Accomplishments at the Great Basin Center for Geothermal Energy

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Keywords
Resource assessments, exploration, Great Basin, Nevada

ABSTRACT

The Great Basin Center for Geothermal Energy (GBCGE) has been funded by DOE since March 2002 to conduct geothermal resource exploration and assessment in the Great Basin. In that time, those efforts have led to significant advances in understanding the regional and local conditions necessary for the formation of geothermal systems. Accomplishments include the development of GPS-based crustal strain rate measurements as a geothermal exploration tool, development of new methods of detecting geothermal features with remotely sensed imagery, and the detection of potential extensions to geothermal fields using InSAR measurements of ground displacement. Regional work with GPS-based measurements of crustal strain, GIS-based favorability modeling, and deep seismic refraction studies have identified two areas in central Nevada, at Buffalo Valley and south of Fairview Peak, that have good geothermal potential but have been incompletely explored to date. Hence, more detailed work using these techniques, as well as fluid geochemistry, are planned in the near future to better understand these areas and determine if they are indeed high potential exploration targets. On the more local scale, Desert Peak-Bradys geothermal area has been extensively studied using detailed geologic mapping, gravity, InSAR, Hymap hyperspectral data, Hg soil gas, and digital field mapping of fumaroles and surface spring deposits in order to assess and help facilitate development of a possible enhanced geothermal system (EGS) resource. Significant improvements in the understanding of the structural controls of the geothermal system have been made with these integrated studies at the Desert Peak-Bradys fields. All new research data are being integrated into a web-based geothermal GIS database accessible to the public and interested stakeholders. Maps of geothermal favorability for the Great Basin are being developed, and estimates of the remaining undiscovered geothermal resources are being made.

Introduction

The Great Basin Center for Geothermal Energy (GBCGE) was established at the University of Nevada, Reno in May 2000 to promote research on and utilization of geothermal resources in the Great Basin of the Western United States (Shevenell and Taranik, 2002). The Center is integrated into the DOE Geothermal Energy Program with a focus on peer reviewed research projects that are awarded on a competitive basis. Other tasks that the Center has undertaken include stakeholder outreach (workshops) and web-based information system development related to GeoPowering the West goals.

Objectives

The mission of the GBCGE is to work in partnership with U.S. industry to establish geothermal energy as a sustainable, environmentally sound, economically competitive contributor to energy supply in the western United States by: 1. Providing needed and timely information on geothermal resources; 2. Promoting the conduct of collaborative geothermal research between academic organizations and industry; and 3. Identifying and evaluating new and emerging technologies for geothermal assessments and exploration.

Currently funded projects address three questions relevant to geothermal development: 1) Why are geothermal resources in the Great Basin where they are? 2) What techniques can be used to find geothermal resources in the Great Basin? 3) Where are the geothermal resources in the Great Basin and how large are they? Through the Center we are conducting the following work to begin to address these questions: Characterizing geothermal resources; understanding controls on resources; identifying favorable exploration targets; evaluating new exploration technologies/techniques such as GPS, GIS, InSAR; and expanding on existing exploration and assessment techniques. In collaboration with industry on some of the research projects, we are contributing expertise and research in support of DOE's priority program in Enhanced Geothermal Systems (EGS).

Results

Desert Peak-Bradys Geologic Studies (Jim Faulds, Larry Garside, Gary Oppliger)

In collaboration with Ormat and GeothermEx, this project is characterizing the links between geothermal reservoirs and stratigraphic and structural features and better defining the boundaries of the reservoir at the Desert Peak-Bradys geothermal system (Fig. 1). Significant improvements in the understanding of the structural controls at Desert Peak-Bradys systems have been made through integrated studies consisting of detailed geologic mapping, structural and stratigraphic analyses, 3-D geologic characterization, modeling and visualization using drillhole data, and gravity studies. Future work will include microearthquake (MEQ) studies at the site, which along with the other components of this project, support the Desert Peak EGS study. This work has also produced a new detailed geologic map and cross sections (Faulds and Garside, 2003) that will be valuable in future well siting and understanding of the system.

