Geochemical sampling of thermal and non-thermal waters in Nevada: Continued evaluation of geothermal resources

Lisa Shevenell[1,2], Paul Lechler[1], Larry Garside[1], Mark Coolbaugh[2]
lisaas@unr.nevada.edu; plechler@unr.edu, lgarside@unr.edu, serano@dimensional.com

Proposal submitted in response to a REQUEST FOR PROPOSALS from the
Great Basin Center for Geothermal Energy
Proposal Deadline: Feb. 18, 2005

ABSTRACT

A minimal level of funding is requested to maintain expertise in geothermal fluid geochemical sampling and analysis at the Great Basin Center for Geothermal Energy (GBCGE). An established laboratory at the Nevada Bureau of Mines and Geology (NBMG) has the resources available to meet this need, and the proposed funds would enable existing staff to continue perfecting sampling and analytical techniques for both liquids and gases.

Under the auspices of the Geothermal Center, this laboratory would provide sampling and analytical services for a variety of geothermal stakeholders. Private landowners could have their hot springs analyzed to estimate subsurface temperatures or to check for environmentally hazardous constituents. Geothermal exploration companies could use the laboratory to check and/or verify earlier analyses conducted elsewhere. Similarly, geothermal research groups at other universities and government laboratories would have an alternate laboratory with which to check analytical results or compare methods of analysis. Finally, the laboratory would provide an efficient, cost-effective, and rapid means of following up on grass-roots exploration targets defined by sister geothermal projects funded by the Center, as has been done in the past.

Targets identified by GIS, GPS and other funded projects have focused fluid sampling in those areas (e.g., Buffalo Valley) in the past, and it is anticipated that there will be a need for such focused fluid sampling, analysis and evaluation in the future.

Requested Federal Funds:

Year 1:	$28,710
Year 2:	$36,975
2-Year Total:	$65,685

[1] Nevada Bureau of Mines and Geology; [2]Great Basin Center for Geothermal Energy.
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Introduction

There has been considerable research on the geochemical characteristics of various Nevada geothermal resources. Considerable hydrologic and geochemical data are available at numerous sites. However, there are numerous other sites throughout the state that may have potential for utilization of geothermal resources, but for which there is insufficient information publicly available to evaluate the potential of these individual resources. Additionally, new targets continue to be identified by projects supported by the Great Basin Center for Geothermal Energy (GBCGE). As these targets are identified, there will be need for additional data in the form of fluid geochemistry. This project proposes a small budget to be available to conduct fluid sampling and analysis to support other funded projects and to help better characterize identified geothermal targets.

In FY02, we began filling in data gaps and collecting and analyzing samples to use in the evaluation of the selected geothermal resources. Sampling continued in 2003 and 2004 with samples collected in 2004 largely being collected from new geothermal targets identified through research conducted by the GIS and other Center-funded projects.

We propose to continue conducting field evaluation and sampling of additional thermal sites in Nevada to determine the geothermal resource potential at these sites. The proposed study will expand and enhance the present knowledge of Nevada's geothermal resources by providing new water chemistry information on less-studied and/or newly targeted 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.

Typically, ≈7 springs will be (and have been) selected from each area, with five thermal springs (including one from the hottest spring in the group) and two (or more) non-thermal springs 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).

Approach

Stable isotope, tritium (^3H) and carbon-14 (^{14}C) data have not yet been collected from any of the areas on which we have focused. These data are required to determine the origins and possible ages of the non-thermal fluids for comparison to the thermal fluids to be sampled. This data analysis will help determine the degree and extent to which aquifers may be hydrologically connected, allowing for evaluation of the geothermal component of the fluids.

Data from previous work (Mariner et al., 1975; Garside, 1994) have been used as a starting point, and a newly compiled geochemical database was constructed in previous phases of the work (http://www.nbmg.unr.edu/geothermal/gthome.htm). Once new sites are selected for sampling, the goals of the proposed work include the same items as the phase 1 work: (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 of ^3H and ^{14}C data to distinguish fluid ages, and (3) evaluation of major and trace element geochemical data in conjunction with (1) and (2).

