Geochemical Sampling of Thermal and Nonthermal Waters in Nevada To Evaluate the Potential for Resource Utilization

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Keywords

Resource assessment, Nevada, geochemistry

ABSTRACT

Nevada has extensive geothermal resources; approximately 216 MW (net) of geothermally generated electricity are produced and low to moderate temperature geothermal fluids are used for space heating and in vegetable dehydration. There is great potential for more use of geothermal resources in all the above categories as well as industrial processing and mineral extraction applications. There are more than 350 known geothermal systems in Nevada; at least 30% of these do not have modern, complete water analyses based on the data compilation by Garside (1994) and Garside and Schilling (1979). Many of these have analyses from only one spring in a group of springs, but it is not known from which spring in a group that the sample was taken or if it was the highest temperature spring in that group. Additional data are available from a previously digitized database containing all springs and wells on 7.5' quadrangles. From these digitized site locations, there are ≈1000 springs 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.

Introduction

There has been considerable research on the geochemical characteristics of various Nevada geothermal resources. Several power plants are currently operational in the state (see Figure 1), as well as several direct use applications. Considerable (but still incomplete) hydrologic and geochemical data are available at these particular sites. However, there is an abundance of additional 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. This paper describes work that had just been initiated as of April 2002, and is to be conducted through February 2003. Data collection had not been initiated on this project at the time of this writing; results of data collection are to be presented at the September 2002 annual GRC meeting.

Figure 1, overleaf, illustrates the current information available for various thermal springs and wells throughout Nevada. The data used to construct this map were obtained from several sources: Trexler, *et. al.* (1983), GEOTHERM, WATSTORE, Southern Methodist University (SMU, 2000) web site, Garside (1994), a file of points digitized from 7.5' quadrangles, and Shevenell, *et. al.* (2000). 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 available, yet 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 as those that do not have temperature data. 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, in this project, we are measuring temperatures, conducting field evaluations, and sampling additional thermal sites in Nevada to determine the geothermal resource potential of sites within areas relatively close to towns or existing power transmission lines. This work will include collection of samples for analysis of major and trace element chemistry, deuterium, oxygen-18, and tritium. Shevenell and Garside will lead the analysis and interpretation of this component of the work. Comple-

