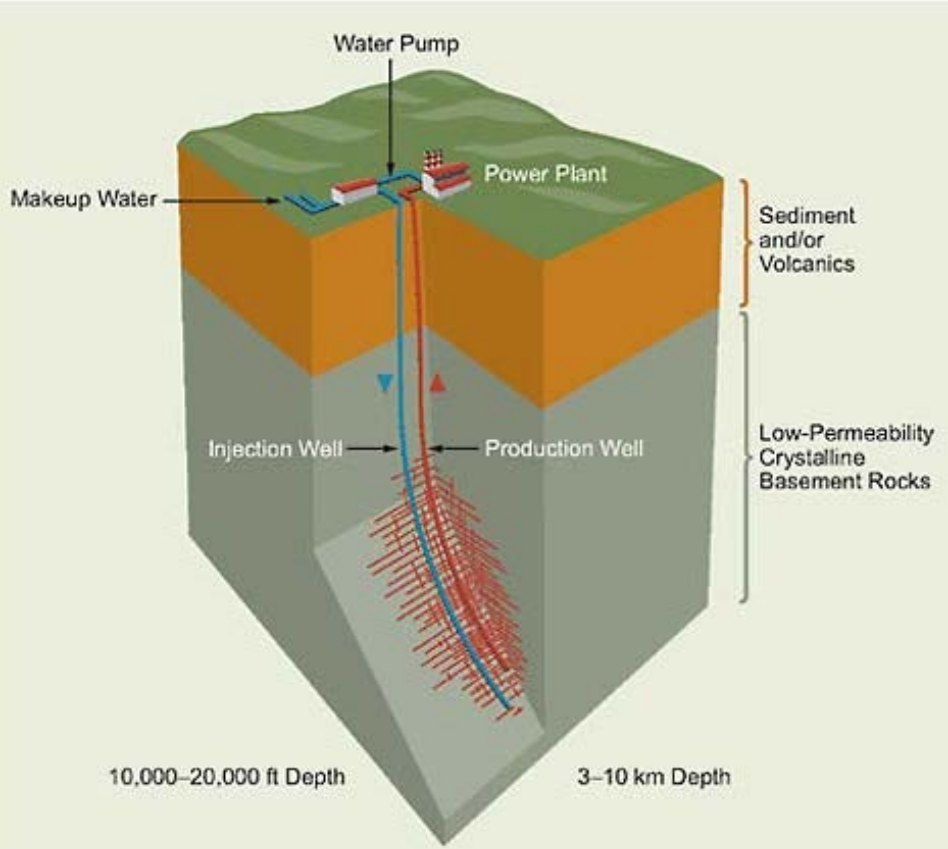
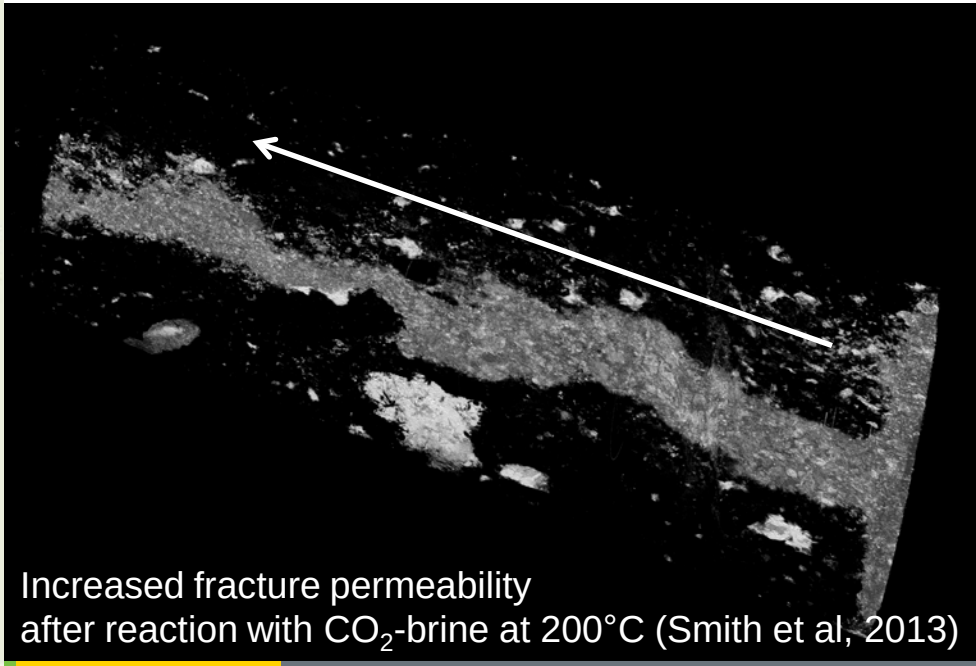


