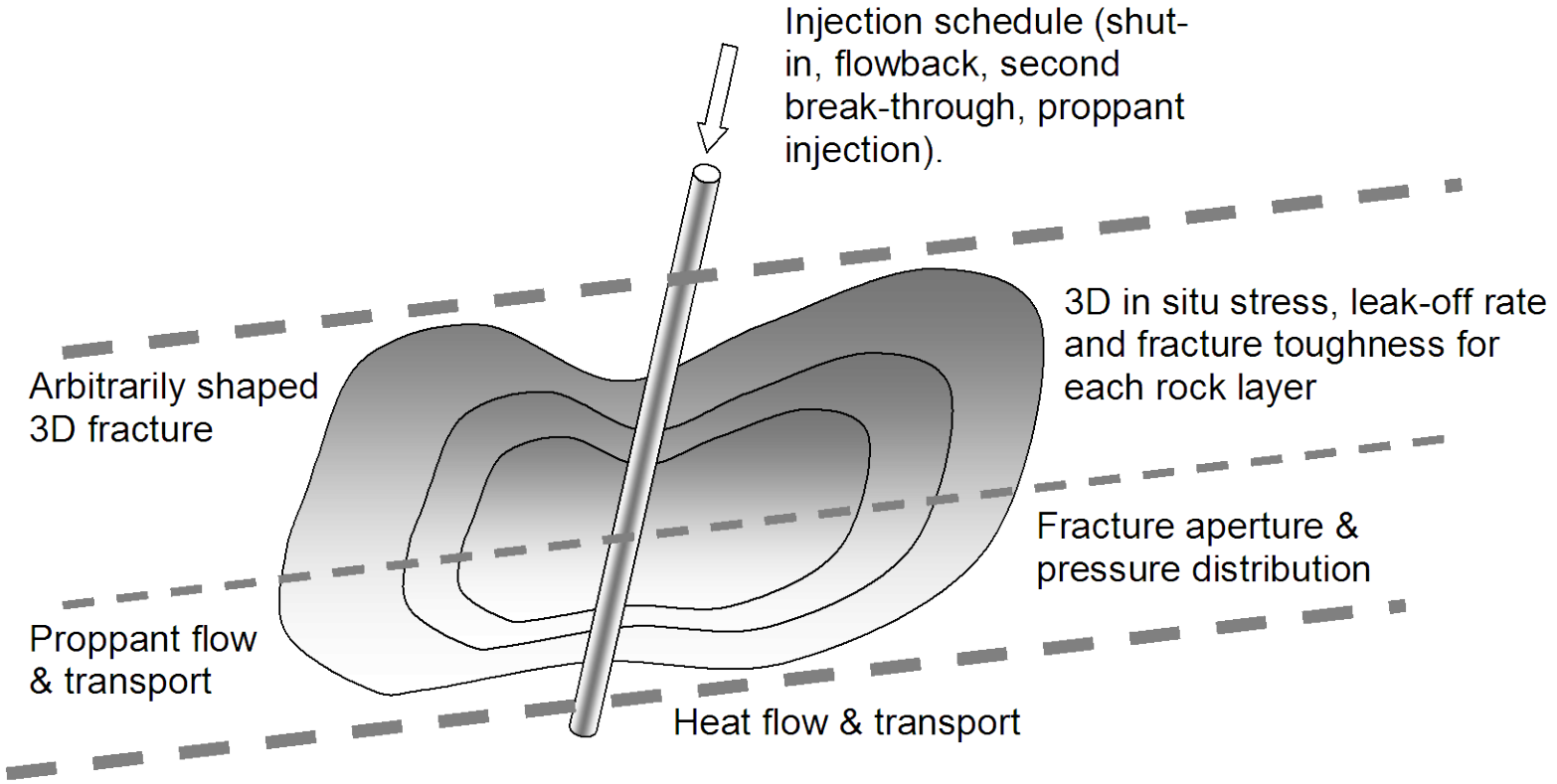


Development and Validation of an Advanced Stimulation Prediction Model for Enhanced Geothermal Systems (EGS)

