Update of Great Basin Center for Geothermal Energy Activities

Lisa Shevenell, John Bell, Geoff Blewitt, Wendy Calvin, Mark Coolbaugh, James Faulds,

Larry Garside, Allen Gates, William Hammond, Chris Kratt, Corne Kreemer, Paul Lechler,

Gary Oppliger, Chris Sladek, and Richard Zehner

Great Basin Center for Geothermal Energy, MS 172

University of Nevada, Reno, Reno, NV 89557-0088

775-784-7018; 775-327-5801 (fax);

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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 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.

To meet these goals, currently funded projects are framed in terms of addressing 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. Funded research projects to begin addressing these issues were selected based on external peer review of submitted proposals in the springs of 2002, 2003, and 2005.

In FY 02, with Senator Harry Reid's assistance, $936,000 was allocated from DOE to support the Center at UNR, and slightly less than $1 million has been allocated in subsequent years to support geothermal resource exploration and assessment in the Great Basin. 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. 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). Other tasks that the Center has undertaken include stakeholder outreach (workshops) and web-based information system development related to GeoPowering the West goals. The purpose of this paper is to summarize the results and accomplishments of the research projects and outreach sponsored by the Great Basin Center for Geothermal Energy.

Overview of 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 and included on a publicly available web page. 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 are being conducted in these areas, including digital field mapping, GIS analysis, GPS strain research, geochemical spring sampling, remote sensing, and seismic studies.

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/; http://www.unr.edu/Geothermal/ExplAssessData.html), available for public download and use. Additionally, a web site has been developed that allows interactive, on-line map creation and retrieval of data from these projects as well as that compiled from previous work (http://www.unr.edu/geothermal/interactive_maps.htm). These data and maps 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 http://www.unr.edu/geothermal/geophysics.html. Historical as well as newly collected data on thermal springs and wells are available at the main page under http://www.unr.edu/geothermal/geochem.html.

Outreach

Through its support from the Department of Energy, the Center is leading educational and outreach programs, organizes workshops and has developed a web-based information system that provides key technical information on geothermal resources.

Geothermal and Renewable Energy Laboratory of Nevada (GRELN) (Allen Gates)

GRELN (the UNR Renewable Energy Center, UNR-REC) is a public/private partnership whose mission is world class geothermal and renewable energy research, education, and outreach (http://www.unr.edu/Geothermal/GRELM.htm). It will principally be located at the Redfield Campus and will be a showpiece for application of geothermal energy for powering, heating, and cooling the Redfield Campus—a totally green campus. It is part of a renewable energy deployment center initiative funded through additional earmarks established under Senator Reid's leadership beginning in 2002. The principal partners are the UNR, the

DRI, the TMCC, ORMAT, Sierra Pacific Power, the Regional Transportation Commission, and the NREL.

Examples of the types of planned research activities are: use of geothermal energy to produce hydrogen, development of new binary power cycles for more efficient production of electrical power, integration of wind, solar, and geothermal energy systems, production of biodiesel fuel from waste, design of high efficiency heat exchangers, and development of materials and components for hydrogen storage. Examples of planned education and outreach activities are: education of energy system engineers, training of geothermal and renewable energy power plant operators and technicians, and provision of a multi-media center for public awareness of the benefits and uses of geothermal and renewable energy.

Workshops Organized and Held

The Center has organized, sponsored, or co-sponsored ten informational workshops including: *Geothermal Opportunities in Nevada* (1/11/02), *Introduction to Geothermal Energy* (4/18-19/02; with GRC), *Dixie Valley Workshop* (6/12-13/02), *Great Basin Geothermal Workshop* (11/5/04), among others.

