REVIVAL OF GRASS-ROOTS GEOTHERMAL EXPLORATION IN THE GREAT BASIN (WHERE TO LOOK FOR NEW GEOTHERMAL FIELDS) – A NEW APPROACH TO ASSESSING GEOTHERMAL POTENTIAL USING A GEOGRAPHIC INFORMATION SYSTEM
parts IV and V

Mark Coolbaugh[1], Rick Zehner[1], Corné Kreemer[2], Don Sawatzky[3], Gary Oppliger[3], David Blackwell[4], Lisa Shevenell[1,5], Jim Taranik[6], Gary Raines[7], Jim Faulds[5]

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

ABSTRACT

We propose to expand the existing GIS of geothermal systems in the Great Basin to include several key new features: 1) improved predictive maps of geothermal favorability based on new digital data on crustal strain, fault displacements, heat flux, and other data, 2) maps predicting which portions of the Great Basin are most likely to conceal geothermal systems, and 3) maps showing where undiscovered resources are most likely to be found, which would be created by combining the information in steps 1 and 2 above. In addition, the Center's web site would be expanded to include new digital geothermal exploration data, and new sections containing updated Bureau of Land Management (BLM) lease data, and a help desk where stakeholder questions will be answered by a panel of experts. Existing web server software will be reviewed to identify the most efficient and cost-effective platform for boosting high-speed, interactive, multiple-user access.

The ultimate goal is to revitalize grass-roots geothermal exploration in the Great Basin (ie. exploration for as-of-yet unknown geothermal systems). Favorable sites identified by the geothermal potential maps will be "reconnaissance field-checked" for evidence of Quaternary faults, drill-holes or wells, and past or present surface hydrothermal activity. Sister research projects may sample existing springs and wells to calculate geothermometer temperatures and measure down-hole temperatures to calculate temperature gradients. The approach would be to conduct the minimum amount of field work needed to verify the promising exploration potential of these areas, so they can be highlighted and promoted to industry to encourage a greater degree of reconnaissance geothermal exploration.

Total Federal Funds Requested: $149,966/yr x 2 yrs = $299,932.

[1] Great Basin Center for Geothermal Energy; [2]Nevada Geodetic Laboratory; [3]Arthur Brant Laboratory for Exploration Geophysics; [4]Southern Methodist University Geothermal Laboratory; [5]Nevada Bureau of Mines and Geology; [6]Mackay School of Earth Sciences and Engineering; [7]United States Geological Survey.

DESCRIPTION OF PROJECT

Introduction

Grass-roots exploration (the exploration for new fields) is an important component in the expansion of any earth resource, but in the case of geothermal resources, grass-roots exploration in the Great Basin has not yet revived or even approached the levels of activity seen in the 1970s and 1980s. However, the recent rise in energy prices and passing of energy-related legislation has helped reignite interest in developing new geothermal energy projects in the Great Basin, and projects are being developed which could lead to a significant increase in the level of geothermal energy production. To date, almost all of this new industry interest is focused in known geothermal areas, and with good reason, because this is where new projects can be developed most quickly and with the least risk. However, grass-roots exploration is an important component of a sustained exploration effort, particularly in the Great Basin, where many geothermal systems are "blind" and/or have minimal surface expressions. Grass-roots exploration lags far behind in the amount of investment effort and research expended.

An impediment to grass-roots exploration in the Great Basin is the myth that all known geothermal areas have already been identified. Fortunately, geothermal favorability modeling at the Great Basin Center for Geothermal Energy suggests otherwise. The increasing availability of digital geothermal data, combined with spatial statistical modeling with a GIS, is making it possible to identify significant numbers of unexplored prospects, for which a minimal amount of field reconnaissance can be used to rank and highlight those that are most attractive.

Background

Two types of high-temperature geothermal systems are recognized in the Great Basin: the "magmatic-type" which occur on the margins of the Great Basin (e.g., Long Valley caldera), and the "extensional-type", which are "amagmatic" and occur within the interior of the Great Basin (e.g., Dixie Valley; Koenig and McNitt, 1983; Wisian, et. al., 1999). The locations of "magmatic"-type geothermal systems are relatively easy to predict because they are closely associated with young silicic volcanics. In contrast, the extensional-type systems are more difficult to find because they occur over large areas both inside and marginal to the Great Basin, and they often lack significant surface expressions such as hot springs or fumaroles. A preliminary analysis by Coolbaugh and Shevenell (2004) suggests that total undiscovered geothermal resources in the Great Basin are several times the currently developed resources.

Many disparate types of evidence can be used to help signal the location of a geothermal system. These include the location, orientation, and slip rates of Quaternary faults, regional heat-flux anomalies, crustal strain rates as measured geodetically with GPS stations, anomalous groundwater chemistry, earthquake seismicity, young volcanism, and hydrothermal alteration. A GIS can be used to draw these diverse types of information together and quantitatively assess which types of evidence correlate with each other, and which combinations of evidence correlate best with geothermal activity on a regional basis. Ultimately, this evidence can be integrated to identify regions of greater exploration potential, based not only on where geologic conditions are favorable, but also on a determination of which areas are most likely to conceal subsurface geothermal activity and which areas have not been fully explored.

Significant progress has been made in the last few years compiling digital geothermal data and making it available on the web site of the Great Basin Center for Geothermal Energy (GBCGE) for dissemination to geothermal exploration companies, the public, and other interested stakeholders. The current web site includes an interactive map server and separate pages for ftp-based downloads of digital map data (http://www.unr.edu/geothermal/). Spatial statistical analyses have been used to generate geothermal favorability maps covering Nevada and the Great Basin (Coolbaugh et al., 2002, 2003, 2005a). Similar spatial analysis of that same digital data has led to an increased understanding of the factors controlling the location and occurrence of high-temperature geothermal systems in the Great Basin (Coolbaugh, 2003; Coolbaugh et al., 2002, 2003). Correlations and relationships identified during that analysis has helped seed several new research projects, including the regional analysis of GPS-based geodetic measurements of crustal strain to target geothermal potential (Blewitt et al., 2002, 2003; Kreemer et al., 2004) and the use of fluid geochemistry to identify potential magmatic sources of heat in Great Basin geothermal systems (Arehart et al., 2002, 2003). Related research, in progress now, is clarifying a link between high temperature geothermal systems and the formation of economic gold deposits in the Great Basin (Coolbaugh et al., 2005b). But, more importantly, sufficient information is now being assembled to allow estimation of hidden and undiscovered geothermal systems in the Great Basin, as illustrated by a pilot project recently completed for the state of Nevada (Coolbaugh and Shevenell, 2004).

Project Rationale

The proposed new research would take advantage of the geothermal GIS database developed over the last 3 years, and forge ahead in several new directions, with the overall goal of significantly impacting the level of grass-roots exploration for geothermal resources.

Four primary objectives, restated here, will guide the research:

1) develop significantly improved geothermal favorability maps of the Great Basin using rapidly evolving and improved digital data on crustal strain, fault displacements, heat flux, and other data;

2) predict where hidden and undiscovered geothermal systems are most likely to occur, based not only on where geothermal favorability is high (see 1 above) but also on predictions of where geothermal systems are most likely to remain hidden below the surface, and on maps showing which areas have been explored the most thoroughly already;

3) using maps generated in steps 1 and 2 above, generate a list of worthy grass-roots exploration prospects in the Great Basin, conduct a minimum amount of reconnaissance ground-truthing to verify exploration favorability, and promote/advertise these prospects to industry to help jump-start grass-roots geothermal exploration; and,

4) significantly expand the breadth and capabilities of the GBCGE web site.

These objectives will help meet the goal of increasing geothermal utilization, by:

1) Making diverse types of supporting data on geothermal systems readily available digitally to industry to support their exploration and development efforts,
2) Helping to revitalize grass-roots exploration by highlighting areas with good geothermal potential that have not yet been adequately explored, and,
3) Allowing integration of new research data into the GIS so that relationships with other variables can be quantitatively assessed, to understand better why geothermal systems occur where they do,

Proposed Research and Methods

The proposed research is divided into four main steps (summarized above), which are sequentially discussed below:

Improved geothermal favorability maps: A map of geothermal favorability for the Great Basin, presented at a workshop at UNR in November 2004 (and which is in the process of being published), illustrates the increased level of detail that regional predictive geothermal maps are now capable of achieving. Significantly improved versions of the map would be producible soon because of rapid improvements to the input data used to produce it. This input data includes regional maps of crustal strain derived from GPS stations, maps of Quaternary faults and their slip rates, and maps of heat flux and temperature gradients in the earth's crust. The science of interpolating GPS-station-based velocity measurements is rapidly evolving, and new methods of integrating slip rate data from Quaternary faults and earthquakes are being developed to help constrain and focus the interpolation of GPS-derived strain rate data. In addition, regional gravity gradient maps were recently identified as a key tool (Coolbaugh et al., 2005a) for geothermal modeling, and additional gravity surveys will be sought to augment the maps.

Prediction of hidden and undiscovered geothermal systems: Even if some areas in the Great Basin represent highly favorable environments for high-temperature geothermal systems, it is possible that no new geothermal systems may be found in those areas if past exploration efforts have been sufficiently thorough. Similarly, some portions of the Great Basin may be more likely to harbor concealed geothermal systems (those without active surface expressions) than others, based on the presence of cap rocks, deep water tables, or highly permeable aquifers. A pilot research project by Coolbaugh and Shevenell (2004) recently demonstrated the feasibility of producing map-based estimates of undiscovered geothermal systems, by combining geothermal favorability maps with estimates of the degree of exploration (based in part on where wells have been drilled) and estimates of where concealed geothermal systems were most likely to occur. That pilot project was limited to the state of Nevada. This proposal would extend the analysis to include the entire Great Basin. Because this analysis focuses on assessing the potential for geothermal resources on a regional basis (ie., grass-roots exploration, or exploration for undiscovered geothermal systems), it would augment plans by the USGS to assess the geothermal potential in *known geothermal resources areas* of the United States. In some cases, particularly the state of California, the lack of public availability of water well records could limit the analysis.

Identification of grass-roots exploration prospects: To help revitalize grass-roots exploration for geothermal resources in areas outside known geothermal systems, a list of attractive geothermal prospects identified by the geothermal GIS modeling will be prepared and presented to the public. A recent map of geothermal favorability for the Great Basin (Coolbaugh et al., 2005a) recently demonstrated the feasibility of identifying many such prospects based on a coincidence of favorable geologic factors and lack of previous exploration. Areas identified as favorable on the predictive maps would be reviewed and field-checked. Such a review would include a search for evidence of previous drilling, and a field examination to look for past or presence geothermal activity and evidence of recent faulting and a favorable structural environment. With the assistance of sister research projects, available springs and wells would be sampled to determine fluid geothermometer temperatures, and down-hole temperatures may be measured to determine temperature gradients and heat flux. The objective would be to conduct the minimum amount of field checking necessary to demonstrate the viability (or non-viability) of the identified exploration targets, so that the geothermal industry has enough information to encourage action, in the form of increased exploration and leasing activity.

