

Ogachi HDR site, Japan

Laboratory and Field Experimental Studies of CO₂ as Heat Transmission Fluid in Enhanced Geothermal Systems (EGS)

May 18, 2010

Karsten Pruess
Lawrence Berkeley National Lab.

- The project started in February 2010; end date has not been determined.
- Collaboration between LBNL (Pruess), UC Berkeley (Glaser), Central Research Institute of the Electric Power Industry, Japan (Kaieda) and Kyoto University (Ueda)
 - UC Berkeley: laboratory testing of CO₂ heat extraction
 - Japan: inject brine-CO₂ mixtures into Ogachi HDR site (T ≈ 210 °C, P ≈ 100 bar)
 - LBNL: model reactive chemistry induced by brine-CO₂ injection
- DOE is funding the U.S. portion; FY10: 92.7 k\$ (received), 246 k\$ (expected)
- The project is closely coordinated with an LBNL/INL project on EGS with CO₂
- The research addresses the following barriers identified in the multi-year geothermal R&D plan: F, G, L, M, N, O, W, Y

The project has two thrusts

- 1) Perform laboratory heat extraction experiments with CO₂ and brine-CO₂ mixtures.
- 2) Perform modeling studies of *in situ* chemical interactions between brine-CO₂ mixtures and reservoir rocks at the Ogachi HDR site, Japan.

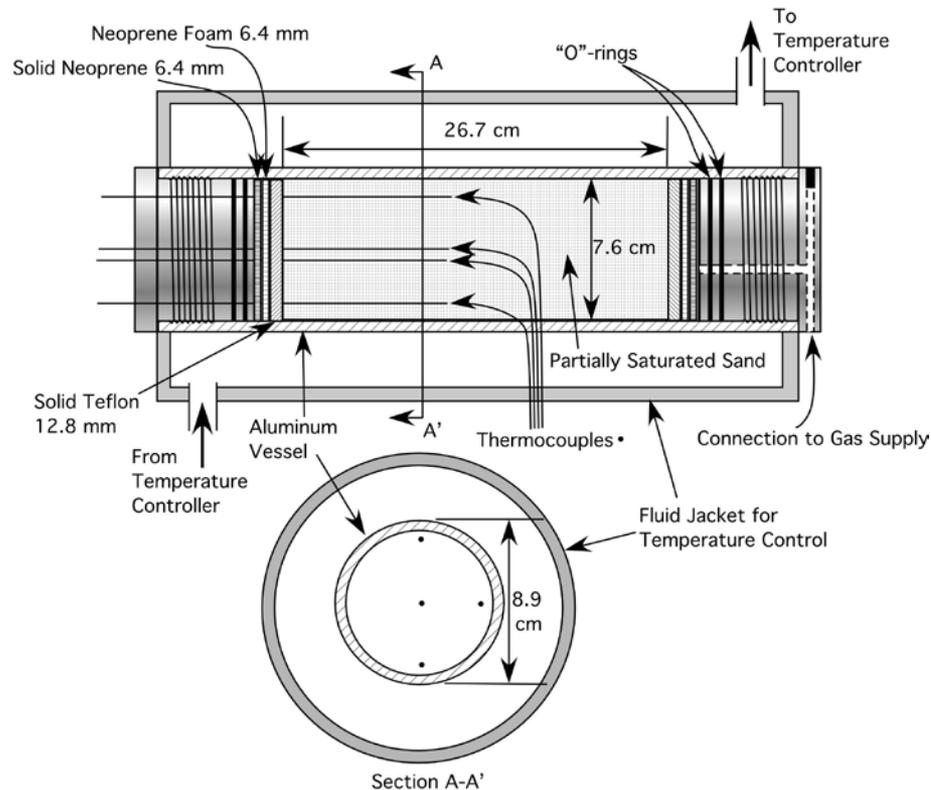
Objectives are to

- obtain basic information on the performance of CO₂-based EGS, and
- enhance and calibrate modeling capabilities for such systems.

- Employ a combination of laboratory, modeling, and field studies.
- The laboratory component will focus on physical aspects of multiphase flow and heat transfer relevant for EGS with CO₂, and will complement a recently funded cooperative LBNL/INL project entitled “Enhanced Geothermal Systems (EGS) with CO₂ as Heat Transmission Fluid.”
- The field component will use data from past, ongoing, and future CO₂ injection experiments at the Ogachi EGS site, Japan, and will concentrate on modeling studies of aqueous chemical evolution and mineral alteration.
- The field experiments at Ogachi are being performed by Japanese researchers and funded by Japanese agencies.

