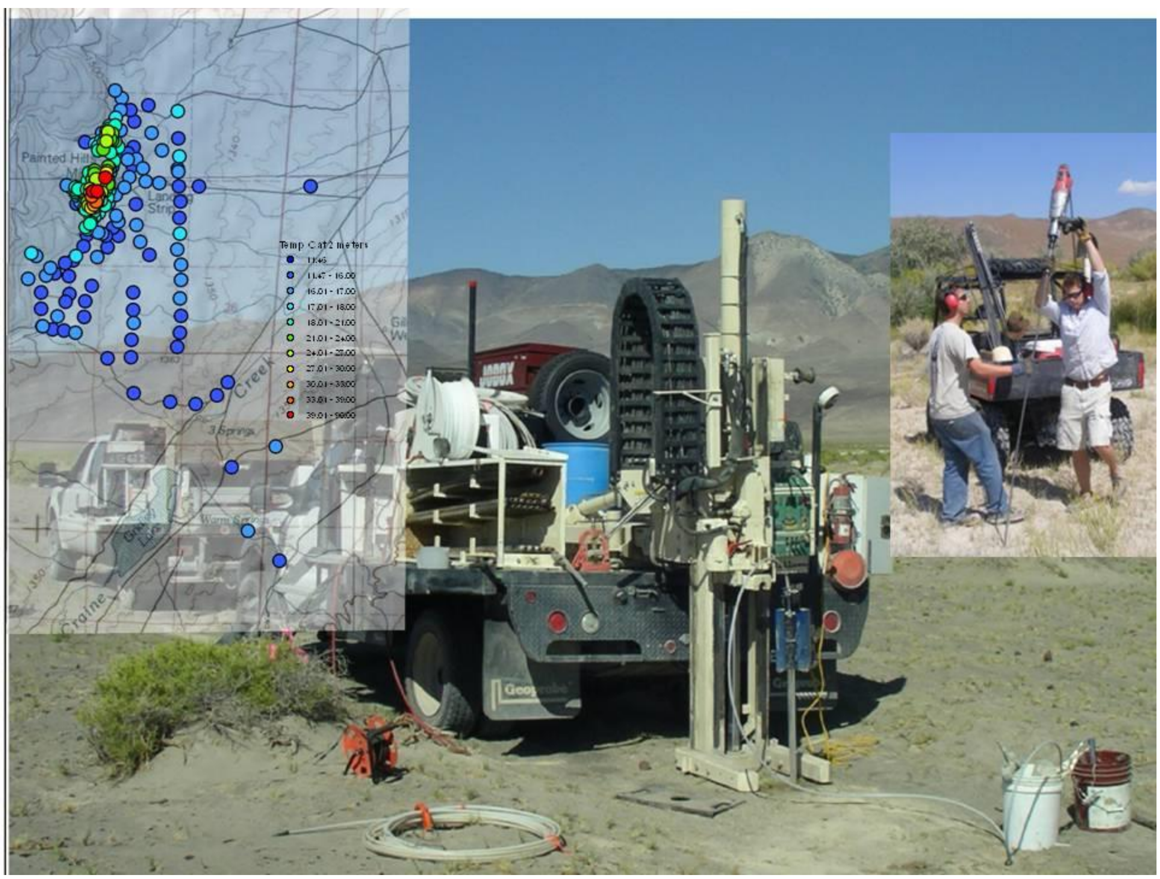
Effectiveness of shallow temperature surveys to target a geothermal reservoir at previously explored site at McGee Mountain, Nevada

FINAL REPORT
U.S. Department Of Energy Grant EE-0002830



Richard "Rick" Zehner
Geothermal Technical Partners, Inc.
Reno, Nevada
March 7, 2014

Executive Summary

The McGee Mountain geothermal area was selected for funding under U.S. Department of Energy Grant DE-FOA-0002830 to test early-stage shallow temperature survey techniques and drill two slim holes to test the resource. Geothermal Technical Partners, Inc., the recipient of the grant, was able to complete only a small portion of the project before lack of funding prevented further exploration work. This work included a shallow (2-meter) temperature survey, a Geoprobe survey, a close-spaced gravity survey, and several reports on geologic and transmission viability.

Besides further exploring the resource at McGee Mountain, the project did fulfill at least some of its original goals of assessing the effectiveness of the two shallow temperature survey techniques. This assessment was augmented somewhat by including 2-meter and Geoprobe surveys at two other geothermal sites in Nevada. Some of the conclusions reached are as follows:

- Both the shallow 2-meter and the Geoprobe surveys are cost-effective methods to detect subsurface thermal anomalies in early-stage exploration, prior to more expensive temperature gradient drilling.
- The major advantages of the 2-meter survey are its extreme portability (no roads needed), cost per site measurement, and low environmental impact.
- The 2-meter survey's disadvantages are its inability to penetrate hard substrates and the noise effects due to solar heating of the ground.
- The Geoprobe's advantages are its ability to collect temperature and uncontaminated water samples, greater depth of penetration (to 60m), relatively low cost, and low environmental impact.
- The Geoprobe's disadvantages are its inability to go off-road or to penetrate hard substrates.
- Costs to perform both types of surveys are low, together less than the cost of one conventional temperature gradient well. Given the potential increase in data that these surveys can provide, this is extreme value for the exploration dollar.

Introduction

Exploration work at the McGee Mountain geothermal area was selected for funding under U.S. Department of Energy Grant DE-FOA-0002830, to validate innovative exploration technologies in order to reduce geothermal exploration risk. This was to be accomplished under a three phase program designed to evaluate two technologies in early-stage geothermal exploration, the shallow 2-meter temperature survey and the Geoprobe, and would be followed by more conventional later stage development including gravity, magnetotellurics (MT), temperature gradient and slim hole drilling. This grant was awarded to Geothermal Technical Partners, Inc. (GP), a subsidiary of Caldera Geothermal, Inc. (Caldera).

Phase 1 work was to involve the compilation of all previously collected data into a project Geographic Information System (GIS) database, including geologic mapping, geophysical surveys, topographic base maps, and drill data. This was to be followed by 1) the innovative shallow temperature and Geoprobe surveys, 2) conventional gravity and MT geophysical surveys, and 3) temperature gradient drilling, in order to understand subsurface geology and heat flow, and delineate a target area.

Phase 2 work would involve the completion of two intermediate depth slim holes.

Phase 3 work would involve flow testing of the slim holes, evaluation of the effectiveness of the innovative technologies towards the siting of the slim holes, and submitting of a final report detailing the results.

Unfortunately, Caldera was unable to raise sufficient funds to complete its share of the cost burden for the project, so in early 2012 GP gave notice that it wished to terminate the project. By that time, sufficient data had been collected to somewhat evaluate the effectiveness of the shallow temperature and Geoprobe technologies to early stage exploration.

The purpose of this report is to 1) document the results of the project up until the time of termination, 2) produce a description of work completed to date at McGee Mountain for future explorationists which are retrievable from the Geothermal Data Repository (GDR), and 3) describe the two innovative early-stage technologies.

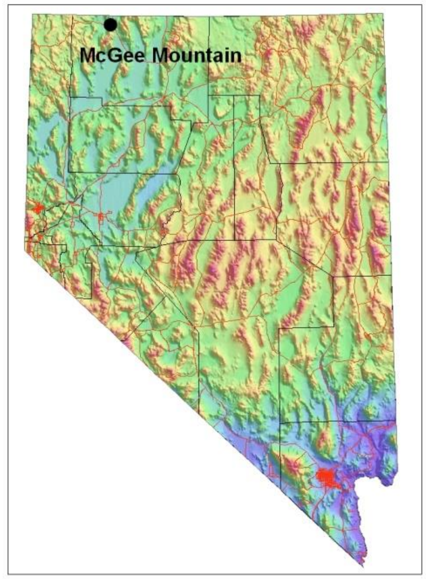


Figure 1. Location of McGee Mountain

Geology of the McGee Mountain project area

The McGee Mountain property is located in Township 45 North, Range 27 East, MDM, in northern Humboldt County, Nevada (Figure 1). The nearest hamlet is Denio, approximately 27 km to the northeast.

Geothermal activity at McGee Mountain occurs along a NNE-striking range front fault system that separates McGee Mountain on the west from the southern end of the Bog Hot Valley to the east (Figure 2). Other geothermal manifestations in the area includes the Gridley Lake Hot Spring (8km to the SSE), Bog Hot Springs (15km to the NNE), and Baltazor Hot Spring (18km to the NE). All of these systems lie along a prominent NNE-striking regional trend that hosts other high temperature (>150^{o}C) systems including the Needle Rocks, Gerlach, Pinto Hot Spring, Borax Lake, Alvord, and Mickey Hot Springs.