Impact of mineral reactions on shear zone permeability is uncertain at EGS conditions because key rate reactions are unknown



Increased fracture permeability after reaction with CO_2-brine at 200°C (Smith et al, 2013)

The Viability of Sustainable, Self-Propping Shear Zones in Enhanced Geothermal Systems: Measurement of Reaction Rates at Elevated Temperatures

Project Officer: Dan King; Total Project Funding: $1,100,000

April 24, 2013

Susan Carroll

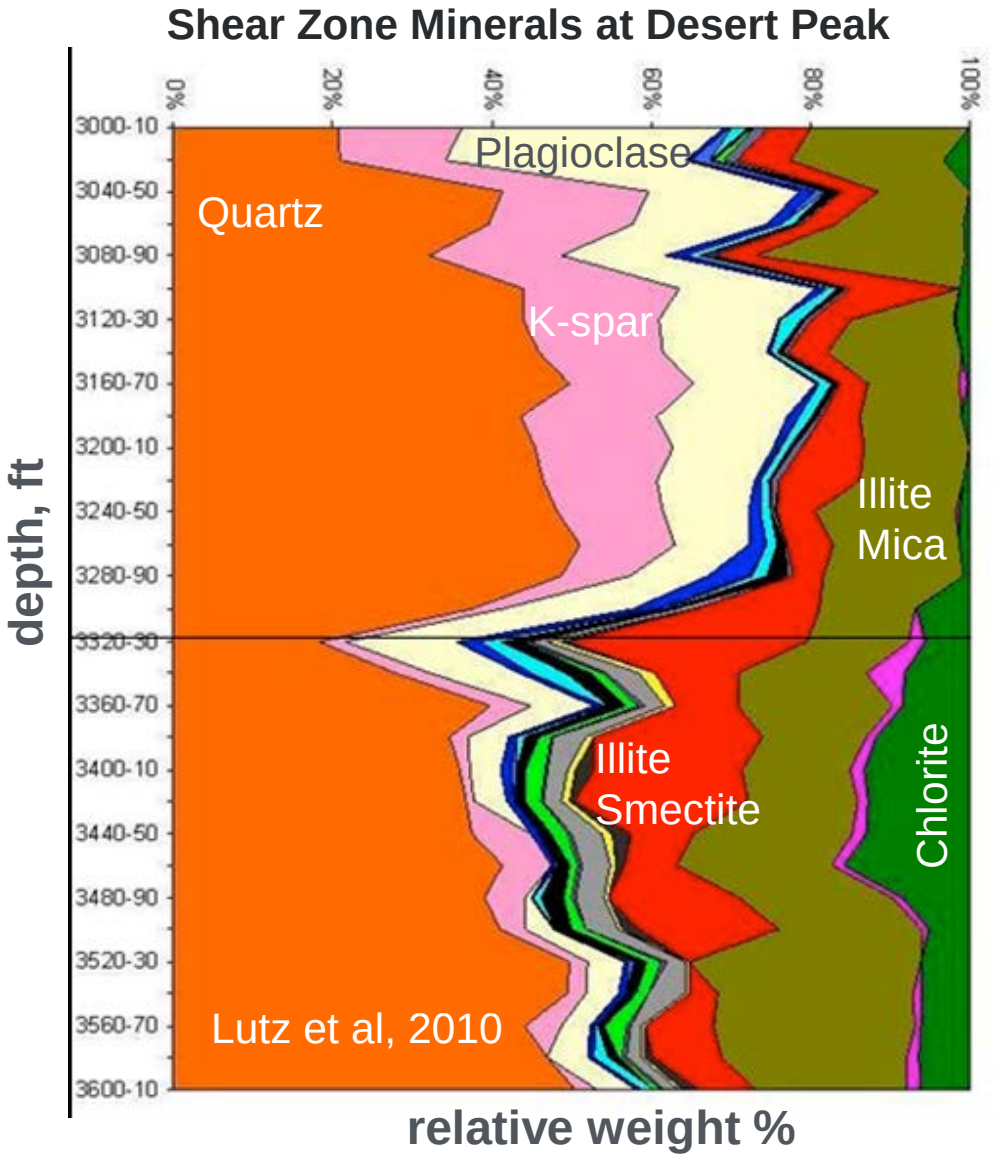
Lawrence Livermore National Laboratory

