One-Stop Shop

The Great Basin Center for Geothermal Energy Offers Solutions for All of Your Exploration, Leasing, and Assessment Needs

By Lisa Shevenell, Director, Great Basin Center for Geothermal Energy – UNR

The Great Basin Center for Geothermal Energy was established at the University of Nevada, Reno (UNR) in May 2000 to promote research on and utilization of geothermal resources in the Great Basin region of the western United States (Shevenell and Taranik, 2002). The Center's mission 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 West 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, federally funded projects at the Center address three questions relevant to geothermal development: 1) Why are geothermal resources in the Great Basin? 2) What techniques can be used to find geothermal resources in the Great Basin? 3) Where are Great Basin geothermal resources located, and how large are they? Funded research projects to begin addressing the following issues were selected based on external peer review of proposals submitted to the U.S. Department of Energy (DOE) from 2002 through 2005. Work currently includes:

- Characterizing geothermal resources;
- Understanding controls on resources;
- Identifying favorable geothermal exploration targets;
- Evaluating new exploration technologies and techniques, such as Global Position Systems (GPS), Geographical Information Systems (GIS), and Interferometric Synthetic Aperture Radar (InSAR); and
- Expanding on existing geothermal exploration and assessment techniques.

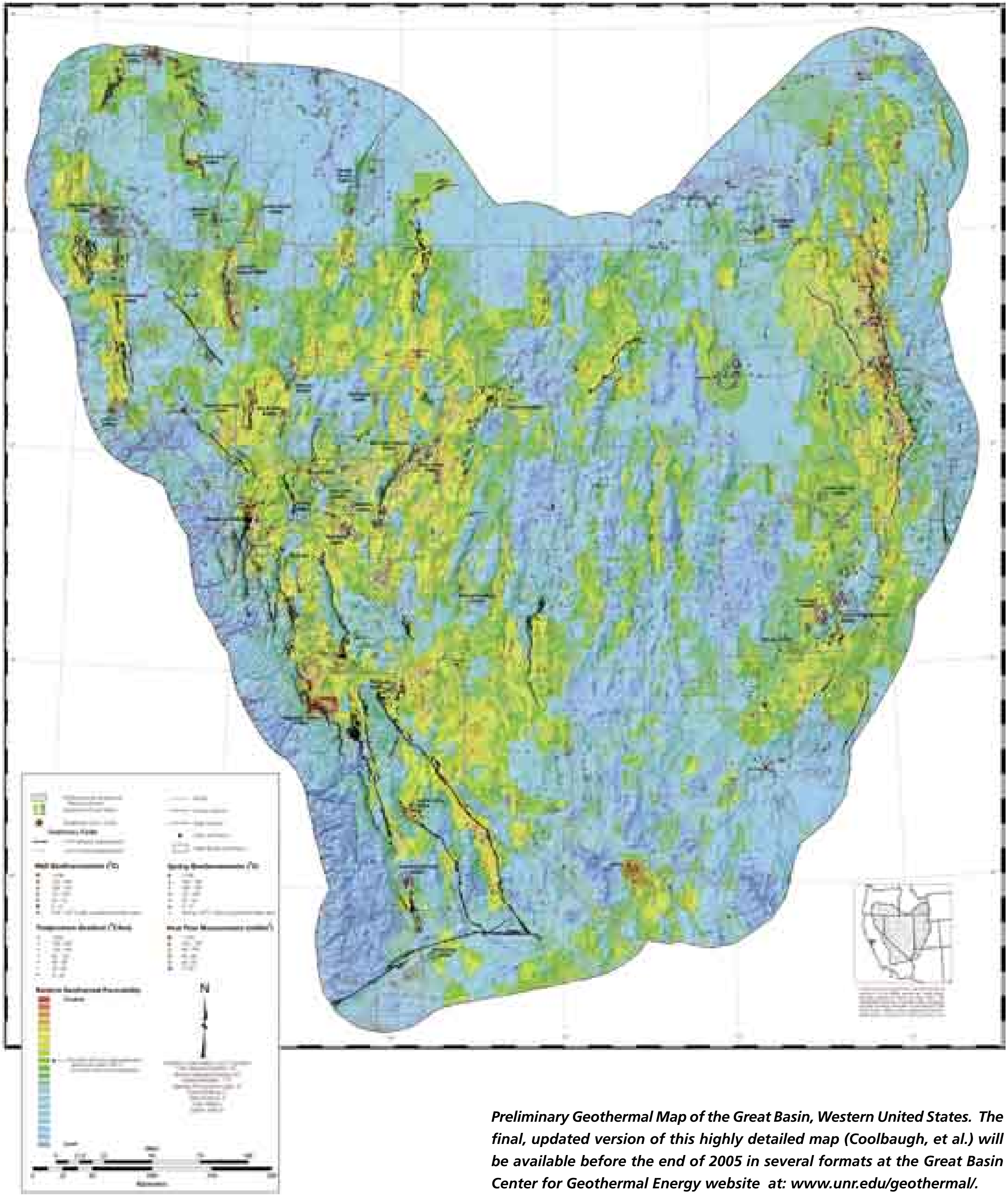
In Fiscal Year (FY) 2002—with assistance from Sen. Harry Reid (D-NV)—$936,000 was allocated by the U.S. Congress from the DOE Geothermal Technologies Program budget to support the Center, and slightly less than $1 million per year has been earmarked since then. With a focus on peer-reviewed research projects awarded on a competitive basis, the Center's program of resource exploration and assessment in the Great Basin is integral to the DOE geothermal program. In collaboration with industry, the Center contributes expertise and research in support of DOE's priority program for Enhanced Geothermal Systems (EGS). The Center has also undertaken stakeholder outreach (workshops) and web-based information system development to enhance the goals of the DOE GeoPowering the West Initiative. This article summarizes the results and accomplishments of research projects and outreach by the Great Basin Center for Geothermal Energy.

