

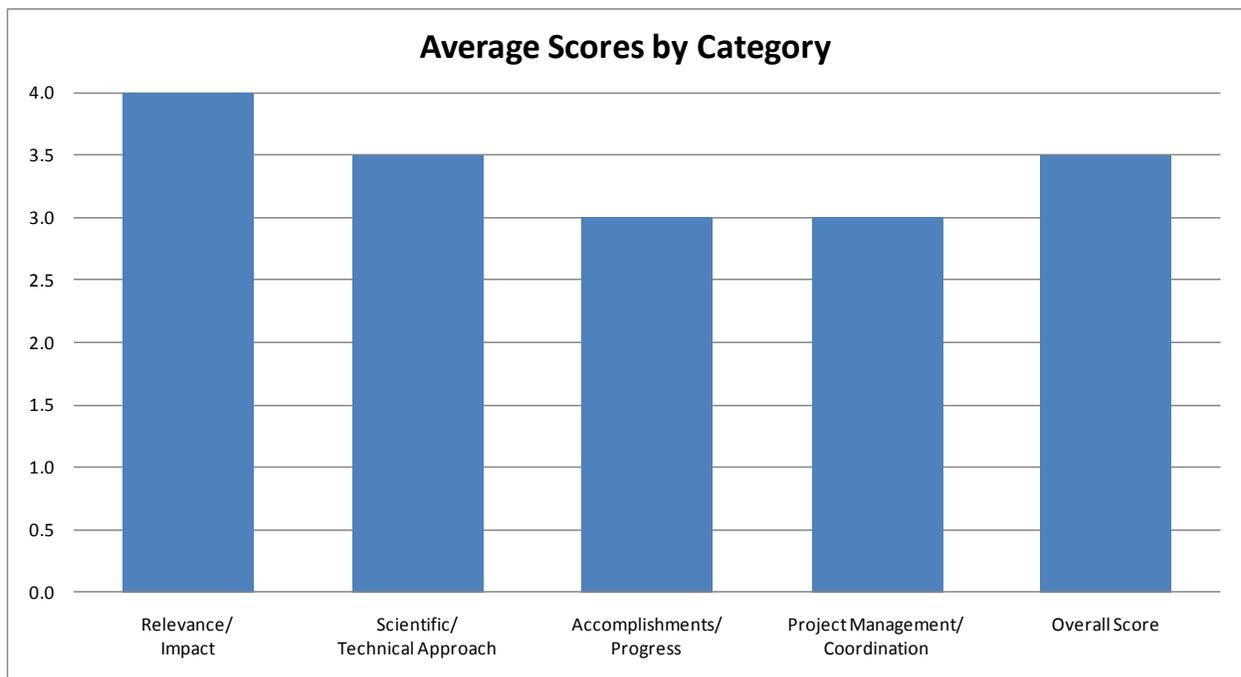
#### 4.5.5 Monitoring and Modeling Fluid Flow in a Developing Enhanced Geothermal System (EGS) Reservoir

**Presentation Number:** 025

**Investigator:** Fehler, Michael (Massachusetts Institute of Technology)

**Objectives:** To better understand and model fluid injection into a tight reservoir on the edges of a hydrothermal field; to use seismic data to constrain geomechanical/hydrologic/thermal model of reservoir; to model for flow network to predict injection and production response of reservoir; and to use model and data analysis to develop improved stimulation methodologies leading to improved production during EGS development.

**Average Overall Score:** 3.5/4.0



**Figure 33: Monitoring and Modeling Fluid Flow in a Developing Enhanced Geothermal System (EGS) Reservoir**

##### 4.5.5.1 Relevance/Impact of the Research

Ratings of Four-member Peer Review Panel: Outstanding (4), Outstanding (4), Outstanding (4), Outstanding (4)

**Supporting comments:**

- This project makes use of a proprietary data set collected by Chevron in the Salak geothermal field in Indonesia. The ultimate goal is to characterize subsurface fracture system and reservoir permeability (possibly, their temporal evolution) using microseismicity. This work is well aligned with DOE goals and holds a promise of substantially improving our understanding of relationships between fluid injection, fracturing, and associated seismicity.

- The work stated here is highly relevant to our understanding of seismicity, flow and crack distribution in geothermal settings. It would be good to see a few more advanced applications being developed.
- The project is trying to tie together explicitly the microearthquakes, velocities, and reservoir behavior (as best known based on data provided). It is very likely going to be the best such study available.
- This combination of detailed high-resolution microseismicity and Green's function interferometry with a state-of-the-art geomechanical model to characterize a stimulation project, if successfully completed at Salak in Indonesia, should make an important contribution to the Geothermal Program EGS mission. The project's activities could solve known technical barriers, such as constraining reservoir models using geophysical data and improving reservoir development scenarios. 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.

