Geochemical Sampling of Thermal Waters in Nevada

Lisa Shevenell and Larry Garside

Great Basin Center for Geothermal Energy; Nevada Bureau of Mines and Geology, MS 178
University of Nevada, Reno, Reno, NV 89557
775-784-1779; 775-784-1709 (fax); lisaas@unr.edu; lgarside@unr.edu

Keywords

Resource assessment, Nevada, geochemistry, geothermomtry

ABSTRACT

There are ≈1000 thermal springs in Nevada for which a location is known, but for which there are no available temperature (or chemical) measurements. Although many of these sites are within known geothermal areas and are located near springs for which temperature and/or geochemical data are available for one of the springs, many of these sites are not so located and require evaluation before the geothermal potential of the area can be assessed. In order to begin filling in data gaps, water sampling commenced in 2002 when over 70 analyses were obtained from springs with previously limited or poor data. A preliminary evaluation of geothermometer temperatures indicates most of the areas have relatively low geothermal potential, however, possible mixing and re-equilibration at lower, near surface temperatures needs to be evaluated at some of the sites. Of the sites evaluated thus far, the following have the highest potential for electrical power production (based on chalcedony geothermometer temperatures): Hot Creek Canyon Area (136°C), Buffalo Valley (130°C), Pumpernickel Valley (Tipton Ranch; 125°C), and Smith Creek Valley (119°C).

Introduction

There has been considerable research on the geochemical characteristics of various Nevada geothermal resources. However, there are many sites throughout the state that may have potential for utilization of geothermal resources, but for which insufficient information is publicly available to evaluate the individual resources. Data collection took place mainly in the summer and fall of 2002 (described in Shevenell *et al.*, 2002), and descriptions of the sites visited are presented here.

Figure 1 (after Shevenell and Garside 2003) illustrates the current information available for various thermal springs and wells throughout Nevada. From this map and the work of Garside (1994), 317 sites (208 springs and 109 wells) have adequate chemical analyses from which preliminary evaluations of the geothermal resource potential can be made. Most of these sites have generally complete major and trace element analyses avail-

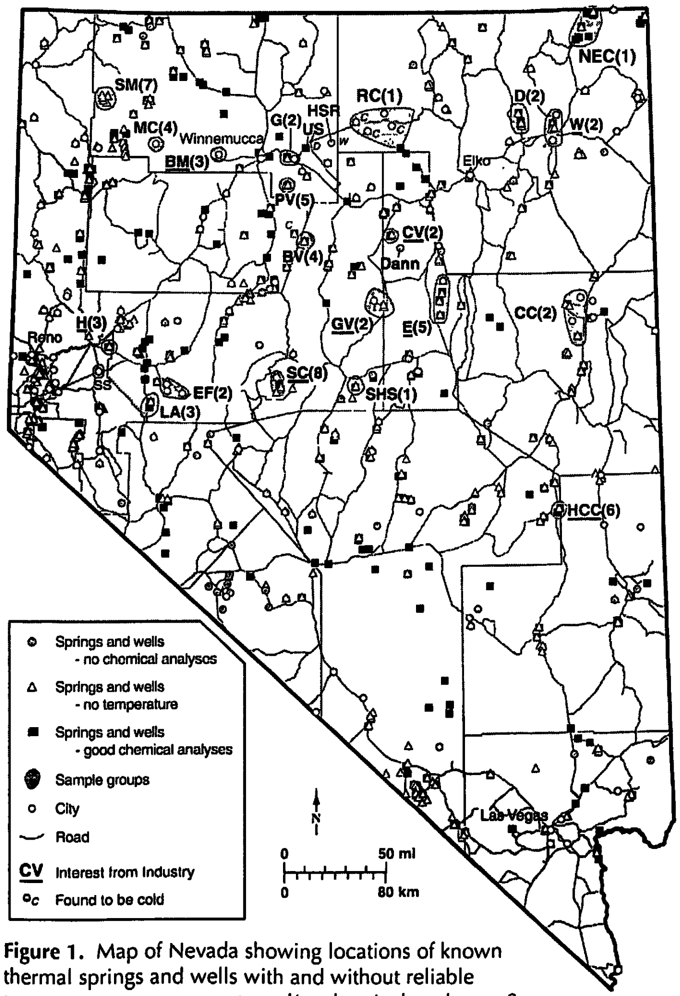

Figure 1. Map of Nevada showing locations of known thermal springs and wells with and without reliable temperature measurements and/or chemical analyses. See text for description of abbreviations. Numbers in parentheses indicate the number of samples collected at the site.