Overview of Great Basin Center for Geothermal Energy Activities

New data generated by ongoing research at the Center is regularly added to a geothermal GIS database, and analyzed to produce maps of regional geothermal favorability. This information is posted on a publicly available webpage. These maps and several Center research projects have independently identified the regions around Buffalo Valley and Fairview Peak in northern Nevada as promising geothermal exploration targets. Research projects identifying one or both of these anomalies included seismic studies, GPS studies, and GIS work. More focused research is being conducted in these areas, including digital field mapping, GIS analysis, GPS strain research, geochemical spring sampling, remote sensing, and seismic studies.

To facilitate expanded geothermal energy production and development of EGS resources, the Center is conducting several concurrent studies in collaboration with ORMAT Nevada, Inc. (Sparks, NV) and GeothermEx, Inc. (Richmond, CA) at the Desert Peak-Brady's geothermal fields. Detailed geologic mapping is the foundation of this work, which also includes gravity, InSAR, remote sensing, digital field mapping of geothermal features, mercury (Hg) soil gas surveys to identify structures, better understand the system's 3-D configuration, and changes through time. Integration of these studies will help develop techniques to better detect concealed geothermal resources and structures.

The Center's website (www.unr.edu/geothermal) offers a large volume of geothermal energy information. A considerable amount of geologic, geochemical, geophysical, remote sensing and GIS data are available (www.unr.edu/Geothermal/ExplAssessData.html) for public download and use. Another webpage (www.unr.edu/



Preliminary Geothermal Map of the Great Basin, Western United States. The final, updated version of this highly detailed map (Coolbaugh, et al.) will be available before the end of 2005 in several formats at the Great Basin Center for Geothermal Energy website at: www.unr.edu/geothermal/.

geothermal/interactive_maps.htm) allows interactive, on-line map creation and retrieval of data from Center research projects and compiled from previous work The data and maps are meant to assist industry in exploring for new systems and understanding existing geothermal areas. The Center website also offers various geophysical data and model results (www.unr.edu/geothermal/geophysics.html), as well as historical and new data on thermal springs and wells (www.unr.edu/geothermal/geochem.html).

