Implications of Shallow Temperature and Soil Gas Surveys at Lee-Allen Geothermal System, Churchill County, Nevada

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Keywords

Geothermal, Lee-Allen, shallow temperature, shallow gas

ABSTRACT

Shallow temperature and soil gas surveys were conducted at Lee-Allen geothermal system. The Lee Allen geothermal system has one hot spring that was generated from drilling activity around the 1930's. Past exploration activity has not led to development of the system but geochemical geothermometers of Lee Hot Spring indicate an economic reservoir temperature of the fluid. Shallow temperature and gas data anomalies occur near two fault intersections at the Site and these fault intersections may be serving as upwelling conduits to a reservoir that occurs southeast of Allen Ridge and at a depth greater than one (1) kilometer. Further, this research shows strong correlation between shallow temperature and shallow gas data at this study area, and is consistent with findings of other surveys of this type in the recent past within the Great Basin.

1.0 Introduction

The objective of this project was to conduct shallow temperature and soil gas surveys at Lee Allen geothermal system (Study Area) and attempt to use that data and other available data to improve the conceptual model of the geothermal system, assess the usefulness of these methods for geothermal exploration, and compare these data to other recent studies within the Great Basin. Fieldwork for this project was conducted in the spring and summer of 2011, and this work was included as part of a master's thesis (Skord, 2012). Part of this work was also included in a 2011 GRC Transactions paper (Skord et al, 2011), but that work did not include any of the soil gas survey data and only had preliminary interpretations.

1.1 Background

The Study area is located in Churchill County, Nevada, about 10 kilometers south of Fallon, Nevada. It occurs near a small outcrop of Mesozoic granite, known as Allen Ridge, and there is one hot spring, Lee Hot Spring (LHS), which resulted from drilling in the early 1930's (Figure 1, e.g. Miller, 1978). Tufa and silica-cemented sands have been mapped (Figure 1; Hinz et al., 2010) mostly occurring in the area of LHS but also in an area north of Allen Ridge. Geochemical geothermometers (Quartz and Cation) of LHS suggest it is supplied by geothermal

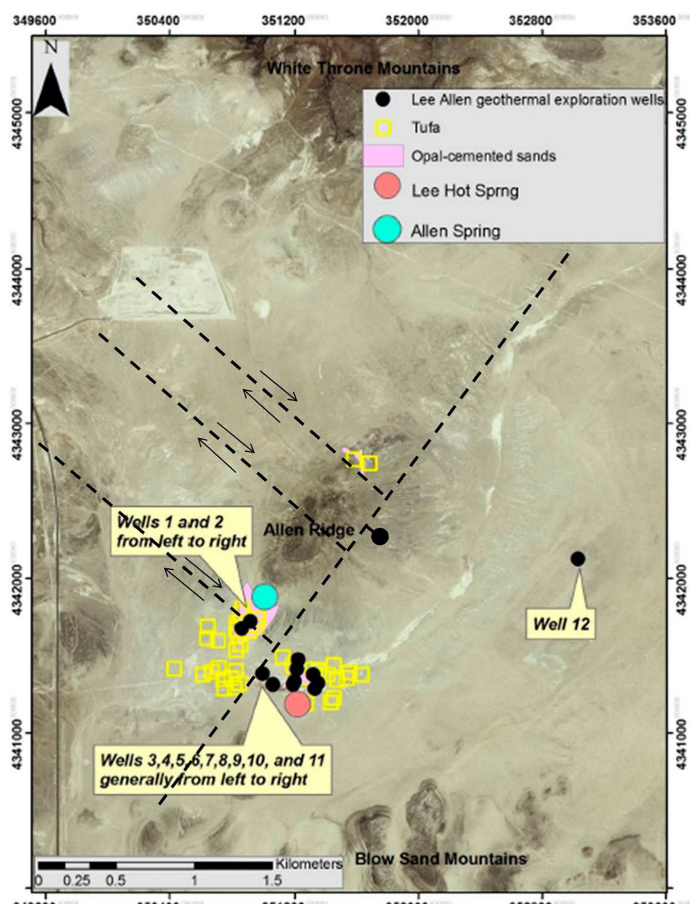

Figure 1. Lee-Allen Geothermal Area.

fluids at a temperature of ~150°C (e.g. Mariner, 1974). Several geothermal exploration wells have been drilled at the Study area (Figure 1, Table 1) and most of the wells encountered hot or boiling water with the exception of wells 1, 2, and 12. Well 3, the deepest (about one kilometer), lost circulation at about a third of the way down but temperatures were high (>100°C; Miller, 1978). Structural mapping shows a northeast-striking, west-dipping normal fault cuts through the Lee Hot Spring area and this normal fault is intersected by a series of northwest-striking right-lateral faults (Figure 1).