able, but few have any stable isotope information, or chemical data from nearby cold waters from which mixing between deep-seated, high-temperature thermal and shallower nonthermal waters can be evaluated. From the data compilation required to construct Figure 1, there are 88 areas, and many more springs, for which there are no reliable chemical analyses available.

The "hot" or "warm" springs and wells that were digitized from 7.5' topographic maps are illustrated on Figure 1 and labeled as "springs and wells, no temperature." From these data, there are ≈1000 hot or warm springs for which there are neither geochemical data, nor even the most basic data of temperature. Therefore, we are measuring temperatures, conducting field evaluations, and sampling additional thermal sites in Nevada to determine the geothermal resource potential of selected sites. This work includes collection of samples for analysis of major and trace element chemistry, δD, $\delta^{18}O$, ^{14}C, ^{13}C, ^{34}S, and ^{3}H.

In 2002 over 70 springs were visited, documented, and sampled. Chemical analyses are available digitally at www.nbmg.unr.edu/geothermal/geochemdata/2002data. Samples from some of these springs may have been collected in previous studies; however, it is unknown if the same springs were re-sampled in this work because it is unknown which spring in a group of springs was sampled in previous studies. In this work, locations of all sampled springs were obtained using a hand-held GPS unit. The study will expand and enhance the present knowledge of Nevada's geothermal resources by providing new water chemistry information on less-studied geothermal areas, and additional data on known, specific springs at areas that have been sampled previously. The purpose of this work is to fill in data gaps and these data will allow delineation of poorly characterized or understood geothermal areas in Nevada that could be developed for electrical power generation or direct-use applications.

Site Selection

In evaluating the Garside (1994) results at locations north of 40° latitude, we identified ≈90 areas that should be sampled, if we avoid the carbonate aquifer terrain of eastern and southeastern Nevada. We also evaluated all sites discussed by Richards and Blackwell (2002) and listed in their Figure 1, and selected some sites from that list for sampling. Many of the un-sampled areas are obscure, poorly located, cooler, not flowing, or wells that may not be accessible. Therefore, not all of these localities have been prioritized for a site visit or sampling in this first phase of work. From Figure 1 and various data compilation exercises, it is clear that there are numerous thermal features throughout the state that require geochemical and temperature data, at a minimum, to begin to evaluate the areas

Results

Numerous sites were visited during 2002, summaries of which appear here. Each site name is listed in italics followed by the Bulletin 91 (Garside and Schilling, 1979, referred to as Bulletin 91 elsewhere) spring group number in brackets, followed by abbreviations for the area name in parentheses. Figure 1 shows the sites visited thus far as shaded areas, labeled with abbreviations followed by the number of samples collected in parentheses. Industry representatives and others have expressed interest in and obtained the data gathered from the sites containing an underline beneath the abbreviation in Figure 1. Detailed discussions of data, geothermometers, and potential of each site will be presented separately.

Churchill County

Eightmile Flat (Salt Wells) (EF) – This area was visited because it contains geothermal wells and springs (?) for which there are no chemical analyses. Borax Spring (T17N, R30E, NE¼ Sec. 14) at the northwest end of the Eightmile Flat part of the Salt Wells Basin, 29 km southeast of Fallon had a reported temperature of 81°C (Garside and Schilling, 1979). Borax spring could not be located ca. 1980 (Trexler *et al.*, 1981) or by us in 2002. However, there are opal-cemented sands (probably sinter-like material) in this area. Presumably these are the same as the sinter deposits reported by Edmiston and Benoit (1984) from an area of inactive hot springs that were reportedly active in the late 19th century (probably Borax Spring).