The Desert Peak geothermal field may ultimately serve as a prototype for identification of blind resources elsewhere in the northern Great Basin, but particularly in west-central Nevada where the Humboldt structural zone intersects the Walker Lane. This project is relevant to applied research areas including 1) inventory of existing geothermal resources in a GIS context, 2) geologic mapping and fault characterization, and 3) assessment of controls of reservoir boundaries. The mapping and structural-stratigraphic analyses will better delineate the late Cenozoic 3-D stress-strain fields and further elucidate relations between faults, strata, and geothermal reservoirs. The gravity work will further constrain the subsurface geometry of major faults and configuration of the Tertiary-basement contact. The MEQ survey will discern the subsurface geometry of faults and fractures that channel fluids. Details of the results of this study are documented in Faulds and Garside (2003) and have also been incorporated into a new tectonic model of geothermal systems in the northern Great Basin (Faulds et al., 2004 - this volume).

Figure 1. View of Bradys geothermal plant and steam vents with I-80 in the background (Photo by Mark Coolbaugh, November 2002).

Fluid Geochemistry Studies (Lisa Shevenell, Larry Garside, Mark Coolbaugh, Chris Sladek)

As part of this work, a database of existing geochemical data was constructed containing over 7000 records. With this database, all data were plotted in ArcView and superimposed on the known locations of thermal features in Nevada. From this compilation, we have determined which sites are lacking modern geothermal fluid analysis, have poor spatially located data, or are completely lacking in fluid chemical analyses. We have been and will continue sampling and analyzing thermal springs that fall into one of these three groups where there are data gaps (Shevenell and Garside, 2003). Contoured geothermometer values show several regional anomalies, some of which correspond with anomalies identified with GIS modeling. Interest from and collaboration with several industry representatives has been on-going as each group seeks the type of geochemical data produced in this project as one important component of their geothermal exploration programs. Geochemical samples also continue to be obtained at and near areas identified as favorable for geothermal potential in other portions of the program (e.g., at favorable geothermal areas identified by GIS, GPS and seismic studies anomalies, and mentioned below).

GIS Studies (Mark Coolbaugh)

The goal of this part of the project is to generate new exploration targets for both conventional and EGS-capable geothermal systems by analyzing regional data in a GIS context. Many types of evidence provide clues as to where such geothermal systems might be found. These include the location and orientation of Quaternary faults, crustal strain rates derived from GPS stations (see next section), heat-flux anomalies, anomalous groundwater chemistry, earthquakes, young volcanism, gravity and other geophysics, and hydrothermal alteration. There have been a number of accomplishments related to this project, many of which are detailed in Coolbaugh et al. (2003) and Coolbaugh et al. (2004; this volume). The GIS modeling has identified regionally favorable exploration targets at both Buffalo Valley and the Fairview Peak-Rawhide areas. As part of this work, a regional structural database is identifying favorable structural environments for the location of productive geothermal resources and identifying controls on fluid flow. In addition, digital field mapping has been initiated at several sites and is being used in conjunction with other studies to better delineate observable, active thermal features as well as sinters and travertines as an aid to locating structures. This is a new layer being added to the GIS. Finally, the geothermal GIS data are being used to estimate the magnitude of remaining undiscovered geothermal resources in Nevada and the Great Basin (Coolbaugh and Shevenell, 2004; this volume).

GPS Studies (Geoff Blewitt)

The objectives of this project are to assess the use of inter-seismic crustal strain rates derived from GPS-stations as an exploration tool for high-temperature geothermal systems, and to use this technique to target potential geothermal resources in the Great Basin. Regions of high extensional crustal strain rates are more likely to contain dilated faults, with deeply circulating fluid. An expanded regional network of 30 GPS stations came on-line in January, 2004 with the goal of identifying regions of high transtensional strain accumulations in the Earth's crust. Initial results from the first 60 days of operation show that station positions estimated every 24 hours repeat to within 1 to 2 mm in longitude and latitude. The major accomplishment from the initial work has been that GPS geodetic measurements of strain rates have been identified to be a useful, regional geothermal exploration tool where strain is correlated with geothermal resources in the Great Basin. This project demonstrated that relative velocities between stations can be resolved to the level of sub-millimeters per year (Blewitt et al., 2003). Several areas of high strain rate (extensional) were identified that likely have a high potential for geothermal exploitation and that warrant more detailed investigation. One such promising area is in the region around Buffalo Valley, Jersey Valley and Pleasant Valley in central Nevada, and another is south of Fairview Peak at the southern end of the central Nevada seismic belt.

