Geothermal Technologies Office 2013 Peer Review

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

GBCGE Research, Education and Outreach

Project Officer: Eric Hass
Total Project Funding: $1,000,000
April 24, 2013

Principal Investigator Wendy Calvin
Great Basin Center for Geothermal Energy, University of Nevada - Reno

Track Geophysics

Relevance/Impact of Research

- Basic and applied research that promotes identification and utilization of geothermal resources.
- PI-lead projects that use geology, geochemistry, geophysics, remote sensing and the synthesis of multi-disciplinary information to create new models of geothermal systems in the Western U. S. and worldwide.
- Public outreach through web and other interfaces, data base development and data dissemination, stakeholder workshops.
- Supports GTP goals related to hydrothermal resource confirmation, systems analysis and EGS.
- Create new trained workforce through graduate education programs.

Scientific/Technical Approach

- Four Primary Activities:

- PI lead Seed Grant Research Projects
- Research and Technical Staff Support
- Graduate Research Fellowships
- GBCGE Center Communication, Administration and Outreach

- Research projects (both faculty and student) are vetted by relevance to GTP objectives and ability to contribute to knowledge of hydrothermal resources.

Faculty Seed Grants

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- Grant Awarded 9/30/2010, Current end date 12/31/13
- Seed Grant RFP finally released April 2012.
- Funding capped at $65,000, plus cost share, one year awards.
- Eight proposals received
- Selection based on scientific merit, relevance to GTP, likelihood of future funding in other programs.
- 6 funded, 2 to DRI faculty, 4 to UNR
- Majority support research faculty with no state salary
- Funding and accounts in place September 2012

Seed Grant Projects

- PI: Donald “Matt” Reeves, Desert Research Institute
  Project: Utilization of Thermal-Hydrologic-Mechanical-Chemical Coupled Modeling to Investigate Fracture Network Permeability Evolution during Enhanced Geothermal System Stimulation at Desert Peak, Nevada.
- PI: John N. Louie, Nevada Seismological Lab
  Project: Understanding Downhole Geophysics in Volcanic Basins: Knowledge Transfer from New Zealand's Geothermal Institute.
- PI: William Hammond, NV Bureau of Mines and Geology
  Project: Reconnaissance InSAR and GPS surface deformation analysis of Salt Wells and Stillwater geothermal areas.

Seed Grant Projects - 2

- PI: Clay Cooper, Desert Research Institute
  Project: Noble Gas and Isotopic Analysis to Delineate Subsurface Flow Patterns North of Pyramid Lake, Nevada.
- PI: Ileana Tibuleac, Nevada Seismological Lab
  Project: Crustal attenuation and stochastic properties as geothermal favorability indicators.
- PI: Patricia H. Cashman, Department of Geological Sciences & Engineering
  Project: Testing Methods for geothermal exploration in the Pacific Northwest.

Research and Technical Staff

- Drew Siler, Post-doc with Jim Faulds
  3D models of “fairway” mapping for multiple geothermal fields.
- Betsy Littlefield, Research Scientist with Wendy Calvin
  Assists with shallow temperature surveys, mineral spectral studies using remote sensing and field instruments on drill core.
- Chris Sladek, technical and field support to Calvin and Shevenell. Maintains and creates 2-m temperature equipment, trains students in techniques.

Graduate Research Fellowships

- Fund students for full duration of degree or bridge funding for those on contracts that have ended.
- Tyler Kent: (Louie) “Direction and rate of deformation in the Soda Lake Geothermal Field using GPS and 3D seismic data.” 5/2013
- Paul Schwering: (Karlin) “A subsurface 3D model of basin geometry and fault architecture at the Dixie Meadows geothermal prospect based on potential field geophysical data.” 5/2013
- Jonathan Payne: (Bell) “The Gabbs Valley, Nevada geothermal prospect: Exploring for a potential blind geothermal resource.” 5/2013
- Sabina Kraushaar: (Cashman) “Geothermal potential at McFarlane Hot Springs using geologic mapping and shallow temperature measurements.” 12/2013
- Three fellowships offered in 2013, one turned down, two pending.