Web Page Development and Maintenance (Richard Zehner, Mark Coolbaugh, Peggy Brown)

The Great Basin Geothermal Center (GBCGE) website is developing into a major information hub serving the geothermal exploration community in many capacities. First and foremost, the site makes available the results of GBCGE research, which focuses on state of the art geodesic, geophysical, and geochemical studies of Great Basin geothermal systems together with sophisticated data-driven spatial modeling. This modeling utilizes GIS-based weights of evidence and logistic regression analysis to create probabilistic favorability or predictability maps of high-temperature geothermal systems within the Great Basin. Currently over eighty spatial data layers can be downloaded from the site for use in GIS-based geothermal exploration. These layers can also be viewed, manipulated, and queried through interactive web pages that contain many features of GIS software that can be accessed wherever a web browser is available. Second, due to the abundance of federal lands in the Great Basin, the GBCGE web site contains up-to-date Bureau of Land Management (BLM) geothermal lease, regulation, and application data. Third, the site contains extensive links to the web sites of most federal and state regulatory agencies, industry organizations, and other sites relevant to Great Basin geothermal exploration. Finally, the site contains recent announcements, press releases, and industry news that are viewable both by list and by interactive map. In short, the GBCGE web site contains raw exploration data, detailed analysis and geothermal favorability maps, regulatory information, papers and presentations, industry news, and links to other sites important to geothermal stakeholders.

Research

Active Faulting along Nevada Geothermal Systems (Bell, Ramelli)

Many of the principal geothermal sites in the Basin and Range are located on or near major late Quaternary faults, yet little is presently known about the neotectonic behavior of most of these faults. There are qualitative indications that there may be some genetic connection between active faulting and localization of geothermal activity. The presence of multiple geothermal sites within the central Nevada seismic belt, a zone of historical surface faulting associated with large-magnitude earthquakes, suggests that high crustal strain release may play a role in geothermal activity. While this and other tectonic parameters, such as fault orientation and contemporary shear strain direction, suggest that connections exist, the relations appear to be complex. In this study, we propose to examine the pattern and rate of active faulting at 37 selected geothermal sites in the Nevada region that have maximum temperatures of 100° C or greater in order to search for other structural-tectonic factors that could provide additional insights into possible connections. Each site will be investigated using conventional paleoseismic techniques: detailed aerial photographic analysis, large-scale surficial geologic mapping, and selected exploratory trenching. Principal research issues to be addressed would include: existence of unrecognized active faults at the sites; spatial and temporal relations between fault age, recurrence, strain rate, magnitude-displacement, orientation, and slip mechanics at the geothermal site. The results of the paleoseismic compilation would be analyzed through a factor or discriminant function analysis to search for neotectonic variables that may statistically favor localization of geothermal activity in the western U.S.

1. The planned scope of work was revised to identify the 15 most important sites for field investigation. Discussions were held with Jim Faulds and Mark Coolbaugh, principal investigators on related research elements, to narrow down the list of targeted areas. The selected sites for characterization are now grouped into 2 principal categories: 1) the Black Rock Desert, and 2) the Carson Sink sets. The Black Rock Desert sites include faults located at the Gerlach, Fly, Trego, Black Rock, WW, TH, and Empire geothermal sites. Preliminary data will also be collected from the Needle Rock area at the northern end of Pyramid Lake. The Carson Sink sites include faults located at the Salt Wells, Stillwater, Soda Lake, 8-mile geothermal sites. The Carson Sink set will also include a synthesis of existing studies from the Dixie Valley and Dixie Comstock sites, and examination of the Kyle and Leach Hot Springs sites.

2. Aerial photograph acquisition was initiated for the sites to be studied. Searches were conducted of existing in-house photography and conventional and low-sun-angle aerial photography in order to determine the extent to which new photography was required. Portions of the Carson Sink sites are covered by existing 1:12,000 and 1:40,000-scale low-sun-angle aerial photography, and planning is currently underway to fly custom 1:12,000 photography over other targeted sites. Planning and ordering is also underway to acquire 1:12,000 orthorectified Quickbird imagery covering each of the targeted sites. This imagery is high-resolution (60 cm) and is designed for high accuracy, GIS-based field mapping.

3. John Bell reviewed the manuscript "Description, synthesis, and interpretation of the thermal regime, geology, geochemistry, and geophysics of the Dixie Valley, Nevada geothermal system" by D.D. Blackwell and R. Smith, eds., submitted to be published as a Nevada Bureau of Mines and Geology Report. Portions of the manuscript related to geologic structure, surficial deposits, faults, seismicity, and paleoseismicity were included in the review. Based on this review of previous studies in the Dixie Valley geothermal area, plans are included in this project to synthesize additional existing fault and structural data in order to develop a complete summary of the relation between geothermal activity and the structural-tectonic setting.