Expansion of the Great Basin Center's web site The expansion and improvement of an interactive web site for Great Basin geothermal data remains a key part of the proposed research. Reflecting that commitment, a new GIS researcher has been hired, Richard Zehner, whose major responsibility is GBCGE web site development. Specific web-related projects budgeted for the next two years include:

a) Posting of new digital data to the web site: A large amount of data potentially useful in geothermal exploration is being compiled from -both inside and outside the GBCGE. Great Basin Center data includes a new regional compilation of Quaternary faults, new strain rate data sets derived from geodetic (GPS) measurements, updated compilations of gravity and magnetic data, groundwater fluid and gas geochemical data, and favorability maps. Data from outside sources that can be modified for use in geothermal exploration include water well and depth to water table data, oil and gas well information, mineral exploration drill hole data, and BLM lease information (see below). Detailed geothermal GIS databases covering individual geothermal systems of the Great Basin, assembled by the Idaho National Laboratory, will also be added to the web site as they become available.

b) Improving the interactive map capabilities of the web site: The spatial data is being migrated to a relational database on a fast server which will facilitate downloads. The current web site of the GBCGE features interactive maps that enable the visitor to view and move around the map, select layers and table attributes, print the map, and download data layers. We plan to build multiple interactive map sites to serve regional and local data as well as the results of the GIS favorability modeling. Finally, new web-based data-server software are becoming available that have the potential for significantly improving the speed and efficiency of web-based data manipulation, examination, and downloading. A review of available server options will be made to determine their value, and if warranted, the web site will be migrated to the new platform.

c) Addition of BLM lease and application data: The BLM has agreed to provide current geothermal lease and application data to the GBCGE along with other files, such as federal lands open to geothermal exploration. A new section of the GBCGE web site will be devoted to this data, and links directly to BLM application pages will allow for "one stop shopping". These layers will also be added to the interactive geothermal GIS pages, allowing the user to evaluate exploration data with lease activity and land status to determine availability.

d) Addition of a "help desk" or "user forum" where a panel of scientists, regulators, and drillers will be available to answer questions from the geothermal community, and to provide a mechanism for discussion current geothermal energy issues: The feasibility of adding a help desk or forum to the web site will be investigated.

Available Resources

This project is a broad collaborative effort of many individuals from multiple institutions, including the Great Basin Center for Geothermal Energy, the Nevada Geodetic Laboratory, the Arthur Brant Laboratory for Exploration Geophysics, the University of Nevada, Reno (UNR), the Nevada Bureau of Mines and Geology (NBMG), the Southern Methodist University Geothermal Laboratory, and the United States Geological Survey (USGS). Although it is expected that each collaborator will provide insights into all phases of the research, the work is divided into tasks into which the collaborators will contribute specific expertise. Mark Coolbaugh will serve as overall principal investigator (PI), and has 4 years of experience specializing in the creation of geothermal GIS databases and analyzing them with spatial statistics. Rick Zehner also has a spatial statistical background, as well as training in the management of large databases and web-based data access, and he will manage the growth of geothermal data server on the web site. Gary Raines teaches graduate-level courses in geospatial analysis, and will serve as a statistical advisor for the project. Don Sawatzky provides computer-programming skills for solving unique data analysis problems. Jim Taranik was the original PI when this research project first began 3 years ago, and has recently been researching alternative means of digital data analysis and web-based data servers. With his industry and academic leadership background, he is in a unique position at UNR to assess the effect of, and to effectuate, possible changes in web-based data servers. Lisa Shevenell provides a strong background in geothermal energy and the geochemistry of geothermal systems, which are important for the correct statistical evaluation of the data.

In terms of the collection and interpretation of digital data, Corné Kreemer, David Blackwell, and Gary Oppliger provide state-of-the art expertise in their respective fields of geodesy, heat flow analysis, and gravity/magnetic geophysical data. Corné Kreemer works with Geoff Blewitt and Bill Hammond at the Nevada Geodetics Laboratory, where they are developing new methods of interpreting crustal strain from GPS-derived geodetic data and integrating that data with strain rates estimated from active faults. David Blackwell is creating new and improved heat flow and derivative temperature maps of the western United States, and is also developing innovative methods of analyzing and interpreting heat flow data.

The field checking of favorable geothermal areas will be conducted by Mark Coolbaugh and Rick Zehner, with consultative assistance from the other investigators. Mark Coolbaugh has mapped the surface geothermal features of many modern and paleo-geothermal systems in detail. Jim Faulds will provide guidance in the reconnaissance structural interpretation of favorable areas. David Blackwell will provide expertise in interpretation and acquisition of temperature gradient data. Lisa Shevenell will provide a geochemical background for obtaining fluid geochemical data and calculating geothermometer temperatures.

More details on the qualifications of each of the investigators can be found in the biographies provided with this proposal.

DELIVERABLES

Deliverables will include:

1) Updated predictive maps of geothermal potential for the entire Great Basin. These maps will be based on the latest geophysical, geochemical, and geological data. Interactive versions of these maps will be made available for viewing and downloading at the GBCGE web site.
2) A map predicting where geothermal systems are most likely to remain undiscovered in the Great Basin. This map will differ from maps discussed in the preceding paragraph, because they will consider where exploration has been focused in the past, and they will be based in part on models predicting where geothermal fluids are prevented from reaching the surface to form hot springs. Interactive versions of these maps will be made available for viewing and downloading at the GBCGE web site.
3) As much of the geothermal GIS database as is possible will be posted on the web site of the GBCGE. Some data will be proprietary and can't be posted (data generated by other research organizations or industry), and for some data, links will direct the public to other web sites, such as, for example, the Southern Methodist University site for heat flow data. However, the majority of the data can be uploaded. Where possible, agreements will be made with sister research organizations to allow sharing and posting of geothermal data.
4) A list and map of favorable targets where concealed geothermal systems could exist in the Great Basin will be prepared and publicized, together with a description of why those areas appear favorable, and why they might not have been discovered already. This list and map will be based on the predictive maps described above, and the favorable sites will have been field-checked.
5) Papers discussing results of the geothermal GIS research will be submitted to the Geothermal Resources Council (GRC) for publication in their annual proceedings in 2005 and 2006. Other talks and papers may be presented as appropriate.
6) A final report describing the significant results of the geothermal GIS research will be submitted for publication at the end of each research year.
7) All required quarterly and annual reports would be submitted to the GBCGE and/or Department of Energy.

PREVIOUS YEAR'S RESULTS

Project Objectives: The objectives of the last two years of research were to 1) integrate and evaluate new geothermal data developed by the GBCGE and other sources into a GIS, 2) regionally assess the potential for both magmatic and extensional-type geothermal systems throughout the Great Basin, 3) evaluate and quantify regional relationships between geothermal activity and geological, geochemical, and geophysical features, and 4) make digital geothermal data of the Great Basin accessible to geothermal developers, researchers, and the public.

Research Benefits: Major accomplishments during the last two years are listed below:

1) Geothermal Web Site: The web site of the GBCGE (http://www.unr.edu/geothermal/) was significantly expanded over the last two years to include new geological, geochemical, and geophysical data. That new data includes fluid geochemical data (including geothermometer temperature estimates and charge balance calculations) obtained in collaboration with the Geo-Heat Center. Also included (before the end of the current research year) are regional crustal strain rate maps calculated from geodetic estimates of GPS station velocities. In cooperation with the Idaho National Laboratory, detailed site-specific geothermal GIS databases are being added to the GBCGE web site. A large number of other geographic, geophysical, geochemical, and geological data have also been incorporated. An interactive maps section of the web site was created to allow the user to select and display map information of interest before deciding which data to download.

2) Predictive Maps of Geothermal Potential for the Great Basin: A new map of geothermal favorability for both extensional and magmatic-heated geothermal systems of the Great Basin (Coolbaugh et al., 2005a) was presented at a November 2004 workshop at UNR and is scheduled to be published through the NBMG before the end of the current year of funding. That map depicts high-temperature geothermal favorability in more detail than previously available and reveals a number of potentially significant targets for follow-up exploration.

3) Undiscovered Geothermal Systems: In a preliminary study involving the state of Nevada, undiscovered geothermal resources were estimated to be several times the current known reserves (Coolbaugh and Shevenell, 2004), demonstrating that grass-roots geothermal exploration still has the potential for identifying hitherto unknown geothermal systems. The estimate was made possible by combining maps of geothermal favorability with maps that estimate the extent of previous geothermal exploration and the ability of geothermal systems to remain concealed.

4) Regional Relationships between Geothermal Activity and Geological, Geochemical, and Geophysical Features: During the construction of geothermal favorability maps of the Great Basin, a regional correlation between gravity gradients and geothermal activity was verified and quantified (Coolbaugh et al., 2005a). Although others had observed this relationship previously, it had not been graphically documented or quantified at such a combination of regional and local scales. In areas in the Great Basin where this relationship does not hold up as well, it is now recognized that different geological forces influence geothermal favorability (Coolbaugh et al., 2005b). In other words, knowledge of where to look for range-front type geothermal systems and where not to look for them, is important in geothermal exploration.

Dramatic improvements have been obtained in the resolution of maps depicting the amount of crustal extension throughout the Great Basin. Strain rates based on Quaternary fault slip rates and strain rates based on geodetic measurements are being combined together to better predict geothermal activity (Coolbaugh et al., 2005a). The modeling of crustal extension rates is an active area of research under this project, and significant near-future improvements are expected.

During the two years that have passed since the submission of the last proposal, this research project earned two "best of session" awards; one at each of the last two annual meetings of the Geothermal Resources Council. In the summer of 2003, this research was ranked first out of 11 DOE-sponsored geothermal science research projects in a peer-review meeting in Golden, CO.

Reports & Articles Published During the Last Two Years of Research:

Coolbaugh, M.F., 2003, The Prediction and Detection of Geothermal Systems at Regional and Local Scales in Nevada using a Geographic Information System, Spatial Statistics, and Thermal Infrared Imagery: Ph.D. dissertation, Reno, Nevada, University of Nevada, Reno, USA, 172 p.

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: Proceedings, Annual Meeting, Morelia, Mexico, Oct. 12-15, 2003, Geothermal Resources Council Transactions, v. 27, p. 9-13. (Won GRC session best paper award)

Coolbaugh, M.F. and Shevenell, L.A., 2004, A method for estimating undiscovered geothermal resources in Nevada and the Great Basin: Proceedings, Annual Meeting, Palm Springs, CA, Aug. 29-Sep. 1, 2004, Geothermal Resources Council Transactions, v. 28, p. 13-18. (Won GRC session best paper award)

Coolbaugh, M.F., Sladek, C., and Kratt, C., 2004, Digital mapping of structurally controlled geothermal features with GPS units and pocket computers: Proceedings, Annual Meeting, Palm Springs, CA, Aug. 29-Sep. 1, 2004, Geothermal Resources Council Transactions, v. 28, p. 321-325.