Communication, Administration, Outreach

- Participation in the geothermal community through contributions to GEA reports, stakeholder workshops, press and public engagement, education integrated across all levels.
- Re-vamped web pages, database transitioned to NBMG under NGDS award.
- New NSF opportunities – US-New Zealand Workshop, I/UCRC with UC Davis
- New USGS collaboration using UAV's for geophysical surveys
- EPRI workshop
- Geothermal sessions at scientific meetings (AGU, GSA)
- Interface with UNR faculty in Engineering programs

Accomplishments, Results and Progress

GBCGE has existed since 2002.

- Previous collection of awards, under ID14311, from a total of $5,865,275 of DOE funding over ten years resulted in $7,853,088 of follow-on funding.
- 22 unique research projects funded over time
- 22 PhD/MS Degrees, 67 undergraduates
- 160 publications and 225 presentations.

Spending under current award 003997 didn't really begin until January, 2012

- Six faculty projects under way.
- Sustained support for 3 research and technical staff
- Four MS students completing degrees in 2013
- 9 presentations and 5 publications in 2012

Original Planned Milestone/ Technical Accomplishment	Actual Milestone/Technical Accomplishment	Date Completed
Fund faculty seed grants	6 new projects under way	Sept. 2012
Fund graduate research	4 funded, 2 potential new students	Ongoing

Future Directions

- Complete faculty seed grants, those funded should submit one proposal for follow on funding.
- Complete existing graduate research, potentially start two new student research projects.
- Prepare final report on ID14311 grant and encourage submissions of summary and overview papers to indexed journals. Collect these in a volume “A decade of exploration in the Great Basin” to be distributed at GRC.

Milestone or Go/No-Go	Status & Expected Completion Date
Complete faculty seed grants	9/2013
Initiate 2 new student projects	6/2015
Summary report on first decade	9/2013

Mandatory Summary Slide

- GBCGE has been successfully contributing geothermal research and educational programs since 2002.
- Faculty and students have a reputation for excellence in analysis and assessment of regional and local geothermal resources.
- We are building on central expertise to expand into new areas of research including 3D modeling, slip dilation, core alteration analysis and modern exploration tools and data, such as LIDAR and cutting edge seismic analysis and processing.
- Faculty involved bridge 6 departments in two Colleges (Science & Eng) at UNR and DRI.
- Collaborations outside UNR are increasing.

Project Management

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- GBCGE receives limited support from UNR in the form of ½ academic year salary for the Director position.
- All staff, students, and research faculty are grant-funded, some limited teaching assistantships.
- I do not have a dedicated admin to help with budget or reporting requirements.

Timeline:

Planned Start Date	Planned End Date	Actual Start Date	Current End Date
10/2010	12/2013	1/2012	12/2013

Budget:

Federal Share	Cost Share	Planned Expenses to Date	Actual Expenses to Date	Value of Work Completed to Date	Funding needed to Complete Work
1,000,000	173,039		381,048		618,952

- Work supported under this grant complements or augments other awards from DOE to UNR (Faulds, Danko, Laca, Shevenell).
- The Center provides an umbrella to publicize all geothermal research on campus.
- Student RA offers are competitive, but still turned down. Offer one fellowship/year to keep a pipeline of students entering the workforce. This year offered two, given past rate of declines.