Early geothermal explorationists were attracted to the area by the intense hydrothermal alteration, mercury mineralization, intermittent fumarolic activity, and mercury mineralization at the Painted Hills mercury mine on the east side of McGee Mountain (Figure 2). Springs and wells in the valley east of and down the hydrologic gradient from the mercury mine and fumarole area show locally elevated temperatures (up to 42^{o}C) along with silica and cation geothermometer temperature up to 200^{o}C (see below). Several other non-thermal springs and wells in the area also have highly elevated geothermometer temperatures.

Previous exploration work on the property includes geologic mapping (Hulen, 1979), gravity and resistivity surveys (Edquist, 1981), and temperature gradient drilling. Phillips Petroleum drilled a number of shallow temperature gradient holes in the 1970's, one of which encountered 97^{o}C water at a depth of 147m, close to the intermittent fumarole. A subsequent deeper hole (MG 1500-1) drilled by Earth Power Resources in the same area hit 116^{o}C water at 120 meters before the temperature profile reversed and became isothermal (Figure 3). Several shallow holes further away from the range front have slightly elevated temperatures. No actual resource was identified.

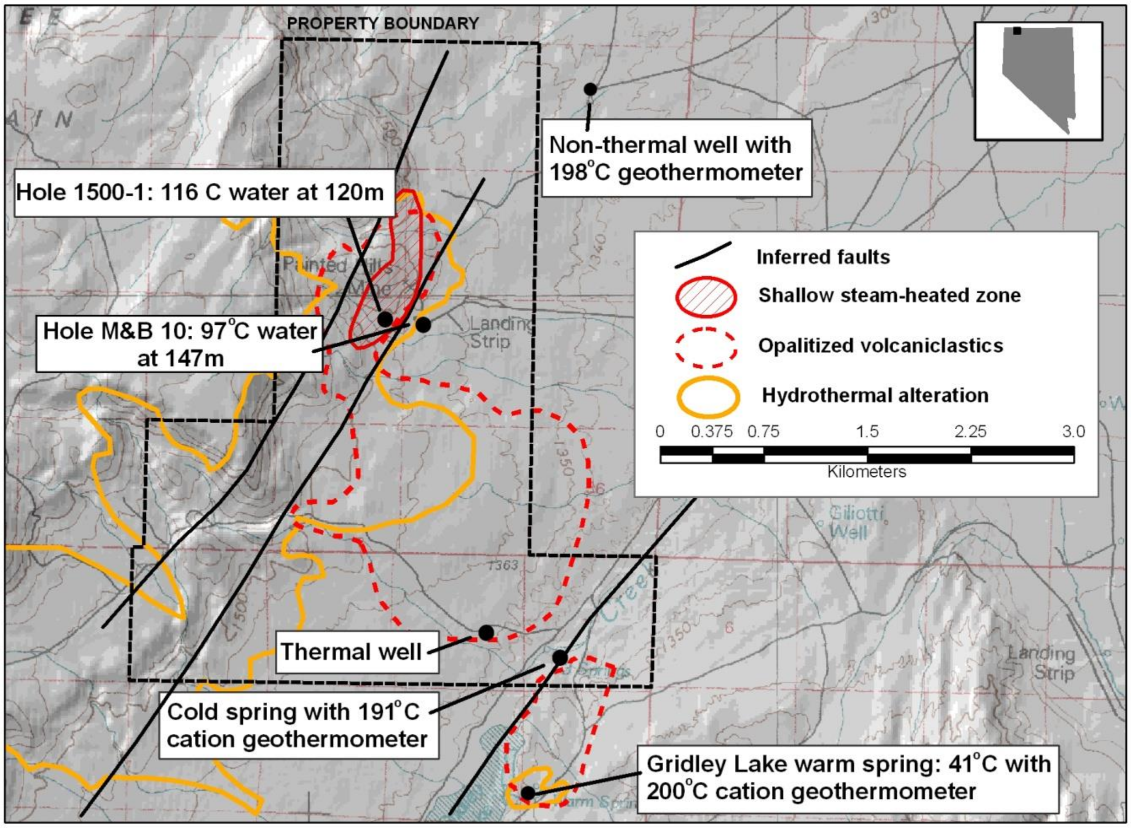


Figure 2. The McGee Mountain geothermal system. The intermittent fumarole is thought to be near the site of Hole 1500-1

At McGee Mountain, a thick sequence of bimodal Tertiary volcanic and volcaniclastic rocks sit unconformably on top of Mesozoic and Paleozoic granitic and metamorphic rocks. This package consists of a thick Miocene section consisting primarily of ashflow tuffs, basalt, and minor volcaniclastic rocks. Near the top of this section is a sequence of flows, domes(?) and ashflow tuffs, the Canyon Rhyolite, dated

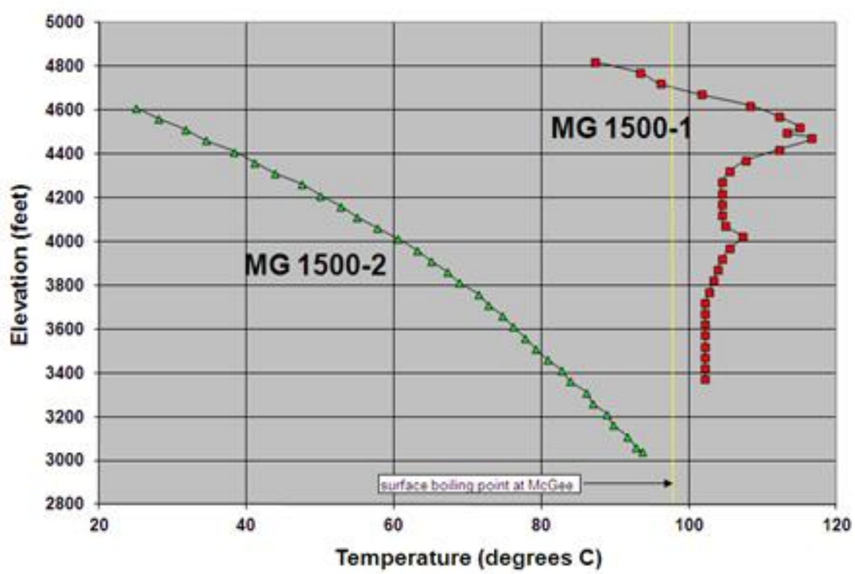


Figure 3. Temperature-depth diagram of two Earth Power Resources holes drilled in the 1970's. From Zehner et al., 2012.

at 14MA (Gardner and Koenig, 1978).

Unconformably overlying the Miocene section is a thinner Pliocene sequence of volcaniclastic rocks, the Thousand Creek Formation. Hulen (1979) describes the Thousand Creek Formation in the Painted Hills area as being comprised of "… ash- and pumice-rich sandstone, conglomerate, and siltstone, tuffaceous mudstone, terrestrial and water-lain ash-fall tuffs and lapilli tuffs and minor non-welded ash-flow tuff." The Thousand Creek Formation forms much of the fill of the Bog Hot Valley and appears to onlap the Miocene section at McGee Mountain.

The McGee thermal area occurs at the intersection of two structural regimes, a NNE-striking regional structure, and the northwest striking Eugene-Denio lineament of Edquist (1981). Movement on these structures is predominantly normal, although slickenside lineations suggest lateral movement as well. Geothermal fluid flow appears to be associated with the intersection of these two structures, along with lateral flow along permeable zones in the volcaniclastic sediments.

Hydrothermal alteration at McGee Mountain is focused around the fumarole area and the Painted Hills mercury mine. Volcaniclastic rocks and tuffs around the intermittent fumarole area and the Painted Hills mercury mine are argillically altered and iron-stained (hence the name). Half a mile south of this area is a strongly silicified (chalcedony), iron-stained ashflow tuff that contributes much of the material of a large landslide slump into the valley to the east.GP geologist suspect this landslide could have been caused by hydrothermal alteration softening the tuffs underneath the ashflow, causing the failure.

Much younger silicification occurs at McGee Mountain, primarily in the Pliocene volcaniclastic rocks. Here opal (reverting to β-cristobalite and chalcedony, according to x-ray diffraction studies) occurs in permeable sandstones and airfall tuffs, forming a low resistant ridge over 3 km^2 in area. The outcrop pattern of the opalitization suggests outflow from the fumarole area at the range front down the hydrologic gradient to the southeast (Figure 2).

