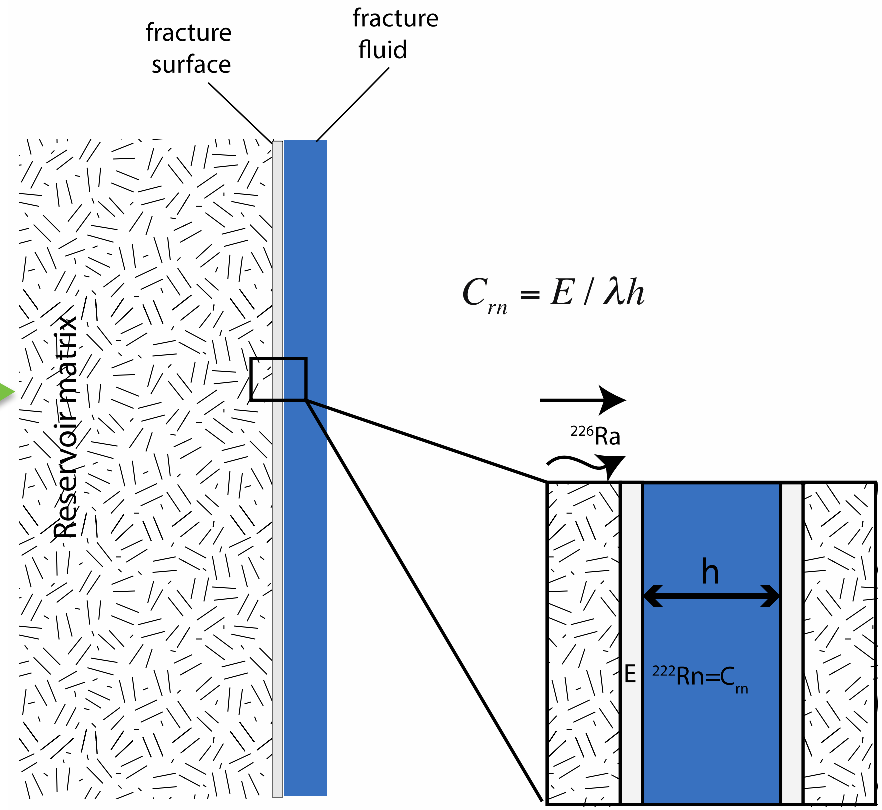

Radioisotope Tracers to Define Fracture Attributes for EGS

Project Officer: Lauren Boyd

Total Project Funding: $1.013M

May 11, 2015

Principal Investigator: John N. Christensen
Earth Sciences Division
Lawrence Berkeley National Lab

Tracers/Zonal Isolation/Geochemistry

Relevance/Impact of Research

Characterization goal:

- Complete 3D reservoir, stress and fracture models constrained by all observations

Contribution:

- Isotopic tracers that will constrain the surface area and aperture of hydraulically conductive fractures
  - Focus on short lived radioisotopes such as ^{222}Rn
  - Compliment with $^{87}Sr/^{86}Sr$ and $\delta^{18}O$ that probe fracture spacing