Table 1. Notes on geothermal exploration wells drilled at Lee-Allen from Miller (1978).

Exploration Well #	Notes
1	20ft; cold; no water
2	535ft; 60°C
3	119°C @ 3000ft but no water; water @ 2000ft
4	65ft and hot water present
5	300ft and hot water present
6	33ft and hot water present
7	80ft, hot water present @ 55ft
8	67ft; 123°C @45ft
9	45ft and hot water present
10	157ft and formed temporary geyser
11	101°C maximum temperature
12	Cold and dry

3.0 Methods

3.1 Shallow Temperature Survey

Two-meter temperature surveys can be used to detect thermal aquifers in the near subsurface. The work was conducted from an All-Terrain-Vehicle (ATV) and a generator was used to power an impact hammer which drove the approximately one-centimeter-diameter two-meter-long steel rod into the ground. A resistance temperature device was inserted into the rod and temperature was recorded after one-hour equilibration. Two-meter temperatures can be affected by factors other than geothermal heat. These effects include seasonal surface temperature shifts (seasonal drift), albedo, slope aspect, and thermal diffusivity (Sladek et al., 2009; Coolbaugh, 2010). In this study, seasonal drift was corrected for, and albedo, slope aspect, and thermal diffusivity were not needed (Skord, 2012).

3.2 Soil Gas Survey

Soil gas surveys can be used to detect subsurface boiling zones associated with the degassing of geothermal fluid, due to depressurization of geothermal fluid as it rises to the surface. A hollow steel probe was inserted into the ground to a depth of one meter, once inserted a loose pin at the bottom of the probe was released, and ten milliliters of gas was extracted from a syringe and injected into an air-tight sample bag. The collected gas samples were run through an inductively coupled plasma mass spectrometer (ICP-MS) and results were given in counts of various elements regardless of specific form. Interpretation on geothermal-related gas anomalies were made based on calculating a percent out of a hundred for each station for the elements of carbon, sulfur, and radon, and adding these three values to get a number for each station out of 300.

Previous studies using the soil gas method have been done in the Great Basin. One study evaluated carbon dioxide, hydrogen sulfide, and radon anomalies at the Brady's geothermal system, not far from north of this Study Area (Jolie et al, 2012). The methods of that study differed from this study in that sampling was conducted specifically for carbon dioxide and hydrogen sulfide (instead of just carbon and sulfur as in this study) using accumulation chambers and a portable diffuse flux meter (for carbon dioxide) and a Draeger Polytron II electrochemical detector (for hydrogen sulfide), and for radon sampling was done with a SARAD RTM 2200 monitor which correlated radiation levels to radon activity. The survey method used in this study is uses different analysis instrumentation (ICP-MS) and takes soil gas measurements at a depth of one-meter instead of at the surface within accumulation chambers. Another previous study of the Desert Queen geothermal system was done with sampling methods more similar to those used in this study, where samples were taken at shallow temperature sites and results for carbon, sulfur, xenon, radon, mercury, and others were analyzed (Lechler et al, 2009).

