4.6.6 Tracer Methods for Characterizing Fracture Creation in Enhanced Geothermal Systems

Presentation Number: 033
Investigator: Rose, Peter (University of Utah)
Objectives: To develop through novel high-temperature tracing approaches three technologies for characterizing fracture creation within Enhanced Geothermal Systems (EGS).
Average Overall Score: 3.6/4.0

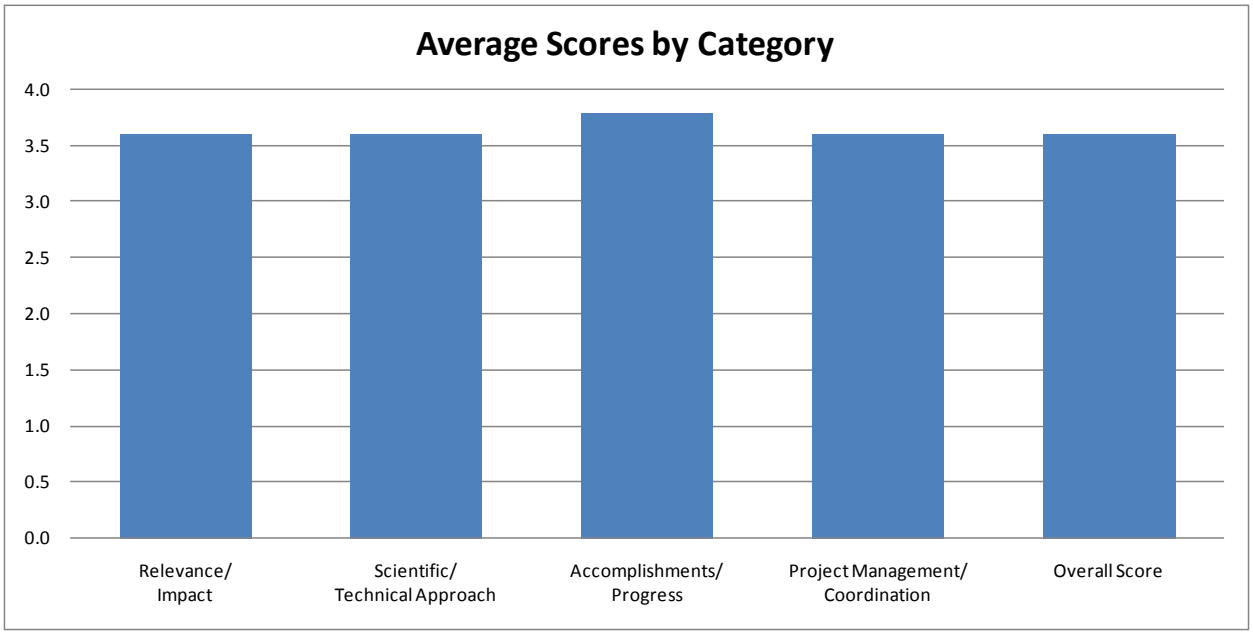

Figure 42: Tracer Methods for Characterizing Fracture Creation in Enhanced Geothermal Systems

4.6.6.1 Relevance/Impact of the Research

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

Supporting comments:

- The use of tracers has significant potential for characterizing some aspects of fractures in geothermal systems. I was less convinced than the PI as to the ability to extract fracture apertures from tracer tests, unless I misunderstood what he meant by fracture spacing. Through systematic evaluation of multiple tracers, it was concluded that safranin O would be a useful tracer with reasonable thermal stability. If information about fracture surface areas and spacing could be gleaned from tracer injection, then this would have important uses in EGS.

- This project deals with a large number of important problems for the GTP, related to tracers, from the identification of proper tracers, the design of numerical tools to estimate fracture

connectivity from tracer tests, and that of measurement tools. This project contributes to addressing key obstacles in the GTP, and provides valuable tools for other applications.

- This research addresses the significant technical barrier relating to measurement of the fluid-rock interfacial surface area - the area that controls heat exchange. This parameter is essential for understanding the productivity of EGS systems and developing the resources most effectively. This study provides methods to measure fracture surface area of injectors and producers and areas near the bore hole via interwell testing using tracers. In addition, a new borehole tool is being developed to enable direct measurements of fluid flow in fractures resulting from stimulation.

  The project demonstrates excellent progress toward goals and objectives - summarized as three primary tasks. As stated it is 37% complete. Each task has many subcomponents, all requiring significant effort. Design and fabrication of a new column reactor to simulate EGS is complete and measurement tools for tracers and effluent have been developed. Successful initial testing of the tracers and experimental setup has been completed. A number of experiments have been conducted with numerous tracers and an ideal tracer identified. Computational modeling is underway.

- Heat exchange in an EGS occurs on the fracture surfaces, and thus, estimating this area is a critical issue for the viability of a site. This project attempts to identify tracers that indicate fracture surface area. The project is also developing a down-hole instrument that is apparently better than current spinner tools for determining fracture flow.

- Investigators are making good progress.