Relevance/Impact of Research

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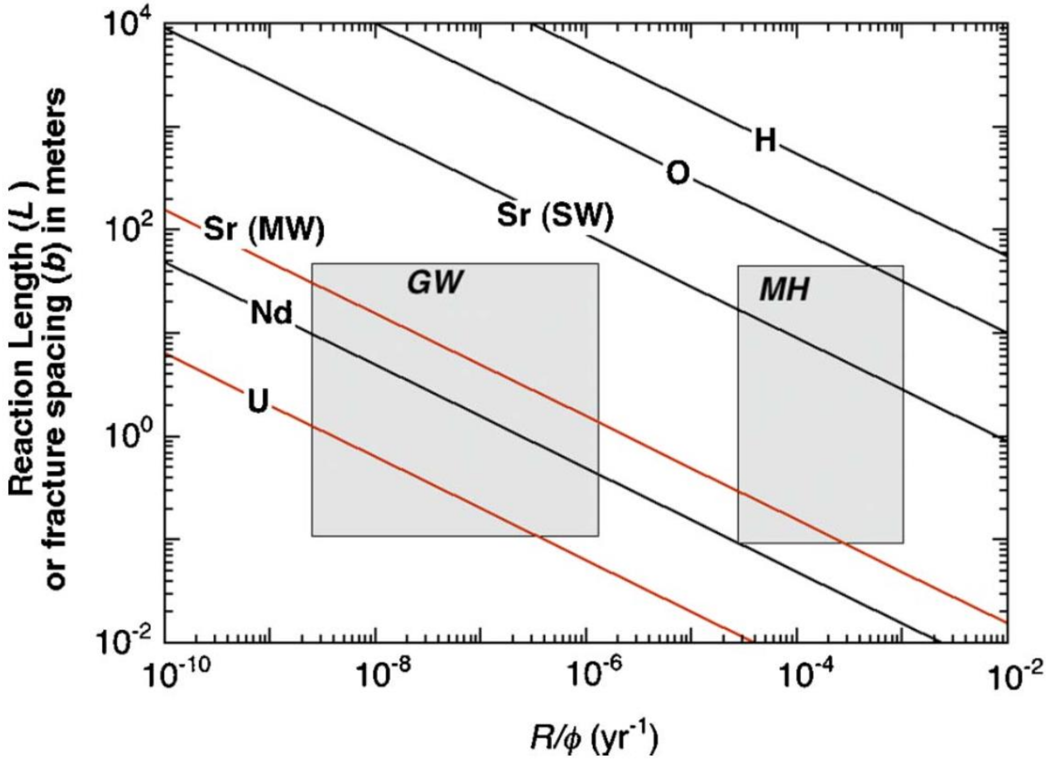
Challenge: The distribution of fractures and their properties (e.g. surface area, aperture, spacing and reactivity) are poorly quantified in both natural enhanced geothermal systems.



DePaolo, 2006

Proposed Solution: Utilize isotopes with differing reactive length scales to quantify surface properties.

Relevance/Impact of Research

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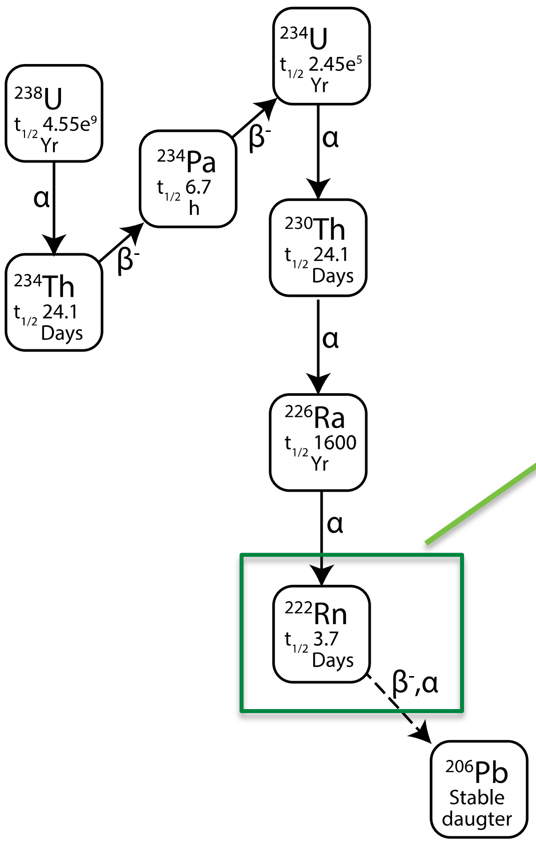
Challenge: Identify isotope tracers that are primarily sensitive to the fracture surface area and limited "communication" with the rock matrix.