The age(s) of hydrothermal alteration in the McGee Mountain area is somewhat controversial. Hulen (1979) states that alteration partially, and perhaps totally predates present thermal activity. He based his conclusion on a strongly silicified ashflow tuff with a 14 MA age date, from an area ½ mile south of the Painted Hills Mine, which he believes reflects the age of much of the Painted Hills alteration. The ashflow itself dates 13.7 – 14 MA, leading Hulen to believe that alteration was temporally contiguous with volcanism. However, the sanidine phenocrysts from that altered rock appear very fresh in hand specimen, suggesting that the age date indicates the age of volcanism, and not alteration. The fact that hydrothermal alteration coincides spatially with temperatures, and the young opal forming an outflow-like pattern down-gradient from the hottest area, suggests that alteration is associated with the currently active geothermal system.

GP became interested in the McGee Mountain area while examining GIS layers from the Great Basin Center for Geothermal Energy, part of University of Nevada, Reno (currently available at http://www.nbmg.unr.edu/Geothermal/Data.html). During an initial field visit, GP geologists discovered a large zone of opalitization >10 km^2 in areal extent within permeable volcanic sandstones of the Thousand Creek Formation that appears to represent a "fossil outflow" zone down the hydrologic gradient from the Hg-mineralized fumarole area. This seemed to indicate the existence of a very recent, hot, robust geothermal system occurred somewhere up-gradient from this opalitization.

Based on this information, GP performed a shallow 2 meter temperature survey and identified a steam-heated thermal anomaly several kilometers long with temperatures reaching 70°C at 2 m depths (Figure 2). Interestingly, no thermal anomaly was detected in the vicinity of the opalitized fossil outflow zone.

Geochemistry

Springs and wells in and around the study area that had been sampled in the past for geochemistry were historically or during this study were downloaded from the Great Basin Groundwater Geochemical Database available at http://www.nbmg.unr.edu/Geothermal/GeochemDatabase.html. During field work additional sites were either sampled or resampled, using standard sampling protocols. Sample locations are shown in Figure 4. Geochemical and estimated reservoir temperatures from silica and cation geothermometry are shown in Table 1. Piper diagrams derived from this data are displayed in Figure 5. Unfortunately, all of the sample sites are at least several miles from the probable center of the McGee geothermal system; water sample data from either the Phillips Petroleum or the Earth Power Resources drilling are available.

The geochemical data indicate that waters from the southern Bog Hot Valley have primarily dilute sodium bicarbonate chemistry, with low chloride and locally significant sulfate concentrations. This is consistent with long down-gradient fluid flow paths and/or mixing with non-geothermal groundwaters.

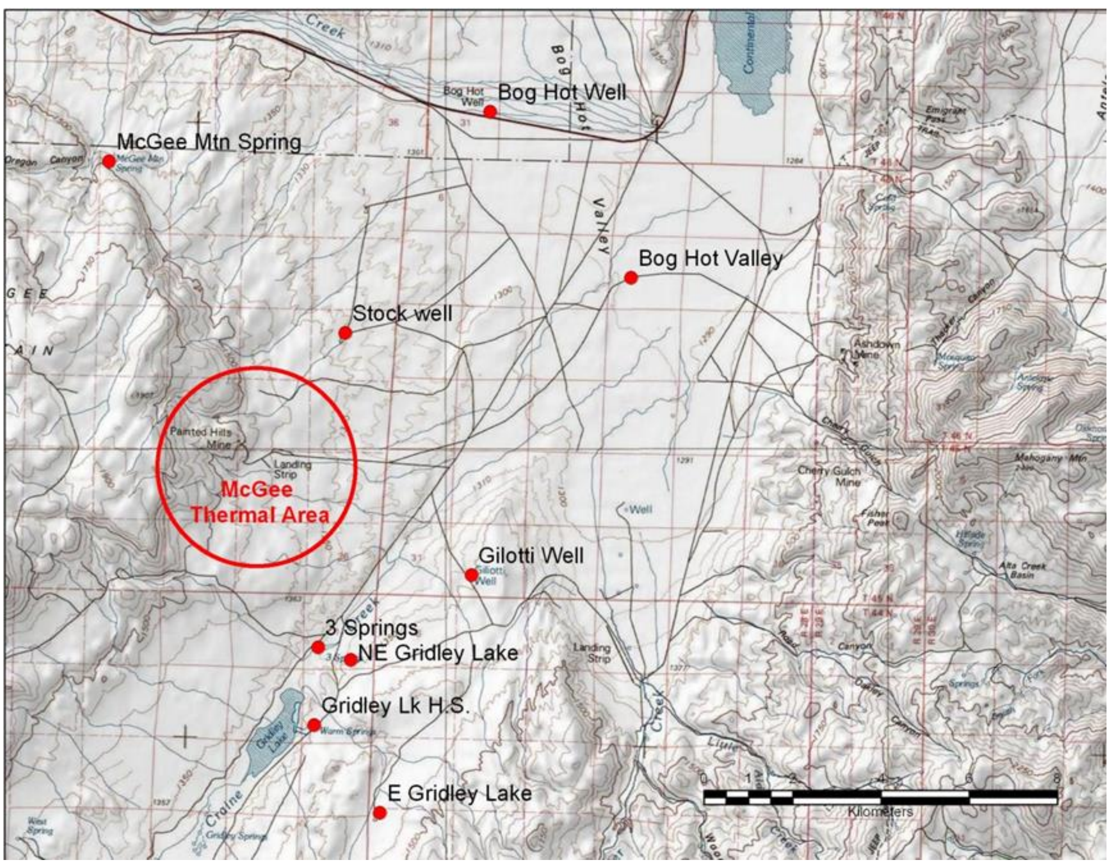


Figure 4. Location of springs and wells mentioned in this report.

Table 1. A. Water geochemistry from the McGee Mountain area. Samples with 'MM' designations were collected during this study; other water geochemistry comes from the Geothermex report (see below). All constituent values are in ppm; location information is in UTM Zone 11, NAD27 projection. B. Calculated cation and silica geothermometer temperatures for this same sample suite. Note: Sample from 'NE PH Mine' is from the Stock Well.

No.	Name	Easting	Northing	TempC	pH	Na	K	Ca	Mg	SiO2	HC03	SO4	Cl	F	B
	3 Springs	347011	4625504	12	7.5	248.0	26.2	19.0	3.3	98.0	223.0	179.0	177.0	2.8	
MM8	Bog Hot Valley	354094	4633863	13	7.7	18.0	5.8	6.9	0.6	2.5	47.0	3.5	7.7	0.1	0.0
	Bog Hot Well	350900	4637615	11	7.5	104.0	14.0	22.0	7.3	45.0	353.0	19.0	16.0	0.8	
	Bog Hot Well	348271	4635486	14	7.5	64.0	10.3	6.9	0.9	63.0	101.0	68.0	6.7	2.4	
MM6	Bog Hot Well	348271	4635486	15	7.8	79.0	16.0	15.0	1.9	65.0	140.0	71.0	14.0	1.0	0.9
MM4	E Gridley Lake	348412	4621772	20	6.6	36.0	6.9	47.0	14.0	70.0	130.0	49.0	43.0	0.3	0.2
MM1	Gilotti Well	350479	4627146	18	8.6	63.0	2.4	5.2	-0.5	55.0	66.0	41.0	16.0	0.8	0.2
	Gilotti Well	350479	4627146	17	8.0	57.0	2.1	3.7	0.1	50.0	88.0	42.0	12.4	0.9	
	Gridley Lk H.S.	346919	4623750	41	7.0	33.0	6.7	1.7	0.1	66.0	62.0	16.8	5.7	0.7	
MM7	McGee Mtn Spr	342274	4636703	12	7.3	13.0	3.2	7.7	1.7	38.5	30.0	7.8	6.0	0.1	0.1
	McGee Mtn Spring	342290	4636490	10	6.5	11.0	3.3	6.9	1.7	36.0	29.3	13.0	3.5	0.2	
MM2	NE Gridley Lake	347750	4625220	12	7.5	98.0	17.0	5.5	-0.5	110.0	100.0	84.0	25.0	2.4	1.2
MM5	NE PH Mine	347697	4632595	16	8.0	190.0	23.0	21.0	1.1	65.0	160.0	190.0	56.0	3.0	3.0
	Stock well	347628	4632616	14	7.7	180.0	22.0	17.0	1.0	65.0	195.0	207.0	55.0	3.5	