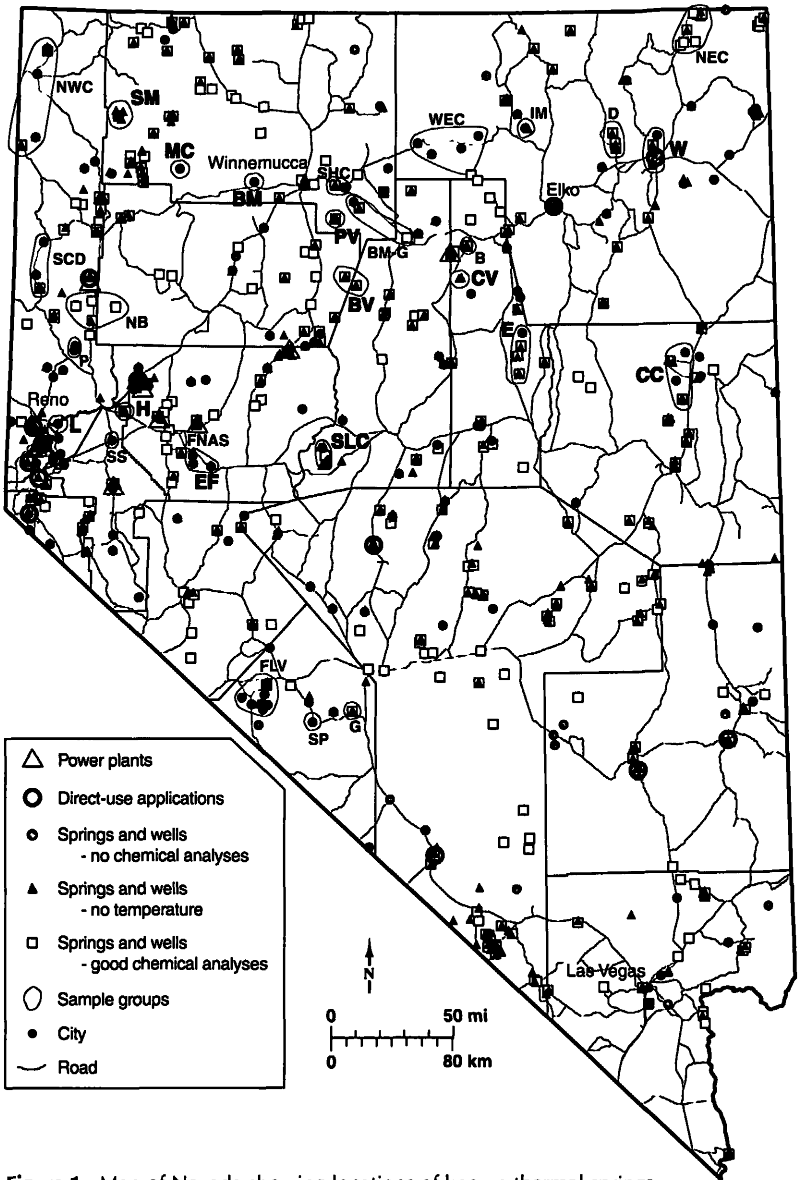

Figure 1. Map of Nevada showing locations of known thermal springs and wells with and without reliable temperature measurements and/or chemical analyses. See list in text for description of abbreviations. Bold abbreviations indicate sites selected for first priority sampling.

mentary work is being conducted in parallel studies by coauthors Arehart who will lead the evaluation of less commonly utilized trace elements, and carbon and sulfur isotopes, and Mack Kennedy and Matthijs van Soest who will lead the evaluation of noble gases and selected isotopes. At present, there are only four sites that have noble gas data in Nevada, and these are Steamboat, Dixie, Beowawe, and Monroe, Ruby Valley. Additional sites will be sampled in order that we can obtain an east-west distribution of noble gases in Nevada.

In order to begin filling in gaps in data on hot and warm springs in the state, ≈100 springs that have previously not been sampled will be visited, documented, and sampled in the summer of 2002. All of the same field sites will be sampled by each of the collaborators. 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. These data will allow delineation of poorly characterized or understood geothermal areas in Nevada that may be developed for electrical power generation or direct-use applications.

Although there are numerous springs and wells in southern Nevada (Clark, southern Nye, and Lincoln Counties) that do not have adequate data to fully evaluate geothermal resource potential, these sites will not be sampled in the proposed work for several reasons. First, most of the sites met the criterion for inclusion on the map of being 10°C above average annual ambient temperature by only a few tenths to a few degrees Celsius, and hence, their potential as a geothermal resource appears borderline. Second, although many of these sites in southern Nevada do not have temperature data, they are near wells and springs with complete temperature and chemical data available from which to evaluate the geothermal potential (e.g., southeast of Amargosa Valley, southern Nye County). Third, a geothermal resource assessment of part of this area was conducted by Flynn, *et. al.*, (1995) and no significant resource potential was identified in the region surrounding Yucca Mountain where most of these points are plotted on Figure 1.

Purpose

The purpose of this work is to fill in data gaps in geochemical analyses of geothermal systems in Nevada and use the newly acquired data at the selected sites to evaluate the resources for potential for direct use applications or electrical power generation.

Site Selection

In evaluating Nevada Bureau of Mines and Geology Open-File Report 94-2 (Garside, 1994) analyses 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. 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. Many of the selected areas are important because they are in the Battle Mountain Heat Flow High and could represent cooled or mixed outflow fluids from a concealed higher temperature resource. Some areas that require additional data collection include those in the following list. These are not listed in any particular order, except that we plan to sample the first group of springs (1 through 13) in the summer of 2002. All areas are labeled on Figure 1 by the abbreviations following each name.