Elko County

Springs near Midas – several springs were visited in September 2002 because they were obscure, and very little was known about them. The next five sites belong to this group. The one from this group that was sampled is labeled on Figure 1 as "RC."

Spring at Headwaters of Hot Creek [70] - This spring is located on the Willow Creek Reservoir 7.5' quadrangle (T38N, R48E, Sec. 11) and is located at the headwaters of "Hot Creek." This site was previously reported by Garside and Schilling (1979) with a comment noting that it was not known if the spring was hot. This spring was visited and the spring is not hot, and has a temperature of 16°C flowing at approximately 15 L/min. Hence this site has been removed from recent maps locating geothermal resources in Nevada (Shevenell and Garside, 2003; available at www.nbmg.unr.edu).

Hot Lake [69] (HL) - When Hot Lake (T38N, R46E, Sec. 25) was visited, the investigators walked around the entire lake measuring temperatures of the lake and seeps flowing into the lake. The lake was very low, and numerous small seeps could be observed flowing into the lake, but all were nearly stagnant, and likely evaporating, such that reliable samples could not be collected. The maximum temperature measured in the seeps was 22.1°C, which is not "hot," although locals have observed steam rising from the lake on very cold mornings in the winter.

Spring near Rock Creek [not included in Bulletin 91] (RC) - This spring (T39N, R47E, Sec. 12) had not been previously reported on geothermal maps or by Garside and Schilling (1979). This spring is located in a remote location east of the town of Midas and forms a pool approximately 3 m across with flow coming into the bottom of the pool. The flow rate of the spring is ≈30 L/min; the measured temperature of the spring is 34°C. The spring fluids must have lost silica in the subsurface because the chalcedony temperature is less than the discharge temperature. Limited geothermal potential is suggested for this area based on the Na-K-Ca geothermometer temperature of 87°C.

Unnamed spring near Midas [65] - This area (T39N, R45E, Sec. 36) consists of numerous small seeps along a hillside, and it is marked by vegetation growth in the marshy areas formed by the multiple seeps. Temperatures of most of the seeping ground were measured throughout the hillside, and none of the fluids were found to be thermal. This site is now removed from the geothermal site location map (Shevenell and Garside, 2003).

Hot Springs Ranch [134] (HSR) – One of the springs (T37N, R43E, Sec. 26) closest to Hot Springs Ranch was visited. It had a measured temperature of 25°C, and was not selected for analysis due to the relatively low temperature and our inability to locate a distinct discharge point.

Possible spring south of Wells and 12-mile spring north of Wells [73] (W) – This system is probably not very hot, but may be mixed with considerable cool waters. Sampling in this area was conducted to help characterize the geothermal system along 24 km of a fault zone and determine if there are any resources that are hot enough for moderate temperature uses. Two springs were sampled near Wells: one at T38N, R62E, Sec. 20 (54°C), and one at T39N, R62E, Sec. 27 (40°C). The chalcedony and Na-K-Ca geothermometer from the sites are only slightly greater than measured temperatures.

Northern Elko County area [47,48,54,56](NEC) – One 42°C spring was sampled in this area at T47N, R65E, Sec. 15. The chalcedony temperature is less than the measured discharge temperature and the Na-K-Ca temperature is only slightly greater (60°C) than the measured temperature.

Eureka County

Hot Springs Point (Crescent Valley) [96] (CV) – There are 10 known springs, only two of which had chemical analyses, but none had reported Li. Therefore, two springs were sampled in 2002. We sampled a 46 and 51°C spring at T29N, R48E, Sec. 1 and 11. The Na-K-Ca geothermometer temperature was less than the measured temperature at both sites (<30°C), but the chalcedony temperature for the area indicated temperatures between 79-90°C. Samples of cold waters are needed to better evaluate mixing at this and other sites.