	Geothermometers (degrees C)							
Sample Site	K-Mg	Na-K	Na-K-Ca	Cation	Quartz	Chalced	Qtz-Adia	SiO2_Gig
3 Springs	104.4	236.7	191.1	116.7	136.1	109.2	131.8	117.7
Bog Hot Valley	86.8	346.9	85.4	85.4	0.0	-32.7	11.2	-32.3
Bog Hot Well	77.7	257.2	187.0	57.7	97.0	66.7	98.4	72.1
Bog Hot Well	96.6	273.4	199.1	139.4	112.9	83.9	112.1	90.4
Bog Hot Well	98.4	295.7	209.3	137.6	114.5	85.5	113.4	92.2
E Gridley Lake	54.3	290.2	58.0	58.0	118.2	89.6	116.6	96.5
Gilotti Well	-1.0	165.5	76.2	-1.0	106.3	76.7	106.4	82.8
Gilotti Well	83.8	163.5	78.2	78.2	101.8	71.9	102.6	77.6
Gridley Lk H.S.	115.5	296.0	213.9	203.2	115.2	86.4	114.1	93.1
McGee Mtn Spr	60.4	316.1	60.8	60.8	90.0	59.3	92.3	64.2
McGee Mtn Sprin	61.1	338.4	62.3	62.3	87.1	56.2	89.8	60.9
NE Gridley Lake	-1.0	280.5	214.5	-1.0	142.6	116.5	137.2	125.5
Stock Well	116.5	248.0	192.8	172.4	114.5	85.5	113.4	92.2
Stock well	116.6	248.8	194.4	171.6	114.5	85.5	113.4	92.2

Although the only thermal springs immediately down gradient from the McGee thermal area are the Gridley Lake Hot Springs and the East Gridley Lake springs, several non-thermal springs and wells (e.g. 3 Springs, Stock Well) have elevated silica, boron, and/or fluoride indicative of a geothermal component to their fluids. Similarly, silica and cation geothermometer temperatures from these samples range up to 203^{o}C and 142^{o}C, respectively. Although the bicarbonate-sulfate geochemistry and distance from the McGee thermal area suggest mixing and contamination with cold groundwater, the geochemistry is certainly encouraging.

<u>DOE Funded Work</u>

As mentioned above, Caldera Geothermal Inc. ran out of funds, and the project terminated, before Phase 1 work could be completed. The DOE provided cost-share in order to perform the following studies at the McGee Mountain property:

- A Geoprobe survey by Nevada Exploration, Inc., including water sampling (McGee geochemistry is discussed in that section);
- A close-spaced gravity survey by Magee Geophysical Services, LLC;
- A heat-in-place estimate and evaluation by Geothermex; 4) a transmission feasibility study by ZGlobal, Inc.; and
- An archaeological clearance survey for a proposed temperature gradient drill program, by Chambers Group, Inc.

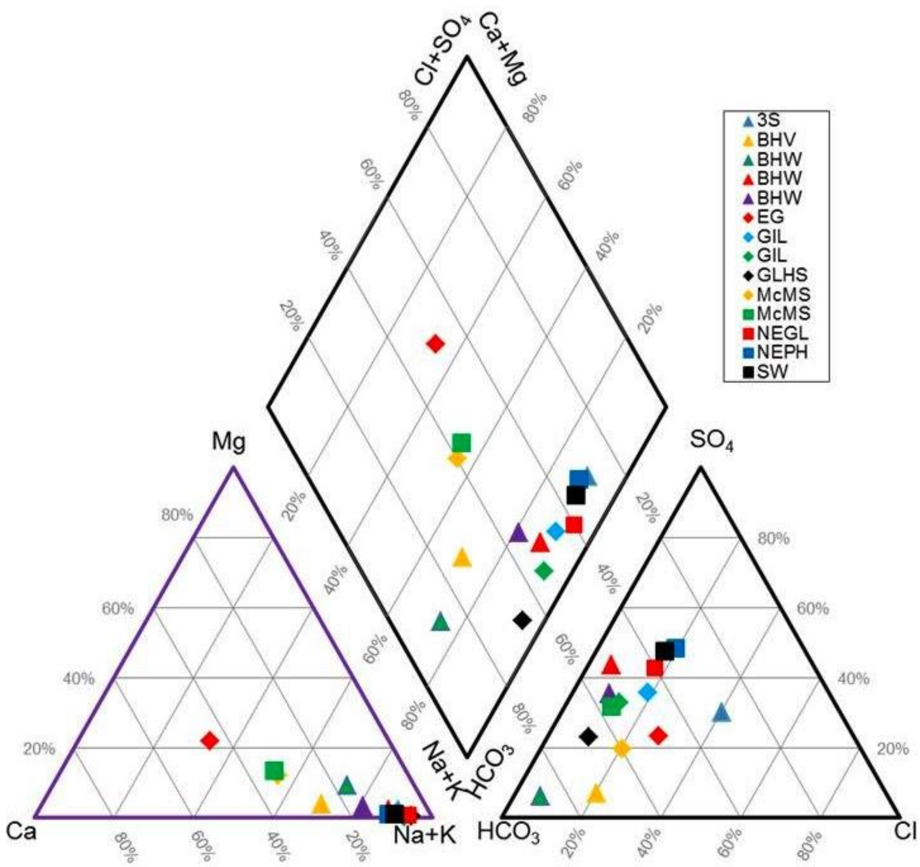


Figure 5. Piper Diagram of geochemical samples from the McGee Mountain area. 3S = 3 Springs, BHV = Bog Hot Valley, BHW = Bog Hot Well, EG = East Gridley Lake spring , GIL = Gilotti Well, GLHS = Gridley Lake Hot Springs, McMS = McGee Mtn. Spring, NEGL = Northeast Gridley Lake spring, NEPH = Northeast Painted Hills, SW = Stock Well.

A brief description of each survey is given below, including the results of the shallow 2-meter survey. In addition, a paper describing the effectiveness of 2m and Geoprobe surveys at McGee Mountain (as well as two other areas) is described.

Shallow 2-meter temperature survey

Detailed descriptions of the 2-meter survey method and equipment design can be found in Coolbaugh et al. (2007) and Sladek et al. (2007), and are summarized here. The survey method was devised to measure ground temperature as far below the zone of solar influence as possible, have minimal equilibration time, and yet be portable enough to fit on the back of an all-terrain vehicle (ATV; Figure 6). This method utilizes a direct push technology (DPT) technique where 2.3 m long, 0.54" outer diameter hollow steel rods are pounded into the ground using a demolition hammer. Resistance temperature devices (RTD) are then inserted into the rods at 2-

meter depths, and allowed to equilibrate for at least one hour. The temperatures are then recorded, the rods pulled out of the ground, and can be re-used at future sites. Usually multiple rods are planted over the course of an hour, and then the sampler returns back to the first station, measures the temperatures, pulls the rods, and so on, to eliminate waiting time. The equipment easily fits into the rear bed of a 2-3 person ATV, making the equipment extremely portable. However, the rods cannot penetrate hard substrates such as tufa, caliche horizons, large cobbles, or bedrock. In areas of hard substrates, rods tend to get stuck, causing delays and reducing the number of rods that can be planted and harvested per day.

Figure 6. Emplacing a rod during a shallow (2-meter) temperature survey.

Temperatures at 2-meter depth were measured at 193 sites at McGee Mountain between November 2008 and March of 2009 (Figure 7). Measured temperatures were adjusted for seasonal changes using repeated measurements at control stations where rods were left permanently in the ground. Anomalous (>18^{o}C) temperatures were encountered along the range front in a narrow north-northeast striking zone approximately 2.3km long. The maximum temperature encountered at 2 meters was 70.6^{o}C, southwest of the Painted Hills mercury mine, and close to the site of the intermittent fumarole and Hole 1500-1 (442m TD). Temperatures were variable over short distances and tapered off rapidly away from the range front. This thermal anomaly is interpreted as a steam-heated fault zone. Curiously, no discernible thermal outflow zone could be identified down the hydrologic gradient from the steam heated fault zone. However, opalitization in the Tertiary sandstones of the range front forms a sort of “fossil outflow zone” down the hydrologic gradient, away from the thermal anomaly area (Figure 2).

<u>Geoprobe Survey</u>

The Geoprobe is a truck-mounted device that uses direct push technology to force a 1.5” diameter hollow tube into soils to depths of up to 60 meters, where groundwater samples can be collected and/or temperatures measured (Figure 8). It has been used in the environmental industry to rapidly sample groundwater down-gradient from contaminated sites. GP became interested in adapting this technique to sample shallow geothermal outflow during early stage exploration. Along with the shallow (2-meter) temperature surveys, the Geoprobe constitutes an innovative technology that could reduce geothermal exploration risk.