May 18-20, 2010

PI: Marte Gutierrez
Presenter: Masami Nakagawa
Colorado School of Mines

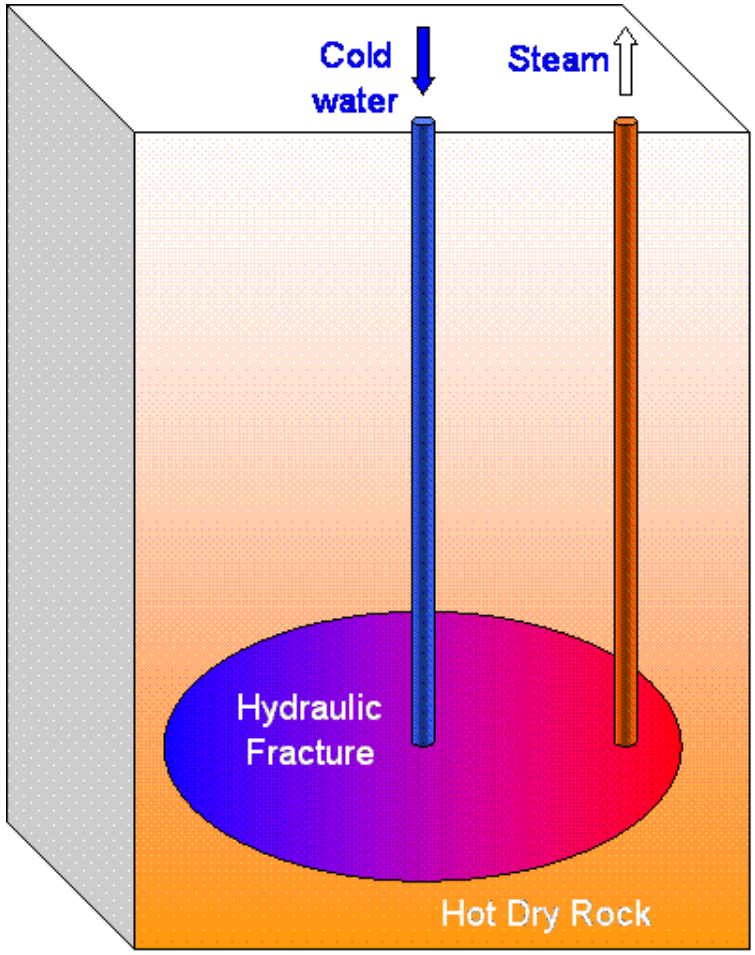
Chemistry, Reservoir and Integrated models

Overview

- Timeline
  - Project start date: January 20, 2010
  - Project end date: December 31, 2012
- Budget
  - Total project funding: $1,170,597
  - DOE share: $860,597
  - Awardee share: $310,000
  - Total funding in FY10: $412,236
- Barriers: Project is slightly delayed due to difficulty of hiring graduate students
- Partners: National Institute of Advanced Industrial Science and Technology (AIST), Japan, and Central Research Institute of Electric Power Industry (CRIEPI), Japan

Relevance of Research

- Hydraulic fracturing is the primary means of creating functional EGS reservoirs at sites where rock permeability precludes cost effective heat recovery.
- EGS reservoir creation requires improved fracturing methodology.
- Applicability of oil and gas stimulation technologies have not been demonstrated for EGS reservoir application.



Project Objectives

- Develop a true 3D hydro-thermal fracturing and proppant flow/transport simulator that is particularly suited for EGS reservoir creation.
- Perform laboratory scale model tests of hydraulic fracturing and proppant flow/transport using a polyaxial loading device, and use the laboratory results to test and validate the 3D simulator.
- Perform discrete element/particulate modeling of proppant transport in hydraulic fractures to validate the proppant transport model.
- Test and validate the 3D hydraulic fracturing simulator against case histories of EGS energy production.
- Develop a plan to commercialize the 3D hydraulic fracturing and proppant flow/transport simulator.

Scientific/Technical Approach

The Stimulation Prediction Model to be developed will have the following capabilities:

- Truly three-dimensional.
- Able to model coupled hydro-thermo-mechanical (HTM) processes involved in EGS reservoir creation
- Incorporates thermally induced stresses and fracturing, and temperature-dependent fluid and rock properties
- Can deal with the entire process of the hydraulic fracturing and proppant flow and transport
- Can deal with layered formations with different rock mass conditions in each layer
- Considers deviated boreholes with arbitrary deviation angles
- Incorporates non-Newtonian rheological behavior of the fracturing fluid and proppants
- Considers variable injection rate and proppant concentration in the injected fluid and time step interval

