Our Evolving Knowledge of Nevada's Geothermal Resource Potential

Lisa Shevenell[1], Mark Coolbaugh[1], Chris Sladek[1], Rick Zehner[1], Chris Kratt[2], James Faulds[1], and Robin Penfield[1]

[1]Great Basin Center for Geothermal Energy, University of Nevada, Reno NV
[2]Desert Research Institute, Reno NV

Keywords
Exploration, Nevada, shallow temperature, remote sensing

ABSTRACT

The Great Basin Center for Geothermal Energy (GBCGE) is conducting site-specific and regional geothermal research both in direct collaboration with industry (typically site-specific) and independently (typically regional exploration), communicating findings with public and industrial partners. These studies are research-oriented and are developing new tools for assessing existing geothermal systems and discovering new geothermal systems.

Research directed towards new geothermal discoveries includes: 1) development of portable, efficient systems of measuring shallow ground temperatures, 2) structural analysis of the controls of existing geothermal systems and development of conceptual models of such controls, 3) use of multispectral and hyperspectral remote sensing to identify borates, sulfates, and other geothermal mineral indicators, 4) assessment of cold spring major and trace element geochemistries to identify thermal water contributions, 5) collaboration with the mining industry to publicize new geothermal discoveries encountered during mineral exploration drilling, and 6) development of new mathematical techniques for integrating diverse exploration data into regional predictive models of geothermal potential. These efforts have collectively been highly successful in identifying new geothermal resources.

Remote sensing-based mapping of borate and sulfate deposits has helped recognize blind geothermal systems at Bonham Ranch, and Rhodes and Teels Marshes, NV. Collaboration with the gold mining industry has led to the announcement of two new significant geothermal discoveries at McGinness Hills and Tungsten Mountain, Nevada. Detailed geological mapping at Desert Peak and other geothermal systems has led to significant improvements in the understanding of structural controls on geothermal fluid flow, which has implications not only for drilling successful production wells but also for recognizing favorable structural environments elsewhere.

GIS-based spatial statistical modeling indicates that a significant undiscovered resource base of blind geothermal systems exists in the Great Basin. Recent exploration successes, in part derived from GBCGE research, confirms that these systems can and will be found, and that geothermal energy can be a major contributor to the renewable energy portfolio in Nevada.

Introduction

It has long been known that Nevada has a significant geothermal resource potential (e.g., Muffler et al., 1978; Garside and Schilling, 1979; Shevenell and Garside, 2005). In the summer of 2005, the Western Governor's Association sponsored a workshop at which experts estimated resource potential at known sites with some available data. It was estimated that Nevada could produce 1500 MW of power within the next 10 years using currently available technology at the 42 sites considered. This estimate did not include any of the 100's of other known sites without sufficient information from which to make an estimate, or any of the as yet undiscovered sites. As research continues and technology improves, additional geothermal sites in Nevada are being located and assessed. This paper summarizes some of the recent achievements by researchers at the Great Basin Center for Geothermal Energy and how those achievements are locating new resources for the industry to develop, resulting in an evolving knowledge of Nevada's geothermal resource potential.

New Exploration and Assessment Methods

In 2005, the Nevada Bureau of Mines and Geology published the first geothermal favorability map for the Great Basin based on work at the Great Basin Center for Geothermal Energy (Coolbaugh, et al., 2005). This map was a result of conducting regional studies and development of GIS models. It was the first of its kind that used GIS to predict geothermal favorability based on geologic coverages, including gravity, depth to groundwater, Quaternary faults, crustal dilation, temperature gradients and seismicity.

On a more local scale, Faulds et al. (2003, 2005a, 2005b, 2006) have conducted structural analysis and detailed geologic mapping at a number of sites throughout Nevada and have found that productive geothermal systems typically occur in one of several structural settings, including step-overs in normal fault zones, near the ends of major normal faults where the faults break into multiple splays, in belts of overlapping faults, at fault intersections, and in small pull aparts along strike-slip faults. These settings generally produce subvertical conduits of increased fracture density, thus enhancing fluid permeability and deep circulation. In addition, many of the geothermal systems occur in critically stressed areas near recent fault ruptures (Faulds et al., 2006; Bell et al., 2007). Characterization of the structural controls in these studies will help in the identification of additional new targets (including blind resources), and improve the success of hitting permeable hydrothermal zones in known systems.