(1) Springs near Cherry Creek (CC), which do not have complete water analyses.

(2) McFarlanes (MC) Bath House Spring, which is a 76.5°C hot spring with no chemical analysis;

(3) Buffalo Valley Hot Springs (BV), which has numerous springs in the area of up to 65°C, and none with complete water chemistry data.

(4) Pumpernickel Valley (PV), which has six springs, and incomplete analyses from three.

(5) Possible spring south of Wells (W) and 12-mile spring north of Wells. This system is probably not a very hot (≈38°C at Wells), but may be mixed with considerable cool waters. Sampling in this area might help characterize the geothermal system along 15 miles of a fault zone and determine if there are any resources that are hot enough for moderate temperature uses. However, available geochemistry will be evaluated prior to any additional sampling.

(6) Blue Mountain (BM) To be sampled and analyzed in collaboration with Continental Ridge Resources, Inc. from their new (spring, 2002) corehole. Mining companies may also release additional, previously obtained data on this area.

(7) Springs near Eureka (E) Interest has been expressed by Jon Hutchings, Eureka County Natural Resource Manager to develop geothermal resources, although insufficient information is currently available to assess the resources.

(8) Eightmile Flat/Carson Sink (EF), geothermal wells and springs for which there are no chemical analyses.

(9) Spring near Silver Springs (SS) This site only has a warm spring, but it is located along a projection of the Walker Lane structural zone.

(10) Several springs in SW Lander County (SLC) where there are approximately 20 hot springs, some of which are boiling, but only one has a chemical analysis.

(11) Springs in Crescent Valley (CV) There are 10 known springs, only two of which have chemical analyses, but no reported Li.

(12) Well near Lockwood (L) This well is near the crushed stone pit north of the Lockwood exit and has a temperature of ≈38°C; due to its location, access will be attempted.

(13) Soldier Meadows Hot Springs (SM) Available water chemistry analysis is not reliable. Numerous high temperature springs occur in the area. All are within the Black Rock National Conservation area, which was recently withdrawn and, therefore, not currently accessible for geothermal development. Perhaps a re-evaluation of that land status can be made in the future if it can be demonstrated that this area has high potential for economic development of geothermal resources.

Some of the other sites that could benefit from initial, or additional, water sampling include the following, although these sites are of somewhat lower priority and will be sampled in subsequent years if funding remains available.

(1) Northern Washoe County (NWC) This area is remote and may be too far from existing power lines. (2) Smoke Creek Desert (SCD) The hot springs are not very hot, but they are in area of high heat flow. (3) Southeast Humboldt County (SHC) There are several springs with poorly characterized chemistry. (4) Western Elko County (WEC) There are some obscure springs, within 50-60 km of Beowawe. (5) Spring in Independence Mountains (IM). (6) Spring near Deeth (D) (7) Some poorly known warm springs 30-50 km north of Bradys (NB) There are higher temperature gradient wells in this area, and there could be concealed resources that these springs might reflect. (8) Springs in Battle Mountain-Golconda area (BM-G), including some near the Humboldt River. These springs could have a large River component, but may indicate concealed resources. (9) Cooler warm springs near Beowawe (B) Sampling would help in evaluation of mixing. (10) Northeast Elko County (NEC) Probably lower priority due to it's location. (11) The Pyramid and Anahoe Island area (P) These would help understand the Needle Rocks geothermal area. The Pyramid Lake Paiute tribe has expressed interest in obtaining data from the springs. Note that the Pyramid may be impossible to sample because springs are under water. (12) Fallon Naval Air Station (FNAS) Data are probably available from the Navy, and they are actively exploring the site. (13) Fish Lake Valley (FLV) There may be company analyses available. Also, because there is active work being conducted there by industry, this site was not selected for sampling at this time. (14) Warm springs and/or wells in Clayton Valley (SP; Silver Peak) The spring there may be dry, and needs to be visited to determine if it still flows. (15) Alkali hot spring north of Goldfield (G) There is only one sample, with no isotope or trace element data. (16) Hazen area (H) Four hot springs and two mud domes (some near boiling) with only one good chemical analysis for one of the hot springs.