- For progress with the laboratory heat extraction experiments, see the closely related LBNL/INL project entitled “Enhanced Geothermal Systems (EGS) with CO₂ as Heat Transmission Fluid.”
- We have established a close working relationship with our Japanese colleagues who are doing the field experiments at Ogachi (the Japanese researchers visited LBNL in January 2010, Tianfu Xu visited Japan in April 2010).
- TOUGHREACT/ECO2N has been enhanced to permit temperatures up to 250 °C (previous limit was 110 °C).
- TOUGHREACT modeling of chemical changes observed at Ogachi in response to injection of brine-CO₂ mixtures is underway.

Schematic of Core Holder for CO₂ Heat Extraction Experiments

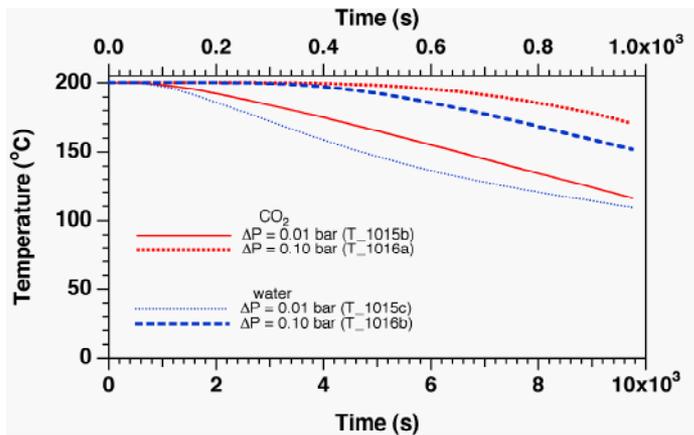


Core Holder and Pump for Heat Extraction Experiments

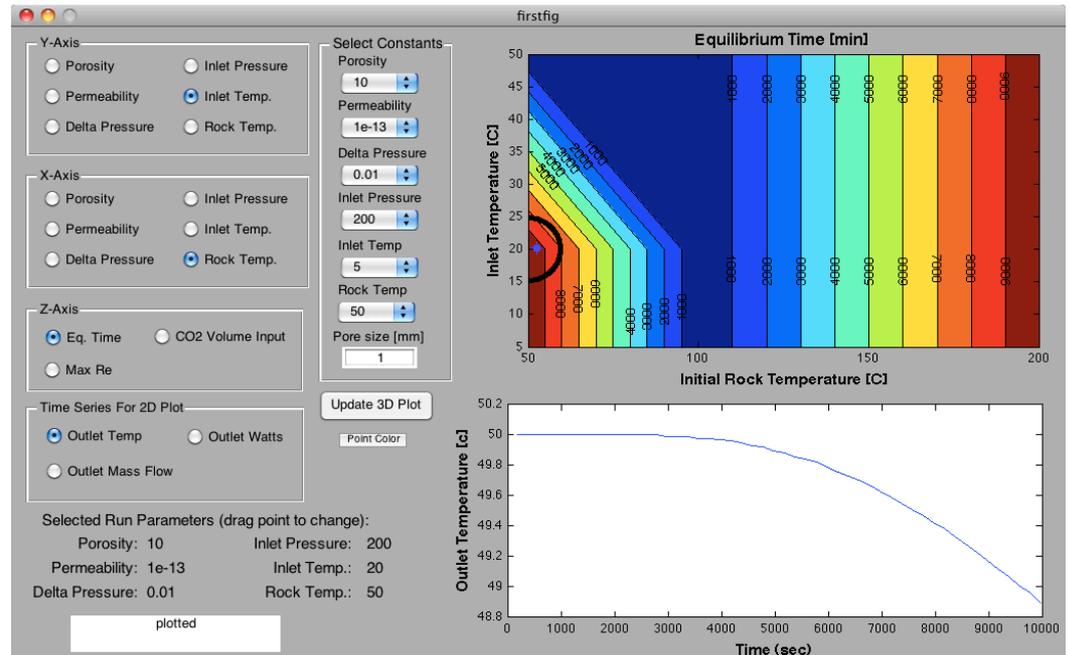


Quizix C-6000-5K high pressure,
high flow rate pump

Design Calculations for Heat Extraction Experiments



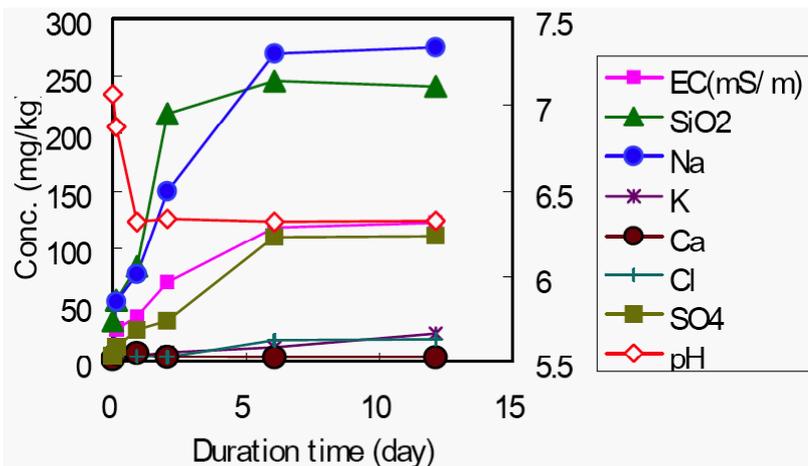
TOUGH2 simulation results for temperatures at the core outlet, for different pore fluids and applied pressure increments.



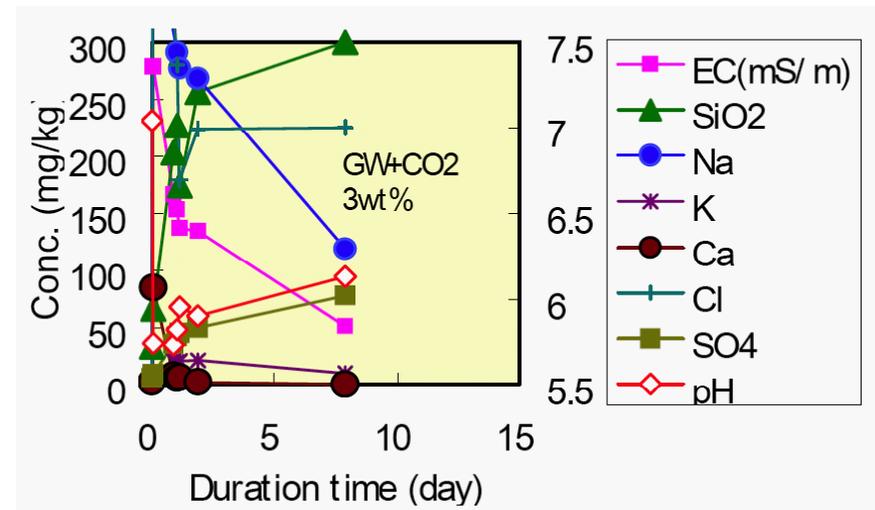
Screen shot of a data browser, displaying results of multiple TOUGH2 runs for different permutations of experimental parameters.

Observed Changes in Water Chemistry at the Ogachi HDR Reservoir in Response to Water-CO₂ Injection

Inject river water



Inject river water with 3 wt.-% of CO₂



(from Kaieda et al., 2009)