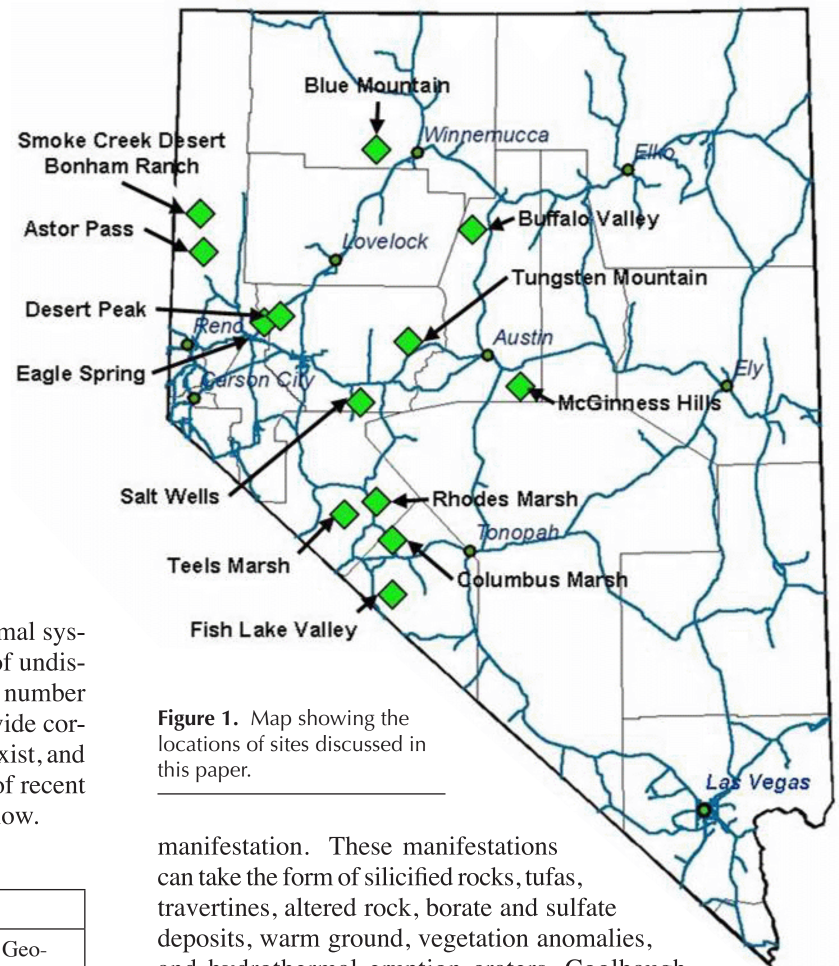

Figure 1. Map showing the locations of sites discussed in this paper.

Undiscovered Resources

We are refining our models of undiscovered geothermal systems and they continue to predict a significant number of undiscovered resources (Coolbaugh and Shevenell, 2004). A number of new geothermal discoveries in the last few years provide corroboration that a large number of undiscovered systems exist, and that they can and will be found. Table 1 provides a list of recent discoveries in Nevada, some of which are discussed below.

Table 1. Recently discovered geothermal areas (see Figure 1).

Site	How Located
Astor Pass	Structural Analysis, Temperature Surveys, Geophysics
Blue Mountain	Gold Exploration
Bonham Ranch	Remote Sensing, Temperature Surveys, Structural Analysis
McGinness Hills	Gold Exploration
Rhodes Marsh	Borate occurrence, Water Geochemistry, Field Mapping
Salt Wells N (better defined)	Structural Analysis, Temperature Surveys
Teels Marsh	Borate occurrence, Temperature Surveys, Water Geochem
Tungsten Mountain	Gold Exploration

Many of these systems are essentially “blind” at the surface, and hence techniques have been developed to detect some of those systems that do not have hot water issuing at the surface.