These sites, and many others requiring improved water chemistry data, are shown on Figure 1. Figures 2 and 3, overleaf, illustrate two specific areas from this list: Soldier Meadows and the Smoke Creek Desert area. Water samples are available from the sites in the 70000 series numbers, but in the cases illustrated here, and in most cases, those sites are not located properly so it can not be determined which of the springs or wells in the area was actually sampled. In addition, in both of these cases, there are numerous springs or wells without chemical analyses of any kind, and often no temperature measurements (unlabeled springs, and the 00700 series of numbers, which are digitized locations from 7.5' topographic maps). From these two examples and Figure 1, 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

Approach

Typically, about seven springs will be selected from each area, with five thermal springs (including one from the hottest

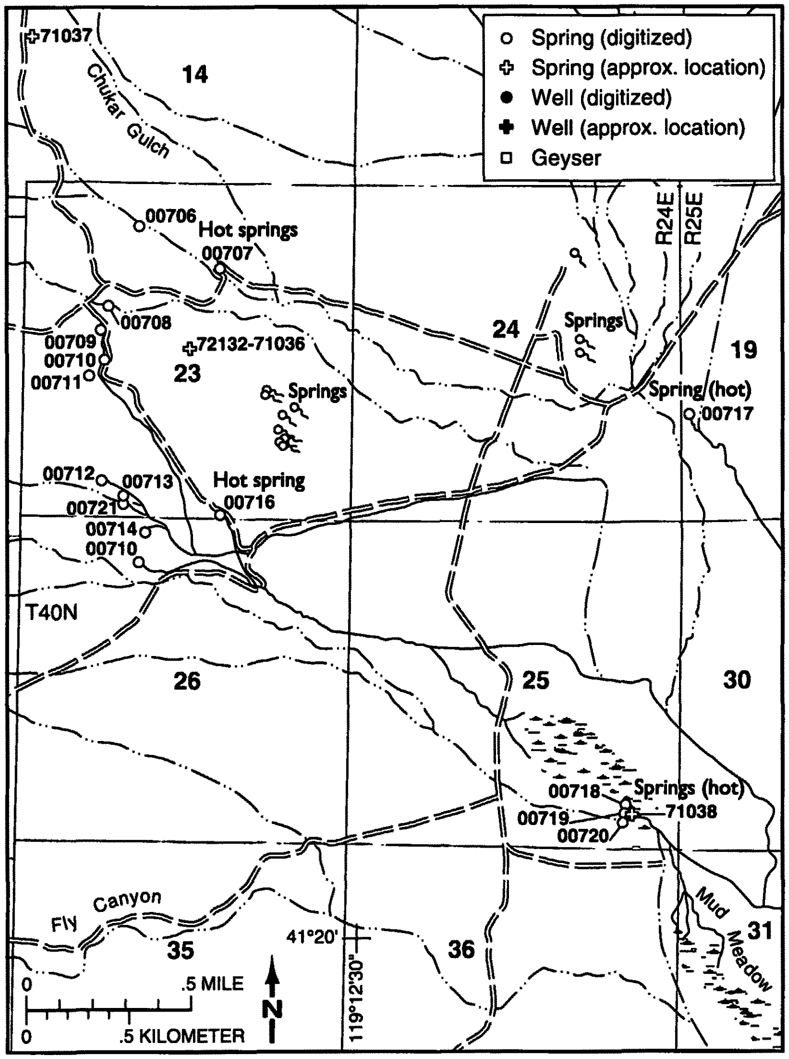

Figure 2. Detailed map showing locations of thermal springs in the Soldier Meadows geothermal area, Nevada.

spring in the group) and two nonthermal springs being sampled, depending on availability at the individual sites or regions. Additional water samples may be collected from cold springs in other areas of the state where geochemical data currently are available for nearby hot waters (Garside, 1994).

