidium values as a tool for geochemical exploration.

The final trace element, arsenic, has been used in soil and water geochemical surveys, in conjunction with mercury analyses. In general, a high arsenic value is usually considered a good indicator of high temperature geothermal systems. The results for the Caliente water samples show, contrary to expectation that the non-thermal waters are higher, on the average, in arsenic than the thermal waters. Although this is interesting and ironic, it unfortunately is not a useful tool for this geochemical investigation.

In conclusion, most of the minor and trace elements do not show any trends with respect to temperature and appear to be consistently low for all water samples, regardless of temperatures. None of the plots show any clear trends and these data will not be used to identify potential drill sites.

Soil Mercury Analyses

Analyses of mercury in soils has proved to be an excellent technique in providing information on the location of faults and areas of abnormally high heat flow. The technique is based on the assumptions that high temperatures at depth volatilize mercury, which, in the vapor state, migrates upward along the most convenient routes. The most convenient routes are generally faults. Therefore, anomalously high mercury contents in the near-surface soil are indicative of areas of high heat flow which may be due to geothermal activity or faulting or a combination of both.

The results of 40 soil mercury analyses are presented in Figure 9. The dominant mercury trend is a north-northeasterly trend through Meadow Valley Wash and the center of Caliente. The trend is separated by a region of lower mercury values which may reflect a groundwater inflow from Clover Creek. A similar groundwater caused shift can be used to explain the offset of the mercury anomaly away from the thermal high north of the County Hospital, compare Figure 5 with Figure 9. This may be caused by the groundwater inflow from Meadow Valley Wash.

The extension of the anomaly up Antelope Canyon correlates to the thermal anomaly which exists near the mouth of Antelope Canyon. The extreme southern portion of the north-northeasterly trend can not be related to any known thermal anomaly, but may possibly be explained by a cold groundwater masking of this area.

Selection of Drill Sites

The location of the two sites for the 500 foot (152 m) test wells are north of the main part of town. Figure 10 shows the location of the proposed sites. Site one is located in an open field north of the senior citizen housing near the hospital. The second site is located in Antelope Canyon slightly east of where the breccia zone cuts the canyon.

Site 1 was selected because of the coincidence of a near surface thermal high as shown by the 2 meter temperature probe survey and by slightly higher soil mercury values in the same area. The site is also near the bedrock outcrops which have crevices that emit warm air at a temperature of 32°C (90°F).

The selection of a site for the second resource confirmation hole was based on geologic structure which terminates the eastern edge of a thrust plate that rests on the Prospect Mountain quartzite. Historic reports indicate that a water well was being drilled in this area and hit steam and hot water and the well was

Soil mercury in parts per billion

0-40

40-80

80-120

Figure 9. Map Showing Soil Mercury Concentrations in parts per billion.

Figure 10. Well Site Locations

abandoned. Shallow temperature probe holes in the area are anomalously high with temperatures of 28°C (82°F) at 1.5 meters.

It is anticipated that 500 foot holes in these areas should confirm the extent of the geothermal resource. It is hoped that temperatures in excess of 80°C (175°F) will be encountered in the Antelope Canyon site.

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