Back Up Slides
Project Specific Information

Reeves

- **Project:** Utilization of Thermal-Hydrologic-Mechanical-Chemical Coupled Modeling to Investigate Fracture Network Permeability Evolution during Enhanced Geothermal System Stimulation at Desert Peak, Nevada
- **PI:** Donald M. Reeves, **Ph.D. Student:** Stefano Benato
- **Relevance/Impact:** Using a THMC model (FLAC3D+TOUGHREACT) to identify mechanisms controlling permeability enhancement during EGS stimulation at Desert Peak, NV. Coupled numerical framework also useful for predicting permeability evolution over longer time scales than EGS experiment, particularly with respect to chemical precipitation.
- **Scientific or Technical Approach:** Use all available data to form conceptual model of site; test likeliness of conceptual model using THMC; form fully-evolved THMC model and calibrate to both shear and hydrofracturing phases of Desert Peak EGS experiment.
- **Accomplishments/Results:** Characterized site (including fracture network and fracture permeability), formed conceptual model of shear failure in low-pressure phase of EGS experiment and successfully tested this conceptual model with a hydro-mechanical coupled model (FLAC3D). These findings are disseminated in a paper presented at the Stanford Geothermal project and will also be presented at several conferences in Europe in late May/early June. A preliminary TOUGHREACT model is up and running.
- **Future Directions:** This project has greatly enhanced the current skill set of coupled fluid flow-mechanical-thermal-chemical modeling within the Nevada System of Higher Education. This skill set is intended to be utilized in the geothermal industry, with the next logical step consisting of the development of a prior-EGS stimulation THMC model of Brady's geothermal reservoir intended to guide this planned EGS experiment. The methods used in this project, including identifying mechanisms of shear failure, stress modeling, fracture permeability, and the overall THMC framework have also been of interest to the unconventional natural gas (i.e., fracking) industry.

Tibuleac

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1) Relevance/Impact of the work

We investigate seismic attenuation and crustal stochastic properties as indicators of Enhanced Geothermal System (EGS) favorability as a new approach, more sensitive to changes in crustal heterogeneity than velocity.

2) Scientific or Technical Approach,

Activities on this project consist of three tasks:

1) Estimate attenuation in Dixie Valley:

a) .Using seismic events;

b). Using noise/signal cross-correlations

(ambient noise extracted Green's Functions and noise coherence estimates).

2) Stochastic waveform analysis

3). Statistical analysis and EGS favorability estimates.

3) Accomplishments Results or Progress

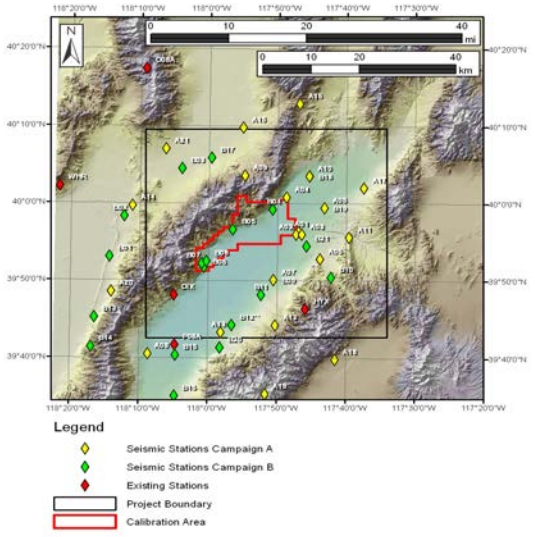
1) Completed the earthquake and explosion database building, and waveform sorting. Currently performing Lg Q and Lg coda Q analysis, modifying algorithms for ambient noise attenuation analysis and starting stochastic parameter investigations using already existing ambient-noise extracted Green's Functions.

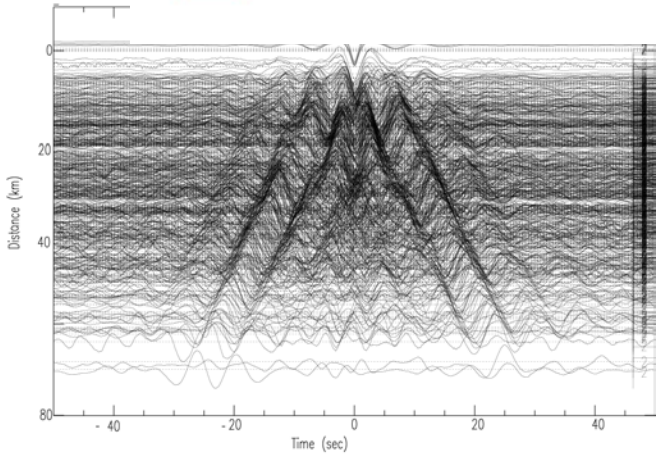
4) Future Directions.