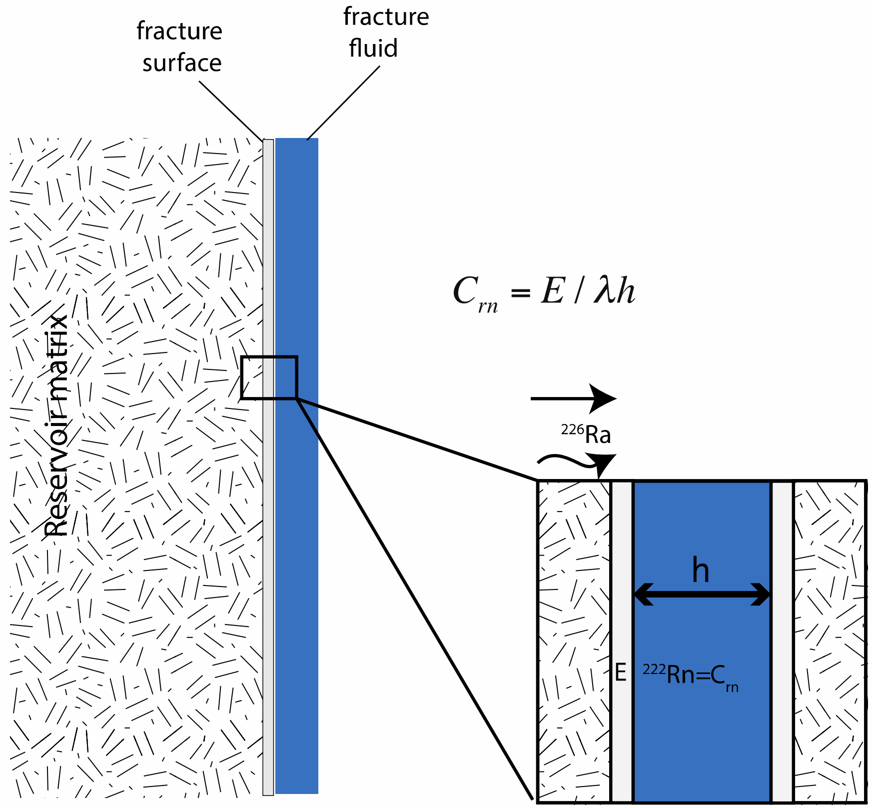
^{222}Rn:

- $t_{1/2}$=3.7 days
- Noble gas
- Nominally low sorption/partitioning to solid phases

Proposed Solution: Short-lived isotopes in the uranium decay series.

Relevance/Impact of Research

Challenge: Prior work using ^{222}Rn to calculate fracture aperture was not widely successful.



We hypothesize a mechanistic understanding of the emanation factor (*E*) at fracture surfaces will make ^{222}Rn a powerful tracer of fracture surface properties.

Proposed Solution: Careful lab experiments coupled with reactive transport modeling.

Technical Approach Summary

1) ✓ Construct simplified analytical and numerical models to approximate uranium series isotope behavior in geothermal water-rock systems

1) ✓ Use preliminary model results to design hydrothermal experiments

2) Characterize the physical, chemical and isotopic properties of the starting rock material