Dann Hot Spring [97] (Dann) – In March 2003 this spring (T28N, R49E, Sec. 10) was 87.3°C flowing at 8 L/min into a circular tank. Samples were not collected at this site because the sampler was asked to leave the site immediately by a nearby landowner before he had a chance to collect any samples.

Springs Near Eureka [101,103,104,105] (E) – Interest has been expressed by Jon Hutchings, Eureka County Natural Resource Manager to develop geothermal resources in the county, although insufficient information was available to assess the resources. Two thermal springs, one cold spring and two cold wells were sampled in collaboration with Mr. Hutchings. The thermal springs located at T24N, R52E, Sec. 23 (40.6°C) and T24N, R53E, Sec. 6 (32.4°C) were sampled. Analyses were not complete at the time of this writing.

Humboldt County

Hot Springs (Tipton) Ranch [146] (PV) – This site has several springs, and only had incomplete analyses from three. Hot springs at Tipton Ranch in T33N, R40E, Sec. 4, 5 have reported temperatures as high as 85°C (Mariner *et al*, 1974), although one spring was sampled in September 2002 with a temperature of 87°C. There are numerous springs and seeps, some discharging gas, that are along a N20°E fault that forms the boundary of the Sonoma Range in that area. The spring deposits are predominantly travertine with a trace of siliceous sinter. Most springs are relatively low flow, but the combined discharge from the area likely exceeds 400 L/min. The "best" estimates of the thermal-aquifer temperature are 194° to 196°C (Mariner *et al.*, 1974), whereas the Na-K-Ca estimate based on 2002 samples is slightly lower at 175 to 192°C. In 1974 Magma Power Co. drilled a geothermal well at Tipton Ranch to a total depth of 919.6 m (3,071 feet). Bottom hole temperature was logged at 135°C after 10 hours of circulation, with the last 91 m having a gradient of 0.16°C/ m (6.5°F/100 ft; Skip Matlick, pers. comm.). In September 2002, the well was flowing at the surface through a leak in the casing and water was depositing travertine over the well head and surrounding area. Wellhead temperature was 95°C.

Golconda area [139] (G) – Hot springs are found in T36N, R40E, SW¼ SE¼ Sec. 29 and SE¼ NE¼ Sec. 32 near the town of Golconda. Temperatures between 29 and 61°C were recorded from several low-flow seeps in the area in September 2002, and samples were collected from a 46.6 and 61°C spring in fall 2002. Geothermometer temperatures are low, with the Na-K-Ca indicating a maximum of 86°C, and the chalcedony indicating a similar temperature of 81°C.

Unnamed Spring [140] (US) – This unnamed spring (T36N, R41E, Sec. 2) is reported in Garside and Schilling (1979) based on the reporting of two thermal (21°C) springs in the area. This area was visited in September 2002, and there was no evidence of any spring discharge at that time. Two springs are shown on the Red House Flat West quadrangle, as is a sizable water body, and no water was found.

Blue Mountain [unknown in Bulletin 91] (BM) – Sampling and analysis was conducted in collaboration with Continental Ridge Resources, Inc. from their new (spring, 2002) corehole. In the early 1990s, ground waters as hot as 88°C were found in gold exploration drill holes in the Blue Mountain area 35 km west of Winnemucca (Parr and Percival, 1991). Later temperature logging of drill holes found temperatures up to 81°C in a 108 m drill hole (Fairbank and Ross, 1999). No hot springs or spring deposits were known from the area. The hot fluids probably circulate along numerous north-striking normal faults in Triassic metasedimentary rocks present in the subsurface along the west flank of Blue Mountain. A 650-m exploration core hole (T36N, R34E, Sec. 23) drilled at this site had temperatures of nearly 150°C. The U.S. Department of Energy has agreed to provide funding ($657,000 over 3 years) to Noramax Corporation to study and help define the resource http: //www.eren.doe.gov/geothermal/

Soldier Meadows Hot Springs [128] (SM) – There are a large number of thermal springs in the Soldier Meadows area, with temperatures reported as high as 53.9°C, although a gaseous spring in T40N, R25E, Sec. 19 with a temperature of 55°C was sampled in August 2002. All springs are within the Black Rock National Conservation area, which was recently withdrawn and, therefore, not currently accessible for geothermal development. Several springs ranging in temperature from 16 to 55°C were sampled in 2002. The Na-K-Ca estimated reservoir temperature (65°C) is near the spring temperatures (Mariner *et al*, 1974), although chalcedony temperatures are slightly higher at 87°C based on 2002 data.