The newly acquired geochemical data will be used in conjunction with the currently available geochemical data (e.g., Garside, 1994, among others currently being compiled) to evaluate geothermal resources at selected sites throughout the state of Nevada. Due to interest by Elko County Commissioners (Warren Russell) and Eureka County (Jon Hutchings), one site in each county will be selected for more detailed evaluations.

Stable isotope data, tritium (^3H) and carbon-14 (^{14}C) data have not yet been collected from any of the springs identified previously. These data are required to determine the origins and possible ages of the nonthermal fluids and compare to the thermal fluids to be sampled. These data will assist in determining the degree and extent to which the thermal and nonthermal aquifers may be hydrologically connected.

Data from previous work (Mariner, *et. al.*, 1975; Garside, 1994) will be used as a starting point. The goals of the work include (where possible): (1) identifying possible recharge waters/areas of the different geothermal systems; (2) estimating mean residence times of selected fluids; and (3) identifying similarities and differences among the waters to evaluate possible mixing relationships in different areas. These three goals will be accomplished by (1) collection and evaluation of stable isotope data, (2) evaluation and modeling of ^3H and ^{14}C data to distinguish fluid ages between the different subsystems, and (3) evaluation of major and trace element geochemical data in conjunction with (1) and (2).

Results

The study will expand and enhance the present knowledge of Nevada's geothermal resources by providing new water chemistry information on known geothermal areas for which there is currently little or no information that is publicly available. These data will allow delineation of poorly understood geothermal areas in Nevada that may be developed for electrical power generation or direct use applications. Geochemical indicators of fluid flow paths and results from the ^{13}C, $\delta^{18}O$, δD, $\delta^{34}S$ data will all be used as natural tracers in the individual groundwaters. These data will allow us to begin to identify distinct and different origins and evolutions of the various waters when used in conjunction with the evaluation of the inorganic chemical variations in the systems. Results from the ^3H and ^{14}C analyses will allow evaluation of differences in mean residence times of the various fluids at selected sites. From the $\delta^{18}O$, δD and radiogenic isotope results, an initial assessment of the timing and location of recharge to selected aquifer systems will be gleaned.

A suite of geothermometers will be computed and evaluated. In conjunction with estimated geothermometer temperatures, possible mixing relationships will be computed using standard methods such as stable isotope data and selected major and trace element data (e.g., B., Cl, Li, Br) for each site or region to provide a preliminary assessment of likely reservoir temperatures from which the mixed spring waters originated. The results of the geochemical analysis and evaluation will be used to assess the hydrologic relationships between the thermal and the nonthermal waters.

Simple, preliminary computations will be used to estimate possible depths to the reservoirs using information such as known heat flow and thermal gradients (Sass, *et. al.*, 1999; SMU, 2000; Richards and Blackwell, 2002), boiling point to depth curves, and an empirical trend identified for Nevada (Flynn and Schochet, 2001). The results of the proposed work will expand our current knowledge of the distribution and characteristics of geothermal resources in Nevada. Present knowledge of resource potential in Nevada will be enhanced by providing an evaluation of selected known resources in the state that are near population centers, and