Fluid samples will be collected from additional springs throughout the state. Sites will be selected based on the new geochemical database information, anomalies identified on new regional geothermal favorability maps identified in a sister research project, results of new and on-going research, and in consultation with stakeholders and industry representatives as was done in year 1. Selected cold springs in the adjacent ranges will be sampled for stable isotopes of water to obtain a better record of variations in these isotopes with elevation.

Major and trace element samples will be filtered through 0.45 μm filter papers to be consistent with previous samplings of other geothermal waters reported (e.g., Garside, 1994). A 100 ml sample for cation analyses (acidified with ultra-pure HNO_3 to pH<2) and a 250 ml sample for anion analyses will be collected and analyzed at the University of Nevada, Reno, Mackay School of Mines (MSM) analytical laboratories that include Micromass Platform inductively coupled plasma-mass spectrometer with Hexapole collision cell and Merchantek UV laser ablation microprobe. Unfiltered water for δD and $\delta^{18}O$ (60 ml sample) and ^{3}H (1 L sample) will be collected. Stable isotopes will be analyzed at the MSM isotope lab, ^{3}H will be analyzed at the University of Miami, and ^{14}C will be analyzed by Betadyne. Due to the high cost of ^{3}H and ^{14}C analyses, only a subset of the springs will be selected for analysis, distributed among the areas selected. For ^{34}S and ^{13}C, two 250 ml polypropylene bottles are used. Slightly less than 250 ml of filtered water is added to each bottle, and 5 to 10 ml of $BaCl_2$ solution then added to each. To the ^{13}C bottle 5 ml of 1% NaOH supplied in a glass vial will also be added. Both will be analyzed at the MSM isotope laboratory. To the 1 L filtered ^{14}C sample, 10 ml of $BaCl_2$ solution and one vial of 4% NaOH are added.

Results

The study is expanding and enhancing 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 provide clearer indications of the potential of new or 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 and ^{34}S can all be used as natural tracers in the individual groundwaters. With the results of this work, we can 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. 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, which provide useful information for developing conceptual models of the individual systems.

The newly acquired geochemical data can be used in conjunction with the currently available geochemical data (e.g., Garside, 1994; http://www.nbmg.unr.edu/geothermal/gthome.htm) to evaluate geothermal resources at selected sites throughout the state of Nevada. A suite of geothermometers will be computed and evaluated for the new sites sampled. In conjunction with estimated geothermometer temperatures, possible mixing relationships will be computed using 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 non-thermal waters. Relationships relative to fault locations will be illustrated on maps constructed with the use of GIS techniques.

Simple computations will be used to estimate possible depths to the reservoirs using information such as known heat flow, thermal gradients (SMU, 2000), 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, and 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 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.

As a result of the first years of this project, these new data were requested by and shared with numerous individuals in academia, industry and consulting. Because this project has enjoyed such support and interest from advocates for geothermal development, and because the in-house expertise has been established and should be maintained, we believe this project should be continued in subsequent years.

Also as a result of work done in this project, we visited sites that were proven not to be thermal, although they had been located previously on geothermal resources maps of Nevada. These sites are now removed from the Nevada locations database, and a new resource map (NBMG Map 141; Shevenell and Garside, 2004) has been published.

Deliverables

Principal investigators will present results at professional conferences, including the Geothermal Resources Council annual meeting where continuing results of the sampling campaign will be presented. There will be no restrictions on the distribution and use of the acquired data and associated evaluation of the geothermal potential of the sites throughout Nevada. All data will be publicly available for free on an NBMG web page, and individual operators in Nevada will be notified of the existence of the data. Data have been provided continuously to industry in the course of this project.

1. Present summary at annual Geothermal Resources Council meeting Sept 2005
2. Present summary at annual Geothermal Resources Council meeting Sept 2006
3. Complete final report Sept 2006
4. Provide data and preliminary results to industry and other stakeholders ongoing

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SMU, Blackwell, D. gradient hole database. http://www.smu.edu/~geothermal/georesou/nevada.htm.

Budget

See attached Excel file (Shevenell.xls).