Great Basin Center Outreach Efforts

With DOE financial support, the Center takes a leading role in educational and outreach programs, organizes workshops, and is continuously developing an Internet-based information system that provides key technical information on geothermal resources.

Geothermal and Renewable Energy Laboratory of Nevada (Allen Gates). The Geothermal and Renewable Energy Laboratory of Nevada (GRELN) at the UNR Renewable Energy Center, UNR-REC) is a public/private partnership. Its mission is to perform world-class geothermal and renewable energy research, education, and outreach (www.unr.edu/Geothermal/GRELM.htm). GRELN will be located at the new, totally "green" UNR Redfield Campus in south Reno. It will be a showcase of geothermal energy applications for powering, heating, and cooling. GRELN is part of a renewable energy deployment center initiative funded by the U.S. Congress under Sen. Reid's leadership beginning in 2002. Principal partners are UNR, the Desert Research Institute, Truckee Meadows Community College, ORMAT Nevada, Inc., Sierra Pacific Power, the Regional Transportation Commission, and the National Renewable Energy Laboratory (NREL – Golden, CO). Examples of planned research activities include:

- Use of geothermal energy to produce hydrogen;
- Development of materials and components for hydrogen storage.
- Development of new binary power cycles for more efficient production of electrical power;
- Design of high-efficiency heat exchangers;
- Integration of wind, solar, and geothermal energy systems; and
- Production of biodiesel fuel from waste;

Examples of planned education and outreach activities include education of energy system engineers; training of geothermal and renewable energy power plant operators and technicians; and provision of a multi-media center to enhance public awareness of the benefits and uses of geothermal and renewable energy.

Web Page Development and Maintenance (Richard Zehner, Mark Coolbaugh, Peggy Brown). The Center website is developing into a major information hub serving the geothermal exploration community. First and foremost, the website makes available the results of Center research, which focuses on state-of-the-art geodesic, geophysical, geochemical studies, and sophisticated data-driven spatial modeling of Great Basin geothermal systems. This modeling utilizes GIS-based weights of evidence and logistic regression analysis to create probabilistic favorability or predictability maps of high-temperature geothermal systems. Currently, more than 80 spatial data layers can be downloaded from the Center website for use in GIS-based geothermal exploration. The layers can also be accessed, viewed, manipulated, and queried through interactive webpages that contain many features of GIS software. Second, considering the abundance of federal lands in the Great Basin, the Center website contains up-to-date U.S. Bureau of Land Management geothermal lease, application, and regulatory information. Third, the website contains extensive links to websites maintained by most federal and state regulatory agencies, industry and other organizations that are relevant to Great Basin geothermal exploration. Finally, the Center website offers recent announcements, press releases, and industry news that are viewable both by list and by interactive map.

Geothermal Workshops. The Center has organized, sponsored, or co-sponsored 10 informational workshops including: *Geothermal Opportunities in Nevada* (January 2002), *Introduction to Geothermal Energy* (April 2002, with the Geothermal Resources Council), *Dixie Valley Workshop* (June 2002), *Great Basin Geothermal Workshop* (November 2004), among others.