Track 1 - Geochemistry

Relevance/Impact of Research

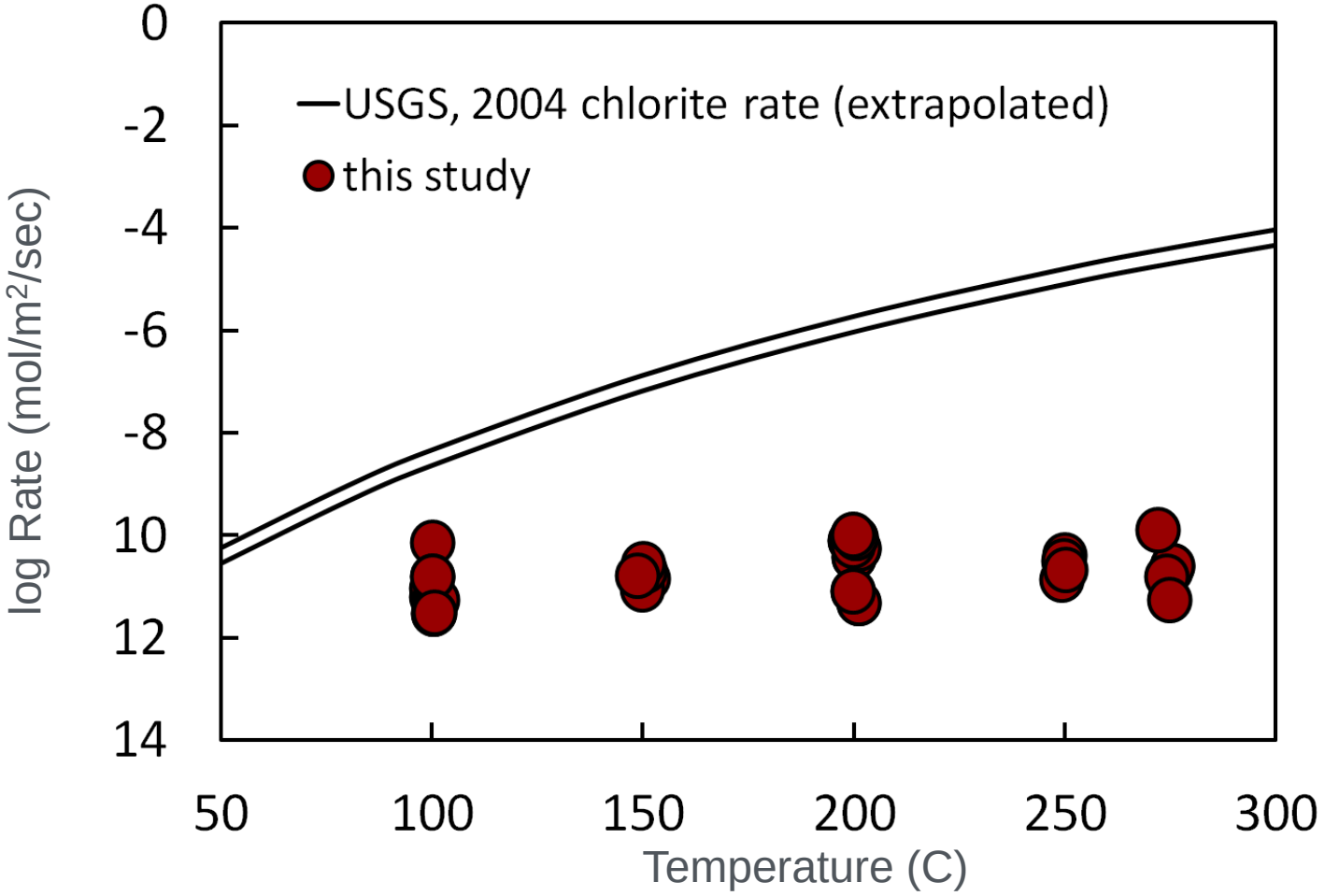
- ***Proposed Technology Improvement:*** Expand geochemical kinetic database for fracture minerals identified in EGS shear stimulation zones to 300°C.

- ***Current Technology Baseline Specifications:*** Current kinetic data and rate equations are lacking for many shear zone minerals at EGS temperatures and are rare even to 100°C.



Relevance/Impact of Research

- Extrapolation of low-temperature rate equations to EGS conditions may result in large errors

