Project Title: Assembling Crustal Geophysical Data for Geothermal Exploration in the Great Basin
CPS Identifier: 12339
Principal Investigator: John N. Louie
Sponsoring Organization: University of Nevada, Reno
Other Investigators: none

Project Purpose
This project is assembling a three-dimensional reference model of seismic velocity for the western Great Basin region of Nevada and eastern California. The first three project years developed and tested new regional seismic-refraction surveying technology, conducted three large experiments across the region, and gathered pre-existing crustal geophysical data. Continuing into a fourth year with new funding, the project will now focus on refining a geophysical model of the western Great Basin, and making it available to industry and other groups conducting regional exploration and assessment.

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

This project contributes to subprogram 3.1.1 on Exploration Technologies by improving regional models of geothermal systems geology, applying seismic refraction technologies developed for other uses and applying it to geothermal exploration and assessment, and assisting in the national geothermal assessment being conducted with the U.S. Geological Survey.

Project Objective(s)
The objective of this continuing project, starting its fourth year, is to assemble a three-dimensional reference
model of crustal seismic velocity for the western Great Basin region of Nevada and eastern California. The resulting seismic velocity model consists of simplified rule-based representations of some of the region's crust to 50 km depth, and more detailed characterization of geothermal areas and sedimentary basins. With the resulting more complete sampling of the crustal geophysical characteristics of geothermal resources in the Great Basin, these measures are contributing to quantitative analyses of the associations between different indicators. Under the Great Basin Center for Geothermal Energy’s goal "(1) Geothermal Resource Assessment and Exploration: B. Identification and Characterization of New Potential Geothermal Resource Targets,” this project is contributing critical data toward the effective exploration for new geothermal resources. This project also assists the Center’s goal to enhance the academic infrastructure and technical workforce in geothermal science and technology.

### Funding

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<th>Fiscal Year</th>
<th>DOE Funding ($k)</th>
<th>Cost Share ($k)</th>
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DOE funding to the University of Nevada, Reno has been delayed approximately one year for this project. FY 05 funding has not yet been received.

### Plans and Approach

The project’s work plan has five tasks:

1. Compile crustal geophysical information from sources in the literature, results of previous seismic experiments and earthquake-monitoring projects, and data donated from mining, geothermal, and petroleum companies.

2. Establish a new facility at the University of Nevada for long-range crustal refraction surveys. About half of the first project year’s budget was devoted to acquisition of the seismic recording system, and computer equipment to support the collection of refraction data and dissemination of our results.

3. Develop an efficient new regional seismic-refraction surveying technology, using large mine blasts and earthquakes as seismic energy sources, instead of costly dynamite refraction shots in boreholes.

4. Collect, in May 2002, August 2004, and August 2005, three new crustal refraction profiles across the northern Great Basin. These crustal geophysical sections had not been well characterized in previous work by others. Interpret the results from these new surveys for crustal geophysical parameters.

5. Integrate the results of the new surveys with the pre-existing regional information; create a regional crustal geophysical model for the western Great Basin; make this model available to collaborators, the geothermal industry, and interested agencies; and receive feedback on the model and its access from users.
Milestones (numbered according to work plan):

1.1 Completed initial assembly of pre-existing data and prelim. model 9/30/02
1.2 Refined preliminary model with selected data, posted on web 11/5/04
2.1 Established new refraction facility at UNR 7/31/02
2.2 Completed facility computer and software upgrades 6/15/05
3.1 Developed and tested cost-effective crustal surveying technology 4/29/05
3.2 Reported on surveying technology improvements at conferences 4/29/05
4.1 Collected No. Walker Lane seismic refraction transect 5/30/02
4.2 Published No. Walker Lane transect results in technical journal 12/15/04
4.3 Collected Idaho-Nevada-Calif. (INC) seismic refraction transect 8/30/04
4.4 Reported preliminary INC transect results at conferences 4/29/05
4.5 Publish INC transect results in technical journal 9/30/05
4.6 Collect Nevada-Utah seismic refraction transect 8/30/05
4.7 Report preliminary Nevada-Utah transect results at conferences 9/30/06
4.8 Publish Nevada-Utah transect results in technical journal 9/30/07
5.1 Reported initial model and exploration potential indices at GRC mtg. 9/25/02
5.2 Reported refined model and geothermal correlations at Nevada Geothermal Conference 11/5/04
5.3 Released 1st web-portal pack for supercomputer rendering of model 4/29/05
5.4 Complete integration of new results into model 9/30/06
5.5 Complete gathering of industry feedback on model 9/30/06
5.6 Publish crustal model, deliver on web, to assessment collaborators 9/30/07

Results

The completed milestones listed above (1.1, 1.2, 2.1, 2.2, 3.1, 3.2, 4.1, 4.2, 4.3, 4.4, 5.1, 5.2, and 5.3), together with the papers and presentations listed below, embody the results of this project.