InSAR Studies (Gary Oppliger)

The purpose of this research is to evaluate the utility of satellite interferometric radar retrospective ground displacement studies as a means of characterizing the progression of geothermal reservoir development and assist in reservoir management, expansion, and assessment. The technique is first being tested at the Desert Peak-Bradys geothermal field in Nevada. The relationship between geothermal reservoir compaction, geometry, and production rates are being investigated using a ten-year InSAR micro-displacement history. Preliminary InSAR studies show very promising results in the Desert Peak- Bradys area. An interferometric phase anomaly at Bradys shows a NNE trending region of micro-displacement, which appears to have a spatial association with production along a 7-km length of the Brady fault. A much smaller and less distinct area of micro-displacement may be associated with the Desert Peak field. Future work will include additional imaging and analysis to look at changes year to year to help assess how the reservoir has changed through time in response to production and changing injection scenarios. This information will provide a new perspective of the reservoir that will likely be useful to reservoir engineers and modelers. This satellite radar-based methodology will assist reservoir management and expansion at study area fields and is well suited to semi-arid regions; hence the results will serve as a technology template for all Great Basin geothermal fields. Discussion of the results to date are documented in Oppliger et al. (2004; this volume).

Mercury (Hg) Soil Gas Studies (Paul Lechler, Mark Coolbaugh, Chris Sladek)

The purpose of this project is to conduct a detailed Hg soil gas survey to delineate concealed structures at the Desert Peak geothermal field, including the area being evaluated for EGS technology. Mercury vapor is capable of penetrating sand and soil cover, which makes it useful for identification of buried structures favorable for fluid transport in geothermal systems. Combined with structural, geophysical, and thermal data, Hg soil gas surveys can yield valuable information to help identify geothermal targets. Results of a preliminary Hg vapor survey conducted at the southwest end of the Bradys geothermal system indicate a positive correlation with areas of steaming and warm ground. This area was used as a test of the method because the structure at Bradys is visible via fumaroles discharging at the surface. Peak to background resolution for this method was found to be good at Bradys. A GIS database of geological, structural, and geothermal data from Desert Peak was used to design an optimum grid of Hg vapor sample locations, with continued sampling being conducted in the spring of 2004.

Remote Sensing Studies (Wendy Calvin, Chris Kratt, Mark Coolbaugh)

This research seeks to define surface identifiers of geothermal resources through analysis of remote sensing imagery to characterize mineral, vegetation, and thermal properties at known geothermal areas. In this project, high-resolution airborne coverages are being analyzed to find past geothermal centers and fault zone extensions. The methods are establishing mineral and thermal markers at known sites and extrapolating this knowledge to unexplored areas in an effort to find new geothermal systems. Remote sensing techniques have been used to identify tufa and sinter deposits, which has assisted in identifying previously unknown structures. By identifying potential resource zones through remote imagery, costly and detailed field methods (drilling, geochemical surveys and sampling) can be focused on the highest priority sites. Details of some of the results of this work are documented in Calvin et al. (2002), Kratt et al. (2003) and Coolbaugh et al. (2004, this volume).

Seismic Studies (John Louie)

The thrust of this part of the work is assembling a database and a three-dimensional reference model of seismic velocity for geothermal exploration in the western Great Basin. A major accomplishment of this project was the identification of a region of unexpectedly thin crust southwest of Battle Mountain that may have greater geothermal potential due to the thinner crust in that area relative to many areas throughout Nevada. The results thus far partially explain the location of part of the Battle Mountain heat flow high that was broadly identified with heat flow studies in the 1970s (e.g., Sass et al., 1976, and subsequent versions of the map). A second seismic survey scheduled for June 2004 will test the limits this anomaly. Preliminary results of this work can be found in Louie et al. (in press).