Completion of computation of new ambient-noise cross-correlations, completion of computations of attenuation and stochastic parameter maps and statistical analysis and EGS favorability estimates.

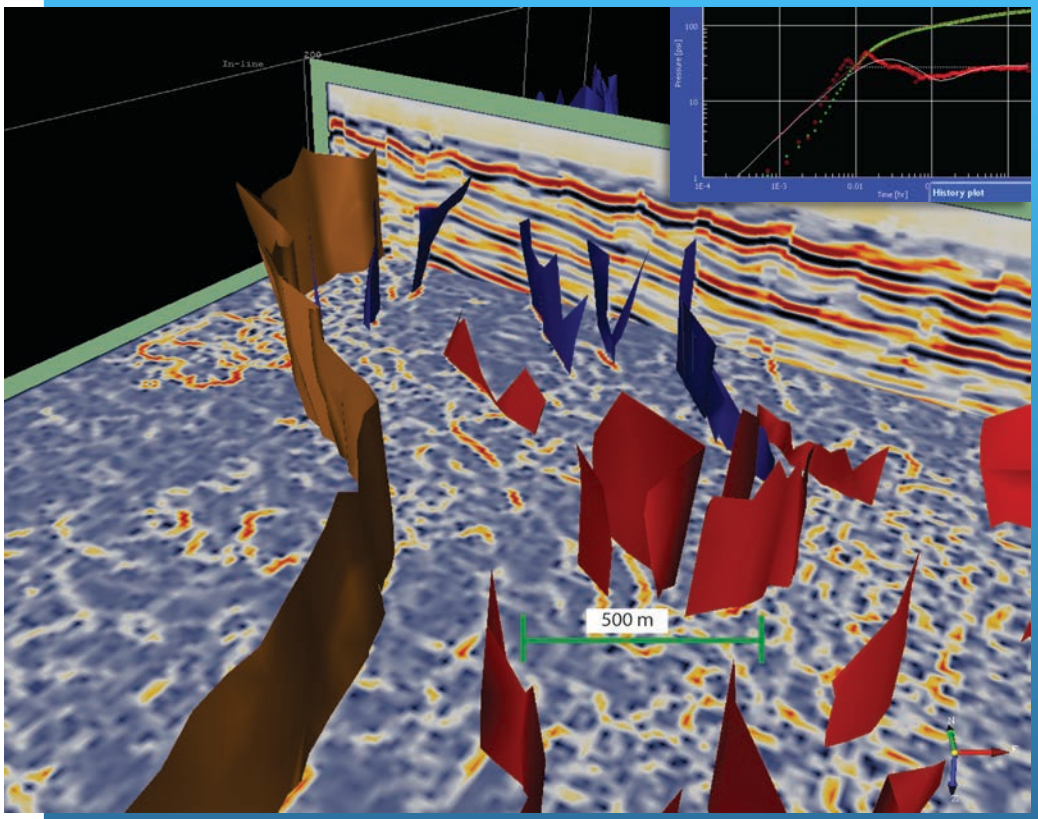
Opportunities for follow-up funding

A significant advantage of this new exploration method is transportability to other potential EGS sites and potential applicability to ground motion estimation, thus to hazard mitigation. Because it uses ambient noise, the method can be applied in new areas where very low seismicity is observed between major events.





Louie- Understanding Downhole Geophysics in Volcanic Basins: Knowledge Transfer from New Zealand's Geothermal Institute



Picked faults are sticking out of a horizontal section of the P-reflection similarity attribute at 290 m (950 ft) depth in Magma's 3D-3C seismic volume at Soda Lake, NV. A cross-line illustrates the fault-enhanced seismic volume. Inset shows pump-test results from the field indicating both granular and fracture porosity.