Coolbaugh, M.F., Zehner, R., Kreemer, K., Blackwell, D., Oppliger, G., Sawatzky, D., Blewitt, G., Pancha, A., Richards, M., Helm-Clark, C., Shevenell, L., Raines, G., Johnson, G., and Minor, T., 2005a, Preliminary Geothermal Potential Map, Great Basin: Map to be published through the Nevada Bureau of Mines and Geology.

Coolbaugh, M.F., Arehart, G.B., Faulds, J.E., and Garside, L.J., 2005b, Geothermal systems in the Great Basin: modern analogues to the roles of magmatism, structure, and regional tectonics in the formation of mineral deposits; *in* Symposium 2005 – Window to the World: Geological Society of Nevada Symposium Proceedings, May 11-21, 2005, *under review*.

Faulds, J.E., 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: Proceedings, Annual Meeting, Palm Springs, CA, Aug. 29-Sep. 1, 2004, Geothermal Resources Council Transactions, v. 28, p. 649-654.

Shevenell, L., Coolbaugh, M., Faulds, J., Oppliger, G., Calvin, W., Louie, J., Blewitt, G., Kratt, C., Arehart, G., Sladek, C., Lechler, P., and Garside, L., 2004, Accomplishments at the Great Basin Center for Geothermal Energy: Proceedings, Annual Meeting, Palm Springs, CA, Aug. 29-Sep. 1, 2004, Geothermal Resources Council Transactions, v. 28, p. 47-51.

Presentations Made in During the Last Two Years of Research:

Blewitt, G., Coolbaugh, M., Sawatzky, D., Holt, W., Davis, J., and Bennett, R., 2003, Targeting of potential geothermal resources in the Great Basin from regional to basin-scale relationships between geodetic strain and geological structures: Proceedings, Annual Meeting, Morelia, Mexico., Oct. 12-15, 2003, Geothermal Resources Council Transactions, v. 27, p. 3-7.

Coolbaugh, M.F., 2003, Regional Assessment of Exploration Potential for Geothermal Systems in Nevada using a GIS: U.S. Department of Energy Geothermal Technologies Program Annual Peer Review Report: Golden, CO., July 31, 2003.

Coolbaugh, M.F., 2004, Regional prediction of geothermal systems in Nevada using spatial analysis in a GIS. Presented as part of a USGS workshop on software for spatial analysis in a GIS, Reno, NV., Aug. 14, 2003.

Coolbaugh, M.F. (and Shevenell, L.A.), 2004a, Overview of Nevada's geothermal resources: presentation to the Alaska-Nevada Trade Mission, Reno, Nevada; sponsored by the Nevada Division of Minerals, Peppermill Hotel, Reno, Nevada, June 9-11, 2004.

Coolbaugh, M.F. (and Shevenell, L.A.), 2004b, A method for estimating undiscovered geothermal resources in Nevada and the Great Basin: Basin and Range I Session, Annual Meeting, Palm Springs, CA, Aug. 29-Sep. 1, 2004.

Coolbaugh, M.F., (and Sawatzky, D.L., Oppliger, G.L., Minor, T.B., Raines, G.L., Shevenell, L.A., Blewitt, G., and Louie, J.N.), 2003a, Geothermal GIS coverage of the Great Basin, USA: Defining regional controls and favorable exploration terrains: Basin and Range Session, Annual Meeting, Morelia, Mexico, Oct. 12-15, 2003.

Coolbaugh, M. (and Raines, G., Sawatzky, D., Blewitt, G., Bedell, R., Shevenell, L., Minor, T., and Taranik, J.), 2003b, Predicciónes regiónales para buscar a las aguas termales subterráneas en Nevada USA con análisis espacial por medio de SIG (sistemas de información geográficos); presentation to the Institute for Scientific and Technological Research of San Luis Potosi, San Luis Potosi, Mexico, Oct. 17, 2003.

Coolbaugh, M. (and Faulds, J., Blewitt, G., and Henry, C.), 2004a, Geothermal Activity: Another Clue for Unraveling Recent Great Basin Tectonics: presentation at GreatBreak Earthscope Workshop; in conjunction with Nevada Seismological Laboratory; Tahoe City, CA., June 21-23, 2004.

Coolbaugh, M.F. (and Sladek, C., and Kratt, C.), 2004b, Digital mapping of structurally controlled geothermal features with GPS units and pocket computers: Exploration – New Fields Session, Annual Meeting, Palm Springs, CA, Aug. 29-Sep. 1, 2004.

Coolbaugh, M.F. (and Zehner, R., Kreemer, K., Blackwell, D., Oppliger, G., Sawatzky, D., Blewitt, G., Pancha, A., Richards, M., Helm-Clark, C., Shevenell, L., Raines, G., Johnson, G., and Minor, T.), 2004c, Preliminary Geothermal Potential Map, Great Basin; presentation at Great Basin Center for Geothermal Energy November 5, 2004 Workshop.

Shevenell, L. (and Coolbaugh, M., Faulds, J., Oppliger, G., Calvin, W., Louie, J., Blewitt, G., Kratt, C., Arehart, G., Sladek, C., Lechler, P., and Garside, L.), 2004, Accomplishments at the Great Basin Center for Geothermal Energy: Basin and Range I Session, Annual Meeting, Palm Springs, CA, Aug. 29-Sep. 1, 2004.

LIST OF REFERENCES

Arehart, G.B., Coolbaugh, M.F., and Poulson, S.R., 2002, Geochemical characterization of geothermal systems in the Great Basin: implications for exploration, exploitation, and environmental issues: Proceedings, Annual Meeting, Reno, NV., Sept. 22-25, 2002, Geothermal Resources Council Transactions, v. 26, p. 479-481.

Arehart, G., Coolbaugh, M.F., and Poulson, S.R., 2003, Evidence for a magmatic source of heat for the Steamboat Springs geothermal system using trace elements and gas geochemistry: Proceedings, Annual Meeting, Morelia, Mexico, Oct. 12-15, 2003, Geothermal Resources Council Transactions, v. 27, p. 269-274.

Blewitt, G., Coolbaugh, M.F., Holt, W., Kreemer, C., Davis, J.L., and Bennett, R.A., 2002, Targeting of potential geothermal resources in the Great Basin from regional relationships between geodetic strain and geological structures: Proceedings, Annual Meeting, Reno, NV., Sept. 22-25, 2002, Geothermal Resources Council Transactions, v. 26, p. 523-525.

Blewitt, G., Coolbaugh, M., Sawatzky, D., Holt, W., Davis, J., and Bennett, R., 2003, Targeting of potential geothermal resources in the Great Basin from regional to basin-scale relationships between geodetic strain and geological structures: Proceedings, Annual Meeting, Morelia, Mexico., Oct. 12-15, 2003, Geothermal Resources Council Transactions, v. 27, p. 3-7.

Coolbaugh, M.F., 2003, The Prediction and Detection of Geothermal Systems at Regional and Local Scales in Nevada using a Geographic Information System, Spatial Statistics, and Thermal Infrared Imagery: Ph.D. dissertation, Reno, Nevada, University of Nevada, Reno, USA, 172 p.

Coolbaugh, M.F. and Shevenell, L.A., 2004, A method for estimating undiscovered geothermal resources in Nevada and the Great Basin: Proceedings, Annual Meeting, Palm Springs, CA, Aug. 29-Sep. 1, 2004, Geothermal Resources Council Transactions, v. 28, p. 13-18.

Coolbaugh, M.F., Taranik, J.V., Raines, G.L., Shevenell, L.A., Sawatzky, D.L., Minor, T.B., and Bedell, R., 2002, A geothermal GIS for Nevada: defining regional controls and favorable exploration terrains for extensional geothermal systems; Proceedings, Annual Meeting, Reno, NV., Sept. 22-25, 2002, Geothermal Resources Council Transactions, v. 26, p. 485-490.

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: Proceedings, Annual Meeting, Morelia, Mexico, Oct. 12-15, 2003, Geothermal Resources Council Transactions, v. 27, p. 9-13.

Coolbaugh, M.F., Zehner, R., Kreemer, K., Blackwell, D., Oppliger, G., Sawatzky, D., Blewitt, G., Pancha, A., Richards, M., Helm-Clark, C., Shevenell, L., Raines, G., Johnson, G., and Minor, T., 2005a, Preliminary Geothermal Potential Map, Great Basin: Map to be published through the Nevada Bureau of Mines and Geology.

Coolbaugh, M.F., Arehart, G.B., Faulds, J.E., and Garside, L.J., 2005b, Geothermal systems in the Great Basin: modern analogues to the roles of magmatism, structure, and regional tectonics in the formation of mineral deposits; *in* Symposium 2005 – Window to the World: Geological Society of Nevada Symposium Proceedings, May 11-21, 2005, *under review*.

Koenig, J.B. and McNitt, J.R., 1983, Controls on the location and intensity of magmatic and non-magmatic geothermal systems in the Basin and Range province: Geothermal Resources Council Special Report No. 13, May 1983, p. 93.

Kreemer, C., G. Blewitt, B., Hammond, W.C., and Coolbaugh, M.F., 2004, A new strain rate model for the Great Basin and its application to tectonic and geodynamic studies; Eos Trans., AGU 85(47), Fall Meet. Suppl., Abstract G31D-06.

Wisian, K.W., Blackwell, D.D., and Richards, M., 1999, Heat flow in the western United States and extensional geothermal systems: Proceedings, 24th Workshop on Geothermal Reservoir Engineering, Stanford, CA., p. 219-226.

MILESTONES*

Submission of paper for annual GRC meeting 2005:	May 13, 2005
Publish preliminary geothermal potential map of Great Basin:	June 30, 2005
Presentation of preliminary results, GRC annual meeting:	Sept. 28, 2005
Completion of preliminary report to determine optimal web server:	Oct. 31, 2005
Posting of geothermal GIS data on web:	ongoing
Updating GIS with new GIS data:	ongoing
Completion of report discussing year 2005 research results	Dec. 31, 2005
Completion of assessment report to determine optimal web server:	Mar. 31, 2006
Submission of paper for annual GRC meeting 2006:	May 31, 2006
Presentation of interim results, GRC annual meeting:	Sept. 28, 2006
Creation of 1st year predictive geothermal maps for Great Basin:	Nov. 15, 2006
Creation of 1st year "undiscovered resources" maps for Great Basin:	Nov. 15, 2006
Completion of final report discussing 1st year research results	Dec. 31, 2006
Installation of new web server software platform (if recommended)	Mar. 31, 2007
Submission of paper for annual GRC meeting 2007:	May 31, 2007
Presentation of final research results, GRC annual meeting:	Sept. 28, 2007
Publish updated geothermal potential maps of Great Basin:	Oct. 31, 2007
Completion of updated "undiscovered resources" maps for Great Basin	Oct. 31, 2007
Completion of final report discussing 2nd year research results	Dec. 31, 2007

*All reports and presentations listed under milestones will discuss grass-roots exploration potential.