Finding Blind Resources

Remote Sensing

Remote sensing techniques have been developed and deployed in order to help locate some of these “blind” systems. Most systems do in fact have some surface signature suggesting a geothermal resource at depth, and all currently producing “blind” systems in the Great Basin have some type of surface manifestation. These manifestations can take the form of silicified rocks, tufas, travertines, altered rock, borate and sulfate deposits, warm ground, vegetation anomalies, and hydrothermal eruption craters. Coolbaugh et al. (2006) and Kratt et al. (2006) determined that geothermal fluids are sometimes associated with evaporitic borate crusts on the surfaces of playas. They demonstrated that these borates can serve as effective geothermal exploration tools in Nevada’s arid environment. Kratt et al. (2006) demonstrate the effectiveness of using a field-portable ASD Fieldspec® spectroradiometer and satellite-based Advanced Spaceborne Thermal and Emitted Reflectance Radiometer (ASTER) imagery for mapping borate minerals in the field. Borate crusts that were partially mined during the 1800s were identified and mapped at Rhodes, Teels, and Columbus Marshes (playas), all in western Nevada (Figure 1). Subsequent field verification and chemical analyses of well, spring and groundwater samples indicated the presence of hidden subsurface geothermal reservoirs. Cation and quartz geothermometry indicate subsurface reservoir temperatures between 118º C and 162ºC at all three areas based on results from waters sampled proximal to borate crusts. Shallow temperature surveys were conducted at several of these sites to determine if there were any temperature anomalies associated with these borate crusts (discussed below).

Collaboration with Mining Industry

Collaboration with the gold mining industry has brought two new geothermal discoveries to the attention of the geothermal community. Exploration holes at Tungsten Mountain and McGuiness Hills (Figure 1) in 2004 and 2005 encountered hot water and steam at depths of ≤300 meters with fluid geothermometry indicating reservoir temperatures of 170 to 200ºC. More information can be obtained from the Nevada Bureau of Mines and Geology web site (www.nbmg.unr.edu/geothermal/gtmap.pdf), and from a PowerPoint presentation titled "Geothermal Exploration Short Stories…" posted on the Geothermal Resources Council web site (www.geothermal.org/powerpoint06_explor.html).

Fluid Geochemistry

The GBCGE has also been exploring the utility of geothermometer temperature estimates from cold springs and wells, and has found that even though absolute reservoir temperatures may be inaccurately predicted (often underestimated), the geothermal origin of the waters can usually be determined and a rough idea of the temperature obtained. Examples from eight known geothermal systems are listed in Table 2. Calculated geothermometers show anomalous temperatures (121º–159ºC) for each of these sites. Cold/warm waters collected from Rhodes Marsh and Teels Marsh suggest the possible presence of high temperature resources beneath these playas, which corroborates remote sensing investigations that indicated borate deposits in both of those playas (see previous section).