The percussive force is supplied by a hammer operating at 32 Hz (1,920 cycles per minute) in order to provide a downward force of 32,000 lbs. The retraction force is 42,000 lbs. Although the Geoprobe has much greater “push” than the demolition hammer used in the 2-meter setup, it still cannot penetrate large amounts of the same obstacles, including boulders, sinter, and bedrock. The heavy rig can engage most 4WD roads, but cannot be taken off road, thus limiting its range. Although permitting is much easier than conventional drill rigs (some BLM offices have declared it “casual use” and require only notification), minimal permitting is usually required. Hole abandonment is subject to state drill hole abandonment laws.

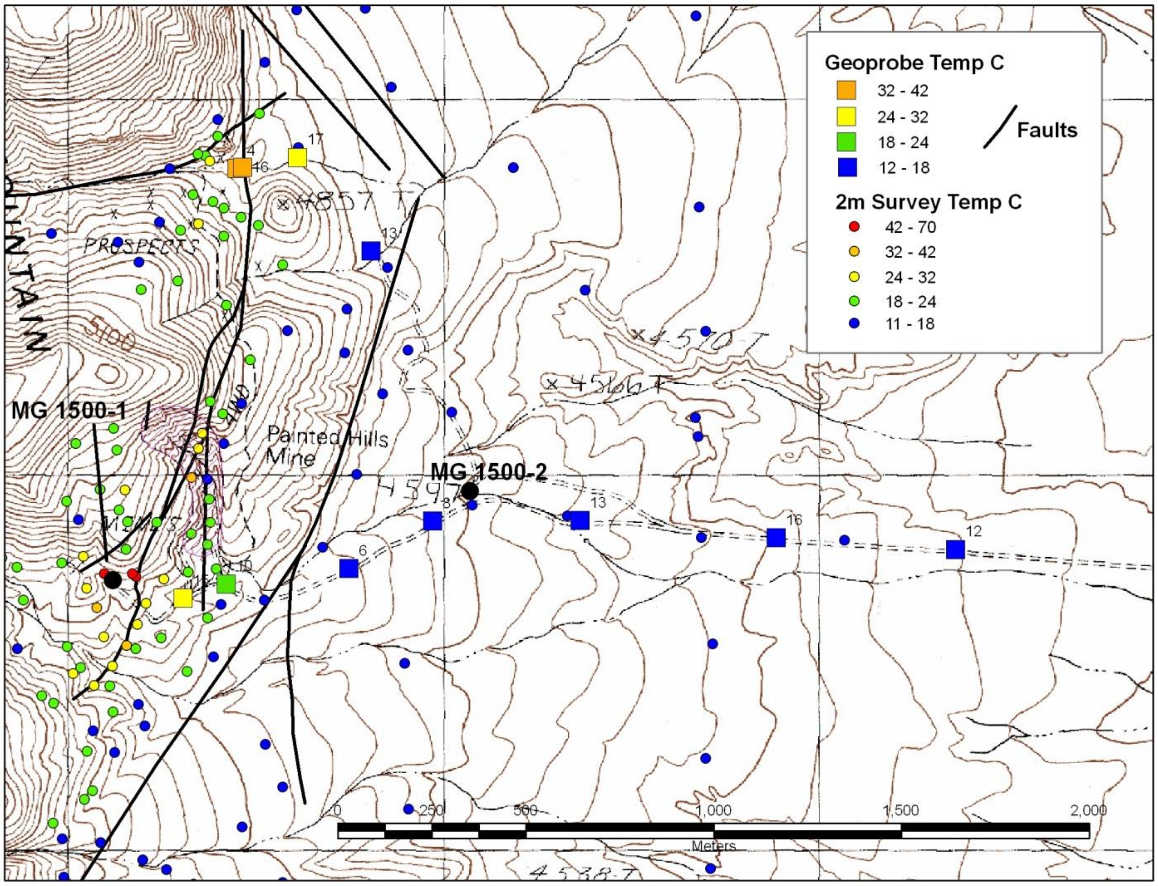


Figure 7. Location and measured temperatures from 2-meter and Geoprobe surveys at McGee Mountain. From Zehner et al., 2012.

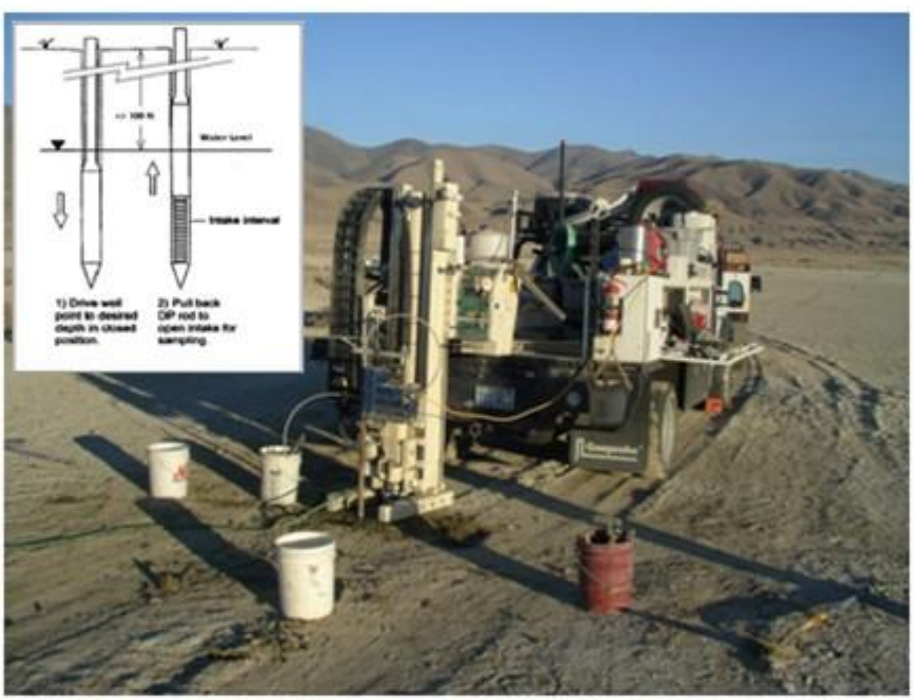


Figure 8. Geoprobe with tool string in ground.

Nevada Exploration, Inc. perfected Geoprobe sampling in pediment areas of Nevada to detect blind epithermal ore deposits via groundwater geochemistry. Since the closest groundwater samples to McGee Mountain were miles down the hydrologic gradient, it was thought that water sampling would help confirm the known geothermometry. One modification made to the Nevada Exploration equipment was to adapt the sample tubing to accommodate a RTD for temperature sampling at the bottom of the hole. This would allow deeper temperature measurements and the ability to compare and calibrate temperature measurements between the 2-meter sampling, Geoprobe, and temperature gradient measurements.

The Geoprobe survey at McGee Mountain was completed in May of 2010. 23 holes totaling 261m (857 feet) were completed on the property (Figures 7 and 9). Sampling within the range front target was hampered by both low road density and a substrate of coarse alluvium containing boulders, which reduced penetration depths. Although it was hoped that water samples from within the thermal area could be collected, the water table was not intersected in any Geoprobe hole, so no water samples were taken. Still, bottom hole temperatures were measured.

Geoprobe bottom-hole temperatures corresponded well with those of adjacent 2-meter sample sites. Figure 10 shows a depth-temperature graph, which combines sampling from shallow 2-meter temperature surveys with Geoprobe temperatures at McGee Mountain, the Hot Pot in north-central Nevada, and the Teels Marsh geothermal system in Mineral County, Nevada (from Zehner et al., 2012). It compares the closest 2-meter site to a corresponding Geoprobe site, with a maximum radius of 100m.