Macfarlanes Bath House Spring [132] (MC) – This is a 76.5°C hot spring with no published chemical analysis, although geothermometer temperatures have been previously reported. Macfarlanes is a group of small springs and seeps that form a travertine mound (4 m high, 180 m long) in T37N, R29E, Sec. 27. Historically, the reported temperature was 76.6°C, and temperatures between 69 and 78°C were measured in August 2002: two of the hot springs were sampled in 2002. Based on these analyses, chalcedony geothermometer temperatures are 103°C, indicating either a relatively cool source reservoir or loss of SiO_2 during fluid ascent by dilution or precipitation. Previously reported estimates indicate reservoir temperatures <140°C using the Na-K-Ca geothermometer, although chemical data were not reported (Sibbett *et al*, 1982). The Na/K, quartz, and chalcedony geothermometers indicated temperatures in the range of 80 to 120°C, although the maximum chalcedony temperature in 2002 was 98°C, with the Na-K-Ca being less than the discharge temperature. The springs are currently (2002) only flowing out of the west end of the east-west trending travertine mound that has a visible vein running down the middle of the mound.

Lander County

Buffalo Valley Hot Springs [151] (BV) – Buffalo Valley Hot Springs are located in the southeast part of Buffalo Valley (Lander County), in T29N, R41E, SE¼ Sec. 23. This area has previously been reported to have numerous springs of up to 79°C, but none with complete water chemistry data. In 2002, we measured temperatures in 58 springs, and sampled four of them ranging in temperature from 12-77.3°C. The estimated thermal reservoir temperature using the silica geothermometer is 125°C (Mariner *et al*, 1974). The Na-K-Ca temperature from 2002 data is 130°C.

The Buffalo Valley Hot Springs are a subcircular group of numerous springs of low flow. They emerge from a mound of marly material that is a 1 to 2 m higher than the surrounding flat. A few of the hottest springs deposit travertine, but many are too cool or have too low a flow to accumulate any deposits (Garside and Schilling, 1979). A modern spring mound of about 0.16 km^2 is located within approximately 1.6 km^2 of older spring deposits (Garside and Schilling, 1979). The main spring area has 80 or more low-flow seeps trampled by cattle (2002 visit), thus, many of the waters were full of organics. Temperatures of the 80+ springs ranged from 14 to 78°C in the 600-m-diameter area. Two major spring areas occur in this 600 m area, and are noted by springs distributed over each of the two 1-2 m high travertine and mud mounds.

There are additional springs reported by Wollenburg *et al.*, 1977 that are located 6.4 to 8 km northwest of the Buffalo Valley hot springs located near the middle of the playa. Wendy Calvin (University of Nevada, Reno) has obtained ASTER and Landsat imagery over Buffalo Valley, and that imagery reveals subtle variations in vegetation and playa features that may be these springs, and the imagery should help in locating those and other springs and seeps in the area. These springs, if thermal, will be sampled in the future.

Grass Valley [102,157,158] (GV) – Two springs (T24N, R47E, Sec. 15) were sampled in this area, one with good gas flow. The measured temperatures were 68 and 91°C. The chalcedony geothermometer temperatures are near the discharge temperature (≤97°C), and the Na-K-Ca temperature had a maximum indicated temperature of 88°C, which is less than the maximum discharge temperature.