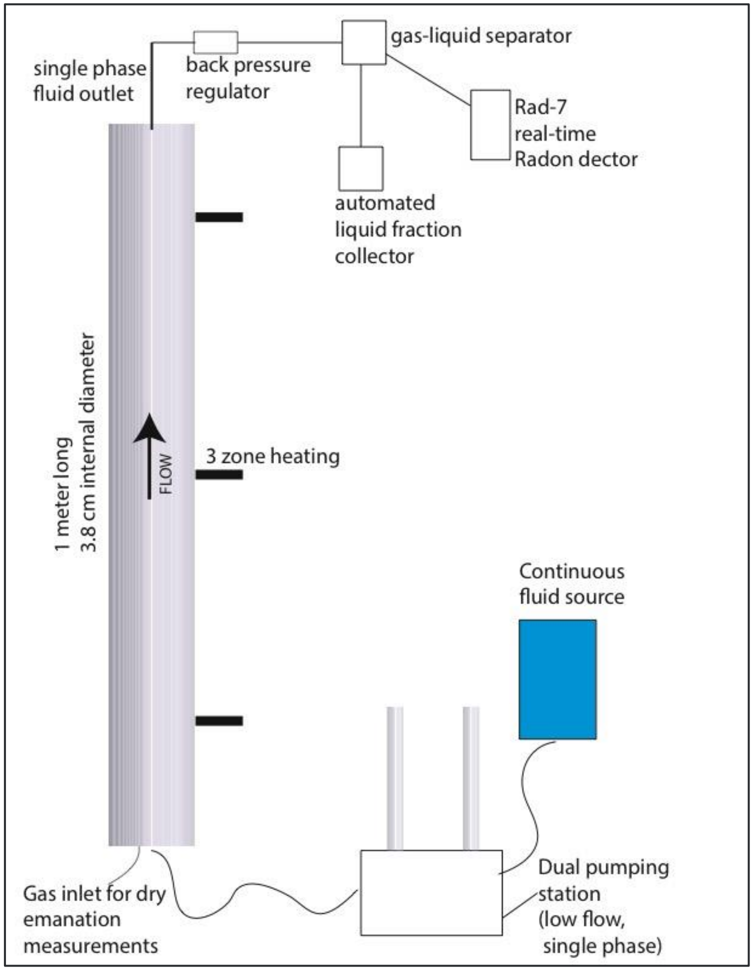
   In progress

3) Conduct reactive transport experiments

   Beginning ~25th of May

4) Compare experimental and model results, revise hypotheses as necessary

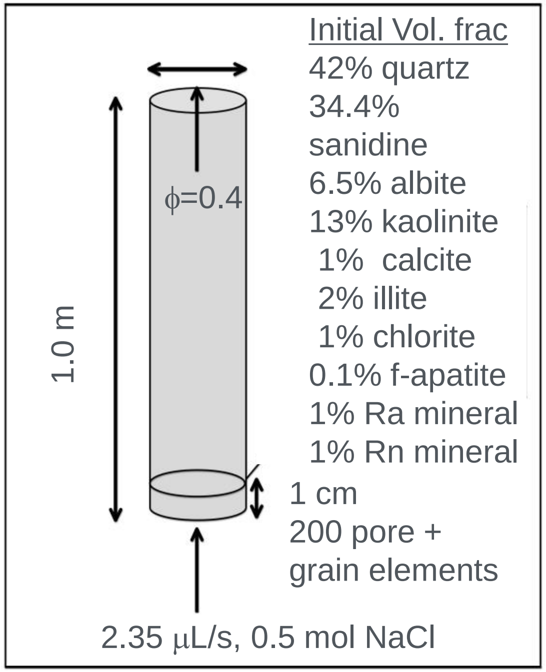
Technical Approach Summary: Reactor Design



Key features:

- Precise control of T, P and fluid velocity
- Continuous and automated influent
- Continuous and automated ^{222}Rn
- Fraction collection of fluid samples
- Ability to adapt for temperature gradient non-H_2O fluids (e.g. CO_2) in the future