Volcanic Rock Dating (Greg Arehart, Mark Coolbaugh)

Geothermal systems in the Great Basin are of two types: those associated with rhyolitic magmatism (magmatic) on the margins, and those having no clearly associated young igneous rocks (extensional) in the interior of the Great Basin. Minor young basaltic volcanic rocks are in some cases associated spatially with extensional systems, but the ages of these basaltic rocks are generally poorly constrained in terms of age. For magmatic systems, high-precision dating of multiple rhyolitic rocks may provide important insights into time-space variations in volcanism that may potentially be related to recent and present-day strain in the crust. For extensional systems, high-precision dating of basaltic rocks may provide important insights into temporal relations with active geothermal systems. Initial age dates for the first group of rock samples are pending.

Integrating the Studies

The new data generated by ongoing research is being added to a geothermal GIS and analyzed to produce maps of regional geothermal favorability. These maps and several of the research projects have independently identified the regions around Buffalo Valley and Fairview Peak as promising exploration targets. Research projects that identified one or both of these anomalies include the seismic studies, GPS studies, and GIS work. More focused studies will be conducted in these areas, including digital field mapping, GIS analysis, GPS strain research, geochemical spring (Fig. 2) sampling, remote sensing, seismic studies, and volcanic rock dating.

Figure 2. Spring on small travertine terrace at Buffalo Valley Hot Springs (photo by Mark Coolbaugh, October, 2002).

Several concurrent studies, or components of studies, are being conducted at the Desert Peak-Bradys fields in collaboration with Ormat and GeothermEx in order to facilitate efforts to expand geothermal production and develop EGS resources. Detailed geologic mapping is the foundation of this work, and gravity, InSAR, remote sensing, digital field mapping of geothermal features, Hg soil gas surveys and microearthquake studies are all being conducted to identify structures and better understand the 3-D configuration of the system and its changes through time. These various studies are being integrated to develop techniques to better detect concealed geothermal resources and structures.

Considerable geologic, geochemical, geophysical, remote sensing and GIS data are now on the Center's web page (http://www.unr.edu/geothermal/) available for public download and use. These data should assist industry in their efforts to explore for new systems and better understand existing geothermal areas. Various geophysical data and model results can be found at that web site under /evaluatingresources/geophysics.html. Historical as well as newly collected data on thermal springs and wells are available at the main page under /evaluatingresources/geochem.html. Interactive maps containing many of the data layers produced in this work can be found at http://able1.mines.unr.edu/Geophysics_website/ Geothermal_GIS_build/interactive_maps.htm

Conclusions

In slightly over two years, the Center's projects have produced numerous products in the form of papers and web pages, and achieved numerous accomplishments in the areas of resource exploration and assessment in Nevada. In these two years, the projects have published 24 papers and the investigators have given 42 presentations at local, regional, national, and international meetings. Remote sensing and geophysical data are being used in new and expanded ways to identify geothermal resource potential. A comprehensive digital GIS database is under development as a tool for interpreting complex, multiple sources of data on potential and proven geothermal reservoirs. The on-line version of this database is a resource for the geothermal community in the Great Basin and serves as a center of outreach in that regard.

The main accomplishments of the Center's work over the two-year period include the following:

- InSAR has detected production induced micro-displacement, which helps to image the structure controlling geothermal fluid flow and will also result in improved reservoir characterization and management at Bradys.
- GPS-strain measurements have been used to identify exploration targets, including areas in central Nevada near Buffalo Valley and Fairview Peak.
- GIS modeling has been used to quantify relationships between geothermal systems and crustal strain rates, produce regional maps of geothermal favorability, identify local areas worthy of follow-up exploration work, and is beginning to be used to quantify remaining hidden geothermal resources in the Great Basin.
- Seismic studies have identified a large area of thin crust in central Nevada, partially coincident with the GIS and GPS anomalies near Buffalo Valley.
- Hg soil gas study results indicate hidden structures can be identified using this technique
- Significant improvements have been made in the understanding and characterization of structural controls and subsurface structural framework at the existing field at Desert Peak.
- It has been recognized that fields in the northwestern Great Basin are related to the evolving plate boundary, which is the terminus of shear in Walker Lane
- Analyses of geothermal fluids from previously un-sampled sites and construction of maps of contoured geothermometers have helped identify additional potential exploration areas on a regional basis.
- Remote sensing is being used to establish mineral and thermal markers at known sites and extrapolate to unexplored areas. Previously unknown sinters have been located, and faults have been extended beyond originally mapped extents.