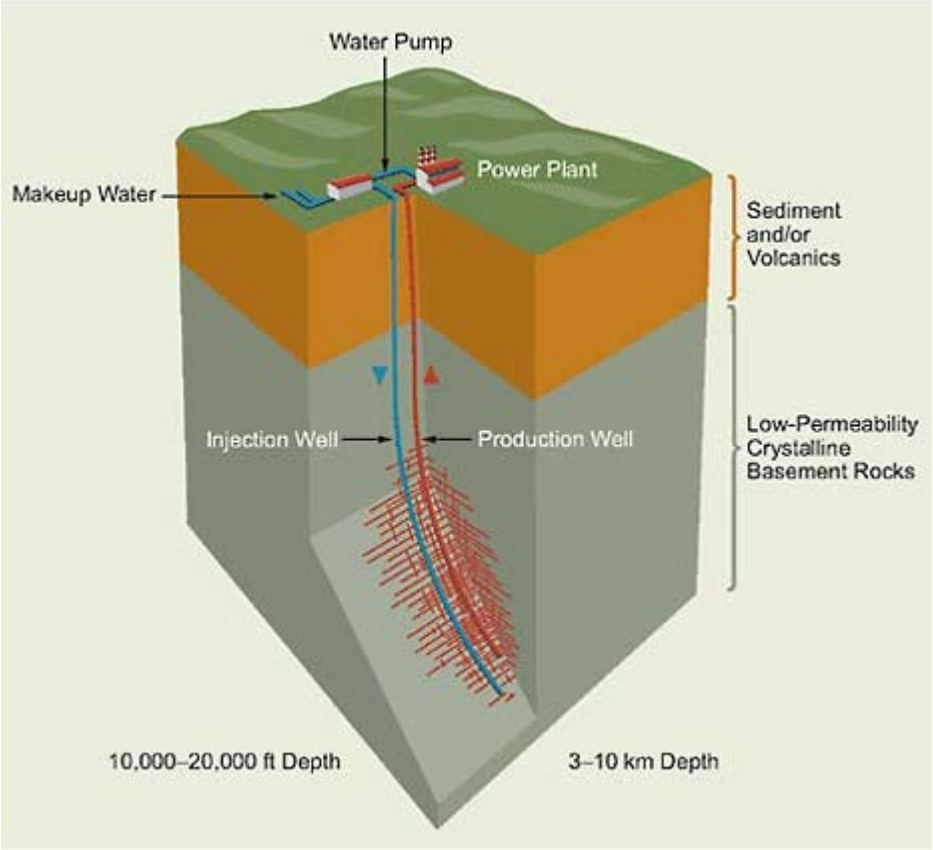


GTO Goal: Enhanced Geothermal Systems

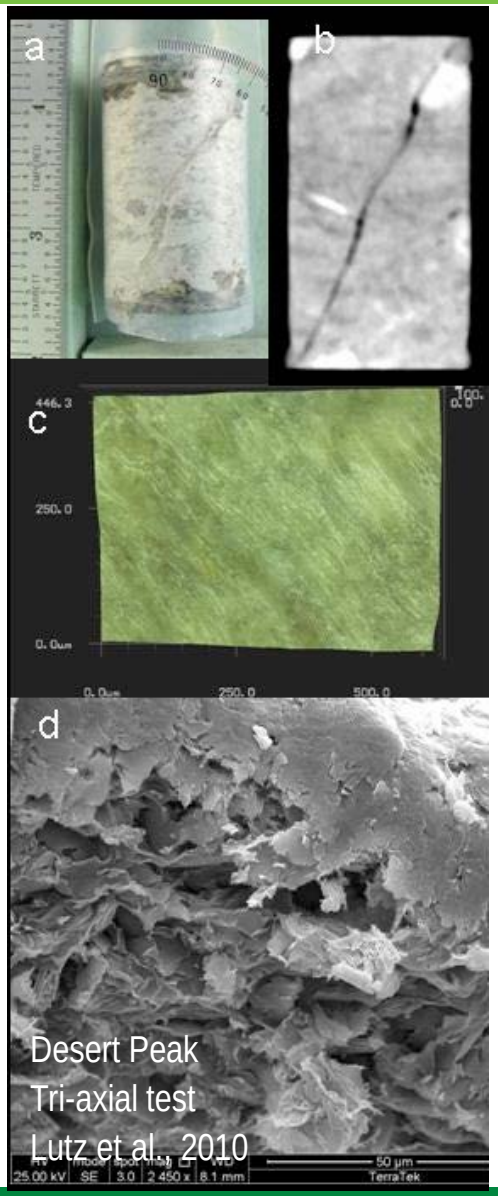
- ***Target Technology Specifications:*** Results will allow chemical affects to be included in modeling, allow realistic estimates of risk from chemical reactions, and assist in designing economically viable EGS systems.