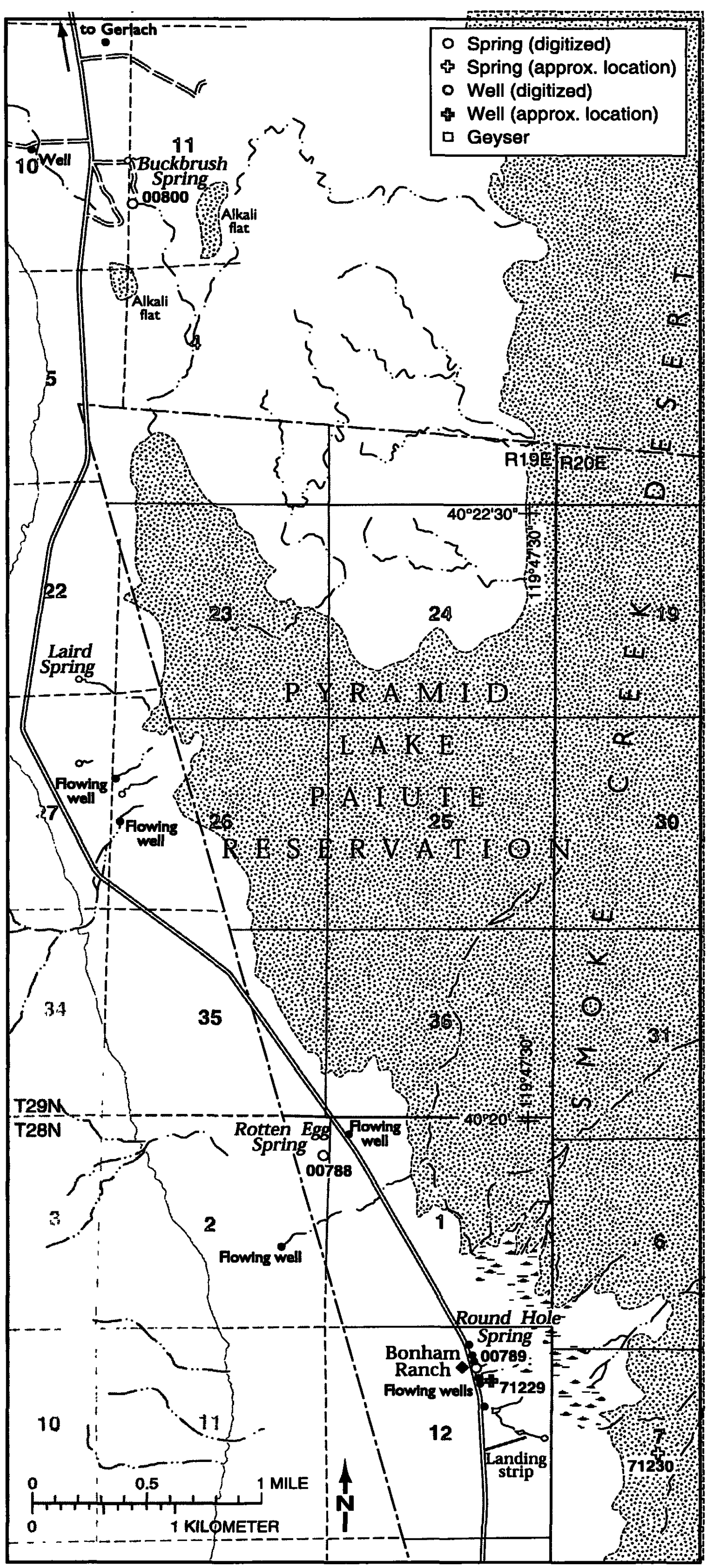

Figure 3. Detailed map showing locations of thermal springs in the Smoke Creek Desert geothermal area, Nevada.

noting likely temperature and depth of the resource, and whether the resource might be used for electrical power generation or direct use applications. Trace elements deleterious or favorable to aquaculture will also be analyzed and reported. The results of the proposed work will be publicly available and can be used by others to move to the next step in the exploration process to verify the resource These tasks will be accomplished by February, 2003 for the sites selected, and additional sites will be added in subsequent years if funding becomes available.

Acknowledgments

This material is based upon work supported by the U.S. Department of Energy under instrument number DE-FG07-02ID14311.

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