4.0 Results

High two-meter temperatures were found in the area of LHS, northeast of LHS, and north of Allen Ridge (Figure 2). Soil gas anomalies were fairly consistent with the temperature data

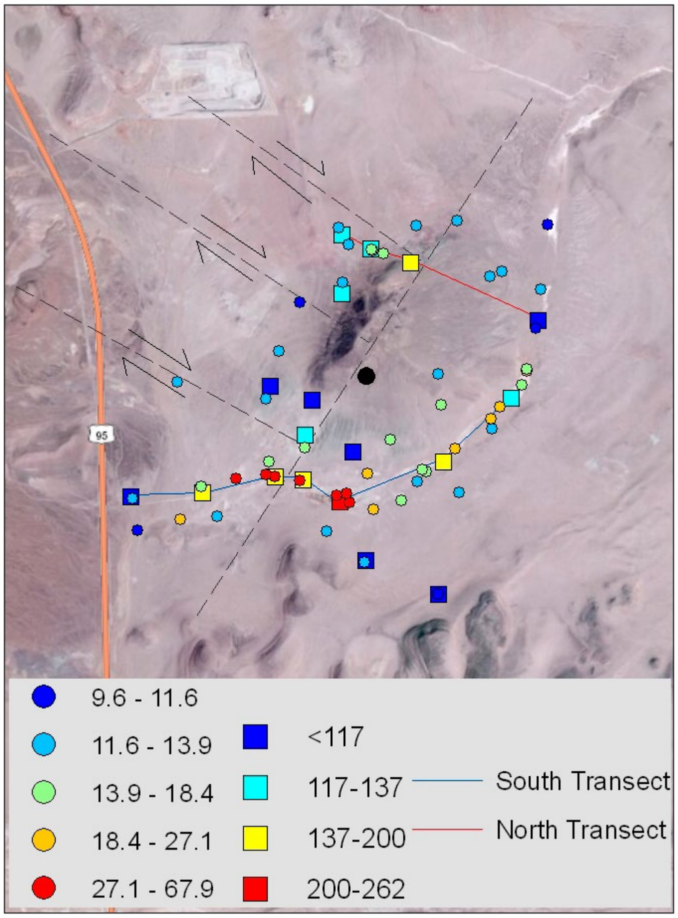

Figure 2. Shallow temperature in degrees Celsius and gas value based on ICP-MS count results for carbon, sulfur, and radon.

(Figure 2). The soil gas result is based on the results from the ICP-MS for carbon, sulfur, and radon, where each station's count value for each of the three elements was divided by the maximum count level for that respective element and multiplied by 100 to get a percent value. The three percent values were then added to get a total soil value out of 300.

5.0 Correlation of Soil Gas and Shallow Temperature Data

Many of the shallow temperature measurements and gas measurements were made roughly in the same place. There is a fairly consistent general trend of increasing temperature with increasing soil gases (Figure 4), variation seen in the plot may be due to measurement errors or possibly because in some areas a shallower water table may increase shallow temperature but not soil gases because of increased distance from a degasing or boiling zone and vice versa for a deeper water table nearer to a upwelling zone.

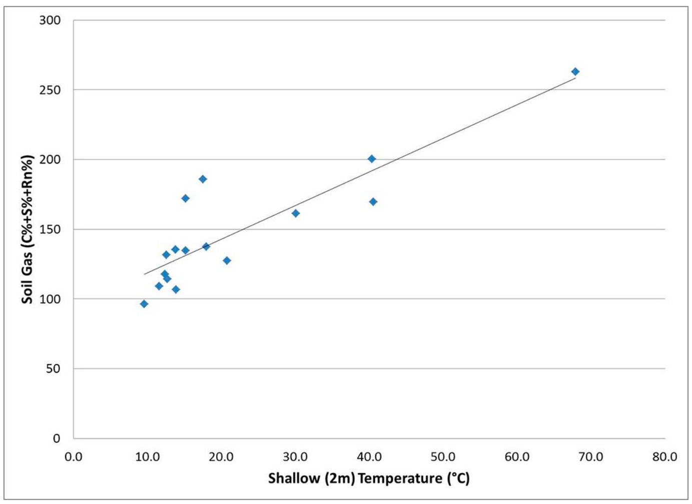

Figure 3. Correlation of shallow temperature and soil gas results.