Research Activities

Desert Peak-Brady's 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 Brady's geothermal systems. Significant improvements in understanding of the structural controls at Desert Peak-Brady's systems have come 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 Brady's 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 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 7,000 records (available on the Center website at: www.nbmg.unr.edu/geothermal/databases.htm). The data were used to determine sites that lack modern geothermal fluid analysis, have poorly located data, or are lacking fluid analyses. To fill data gaps, the researchers sampled and analyzed thermal springs that fall into one of these three groups (Shevenell and Garside, 2003), and added the new information to the Center database. Geochemical samples are also being collected at areas favorable for geothermal potential (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, but it was found that the Reed and Spycher (1984) method did not work as well in the highest-temperature systems. Results suggest that this method may achieve better estimates when traditional geothermometers do not agree with one another, and in systems <180º C, 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 geothermal resources. Center researchers have found that cold springs can also provide anomalous geothermometer temperatures indicating a geothermal resource, and that sampling of 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 about 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). The project has developed a new map of geothermal potential of the entire Great Basin to help focus geothermal exploration toward the best regions. As part of this work, a regional structural database is being constructed that will help researchers identify favorable structural environments for locating productive geothermal resources, and to identify controls on fluid flow. In addition, digital field mapping at several sites is being used in conjunction with other studies to better delineate observable, active thermal features (including sinters and travertines) to help locate fluid-controlling structures (Coolbaugh et al., 2004). Finally, 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 (Coolbaugh and Shevenell, 2004), and "grassroots" geothermal exploration should have a relatively good chance of making new discoveries 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. Such a system would improve conceptual models of non-magmatic geothermal systems, enabling discovery of more exploitable resources. Regions of high extensional crustal strain rates are more likely to contain dilated faults with deeply circulating fluid. The regional network Mobile Array of GPS for Nevada Transtension (MAGNET) 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, enabling relative velocities between stations to be resolved to <1 mm/year by the summer of 2006 (Blewitt et al., 2003). A major accomplishment from 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 transtensional strain rate have been identified, with likely high potential for geothermal exploitation. Promising areas warranting more detailed investigation 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 producing 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 drilling and operating costs associated with optimizing field production and longevity. Basic measurements and interpretations developed in this study will assist reservoir management and expansion at the Brady's and Desert Peak geothermal fields, and the Desert Peak EGS study area (80 km NE of Reno, NV), and 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's Geothermal Field. Delineation of this reservoir production signal is a significant technical result, indicating that 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 that closely follows the mapped Brady's fault. The anomaly continues in a weaker, but clear, form for a total length of ~11 km, adding 6 km of length to the known 5-km Brady's fault and reservoir system. Key results to date are documented by 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 an 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 Brady's 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 Brady's structure is visible via fumaroles discharging at the surface. Peak to background resolution for this method is good at Brady's. 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 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 associations between different geophysical parameters. This project is assembling a 3-D 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 on the Internet for grid computation at: www.seismo.unr.edu/geothermal#ma. An unexpected result of the surveys (Louie et al., 2004), was discovery of great variations in crustal thickness within the Great Basin. Although counter to the "conventional wisdom" during the 1980s of a flat Moho from surveys along the "40°N transect," careful re-examination of the mass of conflicting data bears this conclusion out. Both 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 have 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 website that offers 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 grassroots geothermal exploration in the Great Basin.

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For more information about the Great Basin Center for Geothermal Energy, visit its website at: www.unr.edu/geothermal. Or contact **Lisa Shevenell**, Director, Great Basin Center for Geothermal Energy, MS 172, University of Nevada, Reno, Reno, NV 89557-0088. Phone: (775) 784-1779. Fax: (775) 784-1709. Email: lshevenell@charter.net.

INTRODUCTION TO GEOTHERMAL ENERGY

GREAT FOR NEW HIRES AND NON-TECHNICAL STAFF

Tuesday, September 27, 2005 – 1:00 to 5:00 P.M.
Reno Hilton Hotel

The GRC will once again host a Public Information Workshop, presented by the Geothermal Education Office at the Annual Meeting. This free and fun event — sponsored this year by ORMAT Technologies, Inc. and by DOE's GeoPowering the West Program — is open to anyone interested in learning about geothermal energy. Attendees may include educators, staff of regulatory agencies, utilities, special interest groups, and, of course, geothermal companies. Media representatives are welcome.

This non-technical program features slide presentations by seasoned goethermal speakers, covering geology, exploration, drilling, generation of electricity, and direct-use technologies. After the formal program attendees are invited visit the geothermal exhibits and poster session.

Preregistration is appreciated. For more information, contact Marilyn Nemzer at geo@marin.org.

GRC Annual Meeting attendees and spouses: Drop in anytime during the session!