- Rate equation
  - Temperature
  - pH
  - Solution chemistry
  - Surface area

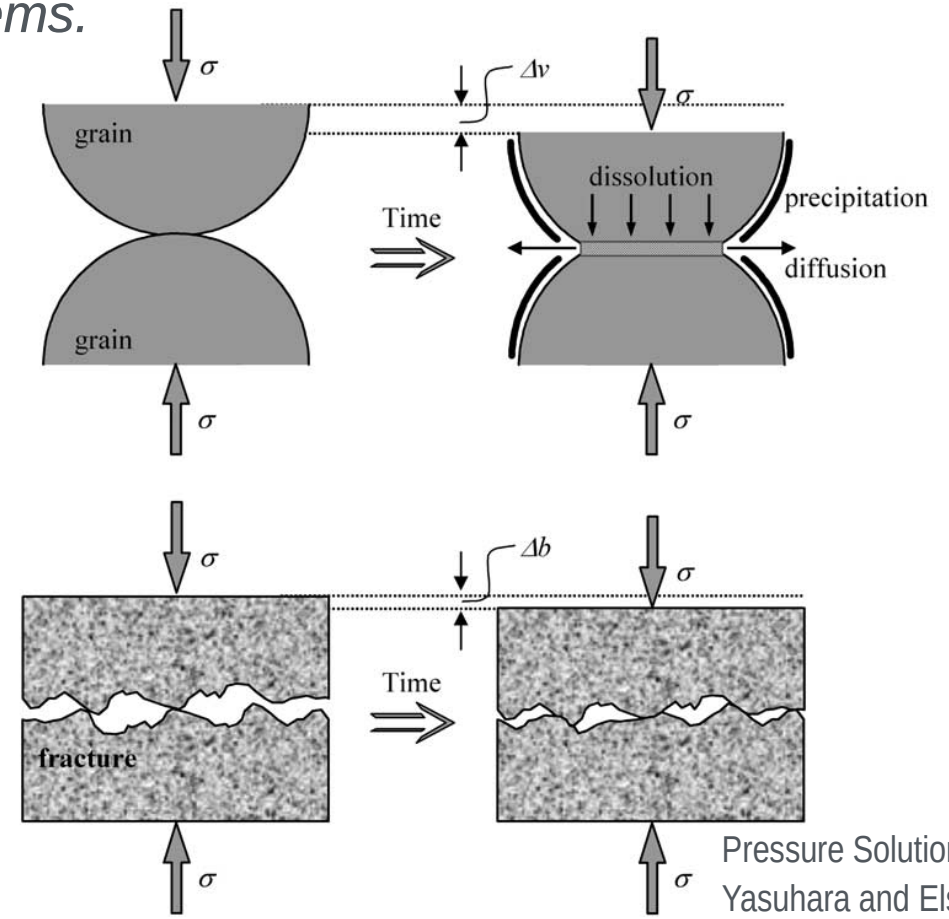
$$\boldsymbol{Rate\ (mol\ mineral\ s^{-1})} = -S\left(k_{298.15,acid}\{H^+\}^n + k_{298.15,neutral} + k_{298.15,alkaline}\{OH^-\}^m\right)e^{-\frac{E}{R}\left(\frac{1}{T}-\frac{1}{298.15}\right)}\left(1-\frac{Q}{K}\right)$$



GTO Goal: Enhanced Geothermal Systems



- *Kinetic data are critical to linking geochemical and mechanical process responsible for sustaining shear zone permeability for EGS systems.*