6.0 Soil Gas Transects

Previous studies at geothermal systems in the Great Basin have also attempted to correlate soil gas data with the location of permeable fault zones (Jolie et al, 2012). The study at Brady's took numerous measurements arranged in a grid pattern over a series of faults and has worked to correlate those anomalies from that data to the mapped faults. Two east-west trending transects at this Study Area show soil gas anomalies where the transects cut through the northeast trending normal fault in the area south and north of Allen Ridge (Figure 3, 4). The area south of Allen Ridge is a stronger anomaly possibly because of excessive drilling in this area has generated man-made permeable conduits for boiling gases and fluids, and also possibly because of a shallower water table in this area, or this area simply may be a stronger upwelling zone because of a closer proximity to the reservoir or an increased fracture network associated with the intersection of more than just the northeast normal fault and northwest right-lateral fault. Shallow temperatures over the same area are much stronger in the south transact than in the north.

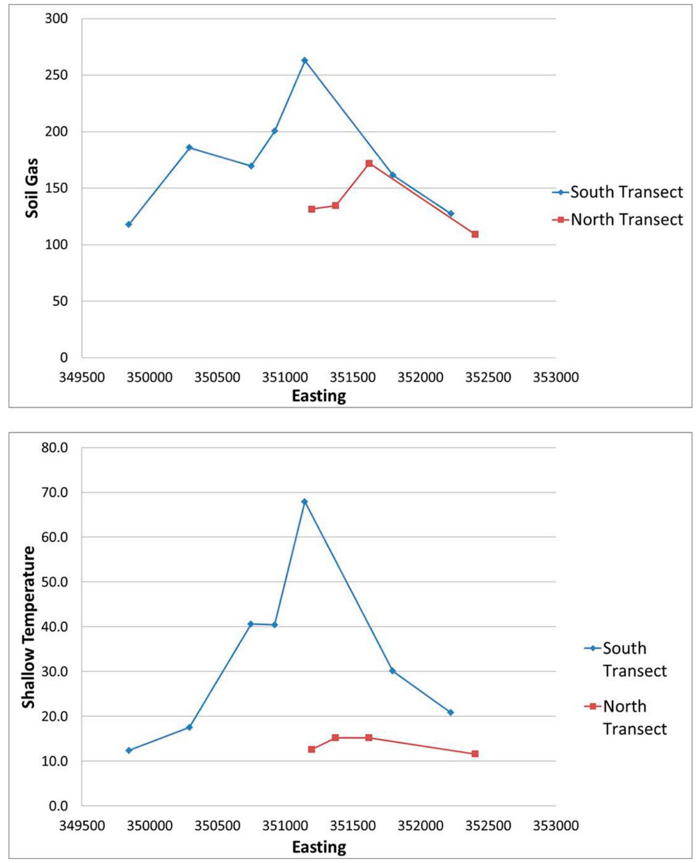

Figure 4. Soil gas and Shallow Temperature transects at the Study Area.

7.0 Conceptual Model

The shallow temperature and gas data obtained in this study, as well as other relevant data at the Site, support the following conceptual model. The two fault intersections, one of them adjacent to Allen Ridge on the north and the other adjacent to Allen Ridge on the south, may serve as upwelling conduits bringing geothermal fluid from a reservoir to the near surface. Assuming that the upwelling conduits are consistent with the strike and dip of the normal fault that cuts through LHS then the reservoir is likely at least 500 meters southeast of Allen Ridge and, based on deeper drilling data, occurs at depths greater than one kilometer. The reservoir, based on the local geology, is either in fractured granite similar to that which composes Allen Ridge or Tertiary Volcanic rocks, which makeup much of the bedrock exposures in the general area. The shallow temperature anomalies observed northeast of LHS may be the result shallow thermal aquifers that are slightly thermal due to outflow from the nearby upwelling zones and underlying geothermal reservoir.

This data and interpretations presented in this study, in coordination with other data available at the Study Area including: drilling logs (Miller 1978), a gravity survey (Hinz et al, 2011), geologic mapping (Hinz et al, 2011), and geochemical water sampling (Great Basin Center for Geothermal Energy; Mariner, 1974) could be used to develop 3d models of this geothermal system as is currently being done at a number of geothermal systems within the great basin such as Brady's (Jolie et al, 2012).

8.0 Acknowledgements

Patricia Cashman, Mark Coolbaugh, Nick Hinz, Wendy Calvin, Chris Sladek, Chris Kratt, and Mario Desilets all contributed to this research project enormously and on many levels. This work was funded in part by the Nevada Renewable Energy Consortium and the Great Basin Center for Geothermal Energy.

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