Scientific/Technical Approach

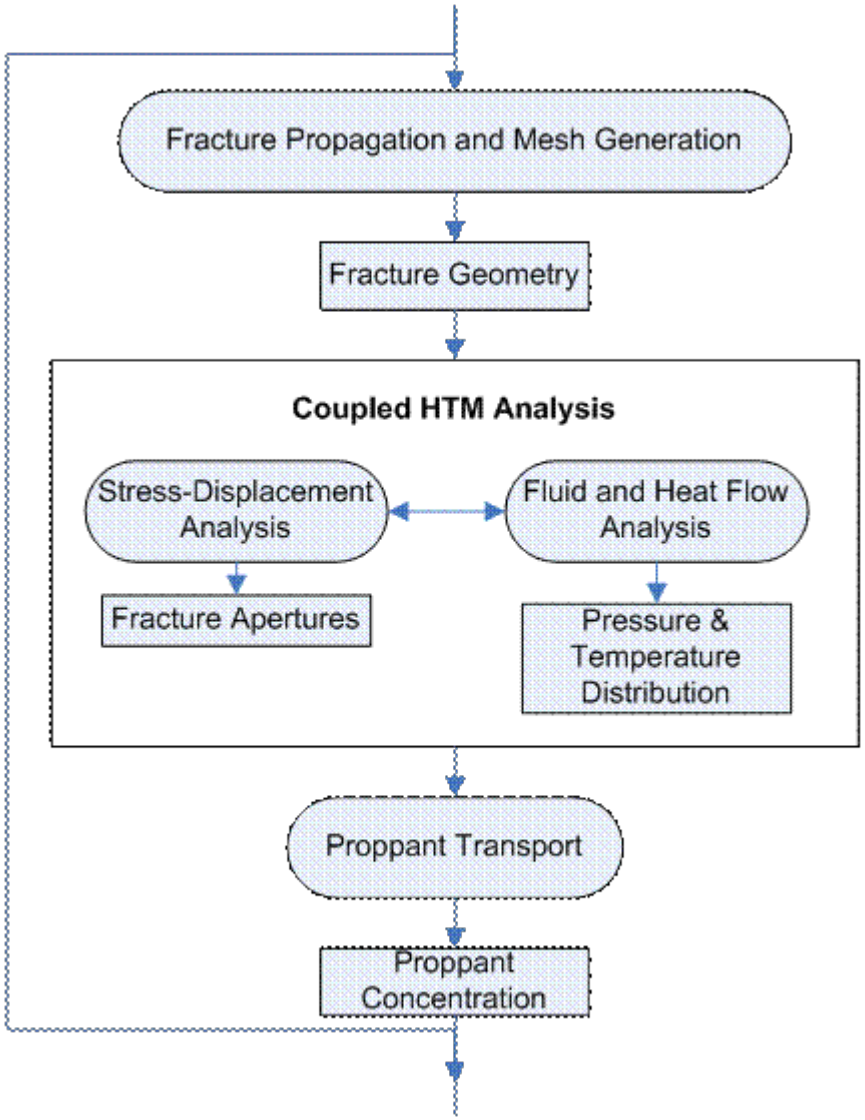
The following technical approach will be followed in the development of the Stimulation Prediction Model:

- Three-dimensional hydro-thermal fracture propagation modeled using the 3D Displacement Discontinuity (DD) method and adaptive remeshing
- Fracturing fluid modeled as Non-Newtonian fluid and as a two-dimensional planar flow in the plane between parallel fracture surfaces
- Temperature changes induced by the injection of a fracturing fluid modeled as heat conduction and advection problem
- Fluid flow and rock deformation treated as coupled processes
- Proppant flow and transport modeled as a multiphase flow of a mixture of solid particles in a fluid
- Proppant simulator validated by particulate modeling
- 3D hydro-thermal fracturing simulator validated against polyaxial scale model tests and against field monitoring data from two EGS Test sites in Japan

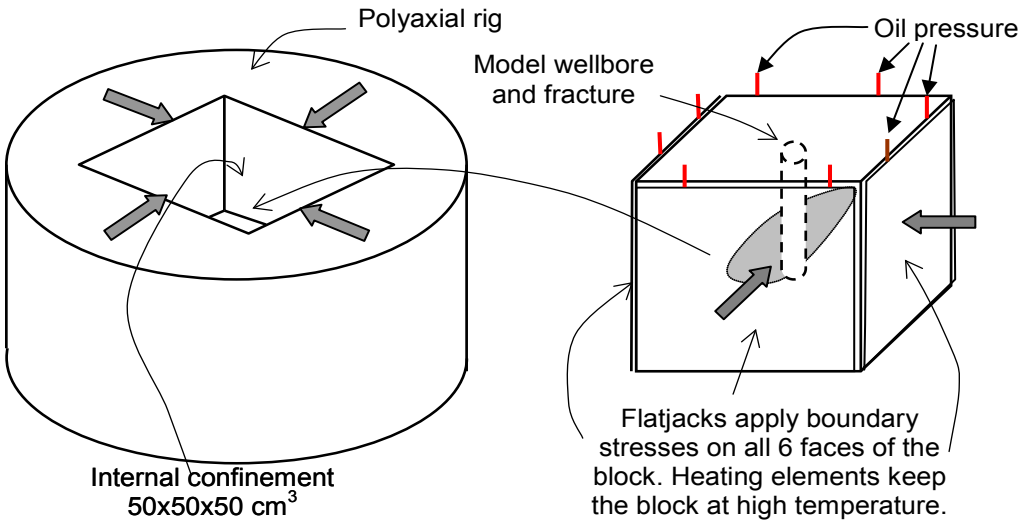
Scientific/Technical Approach

Four modules:

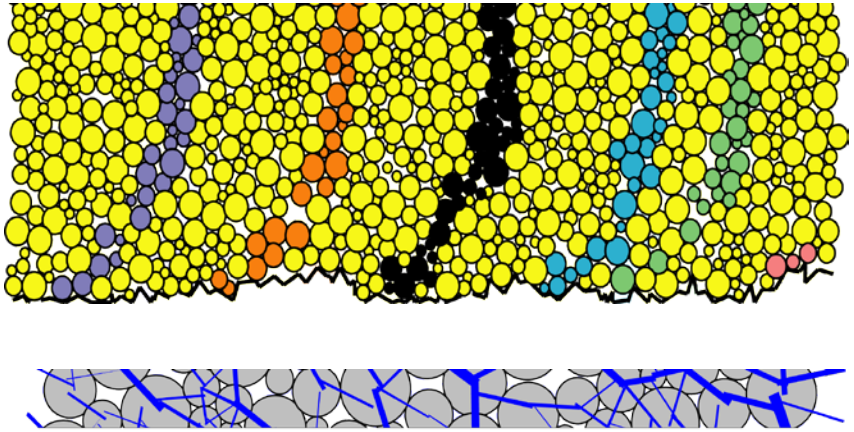
- Fracture propagation and mesh generation
- Stress-displacement fracture aperture
- Fluid flow and thermal analysis
- Proppant transport



Scientific/Technical Approach

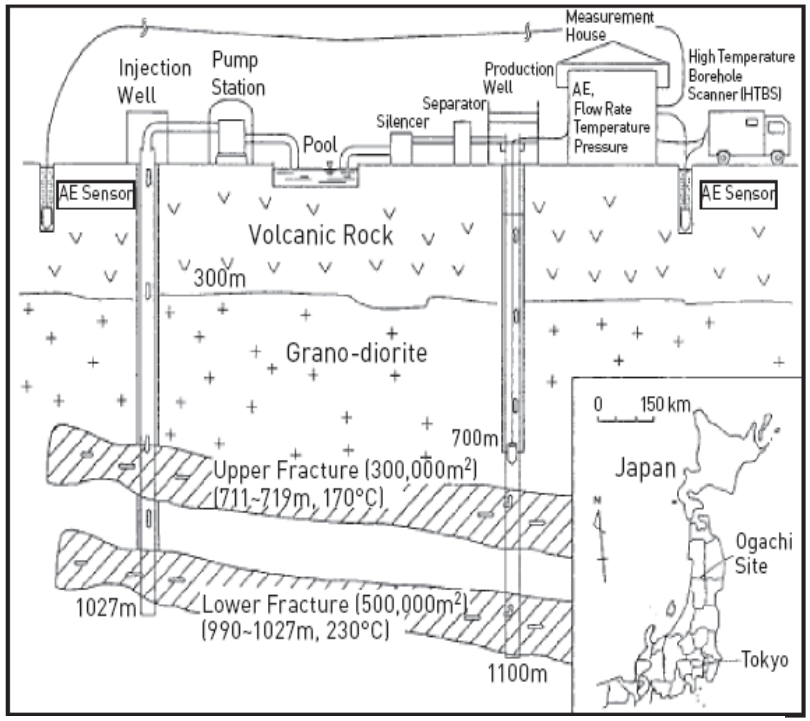


Details of the polyaxial rig that will be used for scale model testing and validation of hydro-thermal fracturing in rocks

