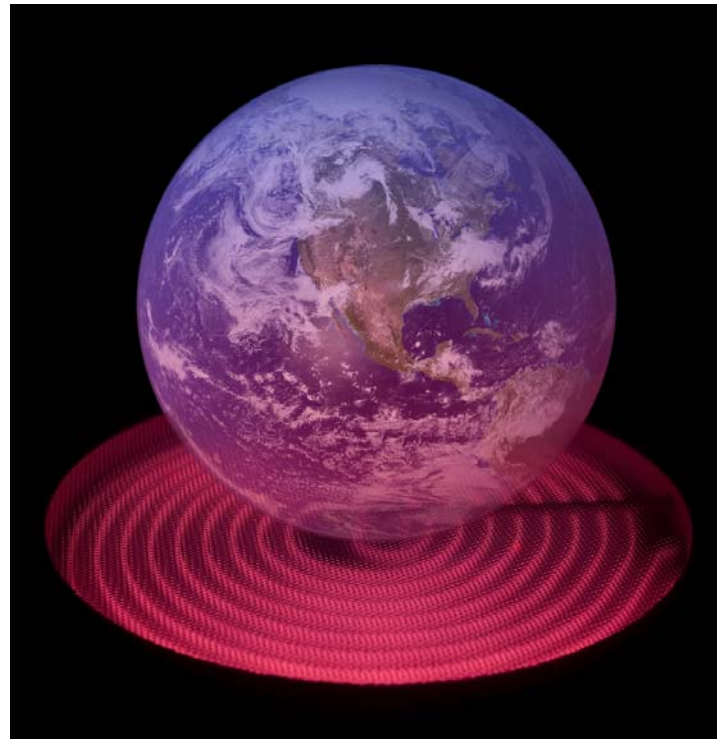


Geothermal Technologies Program Special Topics



Proposed National Geothermal Database

Applications

- Systems analysis
- Resource assessment
- Prospect identification/evaluation
- Statistical analysis
- Performance monitoring
- Research

Proposed National Geothermal Database

Scope

- **Critical geothermal site/plant attribute information** such as temperature at depth, seismicity/microseismicity, geology, drilling data, well logs, production data, plant performance, etc.
- **All types of geothermal resources** - hydrothermal, geopressured-geothermal, Enhanced Geothermal Systems, geothermal fluids coproduced with oil and/or gas
- **Information from existing geothermal sources** (eg, USGS resource assessments)
- **Publically available** - focus geothermal exploration activities, thereby mitigating investment risks.

Proposed National Geothermal Database

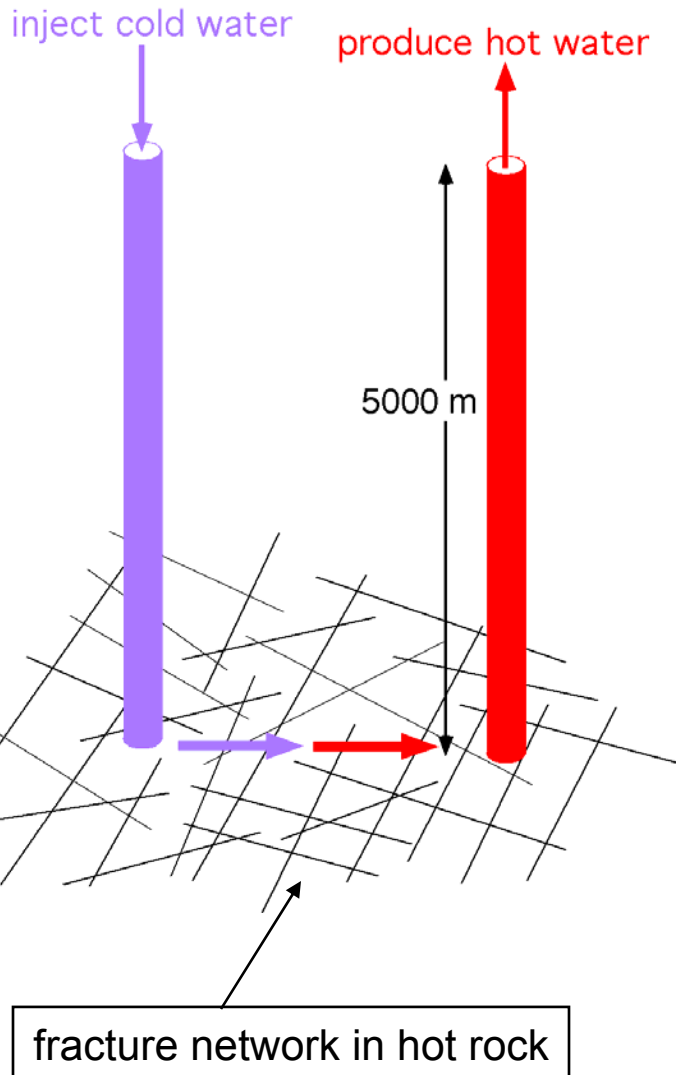
Solicitation

- Cooperative Agreement
- Five Year Project Period
- \$5M Total Project Funding
(FY09 \$1.3M / FY10-FY13 \$3.7)
- Applicants: institutions of higher education, non-profit and for-profit private entities, State/Local Governments, and Indian tribes are eligible to apply.