1) We are searching for a "geothermal seismic signature" that will enable improved geothermal drilling success, lowering the risk and cost of geothermal-power development.

2) We are correlating borehole data against seismic images of Nevada geothermal prospects, assisted by a graduate student's visit to the Geothermal Institute at the Univ. of Auckland, New Zealand last Jan.-Feb.

3) Accomplishments: MS GPH student T. Kent will complete his thesis in May, assembled seismic-attribute and well data from the Soda Lake field, presented an analysis of shear-wave splitting there, and successfully acquired pump-test modeling expertise from Auckland last Dec. and Jan.

4) This project will result in proposals to the next DOE GTP RFP, a project offered to the UNR/UC Davis NSF-I/UCRC collaboration, and collaboration opportunities directly with industry.

Hammond - Reconnaissance InSAR+GPS Surface Deformation Analysis of Salt Wells and Stillwater Geothermal Areas

Importance/Impact of Work:

- Map extent and temporal changes in subsidence from pumping associated with Stillwater and Salt Wells geothermal plants.
- Use information to assess structural controls on reservoir geometry and impact of withdrawal.

Scientific Approach:

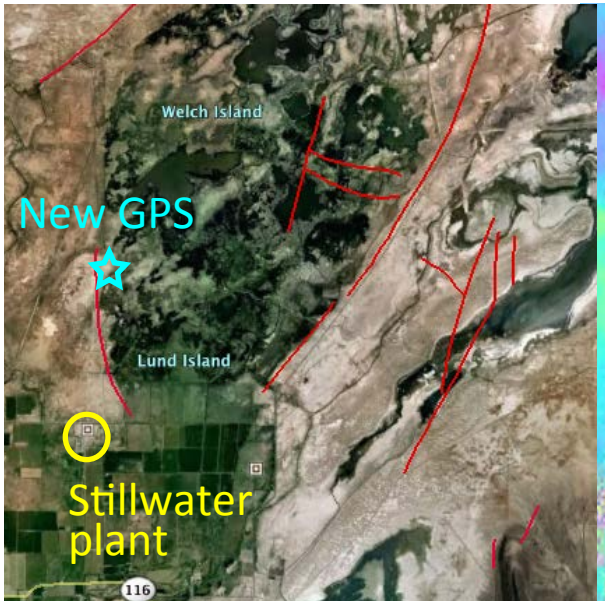
- Surface deformation precisely measured with space geodetic techniques: InSAR and GPS
- Combine InSAR line of sight blanket coverage with 3-component high precision of GPS

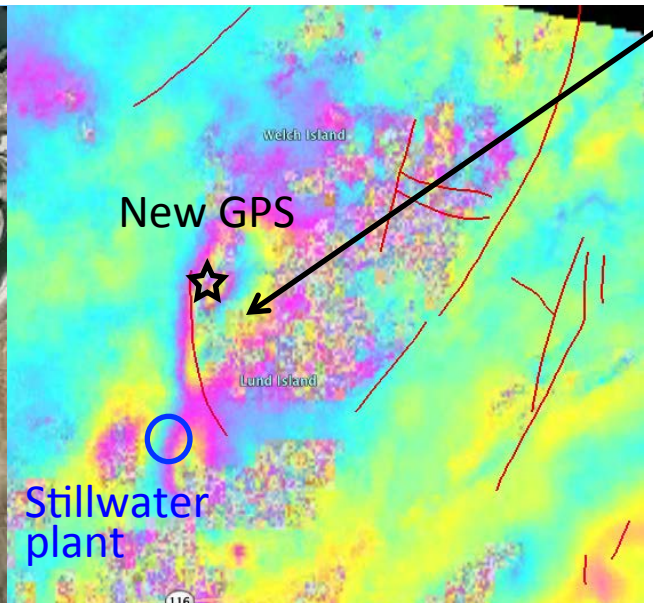
Accomplishments and Progress:

- InSAR data accessed, processed, interpreted. Subsidence fringes detected near Stillwater facility. No deformation detected at Salt Wells.
- 2 GPS stations installed at Salt Wells. Baseline data collected and processed. 1 GPS station location permitted at Stillwater (see figure below).
- Successful proposal for additional InSAR data (TerraSAR-X) and proposal written for ALOS-2 data (satellite to launch in 2014).

