4.5.2  Seismic Fracture Characterization Methods for Enhanced Geothermal Systems

Presentation Number: 022
Investigator: Queen, John (Hi-Q Geophysical Inc.)
Objectives: To develop surface and borehole seismic methodologies using both compressional and shear waves for characterizing faults and fractures in Enhanced Geothermal Systems.
Average Overall Score: 3.3/4.0

Average Scores by Category

![Average Scores by Category](image)

Figure 30: Seismic Fracture Characterization Methods for Enhanced Geothermal Systems

4.5.2.1 Relevance/Impact of the Research
Ratings of Four-member Peer Review Panel: Good (3), Good (3), Good (3), Outstanding (4)

Supporting comments:

- Characterization of fracture properties of subsurface reservoirs has been a challenging task, especially in geothermal areas. Seismic profiling/tomography provides the highest resolution of all available geophysical techniques, but its utility for mapping fluid-filled fractures and/or pore space is yet to be demonstrated. This project is still in the initial phase. Only models have been explored so far. Some presented results look encouraging, but the actual data analysis will be crucial for demonstrating the concept.

- This research is critical for "ground truthing" of geological structures in the geothermal area. The lack of estimation of Q (attenuation), or the lack of the discussion of this problem, prevents
me from assigning an excellent score. The program is focused on one geothermal field so the results will not be transferable to other localities (without significant additional investment).

- This project tries to solve a nagging problem: the inability to image the subsurface in typical EGS fields. It does so by developing highly sophisticated and detailed models for guiding processing of seismic data. It appears to have made good progress, but as in all field projects, the real test will come when data are acquired.

- This advanced seismic imaging and gravity method development project, if successfully completed at Brady's HS, should make an important contribution to the Geothermal Program mission. The project’s activities could solve known technical barriers, such as what was the pre-existing structure and fracture distribution before stimulation. If this project is successfully completed, this reviewer is confident that the EGS program will benefit and that the results will surely add to the knowledge base.

4.5.2.2 Scientific/Technical Approach
Ratings of Four-member Peer Review Panel: Fair (2), Good (3), Outstanding (4), Outstanding (4)

Supporting comments:

- The PIs have done some forward calculations using idealized models of seismic wave propagation through fractured rocks. The subsurface structure of the test site was approximated using a layered structure with subvertical discontinuities representing faults. Seismic velocities were assigned to different layers, and the time-dependent wave field was calculated for the assumed sources. The purpose of this simulation was to demonstrate that the presence of fractures has an effect on the seismic wave propagation (and can be in principle detected using surface and/or borehole measurements). The effect of fractures was simulated by introducing anisotropy in the seismic velocity structure. The PIs have shown a potentially measurable effect, but it remains unclear how robust this approach will be when actual data are analyzed. In particular, effects of randomly oriented cracks on seismic anisotropy are not well understood. Uncertainties in the (isotropic) velocity structure may trade off with effects of anisotropy. Attenuation of seismic velocities is not considered, which may present a problem (attenuation is likely to be increasingly significant in highly fractured reservoirs). Effects of anisotropy may be subtle and difficult to detect.

- The lack of estimation of Q (attenuation), or the lack of the discussion of this problem, prevents me from assigning an excellent score.

- The technical approach brings in the current state-of-the-art in controlled-source seismology, especially including borehole geophysics. At first glance, the project appeared to be a grab bag of technologies, but on questioning, it became clear that there was, indeed, a scheme behind it. The near-offset VSP will be used to provide a better baseline velocity model, on which a
multi-offset VSP and 3-D survey will be designed. The micro-gravity survey will assist greatly with the shallower parts of that model. The timing and sequence of events is appropriate with this goal.

- The overall technical approach is outstanding. Seismic methods at this over-sampled resolution will provide a detailed look at subsurface fractures and faulting which are very important. Coupling these analyses with gravity and merging it all into a 3-D model will be very significant and is considered by this author state-of-the-art R&D. It looks like there are adequate resources and more than sufficient rigor of the work elements, procedures and methods that, if followed, will achieve the project objectives. The design of the project is straightforward and deemed reasonable and the technical approach is adequately described and clearly laid-out in the tasks provided and project timeline.

4.5.2.3 Accomplishments, Expected Outcomes and Progress
Ratings of Four-member Peer Review Panel: Good (3), Outstanding (4), Outstanding (4), Outstanding (4)

Supporting comments:

- The performed work appears to be on schedule. The PIs are qualified to accomplish the tasks specified in the proposal.

- The researchers are making reasonable head way in achieving the stated goals of wave characterization in complex media.

- The past accomplishments of the team, and the resources brought to bear, are impressive. Of course, the work is still in early development stage.

- The overall quality of the research team, equipment and facilities is outstanding given the list of partnering organizations and individual team members. Relevant experience and the balance of appropriate skills of the research team are outstanding with some team members known to this reviewer. There are several accomplishments to date and the results look very promising, and the project is, according to my rough calculations, on schedule (report says 33% scope done in 1.2 years out of 3.3 years total or 37% schedule = on schedule). Was not able to ascertain the accomplishments as compared to costs to date since current costing was not given.

4.5.2.4 Project Management/Coordination
Ratings of Four-member Peer Review Panel: Outstanding (4), Outstanding (4), Outstanding (4), Good (3)

Supporting comments:

- A positive outcome of this project critically depends on the expertise of PIs and efficiency of their collaboration with operators of the target geothermal site. It appears that the "simulation"
phase of the project is completed, and preparation for the field data collection are well under way.

- Project seems to be managed well.
- The project appears to be well-organized and managed.
- The technical, policy, business, and spend plans for the project are well thought-out, make sense and are, at least logistically on track and project decisions points are appropriately placed. This project has very good project management and coordination.

4.5.2.5 Overall
Ratings of Four-member Peer Review Panel: Good (3), Good (3), Good (3), Outstanding (4)

Supporting comments:

- This project is in a "high risk/high potential yield" category. Seismic mapping of subsurface fracture systems is an extremely challenging task, and some of the proposed goals may be overly optimistic. Insights obtained in the course of this work may be valuable for guiding future investigations.
- The two dimensional nature of the modeling from VSP seems somewhat limiting.
- This is a high-risk, high-payout project. It may fail, and if it does, nobody else will attempt this work for a long time, because there are few people who could do it so well as this team. If it succeeds, it will change the way exploration for EGS is carried out.
- Overall, this reviewer enthusiastically recommends that the project proceed ahead. In the reviewers opinion this project is one of the best in all the projects reviewed and should be funded as a high-priority project if funds are limited. The amalgamation of geophysical methods and a 3-D model is a very powerful technique and should provide insightful data and information to the EGS program.

4.5.2.6 PI Response
No response.