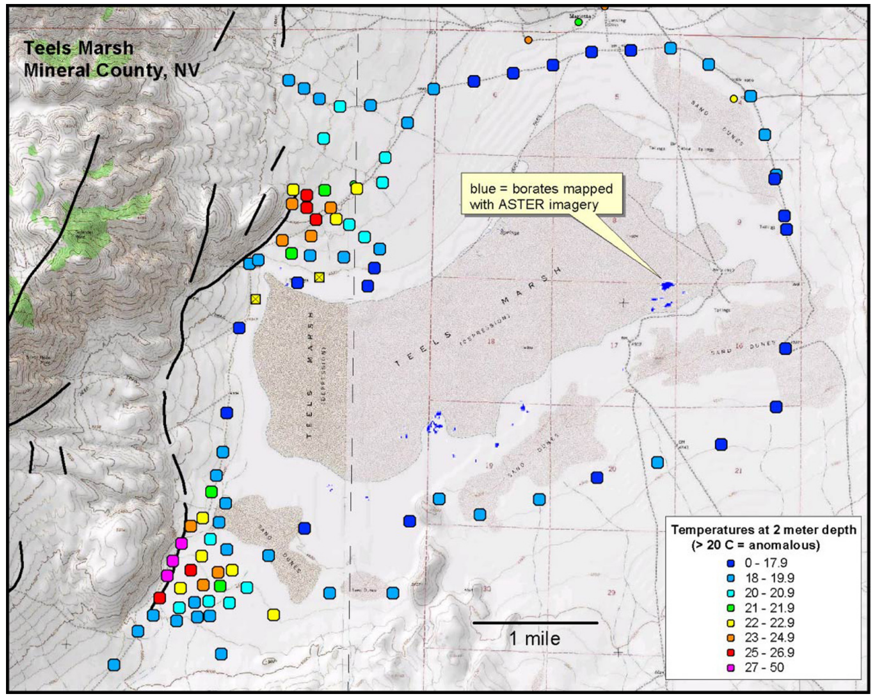

Figure 2. Teels Marsh was located with remotes sensing and was subsequently evaluated with shallow temperature surveys (colored circles) conducted by Chris Kratt, Rick Zehner, Chris Sladek and Mark Coolbaugh. A cold spring was located and the resulting chemistry showed high geothermometer temperatures.

Table 2. Elevated geothermometer temperatures from cold springs indicate a geothermal source (see Figure 1).

	Temperatures (ºC)		
Spring	Measured	Geotherm-ometer	Drilled
Spring N End Buffalo Valley	12.0	121	--
North Side of Teels Marsh	13.0	155	--
Rock Spring at Salt Wells	13.5	121	140
Eagle Spring south of Desert Peak	17.0	142	218
Cold Spring Fish Lake Valley	18.3	149	157
Rhodes Marsh	21.6	159	--
Warm spr. in Smoke Creek Desert	22.1	136	--

Shallow Temperature Surveys

Coolbaugh et al. (2007), Sladek et al. (2007), and Kratt, et al. (2008, this volume) describe a shallow temperature survey system in which temperatures can be measured quickly and inexpensively at 2 m depths. This system was tested at Desert Queen based on its structural setting and availability of thermal gradient well data obtained in the 1970's from which to make thermal anomaly comparisons. The system was subsequently used at Tungsten Mountain and Teels and Rhodes Marshes to help locate blind geothermal systems, (see the Great Basin Center for Geothermal Energy's web site, (http://www.unr.edu/geothermal/tgrad.html) with the results for Teels Marsh reproduced here in Figure 2. Teels and Rhodes Marshes initially attracted interest because of borate salt crusts that were mined in the 1870s. In conjunction with field checking of the borate crusts, existing databases were consulted and a cold spring was found in the literature at Teels Marsh that had a geochemical analysis. Geothermometry from this analysis predicted anomalous subsurface temperatures of 192°C (Mg-corrected Na-K-Ca geothermometer) and 118°C (quartz geothermometer). A shallow temperature survey of the Teels Marsh playa lake perimeter subsequently detected two areas of anomalous temperatures over a total length of approximately 3.5 km subparallel to faults bounding the margins of the playa. The maximum temperature measured to date in the center of the anomaly is 50°C at a depth of 16 feet.

Of the new, blind geothermal sites identified through collaboration with the minerals industry, shallow temperature surveys were conducted at Tungsten Mountain. No hot springs are known in the Tungsten Mountain area, yet the minerals industry located hot waters in their exploration holes. A two meter temperature survey conducted during 2007 identified a strong thermal anomaly at least 6 km long in the vicinity of the mineral exploration drill holes along a hydrothermally altered range front fault (Figure 3, overleaf). The geothermal system, which has geothermometer temperatures of 175°C, occupies a possible step-over in the range from fault on the northwest side of Edwards Creek Valley.

One additional method may be used in the future to locate blind geothermal systems. Several thousand shallow (12") temperature measurements were made for a study conducted at Salt Wells in collaboration with Amp Resources (prior to their being acquired by Enel). After a strong, structurally controlled thermal anomaly was identified on the north end of the study area, a 2 m hole was dug into a playa in which the water temperature at the bottom of the hole was 84.8ºC. Water was allowed to collect in the bottom of the hole and sampled. The chemistry of the sampled water was similar to geothermal waters sampled elsewhere at Salt