Future Directions

- Time series analysis and improved modeling of InSAR and GPS to constrain subsurface fluid movements
- Apply for NSF funds to support further data collection, analysis and modeling.





Stillwater, NV InSAR

- Interferogram July - Aug. 2009
- ~5 cm subsidence
- Structural controls from 1954 Rainbow Mtn. fault ruptures (red lines)

Cooper

Noble Gas and Isotopic Analysis to Delineate Subsurface Flow Patterns North of Pyramid Lake, Nevada

- Relevance: It has been suggested that the fluids discharging from the flowing wells at the Needle Rocks area are from recharge in nearby mountains, and not from northern areas such as Astor Pass, Fox Mountains, and the San Emidio Desert; sampling of dissolved noble gases, environmental isotopes, major ions, and carbon-14 will help determine if the fluids are derived from a common source, and if so, the extent at which there may be mixing in the subsurface.
- Scientific Approach: Use noble gases, isotopes, and major ions to fingerprint reservoir fluids and determine source(s) of fluid and degree of mixing in subsurface
- Accomplishments/Progress: Springs and wells for have been selected for March and April 2013 sampling. A preliminary conceptual flow model has been developed
- Future Directions: Funds will be requested from the Geothermal Technologies Program to further develop use these tools in the determination of the basic length and time scales of fluid flow and heat transport in geothermal reservoirs in the Great Basin.

Siler

1) Relevance/Impact

- Reducing the risk and cost of geothermal exploration and development through detailed 3D analysis of geothermal systems

2) Scientific/Technical Approach

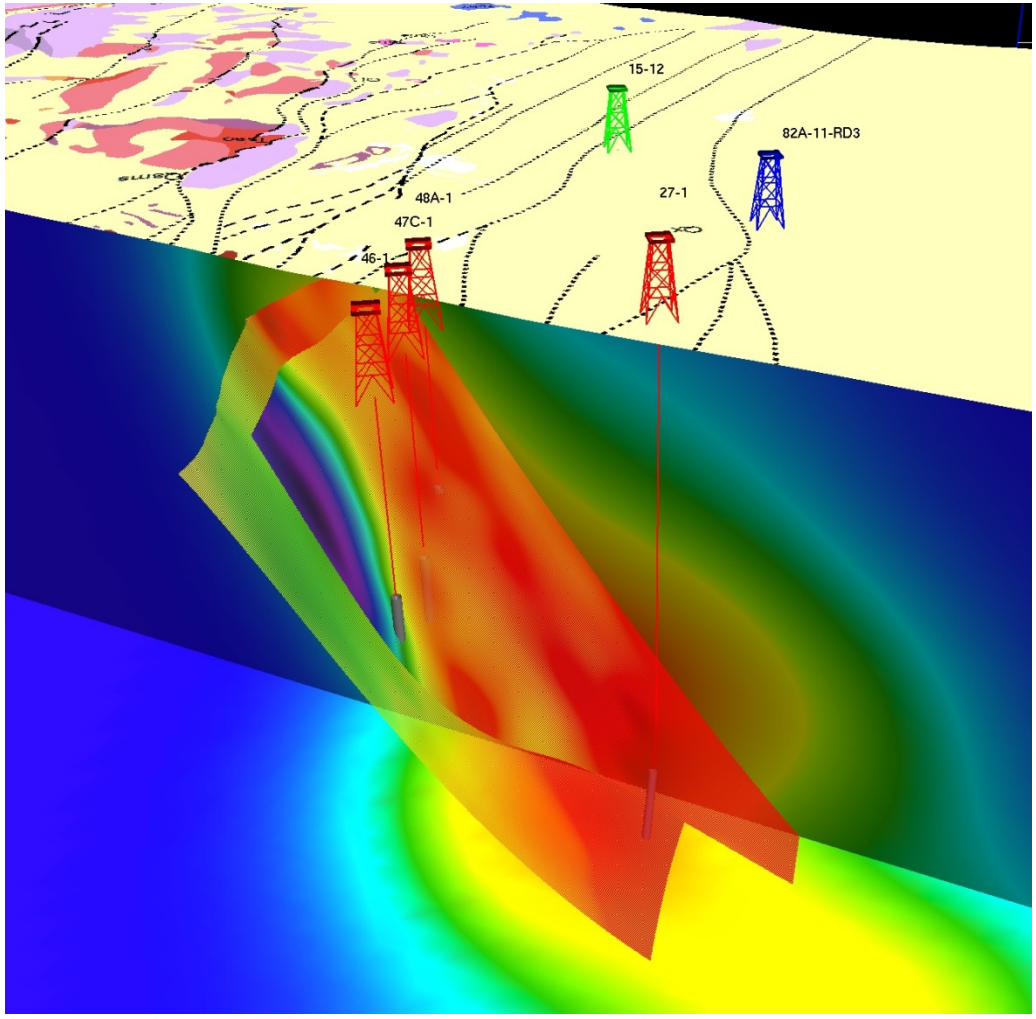
- 3D geologic modeling
- 3D slip and dilation tendency analysis
- 'Fairway' mapping of various indicators of geothermal potential (fault intersection density, slip/dilation tendency, temperature, stratigraphic competence)