Dr. Lisa Shevenell

Education

New Mexico Institute of Mining and Technology	Geology	B.S.	1984
University of Nevada, Reno	Hydrogeology	Ph.D.	1990

Areas of Expertise

Groundwater hydrology, geothermal systems, isotope hydrology, aqueous geochemistry

Research Grants

Thirty (12 geothermal) funded research projects for a total of $5.5 million

Positions

Director, Great Basin Center for Geothermal Energy, UNR, 2004 – present
Associate Director, Great Basin Center for Geothermal Energy, UNR, 2001 – 2004
Research Professor, Nevada Bureau of Mines and Geology, 1993 –present
Research Associate, Oak Ridge National Laboratory, 1990-1993.
Research Assistant, Desert Research Institute, Reno, Nevada 1987-1990.
Research Assistant, Los Alamos National Laboratory, 1984-1987.

Selected Publications (of 27 refereed journal articles, 22 peer reviewed publications, 20 symposium papers, 13 other articles, 75 abstracts, and 78 contract reports)

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Dr. Paul J. Lechler

EDUCATION

Ph.D. Geology/Geochemistry, University of Nevada, Reno, NV, 1995
M.Sc. Geochemistry, Rutgers University, NJ, 1978
B.A. Geology, Montclair State College, NJ, 1974

AREAS OF EXPERTISE

Analytical geochemistry, environmental geochemistry, exploration geochemistry

PROFESSIONAL WORK EXPERIENCE

Chief Geochemist, Nevada Bureau of Mines and Geology, Reno, Nevada (1983-present)
Company Geologist, Reed Rock Bit Company, Houston, Texas (1981-1983)
Research Geochemist, Bendix Field Engineering, Grand Junction, Colorado (1980-1981)
Geochemist, Indiana Geological Survey, Bloomington, Indiana (1977-1980)

SELECTED PUBLICATIONS

Lechler, P.J., Coolbaugh, M.C., and Sladek, C, 2004, Exploration for concealed structures at Desert Peak using mercury soil gas detectors: Geothermal Energy Workshop, Reno.

Noble, D.C., Ressel, M.W., **Lechler, P.J.**, and Connors, K.A., 2004. Magmatic As, Sb, Cs, Bi, Tl, and other elements in glassy volcanic rocks of the Julcani district, Peru, and the Carlin trend, Nevada. Boletin de la Sociedad Geologica del Peru, 97, p.29-50.

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Larry J. Garside
lgarside@unr.edu

EDUCATION

B.S. Geology, Iowa State University, 1965

M.S. Geology, University of Nevada, Reno, 1968

AREAS OF EXPERTISE

Geologic mapping, volcanic geology, energy resources geology, hydrothermal mineral deposits, isotopic dating of igneous rocks and mineralization.

RESEARCH GRANTS

Over 30 funded research projects, as principal and co-principal investigator, for a total of approximately $5 million.

PROFESSIONAL WORK EXPERIENCE

Research Geologist (Rank I - IV), Nevada Bureau of Mines and Geology, (1968-present).

Research Assistant, Nevada Bureau of mines and Geology, (1965-1968)

SELECTED PUBLICATIONS (of more than 130 citations on Nevada geology)

Shevenell, L., Coolbaugh, M., Faulds, J., Oppliger, G., Calvin, W., Louie, J., Blewitt, J., Kratt, C., Arehart, G., Sladek, C., Lechler, P., and **Garside, L**., 2004, Accomplishments at the Great Basin Center for Geothermal Energy: Geothermal Resources Council Transactions, v. 28, p. 47-51.

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Faulds, J.L., **Garside, L.J**., and Oppliger, G.L., 2003, Stratigraphic and structural framework of the northern Hot Springs Mountains, Desert Peak and Brady Geothermal Fields, northwestern Nevada, *in* Foster, S., ed., Oil, gas, and geothermal occurrences in northwestern Nevada: Nevada Petroleum Society 2003 Field Trip guidebook, p. 31-38.

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PROFESSIONAL SOCIETIES

American Association of Petroleum Geologists (Active Member, member Energy Resources Division)
Geological Society of America (Fellow)
Society of Economic Geologists (Fellow)
Association of Exploration Geochemists
Geothermal Resources Council (Charter Member)
Geological Society of Nevada
Nevada Petroleum Society

Dr. Mark F. Coolbaugh
Research Assistant Professor
Great Basin Center for Geothermal Energy, University of Nevada, Reno
Geological Sciences Department, MS 172, Reno, Nevada 89557-0138
Tel: (775) 784-1415; E-mail: cool.78@alum.mines.edu