BUDGET EXPLANATION AND JUSTIFICATION

Salaries: M. Coolbaugh will provide overall project management, coordinate with other researchers and organizations, and will generate statistical analyses and maps of geothermal resource potential. Rick Zehner will focus on web improvements, expansions, and updates, and will also assist with creating geothermal resource maps. Corné Kreemer, David Blackwell, and Gary Oppliger provide state-of-the art expertise in providing digital data from their respective fields of geodesy, heat flow analysis, and gravity/magnetic geophysical data. Corné Kreemer's time is provided through a cooperative understanding between the geothermal GIS project and the geodetics project. Don Sawatzky will provide computer-programming skills for creating new data analysis methods. Lisa Shevenell will provide interpretive guidance with geochemical geothermometers and other geothermal issues. Gary Raines, fully funded through the USGS, will provide an advisory role in GIS spatial statistics and will help provide digital geologic maps of the Great Basin. Jim Taranik will assist in evaluating alternative web data server engines as a possible replacement for ArcIMS. Jim Faulds will assist with reconnaissance structural interpretations of favorable geothermal targets. Graduate students will be used to assist with field work and creation of digital data sets. Additional details on the roles of individual researchers can be found in the preceding section on "Available Resources".

Field Work: Vehicle mileage and per diem will cover the costs of field checking anomalies generated by the predictive maps of geothermal potential.

Meeting Registration: These funds will help defray the costs of presenting results of the geothermal GIS research at one meeting per year.

Consulting, David Blackwell: David Blackwell will provide expertise and assistance in developing heat flow and temperature gradient maps of the Great Basin.

BIOGRAPHICAL SKETCHES

(see next page)

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 on modern geothermal systems using a GIS, spatial statistics, remote sensing, aqueous and gas geochemistry, and GPS-based crustal strain measurements. (For more detail, see research projects listed below.)

Research Assistant and Teaching Assistant, August 1998 – March 2002
Arthur Brant Laboratory for Exploration Geophysics, Dept. of Geological Sciences, UNR. Dissertation research develops geothermal and mineral exploration models using a GIS, spatial statistics (weights-of-evidence and logistic regression), and remote sensing imagery (including ASTER, TIMS, and AVIRIS). Additional research included the use of a GIS to assess natural sources of mercury to the atmosphere.

Exploration Manager – Mongolia, September 1996 - February 1998
Cascadia Chemicals & Minerals Corp., Ulaanbaatar, Mongolia
Developed and managed all corporate exploration programs for copper and gold.

Research Assistant and Teaching Assistant, **July 1995 - August 1996**
University of British Columbia, Vancouver, B.C., Canada
Development of new lithogeochemical exploration tools in the search for mineral deposits, particularly Carlin-type, sediment-hosted gold deposits.

Chief Geologist, April 1994 - June 1995
Carson Gold Corp., Vancouver, B. C., Canada
Designed and managed all corporate overseas exploration programs, with projects in South and Central America, the Philippines, and Mongolia.

Senior Exploration Geologist/Geological Engineer, November 1991 - January 1994
Coeur Rochester, Inc., Lovelock, Nevada, USA
Development of district-wide gold exploration program. Assistance with open-pit mine geology, ore control, and engineering.

Consultant, February 1991 - October 1991
Mine and Exploration Services, Monte Vista, Colorado, USA
Mine permitting and compliance issues, exploration programs, production geology, and ore reserve development.

Chief Geologist/Manager/Senior Geologist, June 1984 - January 1991
Summitville Consolidated Mining Co., Inc., Del Norte, Colorado, USA
Supervision of mine geology and exploration departments responsible for development of ore reserves, open-pit ore control, regional exploration, and land acquisition.

Geologist, **June 1983 - June 1984**
Pegasus Gold Corporation, Reno, Nevada, USA
Management of district exploration program.

Associate Geologist, **June 1980 - Dec. 1982, summers of 1977 - 1979**
Climax Molybdenum Co., div. of AMAX, Golden, Colorado, USA
Geologic mapping and field work for molybdenum exploration and mining.

Underground Motorman’s Assistant, **June 1976 - September 1976**

ASARCO, Inc., Leadville, Colorado, USA
Track haulage of ore, equipment, and supplies in an underground lead-zinc-silver mine.

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*.

Coolbaugh, M.F., Arehart, G.B., Faulds, J.E., and Garside, L.J., 2005, Geothermal systems in the Great Basin: modern analogues to the roles of magmatism, structure, and regional tectonics in the formation of mineral deposits; *in* Geological Society of Nevada Symposium Proceedings, May 11-21, 2005, *under review*.

Coolbaugh, M. F., Gustin, M. S., and Rytuba, J. J., 2002, Annual emissions of mercury to the atmosphere from natural sources in Nevada and California: Environmental Geology, v. 42, n. 4., p. 338-349.

Coolbaugh, M.F. and Shevenell, L.A., 2004, A method for estimating undiscovered geothermal resources in Nevada and the Great Basin: Proceedings, Annual Meeting, Palm Springs, CA, Aug. 29-Sep. 1, 2004, Geothermal Resources Council Transactions, v. 28, p. 13-18.

Coolbaugh, M. F., Taranik, J. V., and Kruse, F. A., 2000, Mapping of surface geothermal anomalies at Steamboat Springs, NV. using NASA Thermal Infrared Multispectral Scanner (TIMS) and Advanced Visible and Infrared Imaging Spectrometer (AVIRIS) data; *In:* Proceedings, 14th Thematic Conference, Applied Geologic Remote Sensing, Environmental Research Institute of Michigan (ERIM), Ann Arbor, MI., p. 623-630.

Coolbaugh, M. F. and Stanley, C. R., 1996, A lithogeochemical evaluation of feldspar hydrolysis, decarbonatization and jasperoid alteration from the Jerritt Canyon district, Nevada, using Pearce element ratio analysis; Technical Document #11, MDRU Lithogeochemical Exploration Research Project, Annual Technical Report, year 1, Dept. of Geol. Sciences, University of British Columbia.

Gray, J. E., and Coolbaugh, M. F., 1994, Geology and geochemistry of Summitville, Colorado: An epithermal acid sulfate deposit in a volcanic dome: Economic Geology, Special Issue on Volcanic Centers as Targets for Mineral Exploration, v. 89, no. 8, p. 1906-1923.

Gray, J. E., Coolbaugh, M.F., Plumlee, G. S., and Atkinson, W. W., 1994, Environmental geology of the Summitville Mine, Colorado: Economic Geology, Special Issue on Volcanic Centers as Targets for Mineral Exploration, v. 89, no. 8, p. 2006-2014.

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.

Richard E. Zehner
Research Scientist/Assistant GIS Specialist
Great Basin Center for Geothermal Energy
MS 172, University of Nevada, Reno
775-784-7055 zehner@unr.edu

Education

University of Montana	Geology	M.S. 1987
University of California, Santa Cruz	Earth Sciences	B.S. 1978

Profession Experience

Research Scientist/Assistant GIS Specialist, July 2004 to present
Great Basin Center for Geothermal Energy, University of Nevada, Reno: Research focusing on identifying active high-temperature geothermal systems in the Great Basin through various GIS modeling approaches, design and implementation of GBCGE web site.

Research Analyst, February 2000 to June 2004
College of Agriculture, Biotechnology, and Natural Sciences, UNR: Laboratory and field research of mercury emissions from natural and anthropogenic sources. Modeling of climatic and geologic controls controlling mercury emission using GIS.

Project Manager, February 1998 to January 1999
Kinross Gold Corporation, central Idaho: Mineral resource assessment, deposit modeling, and core drill program focused on two epithermal gold deposits

Project Manager/Senior Geologist, January 1994 to February 1998
Cyprus Amax Exploration, Sparks, Nevada: Reconnaissance gold exploration and definition drilling of epithermal gold deposits in Nevada and Idaho. Developed exploration model for identifying Fort Knox style gold porphyry systems. Supervised +$1 million exploration program and up to 20 individuals

Geologist, May 1986 to January 1994
Amax Gold Exploration, Inc. Designed and implemented reconnaissance gold exploration and drilling programs in Nevada, Oregon, Idaho, Yukon, and California

Geologist, May 1978 to August, 1983
U.S. Geological Survey Branch of Alaskan Geology. Conducted field mapping and mineral resource assessments of the central Alaska Range and central Sierra Nevada.

Current Obligations

Approximately 50% of my time is devoted to enlarging and enhancing the Great Basin Center web site at http://www.unr.edu/Geothermal .

Selected Publications

Gustin, M.S., Coolbaugh, M,F., Engle, M.A., Fitzgerald, B.C., Keislar, R.E., Lindberg, S.E., Nacht D.M., Quashnick, J., Rytuba, J.J., Sladek, C., Zhang, H., and Zehner, R.E., 2003. Atmospheric mercury emissions from mine wastes and surrounding geologically enriched terranes. Environmental Geology 43, pp. 339-351.

Gustin, M.S., Ladwig, Ken, Xin, Mei, and Zehner, Richard, 2004. An Assessment of the significance of mercury release from coal fly ash. 7th International Conference on Mercury as a Global Pollutant, June 2004, Ljubljana, Slovenia.

Gustin, M.S., Zehner, R.E., and Obrist, D., 2004. Experimental examination of the influence of precipitation and moisture content on mercury emissions from soils. 7th International Conference on Mercury as a Global Pollutant, June 2004, Ljubljana, Slovenia.

Lange, I.M., and Zehner, R.E., 1992. Geological map of the Hog Heaven volcanic field, scale 1:50,000, accompanying 16 pg. text. Montana Bureau of Mines and Geology Map 53.

Lange, I.M., Zehner, R.E., and Hahn, G.A., 1994. Geology, geochemistry, and ore deposits of the Oligocene Hog Heaven volcanic field, northwestern Montana. Economic Geology 89:8, p. 1939-1963.

Nacht, D.M., Gustin, M.S., Engle, M.A., Zehner, R.E., and Giglini, A.D., 2004. Atmospheric mercury emissions and speciation at the Sulphur Bank Mercury Mine Superfund Site, Northern California. Environmental Science and Technology 38, pp. 1977-1983.

Zehner, R.E., and Gustin, M.S., 2003, Modeling mercury vapor flux from natural rocks and soils in Nevada. Nevada GIS 2003 Annual Meeting.