3) Accomplishments/Progress

- Two completed 3D models 'fairway' mapping (Brady's, Astor Pass)
- Several 3D models in progress (Tuscarora, Neil Hot Springs, McGinness Hills, San Emidio)
- Presentations at GRC 2012, AGU 2012, planned Hedberg Conference 2013
- Manuscript in preparation (Astor Pass)

4) Future Directions

- Refinement of fairway mapping technique
- Quantitative assessment of the relative importance of different factors on geothermal system control
- Further 3D modeling



Fairway mapping in geothermal systems. Fault intersection density (volume in background) correlates with structurally controlled permeability. Slip tendency on major faults (fault surfaces in foreground) correlates with fluid conduit potential. When combined with other factors (temperature, stratigraphic competence etc.) a 'fairway' map defining discrete drilling targets is created.

Littlefield

- **Project objectives & purpose**
  - Use remote sensing data and spectral analysis for geothermal exploration. Develop more effective methods for using these techniques. Provide remote sensing and spectral expertise to GBCGE affiliates.
- **Technical approach**
  - Use ASD spectrometer and remote sensing data to identify mineralogy in core, samples, ground surface.
- **Accomplishments**
  - 2 m temperature surveys (Mustang, helped at Gabbs, attended Navy Workshop)
    - Data collection using field equipment; data correction and analysis; production of deliverables
  - Spectral assistance for Schwering (Dixie Meadows)
    - Reevaluation of HyMap remote sensing data, field validation; spectral data collection from samples using ASD spectrometer
  - Core spectral studies (Akutan, Blue Mountain)
    - Analysis of spectra, determine best way to collect data and display results effectively (integration of a variety of software)
  - Study of sinter/travertine mixture identified in spectra (Fish Lake Valley)
    - Thin sections made for examination of opal & calcite relationship
  - Technical meetings
    - US-NZ Joint Geothermal Workshop (Rotorua, NZ); Geothermal Resources Council Annual Meeting (Reno, NV); International LiDAR Mapping Forum Meeting (Denver, CO)
- **Publications & presentations**

Calvin, W. M., E. F. Littlefield, and C. Kratt (2013), Remote sensing for geothermal exploration in the Great Basin, *Remote Sensing*, **submitted**.