Acknowledgments

This material is based upon work supported by the U.S. Department of Energy under instrument number DE-FG36-02ID14311 (changed from DE-FG07-02ID14311 in June, 2003).

References

Blewitt, G., Coolbaugh, M.F., Sawatzky, D.L., Holt, W., and Davis, J.L., 2003. "Targeting of Potential Geothermal Resources in the Great Basin from Regional to Basin-Scale

Relationships Between Geodetic Strain and Geological Structures." Geothermal Resources Council *Transactions*, v. 27, p. 3-7.

Calvin, W., Coolbaugh, M., and Vaughan, R.G., 2002. Geothermal Site Characterization Using Multi- and Hyperspectral Imagery. Geothermal Resources Council *Transactions*, v. 26, p. 483-485.

Coolbaugh, M.F., Sawatzky, D.L., Oppliger, G.L., Minor, T.B., Raines, G.L., Shevenell, L.A., Blewitt, G., and Louie, J.N., 2003. "Geothermal GIS coverage of the Great Basin, USA; Defining regional controls and favorable exploration terrains." Geothermal Resources Council *Transactions* v. 27, p. 9-13.

Coolbaugh, M.F., and Shevenell, L., 2004. "A method for estimating undiscovered geothermal resources in Nevada and the Great Basin." Geothermal Resources Council *Transactions, v.* 28 (this volume).

Coolbaugh, M., Sladek, C., and Kratt, C, 2004. "Digital Field Methods for Mapping Structurally Controlled Geothermal Features on the Surface." Geothermal Resources Council *Transactions*, v. 28 (this volume).

Faulds, J.N., Coolbaugh, M., Blewitt, G., and Henry, C.D., 2004. "Why is Nevada in hot water? Structural controls and tectonic model of geothermal systems in the northwestern Great Basin." Geothermal Resources Council *Transactions*, v. 28 (this volume).

Faulds, J.E., and Garside, L.J., 2003. "Preliminary geologic map of the Desert Peak – Brady geothermal fields, Churchill County, Nevada." Nevada Bureau of Mines and Geology Open-File Report 03-27.

Kratt, C., Coolbaugh, M., and Calvin, W., 2003. "Possible Extension of Brady's Fault Identified Using Remote Mapping Techniques." Geothermal Resources Council *Transactions*, v. 27, p. 653-656.

Louie, J.N., Pancha, A., Biasi, G.P., Thelen, W., Scott, J.B., Coolbaugh, M.F., and Larsen, S., 2004 (in press). "Tests and applications of 3-d geophysical model assembly." submitted to *Expanded Abstracts*, Soc. of Explor. Geophys. 74th Annual Internat. Meeting, Oct. 10-15, Denver, Colorado.

Oppliger, G., Coolbaugh, M., and Foxall, W., 2004. "Imaging structure with fluid fluxes at the Bradys geothermal field with satellite interferometric radar (InSAR): New insights into reservoir extent and structural controls." Geothermal Resources Council *Transactions,* v. 28 (this volume).

Sass, J.H., Diment, W.H., Lachenbruch, A.H., Marshall, B.V., Monroe, R.J., Moses, T.H., Jr., and Urban, T.C., 1976. "A heat-flow contour map of the conterminous United States." U.S. Geological Survey Open-File Report 76-756, 24 p.

Shevenell, L., and Taranik, J.V., 2002. "Overview of Activities of the Great Basin Center for Geothermal Energy." Geothermal Resources Council *Transactions*, v. 26, p. 507-510.

Shevenell, L., and Garside, L., 2003. "Geochemical Sampling of Thermal Waters in Nevada." Geothermal Resources Council *Transactions*, v. 27, p. 27-32