Zehner, R.E., Gustin, M.S., and Rytuba, J.J., 2003. Quantifying mercury emissions from base and precious metal deposits and oil and gas fields. In Proceedings of the Air and Waste Management Association's 96th Annual Conference & Exhibition, San Diego, CA, Paper No. 69220.

Zehner, R.E. and Gustin, M.S., 2002. Estimation of mercury vapor flux from natural substrate in Nevada. Environmental Science and Technology 36, pp. 4039-4045.

Zehner, R.E., and Gustin, M.S., 2000. Estimation of mercury vapor flux from natural geologic sources in Nevada. U.S. EPA Office of Research and Development extended abstract volume, Assessing and managing mercury from historic and current mining activities, pp. 135-140.

CURRICULUM VITAE

CORNELIS W. KREEMER
Postdoctoral Fellow, Nevada Bureau of Mines and Geology

ADDRESS:
Nevada Bureau of Mines and Geology
University of Nevada
1664 N. Virginia street, MS 178
Reno, NV 89557, U.S.A.
Tel. 775-784-6691 ext. 154; Fax. 775-784-1709
E-mail: kreemer@unr.edu
www: http://geodesy.unr.edu/cornekreemer/research.htm
http://www.world-strain-map.org

PERSONAL: Born: Boxtel, The Netherlands; June 8, 1974; Dutch citizen

EDUCATION:

- Ph.D., 2001 — Geosciences, SUNY - Stony Brook, NY, USA
  Thesis: 'A global strain rate model'
  Advisor: Dr. W. Holt
- M.S. (Drs.), 1997 — Geophysics, Utrecht University, The Netherlands
  Thesis: 'Plate boundary deformation in the Explorer region'
  Advisor: Dr. R. Govers

RESEARCH INTERESTS: Plate tectonics; Crustal deformation; Application of space-geodesy in geophysics; Plate boundary dynamics

RESEARCH AND PROFESSIONAL EXPERIENCE:

- 07/2004 – Present — Postdoctoral Fellow, Nevada Bureau of Mines & Geology
  Contributions to team efforts on quantifying crustal deformation by space-geodesy in Great Basin, Supervisor: Dr. G. Blewitt
- 09/2002 – 08/2004 — Postdoctoral Fellow, Collège de France, Aix en Provence
  Kinematic investigations of Aegean and Myanmar in particular, and of oceanic transform and other strike-slip faults in general. Supervisor: Dr. X. Le Pichon
- 12/2001 – 08/2002 — Postdoctoral Fellow, Laboratoire de Géologie, ENS, Paris
  Regional modelling of deformation fields in the Mediterranean. Funded by Exxon and Total-Elf, Supervisor: Dr. X. Le Pichon
- 06/1998 – 11/2001 — Research Assistant, SUNY - Stony Brook
  Global modelling of crustal strain rates and velocities using geodetic, geologic and seismological data; Work under guidance of Dr. W. Holt in close collaboration with Dr. A.J. Haines, Dr. G. Blewitt, and the UNAVCO consortium. Project is under auspices of International Lithosphere Program and supported by NASA.
- 08/1996 – 10/1996 — Research Scholar, Geodynamics Lab, Pennsylvania State University, College Park
  Modelling of seismic strain rates offshore Vancouver Island; Work in collaboration with Dr. K. Furlong, and supported by International Relation Office, Utrecht University.

FIELD

- 2004 – Present — Member, MAGNET Geodetic Team

EXPERIENCE:

Maintenance of semi-permanent GPS network and acquisition of data in western Nevada

- 07/1996 — Member, Scientific Cruise
  Collection of seismic and bathymetric data offshore Vancouver Island to provide additional evidence of localised plate boundary deformation.

TEACHING EXPERIENCE:

- 02/2001 – 06/2001 — Co-lecturer, SUNY - Stony Brook
  Seismology Project 'Women in Science and Engineering'
- 09/1997 – 05/1998 — Teaching Assistant, SUNY - Stony Brook
  Structural Geology - Geophysics - Natural Hazards
- 02/1996 – 05/1996 — Teaching Assistant, Utrecht University
  Math II - Complex numbers & Fourier Series/Transforms
- 1995 – Present — Regular contributor to 'Astruim', Dutch educational periodical on astronomy and planetary sciences

AWARDS:

- Travel Award, awarded by GPS99 meeting committee to attend meeting in Tsukuba, Japan, 10/1999
- Excellence in Teaching Award, SUNY - Stony Brook, 05/1998

REFEREED PAPERS:

Le Pichon, X., **C. Kreemer**, and N. Chamot-Rooke, Asymmetry in elastic properties and the evolution of large continental strike-slip faults, submitted to *J. geophys. Res.*, in press, 2005.

Kreemer, C., N. Chamot-Rooke, and X. Le Pichon, Constraints on the evolution and vertical coherency of deformation in the Northern Aegean from a comparison of geodetic, geologic, and seismologic data, *Earth planet. Sci. Lett.*, *225*, 329-346, 2004.

Kreemer, C., and N. Chamot-Rooke, Contemporary kinematics of the southern Aegean and the Mediterranean Ridge, *Geophys. J. Int*., *157*, 1377-1392, 2004.

Kreemer, C., W.E. Holt, and A.J. Haines, An integrated global model of present-day plate motions and plate boundary deformation, *Geophys. J. Int*., *154,* 8-34, 2003

Kreemer, C., W.E. Holt, and A.J. Haines, The global moment rate distribution within plate boundary zones, in *Plate Boundary Zones*, eds. S. Stein and J.T. Freymueller, *Geodynamics Series*, *30*, pp. 173-190, doi:10/1029/030GD10, AGU, Washington, D.C., 2002.

Kreemer, C., and W.E. Holt, A no-net-rotation model of present-day surface motions, *Geophys. Res. Lett., 28,* 4407-4410, 2001.

Kreemer, C., J. Haines, W.E. Holt, G. Blewitt, and D. Lavallée, On the determination of a global strain rate model, *Earth Planets Space*, *52*, 765-770, 2000.

Kreemer, C., and W.E. Holt, What caused the March 25, 1998 Antarctic plate earthquake?; Inferences from regional stress and strain rate fields, *Geophys. Res. Lett.*, *27*, 2297-2300, 2000.

Kreemer, C., W.E. Holt, S. Goes, and R. Govers, Active deformation in eastern Indonesia and the Philippines from GPS and seismicity data, *J. geophys. Res.*, *105*, 663-680, 2000.

Kreemer, C., R. Govers, K.P. Furlong, and W.E. Holt, Plate boundary deformation between the Pacific and North America in the Explorer region, *Tectonophysics*, *293*, 225-238, 1998.

WEBSITE

Meertens, C.M., L. Estey, C. Kreemer, and W. Holt, Interactive web interface to the global strain rate map project, 2004, http://www.world-strain-map.org

CONFERENCE ABSTRACTS:

~ 50 papers (presentations and posters) at international conferences

Biographical Sketch of Don L. Sawatzky
Mackay School of Mines/172
University of Nevada, Reno, NV 89557-0138
(775) 784-7055; fax (775) 327-2235;
dons@mines.unr.edu

Professional Experience

Research Associate Professor, Arthur Brandt Endowment, Mackay School of Mines, University of Nevada, Reno, since Sept. 1999. Responsibilities are to promote, support, and do research and develop software tools in remote sensing and geographical information systems; manage the web and data server.

GIS Consultant, Homestake Mining Company, Sparks, NV, 1997-1998, Responsibilities were to provide GIS and remote sensing support for mineral exploration programs; manage image analysis and geographic information systems.

Research Professor, Quaternary Sciences Center, Desert Research Institute, Reno, NV, Jul. 1996 to Aug. 1997. Responsibilities were to promote, support, and do research for geomorphology and archeology studies; consultation and support of information systems.

Research Geologist, U.S. Geological Survey, Denver, Co and Reno, NV, 1971 to 1995. Responsibilities were to provide computer-based image analysis support of remote-sensing applications to regional mineral assessment programs and development of geosciences databases in geographical information systems; manage GIS and data servers.

Assistant Professor, Department of Geology, Southern Illinois University, Carbondale, IL, 1965-1971. Instruction in geologic sciences and supervision of master's theses in geology.

Research Engineer, Jersey Production Research Company, Tulsa, OK, 1956-1960. Support of research in seismic geophysics methods and well-log analyses.

Education

Colorado School of Mines, Golden, CO, Doctor of Science, Geology, 1967.

The University of Oklahoma, Norman, OK, Bachelor of Science, Geological Engineering, 1956.

Recent Publications

Raines, Gary L., Sawatzky, Don L., and Connors, Katherine A., 1996, Great Basin Geoscience Data Base: U.S. Geological Survey Digital Data Series DDS-41, CD-ROM.

Sawatzky, Don L., 1992, Great Basin mineral assessment with geographic information systems in Friberg, Steve, *ed.*, American Institute of Professional Geologists, 1992 annual meeting and symposium; Geologic reason, a basis for decisions affecting society: American Institute of Professional Geologists, United States, p. 45.

Sawatzky, Don L.; Raines, G.L.; Doebrich, Jeff L.; Turner, R.L.; Garside, L.J.; McCarthy, J.H., Jr., 1991, Triassic-Jurassic magmatic arc of western Nevada and eastern California; Part IV in Slack, John F. and Kotra, Rama K., *eds.*, A model for the evaluation of Cenozoic basins for concealed mineral systems, USGS research on mineral resources, 1991; program and abstracts: U. S. Geological Survey Circular. P. 67. 1991.

Current Funding

Arthur Brant Research Associate Professor: $7200 (10%) per year.

DOE Projects: 2004: $24,200 (35%).

Gary L. Oppliger

Research Associate Professor
Arthur Brant Laboratory for Exploration Geophysics
Dept. of Geological Sciences and Engineering, University of Nevada, Reno
Tel (775) 784-7056, Email: oppliger@mines.unr,edu

Education

Ph.D. Engineering Geoscience, (1982) University of California, Berkeley, CA, Electromagnetic methods, instrumentation and digital signal processing. Dissertation Advisor: H. Frank Morrison.
M.S. Engineering Geoscience, (1977) University of California, Berkeley, CA
B.S. Engineering Geoscience, (1975) University of California, Berkeley, CA

Areas of Expertise

Satellite radar interferometry and GPS applications, Potential fields and electrical methods for water, mineral and geothermal exploration, Local gravimetric geoid computation for geodetic applications.

Academic Experience

Nov 1999 - present, Associate Research Professor, Arthur Brant Laboratory for Exploration Geophysics, Department of Geological Sciences and Engineering, University of Nevada, Reno.

Industry Experience

1997-1999, District Geophysicist, Kennecott Exploration Co., Reno NV.
1995-1996, Sr. Research Geophysicist, Electromagnetic Instruments Inc, Berkeley, CA.
1990-1995, Sr. Geophysicist, Western Mining Corp. North America, Reno, NV
1980-1989, Research Geophysicist, Newmont Exploration Ltd, Tucson. AZ.