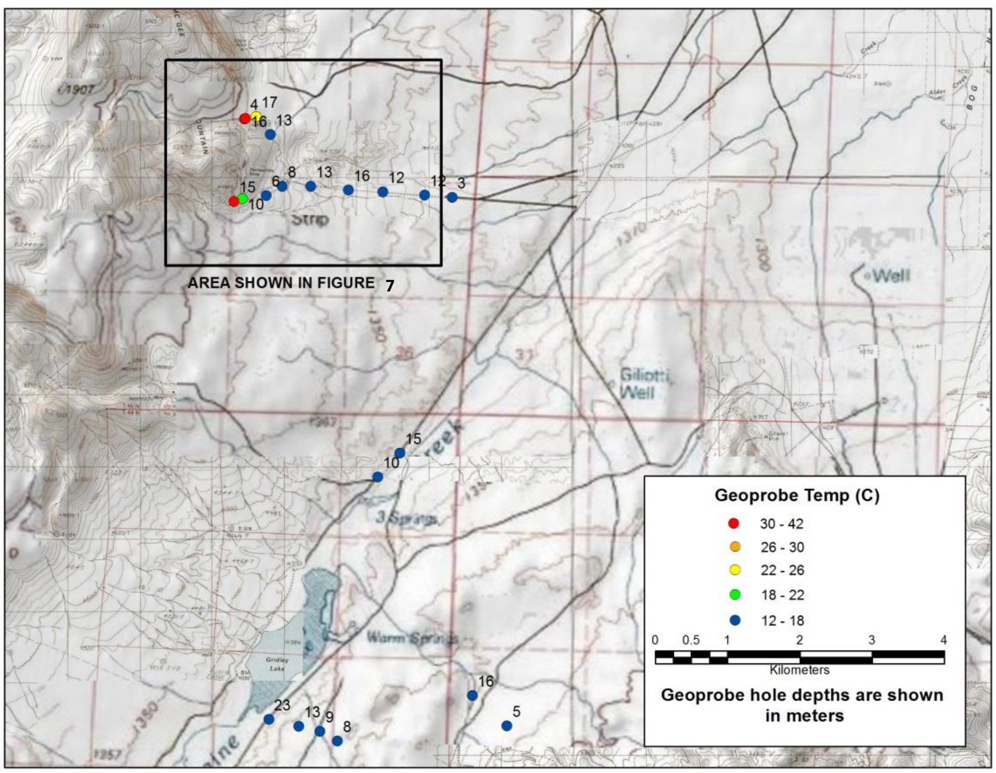


Figure 9. Location of all Geoprobe holes. Hole depth in meters is shown to upper right of location point.

Two features of this graph are worthy of mention. First, for the most part, anomalous and background temperatures identified by the 2-meter survey are more or less (see below) verified by the deeper Geoprobe temperatures. This lends credence to the 2-meter technique as a “first pass filter” to sort areas for their geothermal potential using shallow thermal anomalies, as in grass-roots exploration settings. Second, the higher temperatures at depth as measured by the

Geoprobe tend to correspond to higher temperatures at 2 meters, although the slightly different slopes of the lines indicate some variances in the thermal conductivity of soils. Still, hotter temperatures at 2 meters seems to indicate hotter temperatures at depth. It should be pointed out that although the lines connecting 2 meter temperatures to the adjacent Geoprobe readings are shown as straight, they probably follow a temperature gradient more similar to the line representing the measurements to 9.5 meter depth at Teels Marsh by Kratt et al. (2008) data (Figure 10).

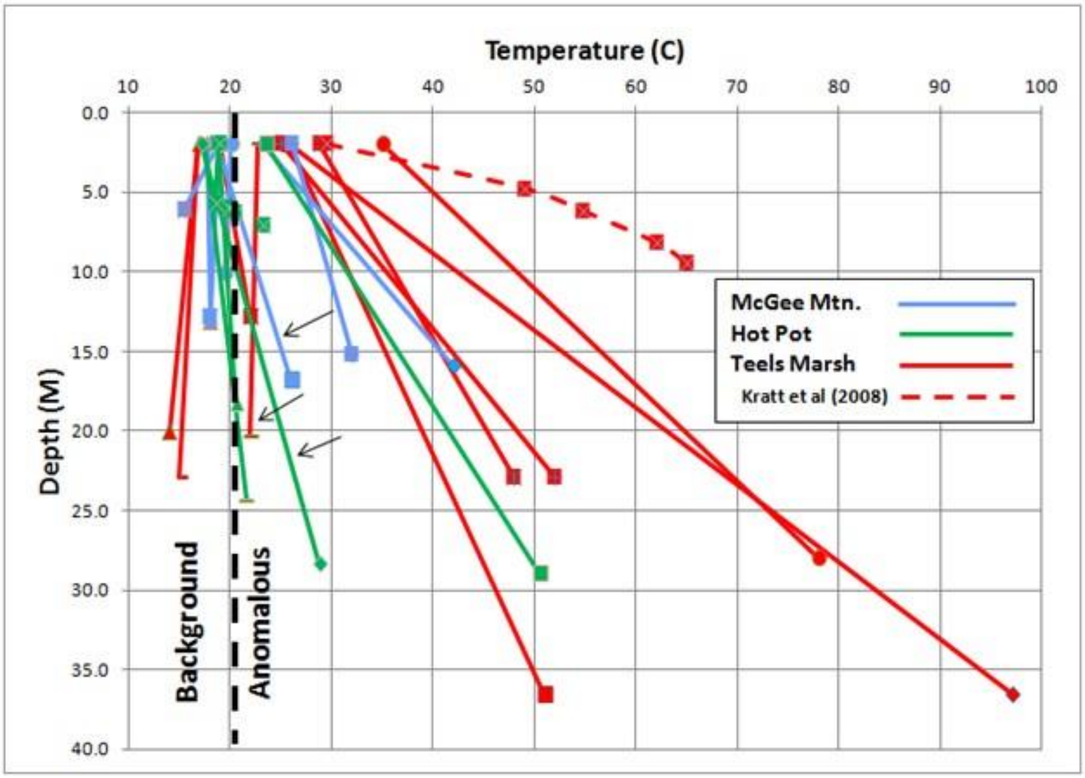


Figure 10. Depth-temperature diagram showing results of 2-meter surveys compared with measured Geoprobe temperatures at McGee Mountain, the Hot Pot, and Teels marsh, Nevada, from Zehner et al., 2012. The colored tie lines join samples that are the closest to each other, within a maximum radius of 100 meters. 2-meter temperatures have been normalized to a cutoff temperature of background versus anomalous of 20°C.

Potential weaknesses in the 2-meter technique are indicated by arrows pointing to the 2m-Geoprobe lines in Figure 10. They point to situations where non-anomalous or background conditions as identified by the 2-meter survey correspond to geothermal anomaly conditions as seen by the Geoprobe. In the instance from Teels Marsh (red line), the 2-meter site is 95m from its corresponding Geoprobe site, perhaps too far for a good comparison. At McGee Mountain (blue line), the 2-meter probe and Geoprobe sites are also close to the 100m limit of comparison. But here, the high variance of temperature with distance in this steam-heated fault zone probably also plays a role. At the Hot Pot property (green line), the 2-meter rod was planted right at (and measured just before) the location of the Geoprobe hole. As mentioned previously, anomalous 20°C to 30°C temperatures measured by the Geoprobe at several Hot Pot sites were not above background, according to the 2-meter technique. This seems to point to a minimum temperature at depth (approximately 30°C), below which a thermal anomaly cannot be detected by the 2-meter technique.

Close-spaced gravity survey

A 334-station gravity survey was conducted at McGee Mountain by Magee Geophysical LLC, between March 23rd and 24th 2010 (Figure 11). Sampling occurred on a grid with 250 meter spacing. The purpose of the survey was to identify subsurface structures and obtain the dip of the range front faults thought to be the conduits of ascending geothermal fluids.

As expected, the Bouger gravity shows a high associated with range front bedrock (Tertiary volcanic), and lows associated with valley fill material (Figure 11). A high gravity gradient between the two is interpreted to represent a steeply north-northeast dipping range front fault system. Just north of the thermal anomaly, offsets on northwest striking faults create the Bog Hot Valley (at upper middle part of picture). To the east-southeast, a relative gravity high out in the pediment indicates a shallow horst block. An incipient graben is being formed adjacent to the range front, between McGee Mountain and the buried horst. A buried saddle appears to be separating the Bog Hot Valley from this buried graben.