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

In collaboration with industry partners Ormat and GeothermEx, this project is characterizing the links between geothermal reservoirs and stratigraphic and structural features and better defining reservoir boundaries at the Desert Peak and Bradys geothermal systems. 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, 3-D modeling and visualization using drillhole data, and gravity studies. The gravity work is constraining the subsurface geometry of major faults and configuration of the Tertiary-basement contact. For example, geologic mapping identified step-over faults between en echelon fault segments that appear to control both the Desert Peak and Bradys geothermal fields. Increased fracture density in these step-over areas appears to accentuate permeability and provide convenient channelways for geothermal fluids (Faulds et al., 2004). This model may be applied to help exploration efforts in other geothermal fields that have a similar structural setting. In addition, 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 similar settings in west-central Nevada where the Humboldt structural zone intersects the Walker Lane. 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 these systems.

Results of this study have also been incorporated into a new tectonic model of geothermal systems in the northern Great Basin (Faulds et al., 2004). This model suggests that the abundant geothermal activity in the northern Great Basin is related directly to the evolving Pacific-North American transform plate boundary. Dextral shear within the Walker Lane terminates in the northwestern Great Basin and diffuses into extension within the Basin and Range province, which induces dilation and fluid flow along major normal faults (Faulds et al., 2004).

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

A database of existing geochemical data was constructed containing over 7000 records (http://www.nbmg.unr.edu/geothermal/databases.htm). The data were used to determine which sites lack modern geothermal fluid analysis, have poorly located data, or are lacking in fluid analyses. We sample and analyze thermal springs that fall into one of these three groups to fill data gaps (Shevenell and Garside, 2003), adding the new data to the database. Geochemical samples are also being collected at areas identified as favorable for geothermal potential in other portions of the Center's exploration program (e.g., Buffalo Valley; Fairview Peak-Rawhide). Cation and silica geothermometers were calculated to estimate reservoir temperatures.

Geothermometers were evaluated using power plant data as controls. Geochemical modeling was conducted to determine if methods more rigorous than traditional geothermometer calculations can improve subsurface temperature estimates. Traditional geothermometers (e.g., quartz geothermometers) worked well at estimating subsurface temperatures at high temperature systems, whereas the Reed and Spycher (1984) method did not work as well at the highest temperature systems. Results suggest that this method may assist in better estimates when traditional geothermometers do not agree with one another and in systems <180ºC, which are abundant in Nevada. No one geothermometer or set of geothermometers can be considered to be the best for estimating subsurface reservoir temperatures of Nevada resources.

We have found that cold springs can also provide anomalous geothermometer temperatures indicating a geothermal resource, and sampling cold springs can be used as an exploration tool in areas with no surface expression of geothermal systems. Cold spring sampling and sampling fluids from holes dug into playas can both be used to locate blind targets.

GIS Studies (Mark Coolbaugh)

The goal of this 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, 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, some of which are detailed by Coolbaugh et al. (2003). This project has developed a new map of geothermal potential of the entire Great Basin to help focus geothermal exploration in the best regions. As part of this work, a regional structural database is being constructed that helps us identify favorable structural environments for the location of productive geothermal resources, as well as 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 including sinters and travertines as an aid to locating fluid-controlling structures (Coolbaugh et al., 2004). 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). Many areas of Nevada could host concealed geothermal systems that have not been adequately explored. Several areas with relatively high potential for undiscovered geothermal systems are indicated in Coolbaugh and Shevenell (2004), and grass-roots geothermal exploration should have a relatively good chance of making a new discovery in those areas.

GPS Geodetic Studies (Geoff Blewitt, William Hammond, Corne Kreemer)

The objective of this project is to develop a new GPS-based system for geothermal exploration in the largely non-magmatic setting of the Great Basin, which would improve conceptual models of non-magmatic geothermal systems and thus enable the discovery of more of exploitable resources.

Regions of high extensional crustal strain rates are more likely to contain dilated faults, with deeply circulating fluid. The regional network MAGNET (Mobile Array of GPS for Nevada Transtensi0on) began producing data in January 2004 with the goal of identifying regions of high transtensional (extension plus shear) strain accumulations in the Earth's crust. Construction of MAGNET is now complete at 60 GPS stations. Results show that horizontal station coordinates estimated every week repeat with a 1-s.d. precision of 0.5 mm, thus relative velocities between stations will be resolved to < 1 mm/yr by summer of 2006 (Blewitt et al., 2003). The major accomplishment from the initial work has been that GPS geodetic measurements can identify where strain is correlated with geothermal resources in the Great Basin. Several areas of high strain rate (transtensional) have been identified that likely have a high potential for geothermal exploitation and that warrant more detailed investigation. Such promising areas include regions of the northern Walker Lane and Central Nevada Seismic Belt.