Professional Activities

Session organizer and chair: Great Basin Center for Geothermal Energy, Workshop, University of Nevada, Reno, Nov 5, 2004.
Reviewer: Society of Exploration Geophysicist annual meeting 2004.
Member: American Geophysical Union; Member, Geological Society of America, Society of Exploration Geophysicist

Representative Journal Publications

Murphy, B. J., **Oppliger, G. L**., Brimhall Jr., G., and Hynes, A. J., 1999. Mantle Plumes and Mountains: *American Scientist*, v. 87, p. 146-153.
Murphy, B. J., **Oppliger G. L**., Brimhall Jr., G., and Hynes, A. J., 1998. Plume Modified Orogeny: an example from the southwestern United States: *Geology* 26:731-734.
Oppliger, G. L., Murphy, B. J., Brimhall Jr., G., 1997. Is the ancestral Yellowstone hotspot responsible for the Tertiary "Carlin mineralization in the Great Basin of Nevada?: *Geology* 25:627-30.
Oppliger, G. L., 1984, Three-Dimensional Terrain Corrections for Mise-a-la-masse and Magnetometric Resistivity Surveys: *Geophysics*, Vol. 49, No. 10; P. 1718-1729,

Representative Conference Publications

Oppliger, G., Coolbaugh, M., 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*, Vol. 28, pages:37-40.

Oppliger, G., Coolbaugh, M., 2004, Imaging structure with fluid fluxes at the Brady, Nevada, U.S.A, geothermal field with satellite interferometric radar (InSAR), *Society of Exploration Geophysicists*, 74th Annual International Meeting, Oct. 10-15, Denver, Colorado., Extended Abstracts Volume, 4 pages, 3 figs.

Faulds, J., Garside, L., **Oppliger, G.**, 2003, Structural Analysis of the Desert Peak-Brady Geothermal Fields, Northwestern Nevada: Implications for Understanding Linkages between Northeast-Trending Structures and Geothermal Reservoirs in the Humboldt Structural Zone, *Geothermal Resources Council Transactions* Vol. 27, pages: 859-864.

Coolbaugh, M., Sawatzky, D., **Oppliger, G**., Minor, T., Raines, G., Shevenell, L., Blewitt, G., 2003, Geothermal GIS Coverage of the Great Basin, USA: Defining Regional Controls and Favorable Exploration Terrains, *Geothermal Resources Council Transactions* Vol. 27, pages: 9-13.

Current Research Support

Washoe County Department of Water Resources and Regional Water Planning Commission: A cooperative study of the relation between satellite radar differential interferometry (D-InSAR) ground deformation observations and groundwater production and level data in the South Truckee Meadows, (PI $18k 10/2004-7/2005.) G. Oppliger.

U.S. Department of Energy: Investigating the relation between geothermal reservoir compaction, geometry and production rates from a ten-year InSAR ground displacement history at the Bradys and Desert Peak Fields, (PI $72k 7/2003-9/2005) G. Oppliger M. Coolbaugh.

U.S. Department of Energy: Regional assessment of exploration potential for geothermal systems in the Great Basin using a geographic information system (GIS) – Part II, (co-PI, $93K, 7/2003- 6/ 2005), M. Coolbaugh, G. Raines, Shevenell, T. Minor, D. Sawatzky, G. Oppliger.

Recent Research Support

NASA EPSCoR core: InSAR-GPS Investigation of Seasonal Groundwater Response in Reno, (PI $8k for 3/2003-8/2004.) G. Oppliger.

U.S. Department of Energy: Geologic and Geophysical Analysis of the Desert Peak-Brady Geothermal Fields: Part II - Structural Controls on Geothermal Reservoirs in the Humboldt Structural Zone (co-PI $98K, 7/2003- 6/2004), J. Faulds, L. Garside, G. Oppliger, R. Anooshehpoor.

Current Dissertation/Thesis committee member for:

Cheryl Goudy, Ph.D. student in Geology
Jim Scott, Ph.D. student in Geophysics Seismology
Jessica Muelhberg, M.S. student in Geology
Blake Morrow M.S. student in Geology
Richard Redd, M.S. student in Hydrology
Kurt Katzenstein, Ph. D. student in Geo Engineering

Recent Collaborators: (not listed above)

Jim Carr, Jim Trexler, Pat Cashman.

RESUME

DAVID D. BLACKWELL

EDUCATION

B.S. Geology and Mathematics, Southern Methodist University, 1963
M.S. Geophysics, Harvard University, 1965
Ph.D. Geophysics, Harvard University, 1967

EXPERIENCE

9/67-9/68	California Institute of Technology, Pasadena, California; Post Doctoral Fellow
9/68-9/73	Southern Methodist University, Dallas, Texas; Assistant Professor
9/70-	University of Texas at Dallas, Dallas, Texas; Adjunct Professor
9/73-9/78	Southern Methodist University, Dallas, Texas; Associate Professor
9/78-	Southern Methodist University, Dallas, Texas; Professor of Geophysics
9/80-	SMU, Dallas, Texas; Hamilton Professor of Geophysics
9/82-8/86	SMU, Dallas, Texas; Chairman, Department of Geological Sciences

SELECTED PROFESSIONAL ORGANIZATION MEMBERSHIPS

Geological Society of America (Fellow)	1965
Author of DNAG Geothermal Map of North America, 1985-92	
Geothermal Resources Council	1971
Member of Board of Directors, 1986-1994 2000-2004	
President, 1991, 1992	
International Geothermal Association	1992
Board Member, 1992-1998	
Received Special Achievement Award	2004
Member of Organizing Committee of World Geothermal Congress 1993-1995	1995
Chairman of Technical Program Subcommittee, World Geothermal Congress 2000, 1999-2000	2000

SELECTED BIBLIOGRAPHY

Roy, R.F., E.R. Decker, F. Birch, and D.D. Blackwell, Heat flow in the United States, J. Geophys. Res., 73, 5207-5222, 1968.

Blackwell, D.D., Thermal structure of the continental crust, pp. 169-184, The Structure and Physical Properties of the Earth's Crust, ed. J.G. Heacock, Am. Geophys. Union Monograph 14, Washington, D.C., 1971.

Roy, R.F., E.R. Decker, and D.D. Blackwell, Continental heat flow, pp. 506-543, The Nature of the Solid Earth, ed. E.C. Robertson, McGraw-Hill Book Company, New York, 1972.

Brott, C.A., D.D. Blackwell, and J.C. Mitchell, Tectonic implications of heat flow of the western Snake River Plain, Idaho, Bull. Geol. Soc. Am. 89, 1697-1707, 1978.

Blackwell, D.D., Heat flow in the northern Basin and Range province, pp 81-92, in The Role of Heat in the Development of Energy and Mineral Resources in the Northern Basin and Range Province, Geothermal Resources Council Special Report No. 13, 384 pp, 1983.

Blackwell, D.D., A transient model of the geothermal system of the Long Valley caldera, California, J. Geophys. Res., 90, 11229-11241, 1985.
Blackwell, D.D., J.L. Steele, L.S. Carter, Heat flow patterns of the North American continent: A discussion of the DNAG Geothermal Map of North America, 423-436, in Neotectonics of North America, eds. D.B. Slemmons, E.R. Engdahl, M.D. Zoback, and D.D. Blackwell, Geological Society Am., Decade Map Volume 1, 1991.
Blackwell, D.D., and J.L. Steele, DNAG Geothermal Map of North America, 1:5,000,000, Geol. Soc. Amer., 1992.
Blackwell, D.D., Analysis of geothermal gradient data from the Pine Flat and Klau Mine areas, Sonoma and Lake Counties, California, Trans. Geothermal Resources Council, 16, 215-220, 1992.
Becker, D.J., and D.D. Blackwell, Gravity and hydrothermal modeling of the Roosevelt hot springs area, southwestern Utah, J. Geophys. Res., 98, 17,787-17,800, 1993.
Wisian, K.W., D.D. Blackwell, S. Bellani, J.A. Henfling, R.A. Norman, P.C. Lysne, A. Forster, and J. Schrotter, Field comparison of conventional and new technology temperature logging systems, Geothermics, 27, 131-142, 1998.
Benoit, D., C. Smithpeter, R. Norman, D.D. Blackwell, and S. Thompson, Design, fabrication, installation, and testing of an advanced wellbore/reservoir monitoring system at the Dixie Valley, Nevada geothermal field, Proceedings, 24th Workshop on Geothermal Reservoir Engineering, Stanford University, Stanford, Ca., January 25-27, pp. 310-324, 1999.
Blackwell, D.D., K. W. Wisian, D. Beniot, and B. Gollan, Structure of the Dixie Valley geothermal system, a "typical Basin and Range geothermal system, from thermal and gravity data, Geothermal resources Council Trans., 23, 525-531, 1999.
Wisian, K. W., D.D. Blackwell, and M. Richards, Heat flow in the western U. S. and extensional geothermal systems, Proceedings, 24th Workshop on Geothermal Reservoir Engineering, Stanford University, Stanford, Ca., pp. 219-226. 1999.
Blackwell, D. D., B. Gollan, and D. Beniot, Thermal Regime in the Dixie Valley, Nevada geothermal system, ed. E. Iglesias, D. Blackwell, T. Hunt, J. Lund, S. Tamanyu, and K. Kimbara, Trans. World Geothermal Congress 2000, 991-996, 2000
Smith, R. P., K. W. Wisian, and D. D. Blackwell, Geological and geophysical evidence for intra-basin and footwall faulting at Dixie Valley, Nevada, Trans. Geothermal Resources Council, 25, p. 323-326, 2001.
Wisian, K. W., D. D. Blackwell, and M. Richards, Correlation of heat loss and total energy production for geothermal systems, Trans. Geothermal Resources Council, 25, p. 332-335, 2001
Blackwell, D. D., M. Leidig, and R. P. Smith, Regional Geophysics of the Dixie Valley Area: Example of a Large Basin and Range Geothermal Resource, Geothermal Resources Council Trans., 26, 519-522, 2002.
Blackwell, D. D., M. Leidig, R. P. Smith, S. Johnson and K. W. Wisian, Exploration and Development Techniques for Basin and Range Geothermal Systems: Examples From Dixie Valley, Nevada, Geothermal Resources Council Trans., 26, 513-518, 2002.
Richards, M. and D. D. Blackwell, A Difficult Search, Why Basin and Range systems are hard to find, Geothermal Resources Council Bulletin, 31(4), 143-146, 2002.
Smith, R.P., V.J.S. Grauch, and D.D. Blackwell, Preliminary results of a high-resolution aeromagnetic survey to identify buried faults at Dixie Valley, Nevada, Geothermal Resources Council Trans., 26, 543-546, 2002.
Richards, M. and D. D. Blackwell, The heat is on, SMU 2002 Geothermal Resources Potential Map, Geothermal Resources Bulletin, 32(3), 117-119, 2003.
Blackwell, D. D., and M. Richards, Geothermal Map of North America, Amer. Assoc. Petrol. Geol., scale 1:6,500,000, 2004.