- The project is a collaboration between LBNL (Pruess and Xu), UC Berkeley (Glaser), CRIEPI (\approx Japanese EPRI, Kaieda), and Kyoto University (Ueda).
- The project is closely coordinated with an ARRA-funded LBNL/INL cooperation project on “Enhanced Geothermal Systems (EGS) with CO₂ as Heat Transmission Fluid.”
- The laboratory experiments at UC Berkeley are performed by a PhD student.
- We have established a good working relationship with the Japanese researchers (mutual visits, exchange of technical information).

- Work with UC Berkeley to assemble and utilize core flood apparatus for CO₂-brine fluid flow and heat transfer experiments.
- Collaborate with Japanese researchers on field experiments probing *in situ* chemical interactions between CO₂-brine-rock at geothermal conditions.
- Perform TOUGHREACT modeling of *in situ* chemical interactions between water-CO₂ mixtures and reservoir rocks at Ogachi.

- Laboratory flow experiments are being assembled to test model predictions and provide crucial input data for models.
- TOUGHREACT modeling is underway for changes in aqueous-phase composition observed in *in situ* reaction experiments at the Ogachi HDR site.
- We have established a good working relationship with the Japanese researchers in the Ogachi field project.
- The project is closely coordinated with an ARRA-funded LBNL/INL cooperation project on “Enhanced Geothermal Systems (EGS) with CO₂ as Heat Transmission Fluid.”