Littlefield, B. (2012), Analysis of remote sensing data for geothermal exploration over Fish *Lake Valley, Esmeralda County, Nevada.* (**oral presentation** at US-NZ Joint Geothermal Workshop)

Littlefield, E. F. , and W. C. Calvin (2013), Geothermal exploration using imaging spectrometer data over Fish Lake Valley, Nevada, *Journal of Geophysical Research*, **submitted**.

Littlefield, W. M. Calvin, P. Stelling, and T. Kent (2012), Reflectance spectroscopy as a drill core logging technique: An example using core from the Akutan geothermal exploration project, *Geothermal Resources Council Transactions, 36*, 1281-1283. (also **poster presentation**)

Shallow (2m) Temperature Survey Methods

Objectives and Purpose

Compile a data base of 2m temperature data, and continue research in improvements in methods and effectiveness.

Technical Approach

2m temperature surveys are typically conducted in the early stages of a project in efforts to provide an early picture of the thermal foot print of a geothermal system. Because of rapid equilibration time of the methods (1 hour), they allow for modifying survey strategy in real time.

Technical Barriers

Surveys effectiveness is limited by high shallow ground water, and more subtle anomalies are difficult to detect.

Accomplishments

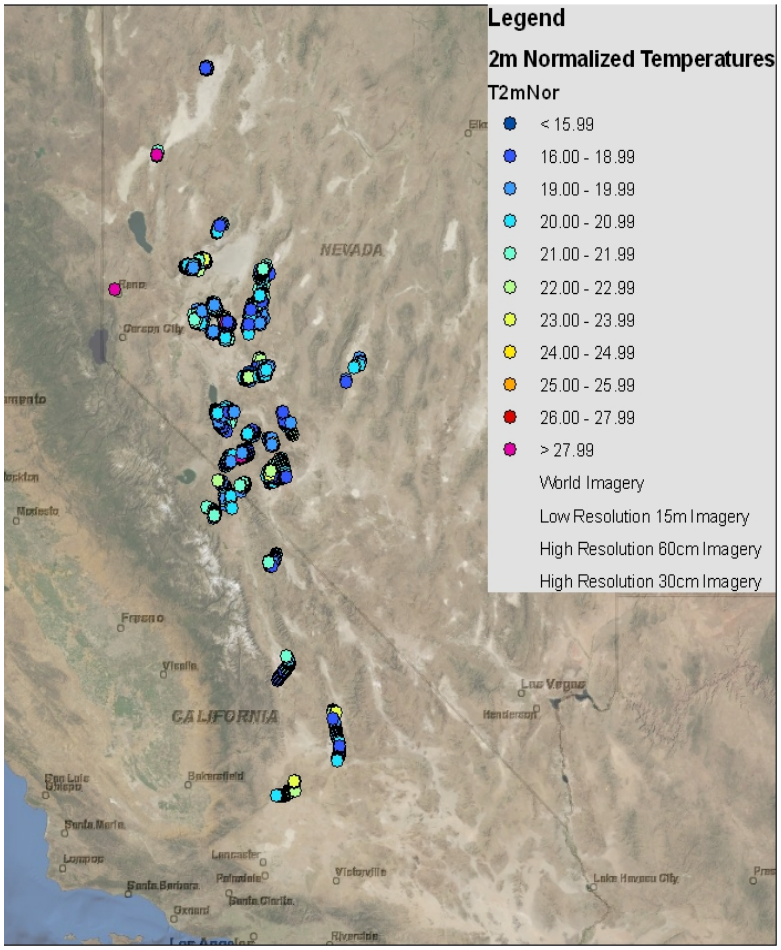
Along with data generated under EE0003997, data of approximately 2000 measurements are being compiled for an interactive online resource.

Specific accomplishments are discussed in individual student projects.

Future Directions

Test the effectiveness in non arid regions, and whether seasonal timing makes shallow temperature surveys useful in areas with higher precipitation rates.

Test the efficiency / improved sensitivity tradeoffs of attempting to reach slightly deeper depths than 2 meters.



Map of approximately 2000 2m temperature measurements made by GBCGE and associates.