Our completion of two 500-km long regional crustal seismic refraction transects, using the new passive-recording technology, may be this project’s most notable achievement (milestones 2.1, 4.1-4.4). These transects, originating at Barrick’s Goldstrike mine and extending across the Walker Lane, the Fallon, Steamboat, and Long Valley Caldera geothermal areas, and the Sierra Nevada, have assessed broad regions not assessed previously.
A third transect will be carried out in August 2005, with FY04 funding. The new passive refraction-recording technology we developed (milestones 3.1-3.2) has allowed us to collect three 500-km-long geophysical transects during FY02-04, with total funding under $318,000. Using traditional seismic refraction methods, each transect would have cost at least $250,000, double the total funds needed with our technology.

An unexpected result of the surveys, related in a journal publication by Louie et al. (2004), is the discovery of great variations in crustal thickness within the Great Basin. Although counter to conventional wisdom developed in the 1980s of a flat Moho from surveys along the “40°N transect,” our careful re-examination of the mass of conflicting data bears this conclusion out (milestones 1.1-1.2, part of 5.4). The crust may thin to 20 km in the vicinity of Battle Mountain, both transects find. The newly discovered areas of thin crust produce a good correlation of crustal thickness with the occurrence of geothermal power resources in extensional tectonic regimes (other resources are magma-related), in an analysis by Mark Coolbaugh of the GBCGE (addressing milestones 5.1-5.2).

Institutionally, completion of the new seismic surveying facility provided UNR geophysicists with capabilities matched by few other institutions worldwide (milestones 2.1-2.2). As well, more than two dozen graduate and undergraduate students from UNR have participated extensively in project activities, in capacities ranging from instrument deployment, through data analysis, to presentations at international professional meetings.

Project Bibliography

The following papers and presentations (milestones 1.2, 3.2, 4.2, 4.4, 5.1-5.3) are available through www.seismo.unr.edu/geothermal. An asterisk (*) marks the names of students supported by this project; a caret (^) marks names of GBCGE and industry collaborators:


The development and successful testing of new, cost-effective regional seismic-surveying technology should have a major impact on regional geothermal-assessment projects. Our demonstration that large areas can be reconnoitered for crustal properties, at less than half the cost of traditional surveying programs, will make possible the discovery of additional hidden geothermal power resources in the West. While the geothermal power industry itself may not become a direct user of this technology, our methods will be used by agencies making regional assessments. Our results for the...
western Great Basin, and the results of future assessments using our technology, will directly assist exploration by power producers. The GBCGE has identified Buffalo Valley near Battle Mountain, Nevada, as a likely new prospect for exploration efforts. Geodetic work and geochemical data, as well as the thin crust discovered by this project, all contributed to locating this prospect.

We have endeavored to transfer the technology developed by this project, and disseminate our results. In addition to our contributions to the GBCGE website (www.unr.edu/geothermal), for the past three years we have operated a website specifically for this project, and for our customers interested in regional geothermal assessments (www.seismo.unr.edu/geothermal). All of our results and presentations are available from this site. As well, we have given the twelve presentations and papers listed in the bibliography above. These include one paper published in a top-flight peer-reviewed earth science journal, Tectonophysics, two papers at GRC meetings, and one paper at the Society of Exploration Geophysicists Annual International Meeting. Since these papers are all subject to review, we have some confidence that our accomplishments are acknowledged by our peers.

This project will help remove barriers to identification of hidden hydrothermal resources, by providing regional assessments and comparisons of potential new geothermal fields prior to field-scale assessments, or drilling. These assessments should assist the technical goal of improving the success rate for finding economic resources at previously undrilled sites to 40%, within the Technical Goals 3.1.1.1.

Seismic-velocity inversions have been carried out in collaboration with Dr. S. Pullammanappallil of Optim LLC. (Optim is the foremost developer of seismic technology for geothermal investigations.) The crustal seismic velocity model from this sub-project has been contributed to the associated sub-projects of the GBCGE (PIs Shevenell, Coolbaugh) to assemble geographic databases of geothermal indicators. We continue to work in close concert with another project, sponsored by LLNL (including S. Larsen), which has developed a velocity model assembler code. Additional seismic recorders were supplied for the refraction experiments by the NSF & DOE-funded IRIS/PASSCAL Instrument Center at New Mexico Tech (including P. Miller). These peers, marked with carets (^) in the bibliography above where they have been involved in the research, are all stakeholders in the technologies of geothermal assessment, although not directly in power production.

Plans for Completion
Completion will be achieved when the future milestones 4.5, 4.6, 4.7, 4.8, 5.4, 5.5, and 5.6 have been met. These milestones do not require additional fieldwork in FY05 or FY06, so funding is reduced for the final two project years. Completing the interpretation and publication of our refraction transect data is the MS thesis project of UNR graduate student Michelle Heimgartner, under John Louie’s supervision. Heimgartner is scheduled to complete her MS degree in May 2007, virtually in sync with the project’s FY06 funding termination on 9/30/2007. As is evident from the large number of students named in the bibliography above, who have contributed to the research, this project can effectively use student research efforts to meet its milestones.