Geothermex Report

Caldera commissioned Geothermex to perform an overall analysis and heat-in-place estimate of the McGee Mountain property in June of 2010. Utilizing historical data together with additional information provided by GP, the report made the following conclusions:

1. The maximum recorded bore hole temperature was 242°F (116°C) at 400 feet (122 m) depth in a hole drilled at the mine area.
2. Geochemistry of spring and well water samples from the area shows dilute sodium-bicarbonate type waters with low chloride and significant sulfate. Geothermometer values in part reflect temperatures consistent with the +100°C temperatures recorded near the fumarole. The most interesting samples are from the 3 Springs and the Stock well, which (though cold) may reflect a higher-temperature system up the hydrologic gradient at/near McGee Mountain. Waters from the Gridley Lake Hot Spring have interesting g geothermometer values, but are chemically distinct from the 3 Springs and thus may represent outflow from another geothermal system.
3. Outflow appears to move towards the SE, as indicated by temperature conditions in drill holes and by a cold spring three miles to the SE that is chemically anomalous and could represent cooled geothermal water. The chemistry of this cold spring water is compatible with temperature conditions that are about the same as the maximum measured 242°F (116°C), but also allows the possibility that the water has cooled from a deep source at about 375°F (190°C) or higher (with an uncertainty of about ±15°C).
4. Results yield a 90%-probable (“P90”) thermal energy-in-place estimate of 87,300 MWth-years (that is, 90% of estimates are higher). We consider this to be a “minimum” likely value. At 50% probability (“P50”) the estimate is 134,000 MWth-years. The minimum (90% probable) estimate for generation potential is about 25 MWe for 30 years (or a total of 750
5. Results yield a 90%-probable (“P90”) thermal energy-in-place estimate of 87,300 MWth-years (that is, 90% of estimates are higher). We consider this to be a “minimum” likely value. At 50% probability (“P50”) the estimate is 134,000 MWth-years. The minimum (90% probable) estimate for generation potential is about 25 MWe for 30 years (or a total of 750 MWe-years) and at 50% probability the estimate is 52 MWe for 30 years (or a total of 1,560 MWe-years). Volume and thickness estimates used for this calculation are shown in Table 2. This may be considered to be an Inferred Geothermal Resource in the sense of the Canadian Geothermal Code for Public Reporting.

Table 2. Volume and thickness estimates used in the Geothermex heat-in-place estimate.

	Thickness (m)	Area (km2)	Temperature (C)
Minimum	0.8	4.4	107
Most Likely	1.1	8.8	174
Maximum	1.7	13.2	227

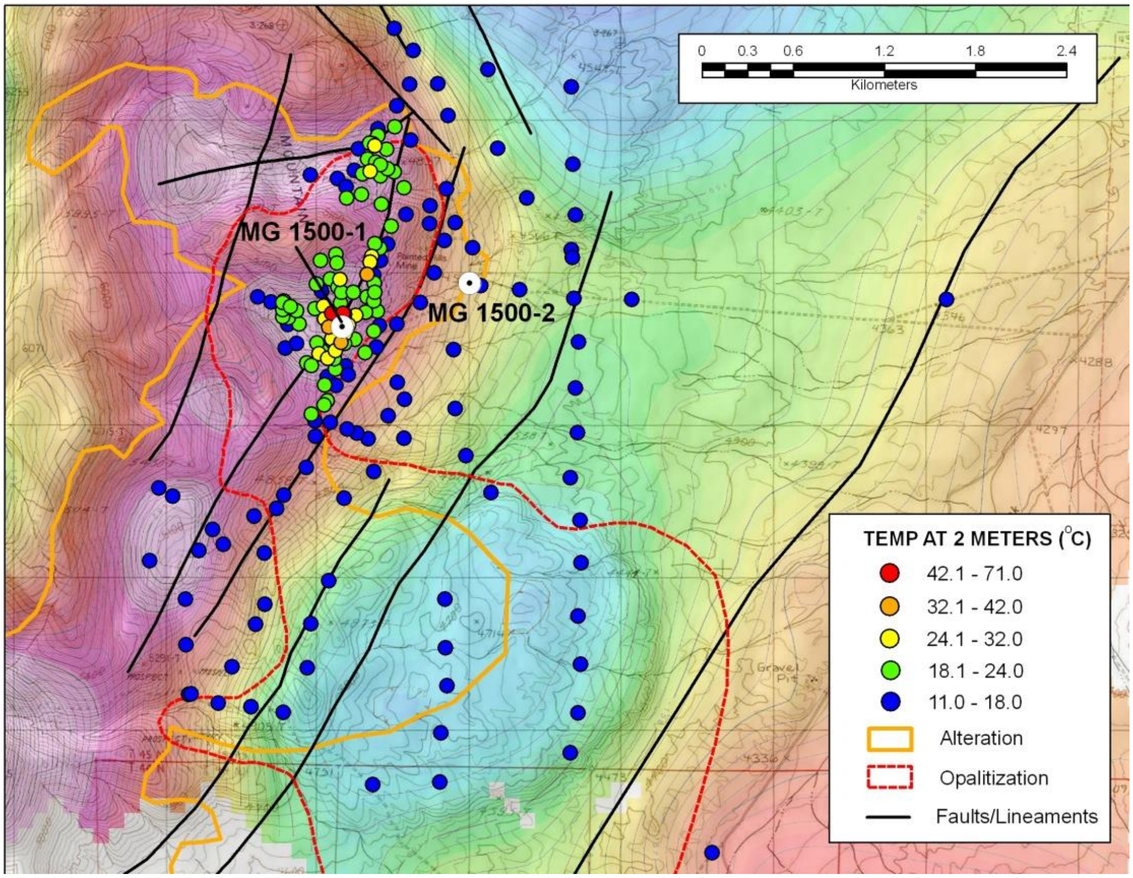


Figure 11. Complete Bouger gravity model for the McGee Mountain project area. Warm colors represent areas of higher gravity; cooler colors indicate lower gravity.

ZGlobal Transmission Feasibility Study

Because distances to the nearest transmission lines and substations were known to be substantial, in June 2010 Caldera commissioned a transmission connection feasibility study by ZGlobal, Inc. McGee Mountain lies within the service area of Harney Electric Cooperative. Harney Electric (HE) is a relatively small cooperative with limited resources and processes to support generation interconnections. However, connections south to the NV Energy grid and north to the Bonneville Power Administration were explored. Major conclusions were:

1. The HEC electric system consists of a single 115 kV circuit that has interconnections to Nevada Energy via Winnemucca NV in the south and to Bonneville Power Administration via Redmond, OR in the north. The HEC system is split electrically into a North and South system, each offering a potential point of interconnection for the proposed project. These

are the Quinn River and Fields 115 kV substations, both of which are roughly 26 miles from the proposed project site.

2. Both systems were found to require significant upgrades due to other proposed generation projects in the area. Fields 115 kV, located on the northern HE system, can essentially be eliminated from consideration due to an overwhelming number of projects (as much as 1400 MW per HE staff) being proposed. This level of generation development will require the development of long distance high voltage (345 or 500 kV) lines to interconnect with neighboring system bulk transmission. Quinn River 115 kV, located in the southern HS system, has fewer projects proposed and was found to be a newer and higher capacity system. There are approximately 230 MW of wind projects proposed for interconnection in addition to McGee Mt.
3. The study considered three scenarios: 1) assume only McGee Mt. (30 MW) is interconnected and evaluated during the impact study, 2) assume all 230 MW proposed as well as 30 MW additional are interconnected, and 3) if the total interconnections exceed a total of roughly 310 MW. For the first scenario, it was found that as much as 80 MW can be added to the Quinn River substation with few if any upgrades assuming no other projects are considered. For scenario 2, it was found that upgrades costs will likely be roughly $6.5m for a 30MW plant at McGee Mountain (on a $/MW basis this equates to $215,400/MW). The third scenario assumed an upgrade in voltage class to 230 kV would be required. If this were the case, the likely upgrades costs assigned to the McGee Mountain project would increase to a total of $48.5 Million, or $485,000/MW pro-rata.