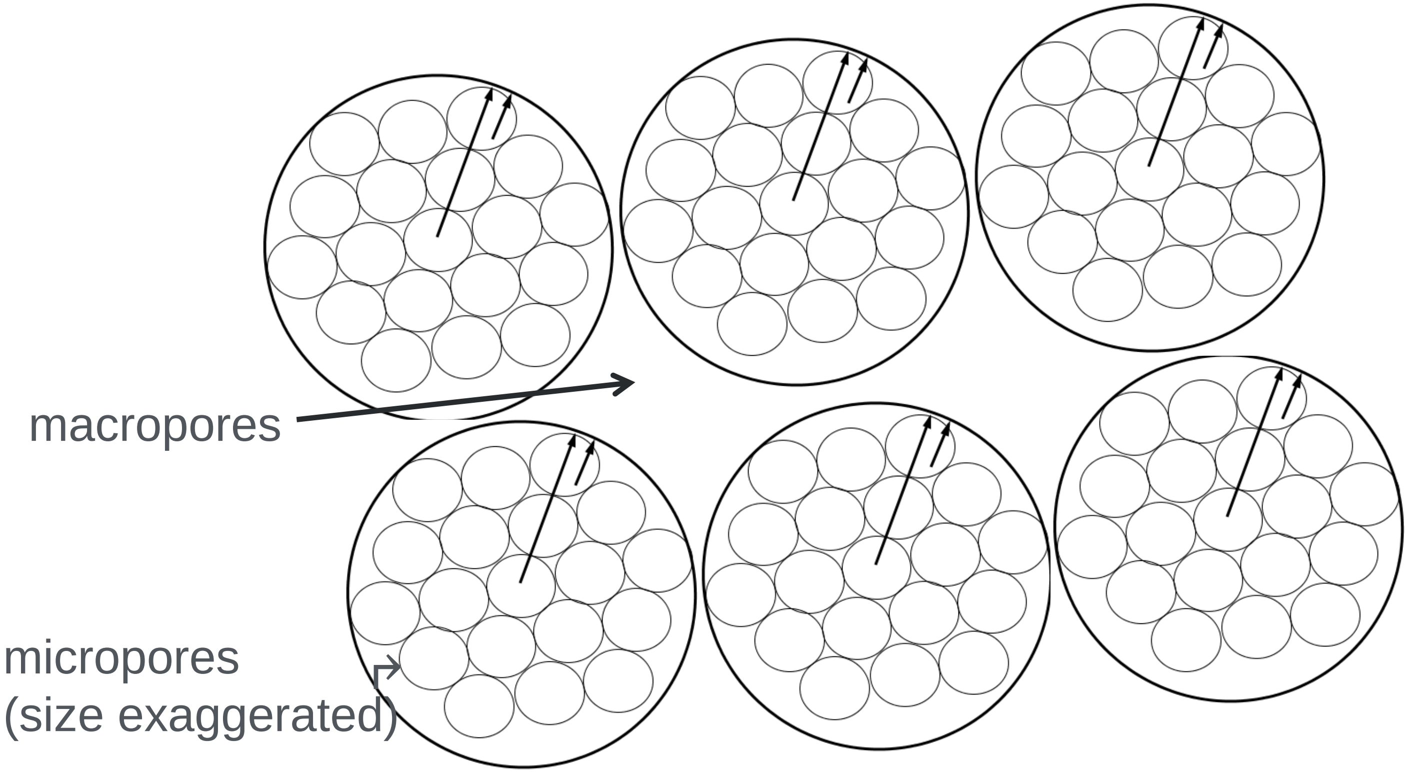
Technical Approach Summary: Modeling Design



1. Dual Porosity 1-D 1 meter column
2. Pore space: $k=10^{-11}\ m^2$, 40% of total volume
3. Grains: $k=10^{-22}\ m^2$, 1% internal porosity
4. Diffusive (dominant) and advective transport between grains and pores
5. 3% "direct" emanation of ^{222}Rn from grains: R = 6.54e-18 mol/s. 6ppm Uranium in bulk rock
6. ^{222}Rn emanation from minerals: 1e-23 mol/s
7. $^{226}Ra+2(aq)$ -> $^{222}Rn(aq)$: R = 1.372 e-11 mol/L/s
8. $^{222}Rn(aq)$ decay: Decay constant = 2.095e-6 1/s
9. Desert Peak Tuff chemistry (will change to Bishop Tuff once characterization is complete)

Pore-Scale Dual-Continuum Model For Porous Grains:

- To capture diffusion, local reactive surface area and equilibria



At each spatial location, there are two coexisting continua: grains and pores.
For a dual-continuum, under transient conditions the distance from internal micropores to external macropores should be ~ 1/6 the radius (Zimmerman et al., 1993).