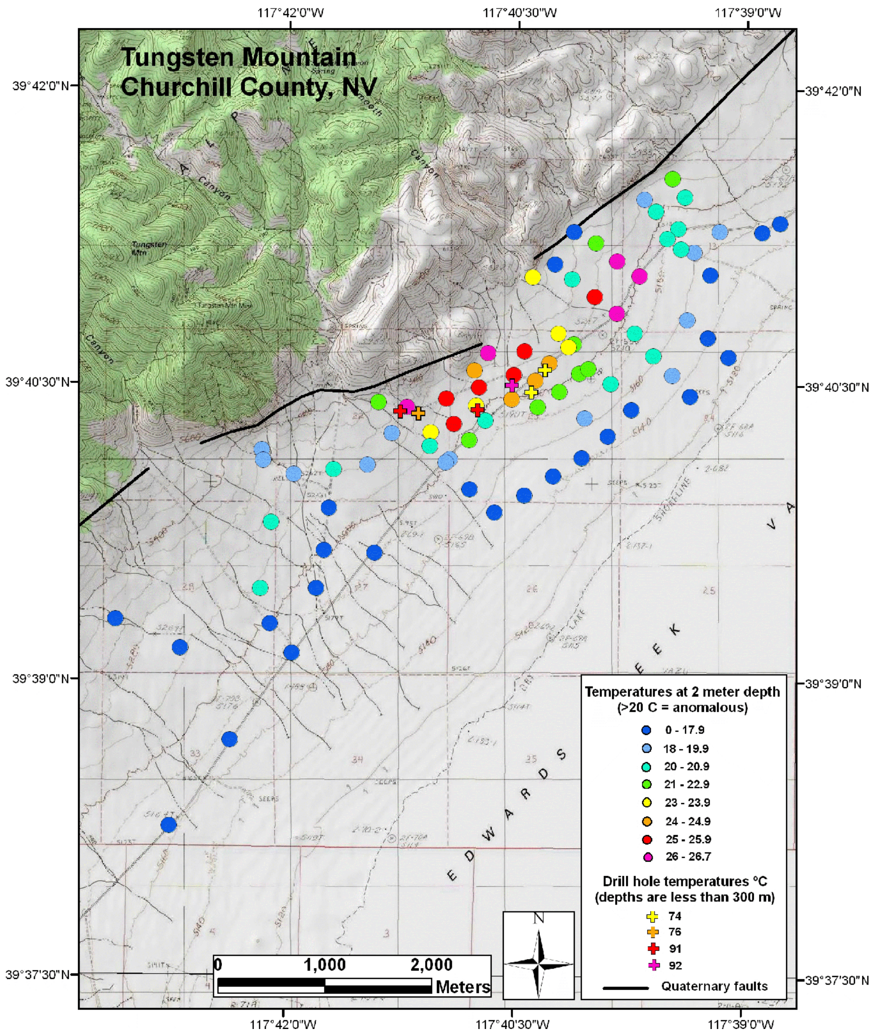

Figure 3. Tungsten Mountain was identified during mineral exploration and was subsequently evaluated with shallow temperature surveys (colored circles) conducted by Chris Kratt and Robin Penfield.

Wells and the calculated geothermometer temperature is 192ºC, suggesting that a high temperature resource may lie beneath the playa. Hence, such playa sampling in other localities may result in additional discoveries.

Summary

Research has enabled the development of significant new evaluation and exploration tools including shallow temperature surveys, remote sensing of borates, and structural analysis to delineate favorable Quaternary fault geometries as prime methods with which to find probable areas for significant hydrothermal circulation. These new tools are helping to identify new geothermal resources and better assess existing ones. Old tools such as geothermometer calculations are likely to help identify additional resources in areas without any hot or warm springs to sample as it appears cold springs can retain a geothermal signature, at least in some cases.

Geothermal energy has the potential to be a major contributor to renewable energy portfolios in Nevada, based solely on the known resources in the state (e.g., 2005 Western Governor's Association Report). Further increasing the likelihood that geothermal energy will be a significant contributor to the state's energy supply is that it appears that the undiscovered resource base in the Great Basin is apparently significant, although unknown. A new, thorough assessment of both known and undiscovered resources is needed. An update of reserve estimates was conducted in March 2008 (Shevenell and Morris, in press) that included the new geothermal areas discussed here, assuming a nominal 5 or 10 MW power plant would be constructed at each. This report indicates that the minimum number of known, developable geothermal resources in the near term with current technology (under suitable political, regulatory and economic conditions) is 1730 MW, and likely closer to 2170 MW. If all of the >1730 MW from geothermal is brought on-line by 2015, geothermal energy would account for 18-23% of Nevada's needed electrical capacity in 2015, based on an assumed 2% increase need in electricity per year starting with the 8200 MW state-wide capacity reported for 2007 by the Nevada State Energy Office. Geothermal energy clearly has the potential to displace significant amounts of fossil fuels and provide Nevada with clean, indigenous, renewable power, improving our economy, quality of life and national security.