Smith Creek Valley [159, 160] (SC) – Locations (T16N, R39E, Sec. 25, 26) and temperatures of over 40 springs and seeps were measured in August 2002, with temperatures of the thermal waters ranging from 44° to 95.5°C. Chalcedony temperatures are 119°C, whereas Na-K-Ca geothermometers indicated temperatures of 178°C, suggesting that additional attention should be given to this area. Many of the springs in this area appear to experience seasonal fluctuations, and a significant change in temperature was noted between June and August 2002 for the spring with the largest surface expression. Between June and August 2002, the elevation and temperature of one high-flow spring dropped by ≈10 cm and ≈30°C, respectively. Some of these springs appear to have been the result of cattle hooves breaking through thin soil surfaces resulting in small seeps or holes with water levels several centimeters below the surface. Despite a small surface expression, these holes appear to have deep feeder channels and can have high temperature gradients.

Lyon County

Hazen [177] (H) – Historical data were available from four hot springs and two mud domes (some near boiling; T20N, R26E, Sec. 18), but there was only one good chemical analysis for one of the hot springs. Thirteen temperatures were measured, and three samples have been collected. The chalcedony temperature is 130°C, whereas the Na-K-Ca geothermometer indicates 178°C. Currently, Advanced Thermal Systems is pursuing a project at this site to produce electrical power.

Silver Springs [no Bulletin 91 number] (SS) – This site only has a warm spring, located along a projection of the Walker Lane structural zone at T18N, R25E, Sec. 17. This spring was visited in May 2002 and was found to be an evaporating pool. The temperature of the spring was 28.3°C. The location of the spring orifice could not be identified due to low flow, and hence, a sample was not collected. A temperature of 34°C was measured deep in the pool in 1984, although the accuracy of the thermometer was somewhat questionable. The spring owners report that the spring temperature is the same as an adjacent well, about 32°C.

Nye County

Hot Creek Canyon [281] (HCC) – This area (T7 and 8N, R49 and 50E) was sampled and analyzed in collaboration with Dick Benoit as a result of recent interest in the area. Six springs ranging in temperature from 12 to 86°C were sampled by Benoit in fall 2002. Reservoir temperatures indicated by the chalcedony geothermometer are 136°C, whereas the Na-K-Ca temperature is only 82°C: however, the cation data indicate that the water is not fully equilibrated.

White Pine County

Cherry Creek [285] (CC) – Prior to 2002, there were no complete water analyses for springs in this area. In 2002, temperatures from four springs were measured, and two samples were taken (from Monte Neva and Salvi Hot Springs). The chalcedony and

Na-K-Ca geothermometer temperatures for the Monte Neva spring are less than the measured temperature of 77.6°C. Salvi Hot spring (60.5°C) has a chalcedony temperature of 112°C.

Conclusions

During the first year of spring sampling, over 70 analyses were obtained from springs with previously limited or poor data. Some of the areas sampled in this work were previously known to have good geothermal potential (e.g.., Hazen). Relatively little was known of many of the remaining sites. Most areas are characterized by relatively low discharge springs. A preliminary evaluation of geothermometer temperatures indicates that most of the areas have relatively low geothermal potential, however, possible mixing and re-equilibration at lower, near surface temperatures needs to be evaluated at some of the sites. At most of the sites, the waters are not fully equilibrated (Giggenbach, 1988), and hence, the Na-K-Ca geothermometer may not be appropriate. Of the sites not previously identified as having high geothermal potential, the following have the highest potential for electrical power production (based on chalcedony geothermometer temperatures, which should provide a conservative estimate): Hot Creek Canyon Area (136°C), Buffalo Valley (130°C), Pumpernickel Valley (Tipton Ranch; 125°C), Smith Creek Valley (119°C). One sample from Smith Creek Valley was apparently a fully-equilibrated water and its Na-K-Ca geothermometer temperature indicates 141°C. Considerable interest has been expressed by individuals in the industry, their consultants, land owners, lease holders and county officials for the data being collected in this study. Data have been requested by and supplied to numerous individuals (see Figure 1) from the following areas: Blue Mountain (BM), Crescent Valley (CV), Eureka (E), Hazen (H), Hot Creek Canyon (HCC), Grass Valley (GV), Smith Creek Valley (SC), and Wells (W).