4.6.6.2 Scientific/Technical Approach

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

Supporting comments:

- Multiple tracers have been evaluated for use in EGS. A flow reactor was constructed in an appropriate way. I have some doubt that applications in real geothermal systems will be as straightforward as suggested in the presentation, due to the complexity of multiple interconnected pathways for fluid flow. The down-hole flow meter design seemed to be an appropriate design.

- This is a very rich project dealing with tracer technology at multiple levels: identification of tracers with optimal sorbtion properties, design of a borehole fluorimeter/flowmeter for measuring fracture flow, and design of an algorithm for the numerical approximation of fracture surface area from tracers. The approach is appropriate.

- The approach is well-designed following a systematic plan from laboratory experiments though model calibration and field testing. Initially, experimental tools and techniques have been developed and tested. Lab experiments are integrated with computational experiments as a means of data inversion. Each of the approaches is carefully designed, monitored and evaluated. Experiments provide the basis for the next stage of measurements that are feedback into the experiments and field tests. The continued evaluation of outcomes that are integrated into future experiments is a successful strategy for maximizing results. All steps appear to be rigorous.

  Little information was presented on the experimental starting materials other than the tracer. Fluid compositions for experiments with tracers should include those typical of EGS reservoirs to determine the effect of fluid chemistry on tracer behavior. No information was presented on the solid matrix used in the experiments to 'simulate' a geothermal reservoir. These data are critical in order to extrapolate to the natural system. Additional flow reactor tests to higher temperature are needed.

- The scientific approach is excellent: identifying candidate tracers, testing their behavior in a designed and fabricated laboratory system and mathematical modeling before proceeding to field testing.

- Good scientific approach and organization.

4.6.6.3 Accomplishments, Expected Outcomes and Progress

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

Supporting comments:

- The PI has made excellent progress assessing tracers, constructing a flow reactor, and designing a down-hole flow meter. The presentation graphs were not of good quality, as various curves were stacked on top of each other, making it difficult to understand some of the results. Collaboration with Pruess at LBNL is a valuable part of this project.

- This project had led to the identification of tracers with optimal properties, the development of a model to calculate fracture surface in injection/backflow tests based upon the kinetics of the thermal decay of tracers. They also designed a borehole fluorimeter/flowmeter for measuring fracture flow following a hydraulic stimulation experiment. Project is essentially on track with the proposed timeline. I am surprised by the lack of publications, considering the magnitude of the work performed.

- Productivity to date is excellent. Tasks 1 and 2 appear to be largely complete. The new laboratory flow reactor and measurement techniques/apparatus have been developed and

testing completed. Numerous tests with various candidate tracers have identified the most promising tracer (with thermal and chemical stability) and will be used in an upcoming field test. Computational modeling has been developed to invert the tracer data to interwell fracture surface area. This modeling is then extended to provide surface area calculations from injection and backflow tests. A new, novel, borehole flowmeter is being developed for down-hole use.

Upscaling of the lab results to field test is an important step for demonstrating the utility of this approach. Quality of the collaborators for modeling is excellent. Characterization of solids could be improved. No publications/presentations have yet resulted from this work. These are encouraged.

- Project has made good progress in identifying possible tracers and testing them in laboratory experiments in an apparatus they have fabricated. Design of the down-hole tool is also progressing despite a major change in design. Project seems to be on a trajectory to provide tracers and a tool for field testing.

- Well qualified performers. They have some good initial results.

4.6.6.4 Project Management/Coordination

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

Supporting comments:

- The project seemed well managed and designed. I have some concern about the field tests of the tracers: they seem to be planned, but apparently no field tests have been done to date. This is a critical issue for the remainder of the project. It seems that the down-hole meter had to be redesigned compared to the original plan, but the PI seems to have made appropriate and flexible decisions.

- Despite its breadth and complexity, the project is essentially on track. It is noted that the project involves collaboration with LBNL and LANL for the numerical modeling, and with multiple test sites operated by several industrial or institutional partners. The balance in fundamental, experimental, and numerical work and their integration is excellent. The technological design work and accomplishment is also very good.

- Based on the progress to date, management of the project is highly effective and well structured. Coordination between collaborators is evident in the multi-faceted approach to testing, experimenting and future directions.

- Project management seems straightforward and work seems well-coordinated with related computational work at LBNL. Plans are in place for review of the down-hole instrument.

Presentation mentions interaction with a number of field projects for use of the products, but this is for the future and understandably a bit vague at this point.

- Limited information on this metric, but no red flags.

4.6.6.5 Overall

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

Supporting comments:

- Not only does this project address the use of tracers in EGS, but it has also evaluated numerous candidate tracers. I have some hesitation about the ease of interpretation of field tests of these tracers. It is intended that the fracture area available for heat exchange could be evaluated in field tests, but my guess is that this will be inconclusive. Perhaps the use of multiple tracers with known characteristics, as well as the use of heat exchange measurements from push-pull tests could extract some useful information, especially when combined with modeling with LBNL.

- This is a very well managed, very successful project.

- The project is well conceived and executed with its many components. All interact in a positive feedback to assure success.

- No comments.

- Important project for geothermal R&D.

4.6.6.6 PI Response

No response.