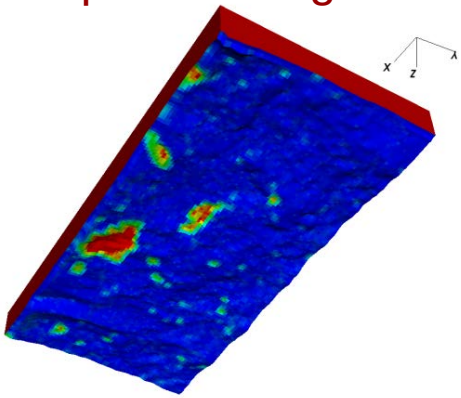


Pressure Solution
Yasuhara and Elsworth, 2004

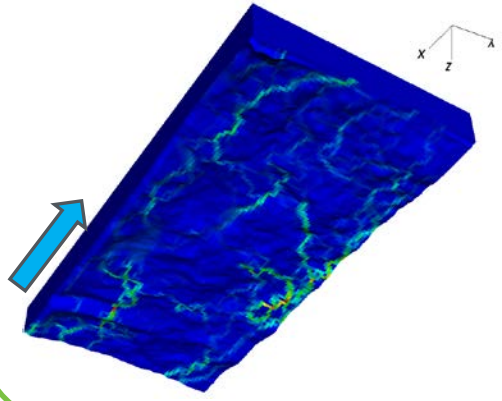
GTO Goal: Enhanced Geothermal Systems

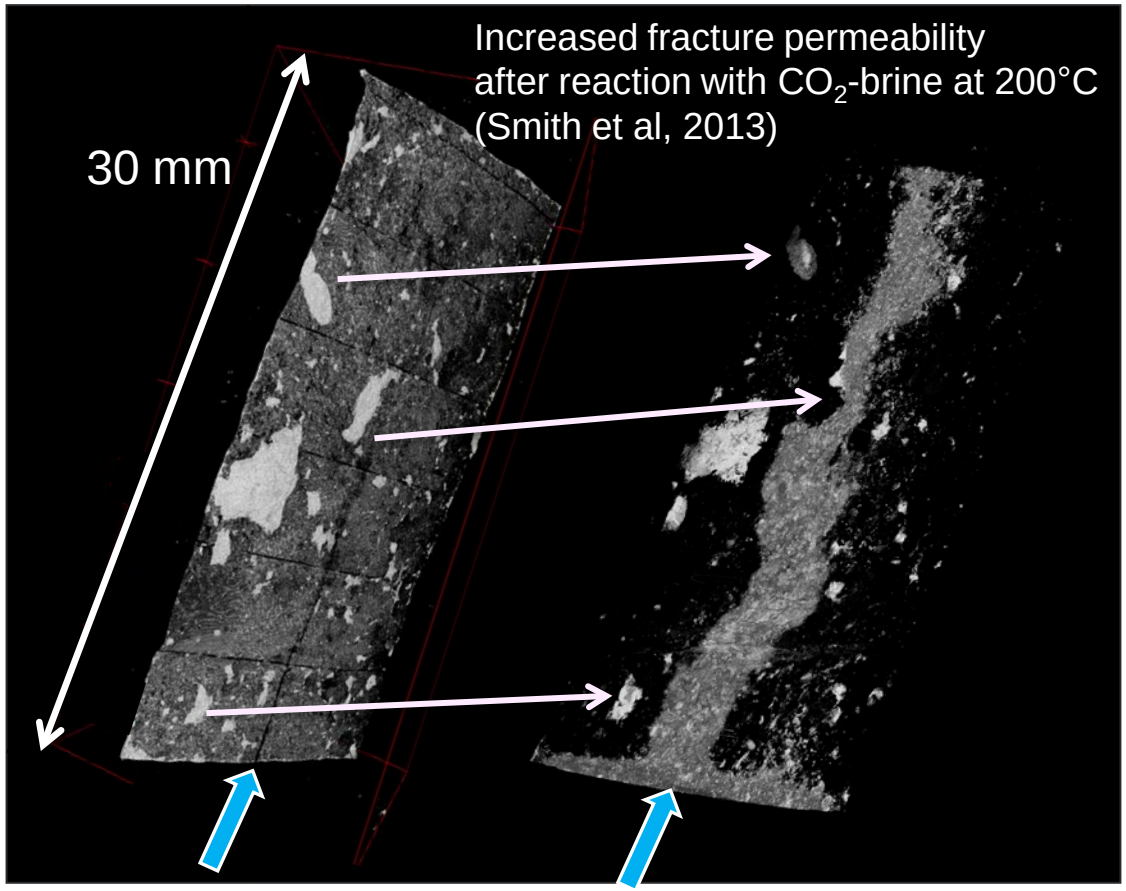
- *Kinetic data are critical to designing and optimizing shear zone permeability for EGS systems.*