Thus 2 reactive surfaces areas: External grains and internal pores

Accomplishments, Results and Progress

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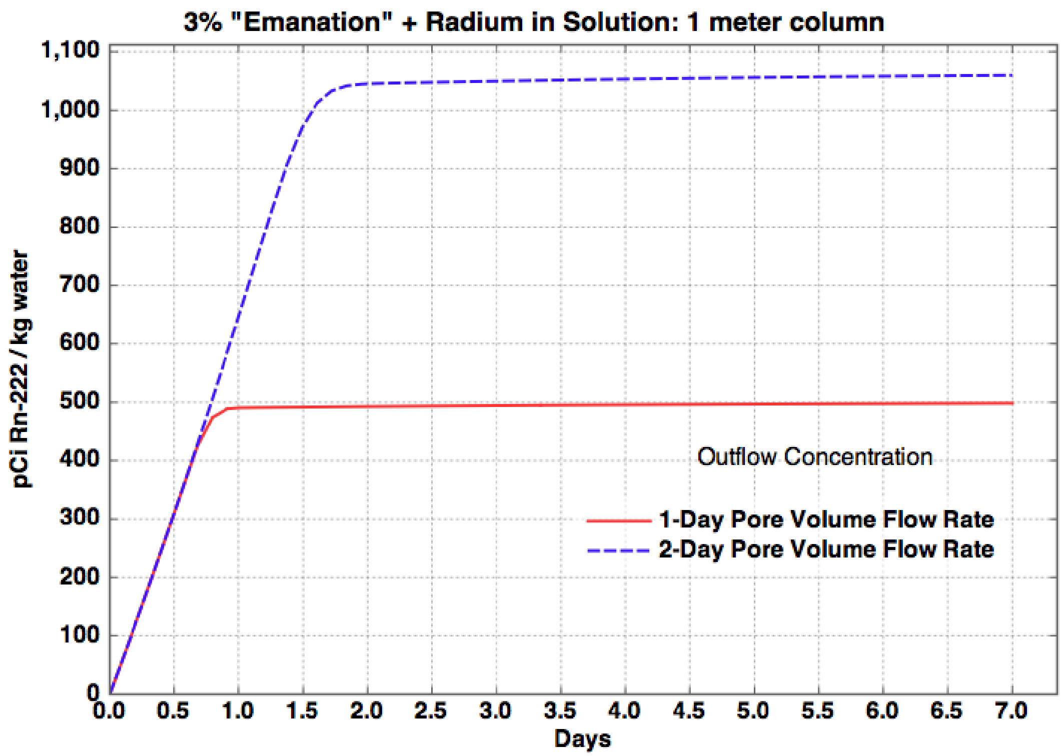
Original Planned Milestone/ Technical Accomplishment	Actual Milestone/Technical Accomplishment	Date Completed
Technical drawings for experimental reactor are completed and procured	Design completed and procurement initiated. Final components will be delivered in Q3	12/2014
Conceptual TMHC model including thermodynamic and kinetic data is compiled and verified	Modeling framework is completed.	3/2015
Preliminary characterization of experimental materials	Raw materials prepared, characterization in progress	*6/2015 target*

Preliminary modeling results:



highlights:

- Predict “steady-state” ~1 pore volume
- Predicted ^{222}Rn activities are within our measurement capability

Future Directions

Milestone or Go/No-Go	Status & Expected Completion Date
Install and test reactor	Expected delivery of reactor in early May Expect installation and safety considerations completed by 6/1/2015
Run first set of experiments	6/1/2015-8/1/2015
Characterize natural fracture coatings and vein minerals to probe parent isotope heterogeneity	In progress/expected completion 9/2015

Mandatory Summary Slide

- Project is in Stage 1 but on schedule.
- Scientific idea and approach is sound
- Project team is engaged and communicating well with one another
- We are leveraging our knowledge from prior EERE and Office of Science funded research to make rapid progress.