InSAR Studies (Gary Oppliger)

This project is investigating how centimeter-level ground displacement histories derived from Satellite Interferometric Synthetic Aperture Radar (InSAR) observations can be applied to delineate and track changes in the stress-state and extent of produced geothermal reservoirs. The work seeks to aid reservoir production, expansion and management through identifying structural controls that influence the flow of produced and injected fluids. It is expected that knowledge of these controls will reduce the drilling and operating costs associated with optimizing field production and will increase field longevity. The basic measurements and interpretations developed in this study will assist reservoir management and expansion at Bradys, Desert Peak, and the Desert Peak EGS study area (80 km NE of Reno, Nevada) and will also serve as a technology template for other geothermal fields.

The study's interferograms have revealed the first surface displacement features (surface deflation) known for the Brady geothermal field. Delineation of this reservoir production signal is a significant technical result indicating InSAR may also be useful over other Great Basin geothermal fields. The surface displacement anomaly indicates the produced reservoir zone has strong hydrologic conductivity zone along a 7 km axis which closely follows the mapped Brady fault. The anomaly continues in a weaker but clear form for a total length of ~11 km, adding 6 km length to the known 5 km Brady fault and reservoir system. Key results to date are documented in Oppliger et al. (2004; 2005).

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

The purpose of this project was to conduct a detailed Hg soil gas survey to delineate concealed geologic 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 are yielding 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 then used to design an optimum grid of Hg vapor sample locations. The results of the Hg survey were used to identify a previously unknown fault that is partially marked by silicified sand. Two concealed faults in the central portion of the survey, inferred from geologic studies, were identified more precisely from the soil gas survey results.

Regional Seismic Studies (John Louie)

Exploration for hidden resources requires a realistic crustal and upper-mantle model to understand the deep sources of geothermal heat. In the western Great Basin, crustal properties and thickness are known only at wide spacing. With the more complete sampling of the crustal geophysical characteristics of geothermal resources in the Great Basin resulting from this study, geophysical measures can contribute to quantitative analyses of the associations between different geophysical parameters.

This project is assembling a three-dimensional reference model of seismic velocity for the western Great Basin region of Nevada and eastern California. The resulting seismic velocity model consists of simplified rule-based representations of some of the region's crust to 50 km depth, and more detailed characterization of geothermal areas and sedimentary basins. The first three project years developed and successfully tested new regional seismic-refraction surveying technology, conducted three large experiments across the region, and gathered pre-existing crustal geophysical data. The project will now focus on refining a geophysical model of the western Great Basin, available for grid computation at www.seismo.unr.edu/geothermal#ma .

An unexpected result of the surveys, related by Louie et al. (2004), is the discovery of great variations in crustal thickness within the Great Basin. Although counter to conventional wisdom developed in the 1980s of a flat Moho from surveys along the "40°N transect," our careful re-examination of the mass of conflicting data bears this conclusion out. Both our 2002 and 2004 transects find that the crust may thin to 20 km in the vicinity of Battle Mountain. The newly discovered areas of thin crust produce a good correlation of crustal thickness with the occurrence of geothermal resources in extensional tectonic regimes in association with the Battle Mountain heat flow high.

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 project is using computer processing methods to increase the size and clarity of thermal infrared anomalies associated with geothermal activity. 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).

Summary

The Great Basin Center for Geothermal Energy has developed a comprehensive interactive web-site containing geothermal databases to facilitate acquisition of exploration data by industry. An accompanying detailed map of geothermal potential of the entire Great Basin has been produced to help focus geothermal exploration in the best regions. The Center has demonstrated new tools for geothermal exploration and site characterization using remote sensing and GIS technologies. New areas warranting detailed assessment have been identified, and the Center has provided a better understanding of the behavior of existing fields. All of these activities have helped revitalize grass-roots geothermal exploration in the Great Basin.

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