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)

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

Shevenell, L., and Garside, L., 2003, Nevada Geothermal Resources. Nevada Bureau of Mines and Geology Map 141.

Skalbeck, J.D., **Shevenell**, L., and Widmer, M., 2002, Mixing of thermal and non-thermal waters in the Steamboat Hills area, Nevada: Geothermics, v. 31, no. 1, p. 69–90.

Garside, L., **Shevenell**, L., Snow, J., and Hess, R., 2002. Status of Nevada geothermal resource development - Spring 2002. Transactions Geothermal Resources Council 26: 527-532.

Shevenell, L., Garside, L., Arehart, G., van Soest, M., and Kennedy, B.M., 2002. Geochemical sampling of thermal and nonthermal waters in Nevada to evaluate the potential for resource utilization. Transactions Geothermal Resources Council 26: 501-506.

Long, J.C.S., and **Shevenell**, L., 2001. The Potential of Geothermal Energy. Testimony prepared for the Secretaries of the Departments of Interior and Energy, presented on November 29, 2001, 6 p.

Shevenell, L., and Goff, F., 2000, Temporal geochemical variations in volatile emissions from Mount St. Helens, 1980-1994. J. Vol. Geoth. Res., 99(1-4): 123-138.

Shevenell, L., and Goff, F., 1995, The use of ^3H in groundwaters to determine fluid mean residence times of Valles Caldera hydrothermal fluids, New Mexico. J. Vol. Geoth. Res., 67(1-3): 187-205.

Shevenell, L., and F. Goff, 1995, Evolution of geothermal waters at Mount St. Helens, Washington, U.S.A. J. Vol. Geoth. Res., 69(1/2): 73-93.

Shevenell, L., and F. Goff, 1993, Addition of magmatic volatiles into the hot spring waters of Loowit Canyon, Mount St. Helens, Washington, U.S.A. Bull. Vol., 55(7): 489-503.

Shevenell, L., 1991, Tritium in the thermal waters discharging in Loowit Canyon, Mount St. Helens, Washington, U.S.A. Chem. Geol. (Isotope Geoscience Section) 94: 123-135.

Shevenell, L., 1990, Chemical and Isotopic Investigation of the New Hydrothermal System at Mt. St. Helens, Washington: University of Nevada, Reno, 282 p.

Goff, F., **Shevenell**, L., Gardner, J.N., Vuataz, F.D., and Grigsby, C.O., 1988, The hydrothermal outflow plume of Valles caldera, New Mexico and a comparison with other outflow plumes: Journal of Geophysical Research, v. 93, no. B6, p. 6041–6058.

Shevenell, L., Goff, F., Grigsby, C.O., Janik, C.J., Trujillo, P.E., Jr., and Counce, D., 1987, Chemical and isotopic characteristics of thermal fluids in the Long Valley Caldera Lateral Flow System, California. Trans. Geoth. Res. Council 11: 195-202.

Goff, F., and **Shevenell**, L., 1987, Travertine deposits at Soda Dam, New Mexico and their implications for the age and evolution of the Valles Caldera hydrothermal system. Bull. Geol. Soc. of Am. 99: 292-302.

BIOGRAPHICAL SKETCH FOR DOE PRINCIPAL INVESTIGATORS

Dr. James V. Taranik, Director
Mackay School of Earth Sciences and Engineering, MS 168
University of Nevada, Reno
Reno, NV 89557-0047
(775) 784-6897, FAX (775) 784-1766, e-mail: jtaranik@mines.unr.edu
http://www.unr.edu/mines/able
DOE Security Clearance: Contact: DRI SSO Russell C. Cullison, (702) 895-0401.

Professional Preparation

Stanford University	Geology	B.S. 1964
Colorado School of Mines	Geology	Ph. D. 1974

Listing of Research and Professional Positions

Director, Great Basin Center for Geothermal Energy, UNR, 1999 - 2000
Regents Professor and Arthur Brant Chair of Geophysics, UNR, 1998 – Present
Director, NASA Space Grant Consortium, University and Community College System of Nevada, 1991 – Pres.
Director and PI, NASA EPSCoR Program, UCCSN, 2001 – Present
President, Desert Research Institute, UCCSN, 1987 – 1998. President Emeritus, 1998.
Member, Bechtel Nevada Test Site Strategic Advisory Board (Advised Department of Energy on science-based nuclear stockpile stewardship, counter-proliferation of weapons of mass destruction, and alternative energy research by three DOE National Laboratories at the NTS, 1996-98.
Member, SIR-C/X-SAR Pre-ship and Pre-launch Engineering Review Board (1993 - 1994). As HQ designee joined six Jet Propulsion Laboratory engineers in reviewing and certifying launch readiness all of the structural and electronic design functions of the $680 million dollar payload (Space Radar Lab-1) for two Shuttle missions, STS-59 and STS-68.
Member, Environmental Task Force, later MEDEA as a consultant to MITRE Corporation, (1993-1998)
Member, Air Force Studies Board, Committee on Strategic Relocatable Targets (1990 –1993)
Member, NASA EOSAR Synthetic Aperture Radar Working Group (1985 - 1988).
Dean, Mackay School of Mines and Prof. of Geology and Geophysics, 1982 – 87.
Chief, Non-Renewable Resources Branch, (Senior Executive Service – Level 4) Office of Space and Terrestrial Applications, NASA Headquarters, Washington, D. C., 1979 – 1982.
Chairman, Joint NASA/EOSAT/NOAA Thermal Infrared Working Group Landsat-6
Member, NASA Space Applications Advisory Committee (SAAC). Chairman of the SAAC Subcommittee on Remote Sensing Atmosphere, Hydrosphere, Biosphere and Lithosphere (1986-88).
Principal Scientist for Geological Applications, (GS-14) U. S. Department of Interior, Earth Resources Observations Systems (EROS) Data Center, 1975 – 1979.

Chief of Remote Sensing, Iowa Geological Survey, 1971 – 1975.
Reserve Officer: (0-3), Strategic Military Intelligence Unit, 1967 – 78.
Engineer Officer: (01,02), Platoon Leader, Battalion Adjutant, 4th Engineers. Staff Geologist for U. S. Army Engineer Command Headquarters, Vietnam, 1966 –67, (Bronze Star).

Honors

NASA Exceptional Scientific Achievement Medal, HQ Program Scientist STS-2.
U. S. Geological Survey Special Achievement Award, EROS Data Center.
Certified: Professional Geologist, AIPG, Certified Mapping Scientist Remote Sensing, American Society of Photogrammetry and Remote Sensing
Elected full member of International Academy for Astronautics, Engineering Sciences Section.
Fellow, American Society of Photogrammetry and Remote Sensing, Geological Society of America and American Association for Advancement for Science, Associate Fellow, American Institute for Aeronautics and Astronautics. Senior Member, IEEE.

Current DOE Funded Research

DOE HQ Office of Non-Nuclear Proliferation (NN-22***): Development of Research Infrastructure in Nevada for the Exploitation of Hyperspectral Image Data To Address Proliferation and Detection of Chemical and Biological Materials*** ($453,000 for three years, PI).

DOE Albuquerque Office: ***Identification and Monitoring of Critical Infrastructure with Integrated Geo-Spatial Data Framework at the DOE Nevada Test Site.*** ($100,000, CO-I Subcontract from Sierra Nevada Corporation)

Publications: Over 173 scientific and technical publications in the form of book chapters, refereed papers in professional journals and technical papers in symposium proceedings.

Gary Raines

Academic Degrees and Fellowships
B.A. – Geophysics, UCLA, 1968
M.Sc. – Geology, Colorado School of Mines, 1971
Ph.D. – Geology, Colorado School of Mines, 1974
NRC Post Doctoral Fellow, USGS, 1974-1976

Assignment Summary
1976-1984 – Research Geologists, USGS, Denver – remote sensing research and application in mineral exploration
1984-1988 – Deputy Chief of the Office of Mineral Resources, USGS, Reston – responsible for geophysics and international activities of the Mineral Resources Program.
1988-1991 – Chief of the Reno Field Office, USGS, Reno – founded, staffed, and managed the Reno Field Office.
1991- Present – Research Geologist, USGS, Reno – described below

Research Interests
My research for the last decade has addressed quantitative methods of spatial data integration. In particular, I have been working on integrating geology, geochemistry, geophysics, and other types of geologic data to predict the locations of undiscovered mineral deposits. In addition, I have advised on environmental applications of this research. This research has involved considerable effort in capture of digital data, development of national standards for digital geologic maps, demonstrations of applications, and computer tools to facilitate and implement the results (tools available at http://geology/usgs.gov and http://ntserv.gis.nrcan.gc.ca/sdm/).

In 1995 and 1996 because of my work in data integration, I worked on a Presidential-mandated project, the Columbia River Basin Ecosystem Management Project. The Columbia River Basin Ecosystem Management Project was the response of the BLM and USFS to a Presidential directive to develop new land management plans and concepts to deal with the threatened and endangered species issues in the Columbia River Basin. The science aspects of the project covered in 18 months all or most of Washington, Idaho, Montana, Utah, Nevada, and California. My task was to provide and interpret digital geology for this region for approximately 170 BLM and USFS biologists and land managers. This work lead to using geology to define areas of plant disease, areas of animal habitat, resources, and landscape characteristics. All of this work had to be done in a GIS and made publicly available in digital form.

In 1996 because of my work on the Columbia River Basin, I was selected as the chairman of a North American committee to define the digital standards for geologic maps. This is a cooperative effort between the USGS, the American Association of State Geologists, the Geological Survey of Canada, and the Consejo de Recursos Minerales (Mexico). These standards primarily address how we intend to capture, store, exchange, and analyze digital geologic maps and the associated descriptive data. This standards and associated tools are publicly available at http://geology.usgs.gov/dm/. Since 2000, I have been working on developing an expert system to generalize geologic maps for geologic and environmental applications. This development work as been focused on the Lake Tahoe Basin.

In order to apply the spatial integration techniques, Dr. Graeme Bonham-Carter of the Geological Survey of Canada and I have developed a series of Arcview extensions to implement various modeling tools. In 1998, we released an extension for weights-of-evidence modeling (http://gis.nrcan.gc.ca/software/arcview/wofe) that was revised in 1999 to include logistic regression, fuzzy logic, and two neural network techniques (http://ntserv.gis.nrcan.gc.ca/sdm), and revised during 2003-2005 as an extension for ArcGIS with a third neural network tool. This tool development work was funded by the USGS, GSC and a consortium of international mining companies and has been downloaded by over 2000 users from over 50 countries for application in 18 different application areas ranging from archeology, business, crime prevention, environmental studies, epidemiology and geology. Gold discoveries based on modeling using our spatial modeling tools in Finland and New Zealand were announced in late 2004.