Acknowledgment

This material is largely based upon work supported by the Department of Energy, Golden Field Office, under Award Number DE_FG36-02ID14311.

References

Coolbaugh, M., Sladek, C., Faulds, J., Zehner, R., and Oppliger, G., 2007, Use of Rapid temperature measurements at a 2-meter depth to augment deeper temperature gradient drilling. Proceedings, Thirty-Second Workshop on Geothermal Reservoir Engineering, Stanford University, January 22-24, 2007 (published on CD).

Coolbaugh, M.F., Kratt, C., Sladek, C., Zehner, R.E., and Shevenell, L., 2006, Quaternary borate deposits as a geothermal exploration tool in the Great Basin: Geothermal Resources Council Transactions, v. 30, p. 393-398.

Coolbaugh, M., et al., 2005. Geothermal Potential Map of the Great Basin, Western United States. Nevada Bureau of Mines and Geology Map 151.

Coolbaugh, M., and Shevenell, L., 2004. A method for estimating undiscovered geothermal resources in Nevada and the Great Basin, Geothermal Resources Council *Transactions* 28: 13-18.

Faulds, J., Garside, L., and Oppliger, G., 2003. Structural Analysis of the Desert Peak-Brady Geothermal Fields, Northwestern Nevada: Implications for Understanding Linkages between Northeast-Trending Structures and Geothermal Reservoirs in the Humboldt Structural Zone, Geothermal Resources Council *Transactions* 27: 859-864.

Faulds, J.E., Henry, C.D., Coolbaugh, M.F., Garside, L.J., Castor, S.B., 2005a, Late Cenozoic strain field and tectonic setting of the northwestern Great Basin, western USA: Implications for geothermal activity and mineralization, *in* Rhoden, H.N., Steininger, R.C., and Vikre, P.G., eds., Geological Society of Nevada Symposium 2005: Window to the World, Reno, Nevada, May 2005, p. 1091-1104.

Faulds, J.E., Henry, C.D., Coolbaugh, M.F., and Garside, L.J., 2005b, Influence of the late Cenozoic strain field and tectonic setting on geothermal activity and mineralization in the northwestern Great Basin: Geothermal Resources Council Transactions, v. 29, p. 353-358.

Faulds, J.E., Coolbaugh, M.F., Vice, G., and Edwards, M.L., 2006, Characterizing structural controls of geothermal fields in the northwestern Great Basin: A progress report: Geothermal Resources Council Transactions, v. 30, p. 69-76.

Garside, L.J., and Schilling, J.H., 1979, Thermal Waters of Nevada: Nevada Bureau of Mines and Geology Bulletin 91, 163 p.

Kratt, C., Coolbaugh, M., and Calvin, W., 2006, Remote detection of Quaternary borate deposits with ASTER satellite imagery as a geothermal exploration tool: Geothermal Resources Council Transactions, v. 30, p. 435-439.

Kratt, C., Coolbaugh, M. F., Sladek, S., Zehner, R., Penfield, R., and Delwiche, D., 2008. A new gold pan for the west: discovering blind geothermal systems with shallow temperature surveys. Geothermal Resources Council Transactions (in press).

Muffler, L.J.P., (Editor), 1978, Assessment of Geothermal Resources of the United States—1978: U.S. Geological Survey Circular 790, 163 p.

Shevenell, L., and C.L. Morris, (2008, in press). Update on Near-Term Geothermal Potential in Nevada. Bulletin, Geothermal Resources Council vol. 37, No. 3.

Shevenell, L., and L.J. Garside, 2005. Nevada Geothermal Resources, Second Edition. Nevada Bureau of Mines and Geology Map 141, Second Edition.

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* 31: 363-368.