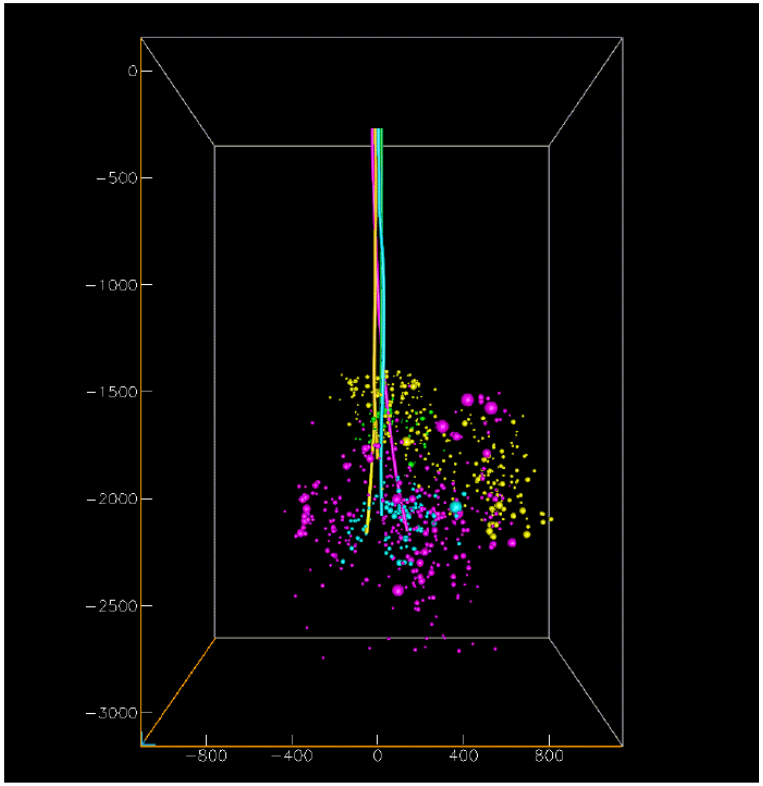


Particulate modeling of proppant flow and transport

Scientific/Technical Approach



Field validation against Ogachi EGS Test Site



Field validation against Hijiori EGS Test Site

Progress and Project Team

Progress to Date:

- Three graduate students hired
- Structural design of polyaxial cell
- Literature review of EGS case histories

Project Team:

- PI: Marte Gutierrez, J.R. Paden Distinguished Professor, (Experimental and Computational Geomechanics)
- Co-PI: Masami Nakagawa, Assoc. Professor (Geothermal Energy and Discrete Element Modeling)
- Four graduate students

Expected Outcomes

- Computer code for 3D hydro-thermal fracturing
- Computer code for proppant flow and transport modeling
- Thermo-mechanical properties of an artificial granite
- Results of scale model testing and validation of the 3D fracturing simulator
- Results of scale model testing of proppant behavior
- Procedures for 2D and 3D particulate modeling of proppant flow and transport
- Results of validations of proppant flow and transport model by particulate modeling
- Database of monitoring data from stimulation and water circulation tests at the Ogachi and Hijiori EGS test sites
- Results of the simulation of hydraulic fracturing and water circulation tests at the Ogachi and Hijiori EGS test sites, and the validation of the 3D hydro-thermal fracturing simulator

Project Management/Coordination

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

Tasks	Quarters after start of project											
	2010				2011				2012			
	1	2	3	4	1	2	3	4	1	2	3	4
1. Develop true 3D hydro-thermal fracturing simulator												
1.1 Complete model formulation and implementation												
1.2 Create pre and post-processors for the simulator								1				
2. Develop proppant flow and transport simulator												
2.1 Complete model formulation and implementation												
2.2 Couple proppant model with the fracturing simulator								2				
3. Validate the 3D hydro-thermal fracturing simulator												
3.1 Design and manufacture a polyaxial cell												
3.2 Create and test an artificial granite			3									
3.3 Perform hydro-thermal fracturing scale model tests												
3.4 Validate fracturing simulator using model test results												4
4. Validate proppant simulator												
4.1 Perform proppant flow and transport scale model tests												
4.2 Validate proppant flow and transport simulator												5
4.3 Perform particulate simulations								6				
4.4 Validate proppant simulator via particulate modeling												7
5. Validate the fracturing simulator using case histories												
5.1 Review and assemble field data from EGS test sites				8								
5.2 Simulate EGS Test Sites using simulator												
5.3 Validate simulator using EGS Test Sites												9
6. Develop dissemination and commercialization plans												
6.1 Form a User's Group												
6.2 Market the software via an EGS service company												

Summary

The simulator to be developed in the research project is envisioned to:

- Clarify the mechanics of the entire process of EGS hydro-thermal fracturing and propping with the fewest assumptions and least empirical knowledge in order to better understand the underlying mechanisms of hydro-thermal fracturing.
- Become a tool for planning and design of efficient hydraulic fracturing for EGS reservoir creation.

Optional Slide

- List any publications and presentations that have resulted from work on this project. Use at least 12 point font.

The project has just started in 1/20/10 and has not produced any publications yet.

Note: This slide is for the use of the Peer Reviewers only – it is not to be presented as part of your oral or poster presentation. These Supplemental Slides will be included in the copy of your presentation that will be made available to the Reviewers.