<u>Archaeological clearance survey</u>

In late 2010, GP was preparing to drill a first round of 9 ~200m deep temperature gradient holes at McGee Mountain. Chambers Group, Inc. was given the job of archaeological clearance for drill pads and road access. Road access in this case involved primitive tracks to the drill site without disturbance by heavy equipment. The layout of the pads and tracks is shown in Figure 12. A summary of the report read "…The recordation and inventory resulted in the recordation a single newly identified prehistoric site (CrNV-2-9605) and five isolated finds (CrNV-2-1490 to 1494). The prehistoric site is a small lithic scatter composed exclusively of chalcedony with two formed tools. CrNV-2-9605 is recommended as not eligible to the NRHP under all Criterion. The isolated finds consist of a single prehistoric flake and four pieces of historic debris. All of the isolated finds are categorically not eligible for the NRHP per the State Protocol

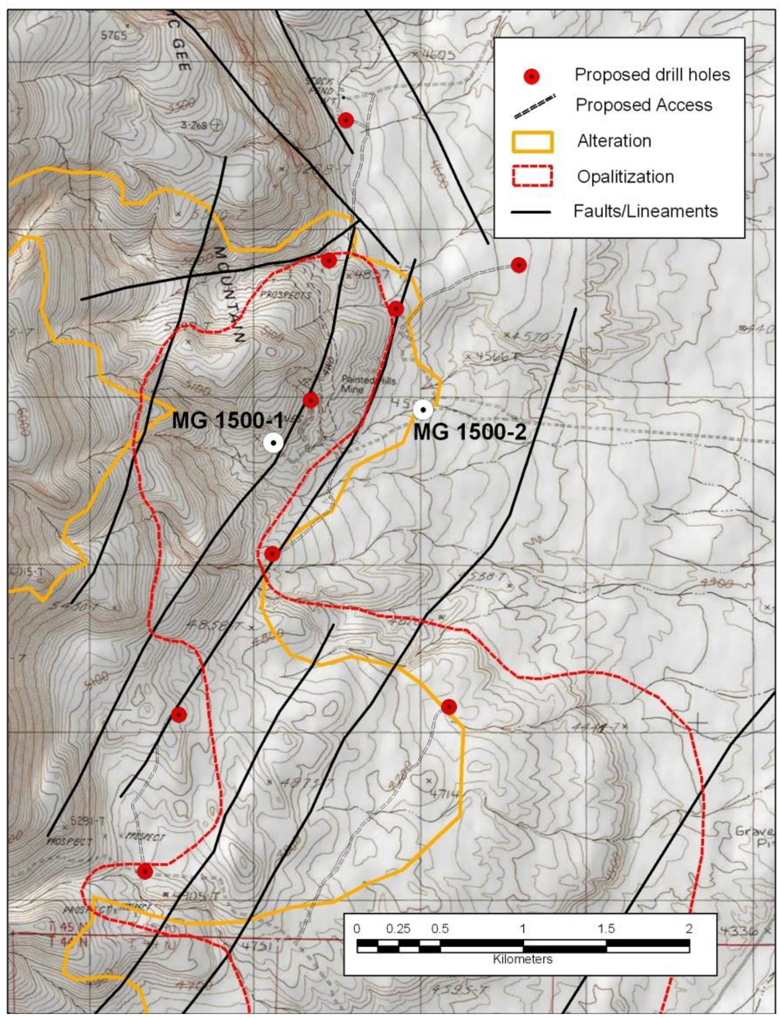


Figure 12. Locations of proposed temperature gradient holes in a Phase 1 drill program.

Agreement between the BLM and Nevada SHPO."

Geothermal Resource Council Paper

The original intent behind the grant was to obtain temperature data from various depths, using different equipment (2-meter, Geoprobe, temperature gradient drilling, and deeper slim hole drilling), and then evaluate the effectiveness of the shallow surveys with respect to the temperatures measured at depth. Since this project never made it to the drilling stage, it was decided instead to utilize the shallow temperature data collected at McGee Mountain, along with two other areas, to compare and contrast the effectiveness of 2-meter surveys with Geoprobe surveys.

To do this, shallow temperature data from McGee Mountain was compared with similar data from the Hot Pot and Teels Marsh geothermal systems in Humboldt and Mineral Counties, Nevada. A paper was written (Zehner, 2012) comparing the effectiveness of these two techniques. All three properties are at the early exploration stage, and representative of typical systems currently being explored in the Great Basin.

The two shallow temperature techniques were compared on the basis of overall effectiveness, mobility, cost, and other factors. The major conclusions of the study are as follows:

- The 2-meter survey is more mobile, and can reach more places than the Geoprobe. Its best use is for early stage delineation of thermal anomalies. The cost per site is less than the Geoprobe. Sampling at 2-meter depth is more prone to solar influences, which can bury the thermal signal of a geothermal system.
- The Geoprobe can collect both temperature and (unlike the 2-meter survey) water samples for geochemistry. Sampling deeper than a 2-meter survey, it is relatively unaffected by solar influences, and gives a less ambiguous signal. It works best as a follow-up tool after a thermal anomaly has already been detected.
- Both 2-meter and Geoprobe surveys work best in non-bouldery, fine-grained substrates where maximum penetration is achievable.
- Both techniques offer very low-cost alternatives to other geothermal exploration techniques in early-stage programs before drilling has started.

Final Conclusions

Although GP failed to complete the desired work, the McGee Mountain property remains an enticing geothermal exploration target. Some geologic points that stand out include:

1. High temperatures encountered in shallow drill holes
2. Geothermometry collected down-gradient of the property arguably demonstrate +150^{o}C temperatures
3. Significant hydrothermal alteration, possibly Quaternary to Recent in age
4. Shallow temperature anomaly more or less contiguous with the hydrothermal alteration
5. Occurrence at intersection of NNE and NW striking regional structures
6. Opalitized "fossil outflow zone" pointing up-gradient to the area with the hottest wells

Currently the biggest problem hindering development of the McGee Mountain geothermal resource is related to transmission. Distance, possibility of expensive utility upgrades, and a renewable energy queue in line to access the available spare capacity are issues that will need to be addressed.

Data

Table 3 shows the name and location of data related to this project that has been deposited into the Geothermal Data Repository, as required by ARRA regulations.

Table 3. Data sets entered into the NGDS from this project.

NAME	TYPE	GDR Title
2-meter Survey Data	Zipped ESRI shapefile	McGee Mountain Shallow (2m) Temperature Survey, Humboldt County, Nevada 2009
Geoprobe Report	PDF file	McGee Mountain Geoprobe Study, Humboldt County, Nevada
Geoprobe Data	Zipped ESRI shapefile	McGee Mountain Geoprobe Survey, Humboldt County, Nevada
Gravity Data	Zip file containing data and georeferenced JPEG's	McGee Mountain Gravity Survey, Humboldt County, Nevada
Geothermex Report	PDF File	Independent technical report: Geothermal resource at the McGee Mountain prospect, Humboldt County, Nevada
Transmission Study	PDF file	McGee Mountain Transmission Interconnection Feasibility Study
Archaeological Clearance Study (redacted)	PDF File	A Class III cultural resources inventory of proposed roads and drill pads for the McGee Mountain geothermal project, Humboldt County, Nevada
This Report	PDF File	Effectiveness of shallow temperature surveys to target a geothermal reservoir at previously explored site at McGee Mountain, Nevada

References

Chambers Group, Inc., 2010, A Class III cultural resources inventory of proposed roads and drill pads for the McGee Mountain geothermal project, Humboldt County, Nevada: BLM Report No. BLM CR3-3111(P), 52 p.

Coolbaugh, M.F., Sladek, C., Faulds, J.E., Zehner, R.E., and Oppliger, G. L., 2007, Use of rapid temperature measurements at a 2 meter depth to augment deeper temperature gradient drilling: Thirty-Second Workshop on Geothermal Reservoir Engineering, Stanford University, Stanford, California, January 22-24, SGP-TR-183.

Edquist, R.K., 1981, Geophysical investigations of the Baltazor Hot Springs Known Geothermal Resource Area and the Painted Hills thermal area, Humboldt County, Nevada: DOE Report DE-AC07-80ID12079, 89 p.

Gardner, M. C., and Koenig, J.8., 1978, Photogeologic interpretation of the Baltazor-McGee (Painted HilIs) geothermal prospects, Humboldt County Nevada: GeothermEx, unpublished report for Earth Power Production Co.

Geothermex, 2010, Independent technical report: Geothermal resource at the McGee Mountain prospect, Humboldt County, Nevada: Report to Caldera Geothermal, 68 p.

Hulen, J.B., 1979, Geology and alteration of the Baltazor Hot Springs and Painted Hills thermal areas, Humboldt County, Nevada: DOE Report EG-78-C-07-1701, 21 p.

Kratt, C., Coolbaugh, M., Sladek, C., Zehner, R., Penfield, R., and Delwiche, B., 2008, A new gold pan for the west: discovering blind geothermal systems with shallow temperature surveys: Geothermal Resources Council Transactions, v. 32, p. 153-158.

Sladek, C., Coolbaugh, M., and Zehner, R., 2007, Development of 2-meter soil temperature probes and results of survey conducted at Desert Peak, Nevada, USA, Geothermal Resources Council Transactions, v. 31, p. 363-368.

Zehner, R.E., Tullar, K.N., and Rutledge, E., 2012, Effectiveness of 2-meter and Geoprobe shallow temperature surveys in early stage geothermal exploration: Geothermal Resources Council Transactions, v. 36, p. 835-841.

ZGlobal Inc., 2010, Transmission interconnect feasibility study, McGee Mountain, Nevada: report to Geothermal Technical Partners, Inc., 22 p.