aperture heights



flow velocities





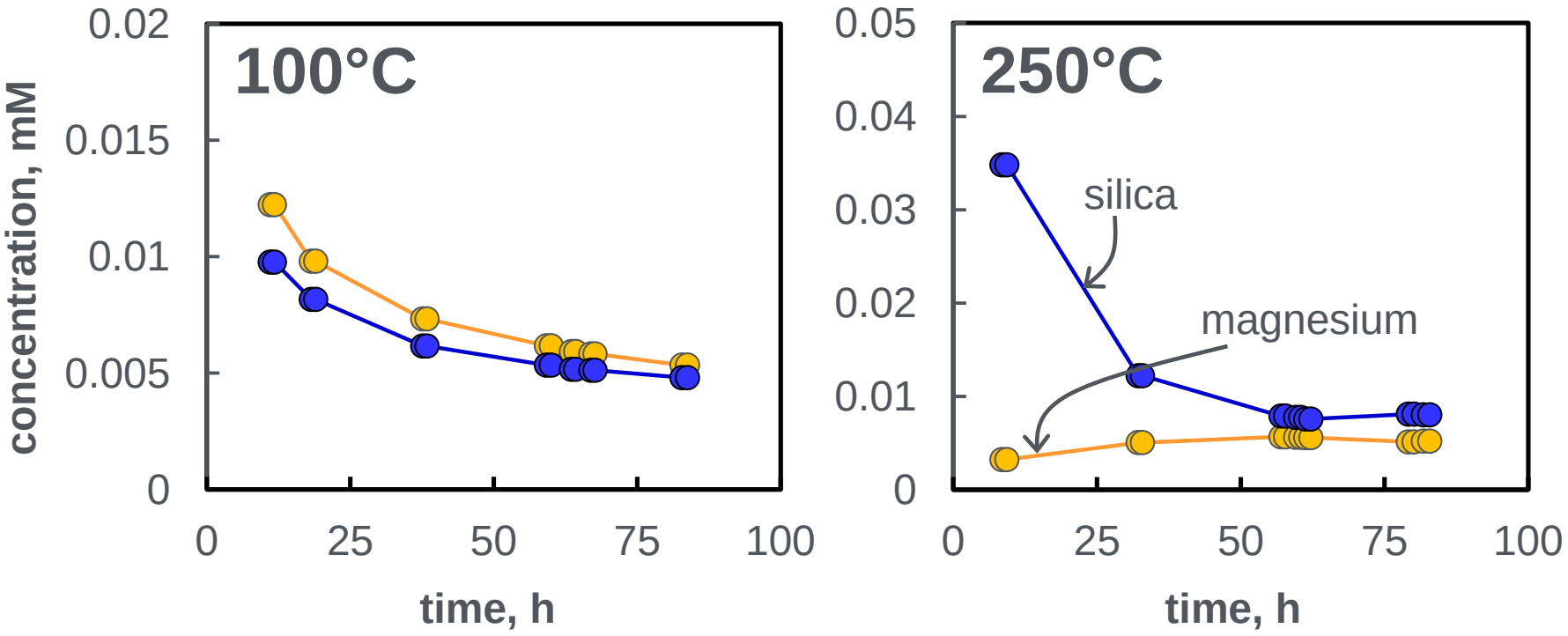
Scientific/Technical Approach

- Measure dissolution rates for shear zone minerals in mixed flow reactors
  - biotite, chlorite, illite, smectite, and plagioclase dissolution rates
  - pH 3 – 10
  - 100 - 300°C
    - Desert Peak, Raft River, Bradys Hot Spring (~200°C)
    - Newberry (200-300°C)
- Derive dissolution rate equations to be used in reactive-transport simulations

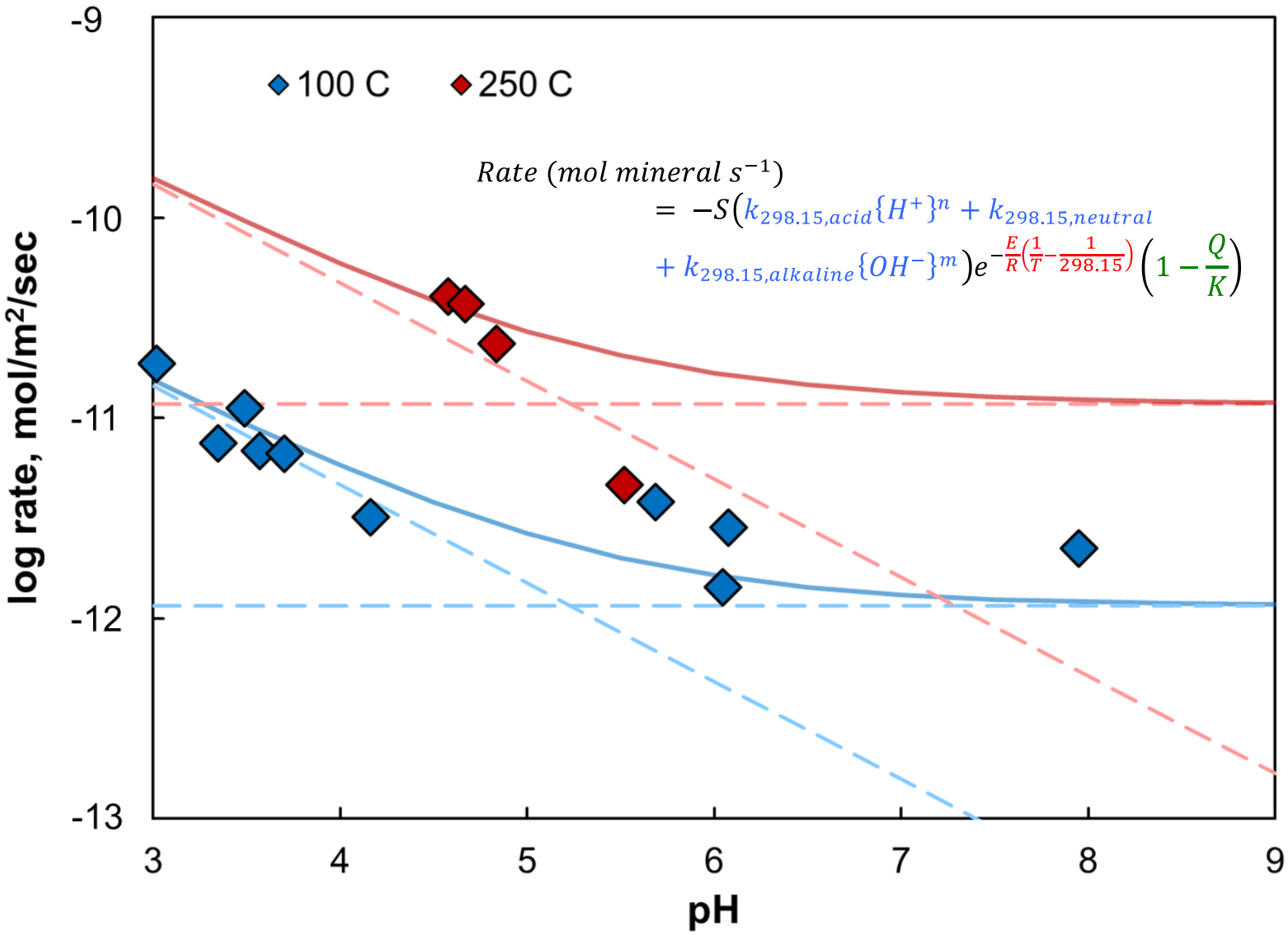
$$Rate\ (mol\ mineral\ s^{-1}) = -S\left(k_{298.15,acid}\{H^+\}^n + k_{298.15,neutral} + k_{298.15,alkaline}\{OH^-\}^m\right)e^{-\frac{E}{R}\left(\frac{1}{T}-\frac{1}{298.15}\right)}\left(1-\frac{Q}{K}\right)$$