Acknowledgments

We thank several individuals for assisting in either the field or the analytical work conducted for this project: Greg Arehart, Dick Benoit, Mark Coolbaugh, Ben Delwiche, Mario Desilets, Jon Hutchings, Paul Lechler, Bret Pecoraro, Andy Ryder, Chris Sladek, Thijs van Soest (Lawrence Berkeley National Laboratory). This material is based upon work supported by the U.S. Department of Energy under instrument number DE-FG07-02ID14311 (changed to DE-FG36-02ID14311 in June, 2003).

References

Edmiston, R.C., and W.R., Benoit, 1984. "Characteristics of Basin and Range Geothermal Systems With Fluid Temperatures of 150°C to 200°C." Geothermal Resources Council *Transactions*, v. 8, p. 417-424.

Fairbank, B.D., and H.P. Ross, 1999. "Geology and Temperature Gradient Surveys, Blue Mountain Geothermal Discovery, Humboldt County, Nevada." *in* Johnson, S.D., *et al.* (Editors), Global Geothermal Resources – Sustainable Energy for the Future: Geothermal Resources Council *Transactions*, v. 23, p. 513-517

Garside, L.J., 1994. "Nevada Low-Temperature Geothermal Resource Assessment." Nevada Bureau of Mines and Geology Open-File Report 94-2, http://www.nbmg.unr.edu/942.htm.

Garside, L.J., and J.H. Schilling, 1979. "Thermal waters of Nevada." Nevada Bureau of Mines and Geology Bulletin 91, 163 p, http://www.nbmg.unr.edu/dox/b91/

Giggenbach, W.F., 1988. "Geothermal Solute Equilibria. Derivation of Na-K-Mg-Ca Geoindicators." Geochimica et Cosmochimica Acta v. 52, p. 2749-2765.

Mariner, R.H., J.B. Rapp, L.M., Willey, and T.S. Presser, 1974. "Chemical Composition and Estimated Minimum Thermal Reservoir Temperatures of the Principal Hot Springs of Northern and Central Nevada." U.S. Geological Survey Open-File Report, 32 p.

Parr, A.J., and T.J. Percival, 1991. "Epithermal Gold Mineralization and a Geothermal Resource at Blue Mountain, Humboldt Co., Nevada." Geothermal Resources Council *Transactions*, v. 15, p. 35-39.

Richards, M., and D. Blackwell, 2002. The Forgotten Ones, Geothermal Roads Less Traveled in Nevada." Geothermal Resources Council Bulletin v. 31, no. 2, p. 69-75.

Shevenell, L., L. Garside, G. Arehart, M. van Soest, and B.M. Kennedy, 2002. "Geochemical Sampling of Thermal and Nonthermal Waters in Nevada to Evaluate the Potential for Resource Utilization." Geothermal Resources Council *Transactions* , v. 26, p. 501-506.

Shevenell, L., and L. Garside, 2003. "Nevada Geothermal Resources." Nevada Bureau of Mines and Geology Map 141, http://www.nbmg.unr.edu/dox/map141.pdf.

Sibbett, B.S., J. Zeisloft, and R.L. Bowers, 1982. "Geology of Macfarlane's Spring Thermal Area, Nevada." Geothermal Resources Council *Transactions*, v. 6, p. 47-50.

Trexler, D.T., B.A. Koenig, T. Flynn, J.L. Bruce, and G. Ghusn, Jr., 1981. "Low-to-Moderate Temperature Geothermal Resource Assessment for Nevada; Area Specific Studies." Final Report, June 1, 1980-August 30, 1981: DOE/NV/10039-3, 203 p.

Wollenberg, H., H. Bowman, and F. Asaro, 1977. "Geochemical Studies at Four Northern Nevada Hot-Spring Areas." California University, Lawrence Berkeley Laboratory Report 6808, 69 p.