Spatial-temporal models, which combine spatial predictive models with temporal modeling approaches involving cellular automatons, are the next frontier being investigated. Pubished in 2002, my research has focused on developing a spatial-temporal model to forecast the activities of the mining industry in Idaho and Montana out to 2010. This model predicts where and how much activity will occur. Working with Dr. Sushil Louis on the Computer Science Dept. at UNR, we have implemented a web-based version of the cellular automaton model on a computer cluster that utilizes a genetic algorithm to calibrate the model. With the addition of several new spatial measures, we have increased the accuracy of the prediction by 20% and improved the time required for calibration and projection from days to hours. Research is continuing to refine this spatial-temporal modeling approach.

Selected Recent Publications

1. Raines, G.L., 1999, Evaluation of weights of evidence to predict epithermal-gold deposits in the Great Basin of the western United States: Natural Resources Research, v. 8, no. 4, p. 257-276.
2. Mensing, S.A., Elston, R.G., Raines, G.L., Tausch, R.J., and Nowak, C.L., 2000, A GIS model to predict the location of fossil packrat (Noetoma) middens in central Nevada: Western North American Naturalist, v. 60, no. 2, pp. 111-120
3. Raines, G.L., Bonham-Carter, G.F., and Kemp, L.D., 2000, Predictive probabilistic modeling using Arcview GIS: Arcuser, v. 3, no. 2, p. 45-48.
4. Raines, G.L., 2002, Comparison and description of geologic maps using FRAGSTATS – a spatial statistics program: Computers and Geosciences, v. 28, no. 2, p.169-177.
5. Raines, G.L., Zientek, M.L., Causey, J.D., and Boleneus, D.E., 2002, Preliminary cellular-automata forecast of permit activity from 1998 to 2010, Idaho and western Montana: Natural Resources Research, Vol. 11, No. 3, p. 167-186.
6. Boleneus, D.E., Raines, G.L., Causey, J.D., Bookstrom, A.A., Frost, T.P. and Hyndman, P.C., 2002, Assessment Method for Epithermal Gold Deposits in Northeast Washington State using Weights-of-Evidence GIS Modeling: U.S. Geological Survey Open File Report OF01-501, http://geopubs.wr.usgs.gov/open-file/of01-501/
7. Raines, G.L., and Mihalasky, M.J, 2002, A reconnaissance method for regional-scale mineral-resource assessment, based exclusively on geologic-map data: Natural Resources Research, Vol. 11, No. 4, p 241-248.
8. Miller, R.J., Raines, G.L., and Connors, K.A., 2002, Spatial Digital Database for the Geologic Map of Oregon, Geology compiled by George W. Walker and Norman S. MacLeod: Open-File Report 03-67, Digital database, version 2.0, map originally published in 1991.
9. Raines, G.L., Connors, K.A., Moyer, L.A., Miller, R.J., 2003, Spatial Digital Database for the Geologic Map of Nevada, Geology compiled by John H. Stewart and John E. Carlson: Open-File Report 03-66, Digital database, version 3.0, map originally published in 1978.
10. Robinson, G.R., Kapo, K.E., and Raines, G.L., 2004, A GIS analysis to evaluate areas suitable for crushed stone aggregate quarries in New England, USA: Natural Resources Research, Vol. 13, No. 3, p.143-159.
11. Louis, S.J., Raines, G.L., 2002, Predicting permit activity with cellular automata calibrated with genetic algorithms: Program and Abstracts, Modeling Complex Systems, Nov 20-21, University of Nevada, Reno, p.37.
12. Raines, G.L., and Bonham-Carter, G.F., 2004 in press, Exploratory Spatial Modelling for Carlin- type deposits, Central Nevada, USA, using Arc-SDM in Harris, J.R. (editor), GIS applications in earth sciences: Special Publication, Geological Association of Canada, 35+p.

James E. Faulds

Education

B.S. University of Montana, Geology, 1981 (highest honors)
M.S. University of Arizona, Geology, 1986
Ph.D. University of New Mexico, Geology, 1989

Areas of Expertise

Disciplines: Structural geology, tectonics, paleomagnetism, and geochronology.
Topical: Segmentation of normal-fault systems, evolution of strike-slip faults, fault kinematics, Extensional-transtensional tectonics, volcanic stratigraphy, evolution of western North America.

Professional Work Experience

1997-present - Research Geologist/Graduate Faculty (associate professor level; tenured 2000), University of Nevada, Reno; structural, tectonic, paleomagnetic research in western Cordillera
1992-1997 – Assist. Professor, Univ. of Iowa; structural geology, tectonics, field geology.
1991-1992 - Visiting Assistant Professor, University of Iowa
1990-1991 - Post-doctoral Research Associate, University of Southern California
1989-1990 - Post-doctoral Research Associate, University of Nevada, Las Vegas
1984-1989 - Silver-Kelley Fellow and Research/Teaching Assistant, University of New Mexico
1981-1984 - NSF Graduate Student Fellow, University of Arizona

Recent Publications Related to Geothermal

Faulds, J.E., 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, p. 649-654.
Shevenell, L., Coolbaugh, M., **Faulds, J**., Oppliger, G., Calvin, W., Louie, J., Blewitt, G., 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: 47-52.
Faulds, J.E., Garside, L.J., and Oppliger, G., 2003, Structural analysis of the Desert Peak-Brady geothermal fields, northwest Nevada: Implications for understanding links between northeast-trending structures and geothermal reservoirs in the Humboldt structural zone: Geothermal Resources Council Transactions, v. 27, p. 859-864.
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.
Faulds, J.E., Garside, L., Johnson, G., Muehlberg, J., and Oppliger, G.L., 2002, Geologic setting and preliminary analysis of the Desert Peak – Brady geothermal field, western Nevada: Transactions Geothermal Resource Council, v. 26, p. 491-494.

Other Selected Recent Publications

Faulds, J.E., Henry, C.D., and Hinz, N.H., 2005, Kinematics of the northern Walker Lane: An incipient transform fault along the Pacific – North American plate boundary: In press.
Henry, C.D., **Faulds, J.E**., and dePolo, C.M., 2005, Geometry and timing of strike-slip and normal faults of the northern Walker Lane, northwestern Nevada and northeastern California: Strain partitioning, sequential extensional and strike-slip deformation, or both? Geological Society of America Special Paper, in press.
Varga, R.J., **Faulds, J.E**., Snee, L.W., Harlan, S.S., and Bettison-Varga, L., 2004, Miocene extension and extensional folding in an anticlinal segment of the Black Mountains accommodation zone, Colorado River extensional corridor, southwestern USA: Tectonics, v. 23, no. 11, TC109 [DOI 10.1029/2002TC001454], 19 p.

Faulds, J.E., Olson, E.L., Harlan, S.S., and McIntosh, W., 2002, Miocene extension and fault-related folding in the Highland Range, southern Nevada: A 3-D perspective: Journal of Structural Geology, v. 24, p. 861-886.
Faulds, J.E., Bell, J.W., and Olson, E.L., 2002, Geologic map of the Nelson SW Quadrangle, Clark County, Nevada (with accompanying text): Nevada Bureau of Mines and Geology Map 134.
Faulds, J.E., Feuerbach, D.L., Miller, C.F., and Smith, E.I., 2001, Cenozoic evolution of the northern Colorado River extensional corridor, southern Nevada and northwest Arizona: Pacific Section of the American Association of Petroleum Geologists Publication GB 78, p. 239–272.
Faulds, J.E., Wallace, M.A., Gonzalez, L.A., and Heizler, M.T., 2001, Depositional environment and paleogeographic implications of the late Miocene Hualapai Limestone, northwest Arizona and southern Nevada, in Young, R.A. and Spamer, E.E., eds., Colorado River: Origin and evolution: Grand Canyon Association Special Volume, p. 81-87.
Faulds, J.E., Price, L.M., and Wallace, M.A., 2001, Pre-Colorado River paleogeography and extension along the Colorado Plateau - Basin and Range boundary, northwest Arizona, in Young, R.A. and Spamer, E., eds., Colorado River: Origin and evolution: Grand Canyon Assoc. Special Vol., p. 93-99.
Bachl, C.A., Miller, C.F., Miller, J.S., and **Faulds, J.E**., 2001, Construction of a pluton: Evidence from an exposed cross section of the Searchlight pluton, Eldorado Mountains, Nevada: Geological Society of America Bulletin, v. 113, no. 9, p. 1213–1228.
Faulds, J.E., and Varga, R., 1998, The role of accommodation zones and transfer zones in the regional segmentation of extended terranes: Geological Society of America Special Paper 323, p. 1-46.
Faulds, J.E., Schreiber, B.C., Reynolds, S.J., Gonzalez, L., and Okaya, D., 1997, Origin and paleogeography of an immense, nonmarine Miocene salt deposit in the Basin and Range: Journal of Geology, v. 105, p. 19–36.
Faulds, J.E., Feuerbach, D.L., Reagan, M.K., Metcalf, R.V., Gans, P., and Walker, J.D., 1995, The Mt. Perkins block, northwestern Arizona: An exposed cross section of an evolving, preextensional to synextensional magmatic system: Journal of Geophysical Research, v. 100, p. 15,249–15,266.

Recent Books

Faulds, J.E., and Stewart, J.H., eds., 1998, Transfer zones and accommodation zones: The regional segmentation of the Basin and Range province: Geological Society of America Special Paper 323, 257 p.
Erskine, M.C., **Faulds, J.E**., Bartley, J.M., and Rowley, P.D., eds., 2001, The geologic transition, High Plateaus to Great Basin—A symposium and field guide: The Mackin volume: Pacific Section of the American Association of Petroleum Geologists Publication GB 78, 430 p.

Professional Societies

American Geophysical Union
Geological Society of Nevada
Geological Society of America
Nevada Petroleum Society
Sigma Xi

Current Support

National Science Foundation: Elucidating physical processes in crustal magma systems - Evidence from Miocene intrusive and extrusive sequences in southern Nevada, **$85,036**, 7/1/04 to 6/30/07, PI.
U.S. Geological Survey, STATEMAP, 2004: Geologic mapping of the Fernley East Quadrangle: 5/1/04 to 8/31/05, **$40,121**, PI.
Department of Energy (DOE) through Great Basin Center for Geothermal Energy: Geologic and geophysical analysis of the Desert Peak-Brady geothermal fields: Structural controls on geothermal reservoirs in the Humboldt structural zone: 10/1/03 to 9/30/05, **$135,392**, PI.
National Science Foundation, Neogene development of the northern Walker Lane: An evolving transform plate boundary: 1/1/02 to 12/31/05, **$272,596**, PI.