Professional Preparation

Ph. D., Geology, 2003
University of Nevada, Reno, Mackay School of Mines, Reno, Nevada
M. S., Geological Engineering, 1985
University of Arizona, College of Mines, Tucson, Arizona
B. S., Geological Engineering, 1978
Colorado School of Mines, Golden, Colorado

Professional Assignments

Research Assistant Professor, March 2002 to Present
Great Basin Center for Geothermal Energy, University of Nevada, Reno.
Research Assistant and Teaching Assistant, August 1998 – March 2002
Arthur Brant Laboratory for Exploration Geophysics, Dept. of Geological Sciences, UNR.
Exploration Manager – Mongolia, September 1996 - February 1998
Cascadia Chemicals & Minerals Corp., Ulaanbaatar, Mongolia
Research Assistant and Teaching Assistant, **July 1995 - August 1996**
University of British Columbia, Vancouver, B.C., Canada
Chief Geologist, April 1994 - June 1995
Carson Gold Corp., Vancouver, B. C., Canada
Senior Exploration Geologist/Geological Engineer, November 1991 - January 1994
Coeur Rochester, Inc., Lovelock, Nevada, USA
Consultant, February 1991 - October 1991
Mine and Exploration Services, Monte Vista, Colorado, USA
Chief Geologist/Manager/Senior Geologist, June 1984 - January 1991
Summitville Consolidated Mining Co., Inc., Del Norte, Colorado, USA
Geologist, **June 1983 - June 1984**
Pegasus Gold Corporation, Reno, Nevada, USA
Associate Geologist, **June 1980 - Dec. 1982, summers of 1977 - 1979**
Climax Molybdenum Co., div. of AMAX, Golden, Colorado, USA
Underground Motorman's Assistant, **June 1976 - September 1976**
ASARCO, Inc., Leadville, Colorado, USA

Selected Publications and Presentations

Coolbaugh, M.F. and Bedell, R., 2005, A Simplification of weights of evidence using a density function and fuzzy distributions: a comparison of probability modeling techniques in the designation of geothermal systems in Nevada; Geol. Assoc. Canada Special Paper "GIS applications in the Earth Sciences", *in press*.

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Current and Past Geothermal Research

1) Regional Assessment of Exploration Potential for Geothermal Systems in the Great Basin using a Geographic Information System (GIS): Collaborators: Mark F. Coolbaugh, Gary L. Raines, Lisa A. Shevenell, Tim B. Minor, Don L. Sawatzky, and Gary Oppliger: funded by DOE.

   A geographic information system (GIS) is being used to integrate diverse types of geologic, chemical, and physical information to predict where high-temperature geothermal systems are most likely to occur in the Great Basin of western North America. Spatial analysis using weights-of-evidence and logistic regression is being used to quantify relationships between geothermal systems and the map data and clarify the conditions necessary for the formation of high-temperature geothermal systems.

2) Remote Sensing for Exploration and Mapping of Geothermal Resources: Collaborators: Wendy Calvin and Mark F. Coolbaugh: funded by DOE.

   Hyperspectral and multispectral remote sensing, in the visible, near-infrared, and thermal infrared ranges, is being used to identify anomalous surface features related to active geothermal systems. These features include areas of high heat flow (thermal anomalies), diagnostic rocks (sinter and evaporite assemblages), hydrothermal alteration (alunite and clay minerals), and vegetation anomalies.

3) Geochemical Characterization of Magmatic-related vs. Extension-related Geothermal Systems in the Great Basin: Implications for Exploration, Exploitation, and Environmental Issues: Collaborators: Greg B. Arehart, Mark F. Coolbaugh, and Simon R. Poulson: funded by DOE.

   This research will identify the distinguishing chemical characteristics of magmatic and extensional geothermal systems, and relate those differences to differences in host rock lithologies, magma compositions, or other physical and chemical parameters. The significance those differences have for exploration, exploitation, and effects on the environment is being reviewed.

4) Targeting of potential geothermal resources in the Great Basin from regional relationships between geodetic strain and geological structures: Collaborators: Geoff Blewitt and Mark F. Coolbaugh: funded by DOE.

   The ability of GPS-based measurements of geodetic strain to identify zones of crustal extension, and the role those zones of extension play in controlling geothermal activity, is being investigated. The Quaternary structural fabric of Nevada is being used to help constrain the mode and location of strain.