Scientific/Technical Approach

- Rate ~ Δ [solution composition] x flow rate / surface area



Results for Chlorite dissolution (March 15, 2013)



Accomplishments, Results and Progress

Original Planned Milestone/ Technical Accomplishment	Minerals	Date Completed
1.0 Measure and derive mineral dissolution rates (pH,T)	FY13: Chlorite and illite	On schedule
2.0 Measure and derive mineral dissolution rates (pH,T)	FY14: Biotite and Plagioclase	
3.0 Measure and derive mineral dissolution rates (pH,T)	FY15: Smectite	
4.0 Conduct experiments using core from EGS demonstration site	Pending funding	

Future Directions

- **Key activities for FY13 and to project completion**
  - Chlorite, illite, smectite, and biotite, dissolution rates
  - All important shear zone minerals at EGS demonstration sites
  - Conduct experiments on core samples from EGS sites (pending funding)
- **Deployment strategy for Geothermal Data Repository**
  - Specific mineral dissolution rates will be provided in a spreadsheet files.
  - Governing rate equations will be provided in document files.
  - Data will be generated continually throughout the project and will be uploaded to the DOE-GDR annually on September 30, 2013 - 2015.
- **Results will be made available to all EGS demonstration projects and researchers**
- **There are no "Go/No-Go" milestones**
  - Laboratory facility in place (budgeted replacement parts)
  - Solid technical approach and team
    - Carroll – geochemist with 30 years expertise and ~ 50 peer-reviewed publication
    - Smith – geochemist, postdoc, carries-out experimental programs for geothermal and carbon storage

Mandatory Summary Slide

- ***Proposed Technology Improvement:*** Expand geochemical kinetic database for fracture minerals identified in EGS shear stimulation zones to 300°C.
- ***Current Technology Baseline Specifications:*** Current kinetic data and rate equations are lacking for shear zone minerals at EGS temperatures and are rare even to 100°C.
- ***Target Technology Specifications:*** Results will allow chemical affects to be included in modeling, allow realistic estimates of risk from chemical reactions, and assist in designing economically viable EGS systems.
- ***Justification for AOP***: Proposed work addresses critical data gap for EGS development and maintains the experimental core competency in geothermal geochemistry for DOE-Geothermal.

Project Management

Timeline:

Planned Start Date	Planned End Date	Actual Start Date	Actual /Est. End Date
10/1/12	9/30/15	10/1/12	9/30/15

Budget:

Federal Share	Cost Share	Planned Expenses to Date	Actual Expenses to Date	Value of Work Completed to Date	Funding needed to Complete Work
$1,100,000	$0	$40,000	$51,000	$62,500	$1,049,000

- Management activities:
  - Monthly review and reporting of project financials and status to LLNL upper management (E Program, Global Security Directorate)
  - Rate equations developed by LLNL will be used to interpret the observations from the shear rock experiments by LBNL.
- Project is on schedule