#### ***4.5.5.2 Scientific/Technical Approach***

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

#### **Supporting comments:**

- The main premise of the project is that induced microearthquakes highlight locations of fractures and fluid pathways within the geothermal reservoir. This is a reasonable assumption, but the details of relationship between induced seismicity and effective hydraulic permeability are still rather poorly understood. One big unknown is the background stress. The PIs hope to characterize stress within the reservoir using earthquake focal mechanism data. It is unclear how efficient this approach will be given difficulties with focal mechanism solutions for small events.
- Application of HypoDD seems complicated and may be a waste of time. The lead PI is an expert in scattering and it would be good if the team concentrated on that aspect.
- The presenter provided almost exclusively the seismicity side of the project, which is, as one might expect, setting new standards for the state of the art. The reservoir modeling side was less well covered, and it is difficult to judge, but is likely to be just about as good, based on what was said.
- The overall quality of the research team, equipment and facilities is outstanding given the list of partnering organization (e.g., Chevron) 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 but most are initiations of tasks not completions. Not a lot of results and it is not clear if the project is on

schedule or not because the scope completion percentage question was not provided. According to the calendar the project should be 34% done. My guess is the project is behind schedule. Also, this reviewer was not able to ascertain the accomplishments as compared to costs to date since current costing was not given.

#### ***4.5.5.3 Accomplishments, Expected Outcomes and Progress***

Ratings of Four-member Peer Review Panel: Good (3), Good (3), Good (3), Good (3)

##### **Supporting comments:**

- Analysis of seismic data has already begun and initial results are encouraging.
- To date the main accomplishment has been to organize the agreements between the participants - scientific accomplishments are at this point a little too sparse to assess fairly.
- Perhaps this should be "outstanding" but the project is still young, and they have just gotten started with the data provided.
- The technical, policy, business, and spend plans for the project are not presented clearly, the individual tasks make sense and are, at least logistically, on track and there is one appropriately placed project decision point. Because this is a University-led project, the technical plan predominates and policy, business and spend plans are not clearly described. It is recommended that an integrated project plan with timeline should be developed.

#### ***4.5.5.4 Project Management/Coordination***

Ratings of Four-member Peer Review Panel: Outstanding (4), Good (3), Good (3), Fair (2)

##### **Supporting comments:**

- The PI is doing a great job coordinating efforts of the MIT and Chevron teams. This is a multi-disciplinary study involving data collection, seismic analysis and geomechanical modeling, all parts being important to the success of the project.
- Project has slowed down due to complex negotiations with partners. We did not get to see any data because of concern for proprietary interests - so it was difficult to assess the long term likelihood of success. The problem of proprietary data is significant because if the PI's cannot share the results with the larger community there will be no significant benefit to those advancing the field.
- Again, this is difficult to judge, but seems to be a network of like-minded scientists/engineers with a common goal and disparate backgrounds and talents. Given the track record of the PI, this method is likely to work well. But it isn't obvious that there are systematic approaches to ensuring progress.

- The technical, policy, business, and spend plans for the project are not presented clearly, the individual tasks make sense and are, at least logistically, on track and there is one appropriately placed project decision point. Because this is a University-led project, the technical plan predominates and policy, business and spend plans are not clearly described. It is recommended that an integrated project plan with timeline should be developed.

#### **4.5.5.5 Overall**

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

#### **Supporting comments:**

- Monitoring of seismicity, fracture system evolution, and productivity of geothermal wells in response to thermal stresses due to injection of cold water is a clever experiment. Insights gained from this work will be directly applicable to strategies for development of Enhanced Geothermal Systems.
- Overall this project looks like it will be promising, but the lack of data presented and the slow initial progress due to partner sluggishness formed a barrier to a clear assessment of progress.
- In spite of some less-than-outstanding grades in specific areas, this project is nearly certain to develop a piece of work that will set the standard for incorporating data and modeling in EGS.
- Overall, this reviewer enthusiastically recommends that the project proceed ahead. In the reviewers opinion this project is one of the top projects among all the projects reviewed and should be funded as a high-priority project if funds are limited. The combination of detailed high-resolution microseismicity and Green's function interferometry with a state-of-the-art geomechanical model to characterize a stimulation project is innovative and should be a very powerful technique that should provide insightful data and information to the EGS program.

#### **4.5.5.6 PI Response**

No response.