Geothermal Educational Program

- **Develop Geothermal Curriculum**
 - Competitively fund institutions of higher education to develop geothermal educational curricula and degree programs
- **Initiate Educational Scholarship Program**
 - Send students to foreign countries with geothermal development and curriculum for education, research and/or internship
- **Initiate University Student Competition**
 - Students will solve real life problems and implement solutions in the field
- **Support Vocational Training**
 - Develop next generation of skilled workers for widespread EGS facility construction and operation
- **Develop K-12 Educational Modules**
 - Provide early exposure to geothermal energy and technology

Supercritical CO₂ for Enhanced Geothermal Systems (EGS)



EGS is currently not economically viable; the chief obstacles are:

- dissolution and precipitation of rock minerals, that may cause anything from short-circuiting flows to formation plugging
- large “parasitic” power requirements for keeping water circulating
- water losses from the circulation system
- inadequate reservoir size - heat transfer limitations
- high cost of deep boreholes (≈ 5 km)

How about using CO₂ as Heat Transmission Fluid?

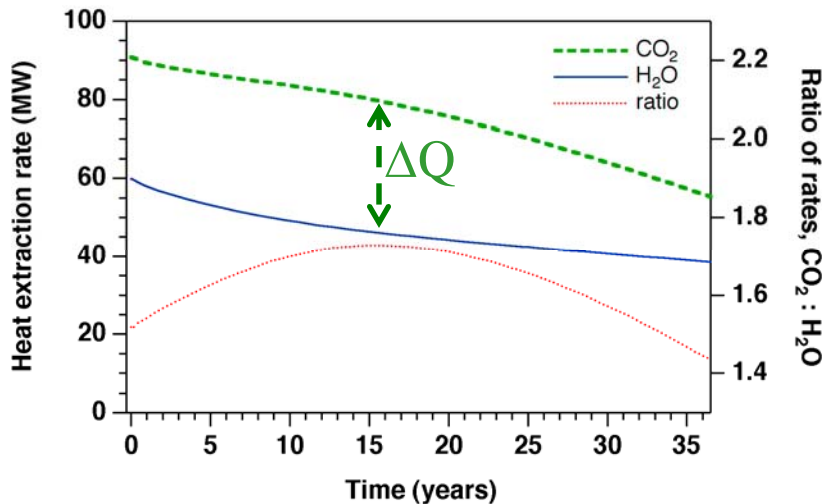
property	CO ₂	water
chemistry	poor solvent for rock minerals	powerful solvent for rock minerals: lots of potential for dissolution and precipitation
fluid circulation in wellbores	highly compressible and larger expansivity ==> more buoyancy, lower parasitic power consumption	low compressibility, modest expansivity ==> less buoyancy
ease of flow in reservoir	lower viscosity , lower density	higher viscosity, higher density
heat transmission	smaller specific heat	larger specific heat
fluid losses	earn credits for storing greenhouse gases	costly

Favorable properties are shown **bold-faced**.

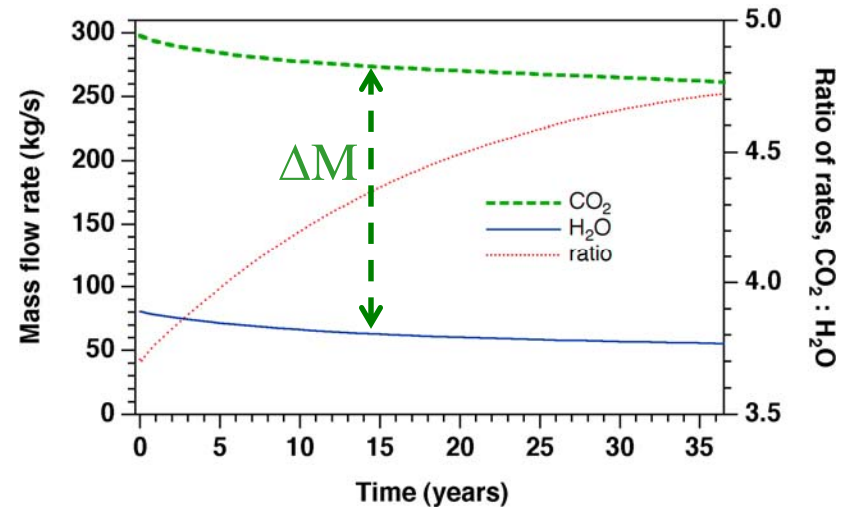
Reference Case

$$T_{\text{res}} = 200 \text{ }^\circ\text{C}, P_{\text{res}} = 500 \text{ bar}, T_{\text{inj}} = 20 \text{ }^\circ\text{C}$$

Heat extraction



Mass flow



- Heat extraction rates are about 50 % larger with CO₂ than with water.
- Mass flow rates are about 4 times larger with CO₂.

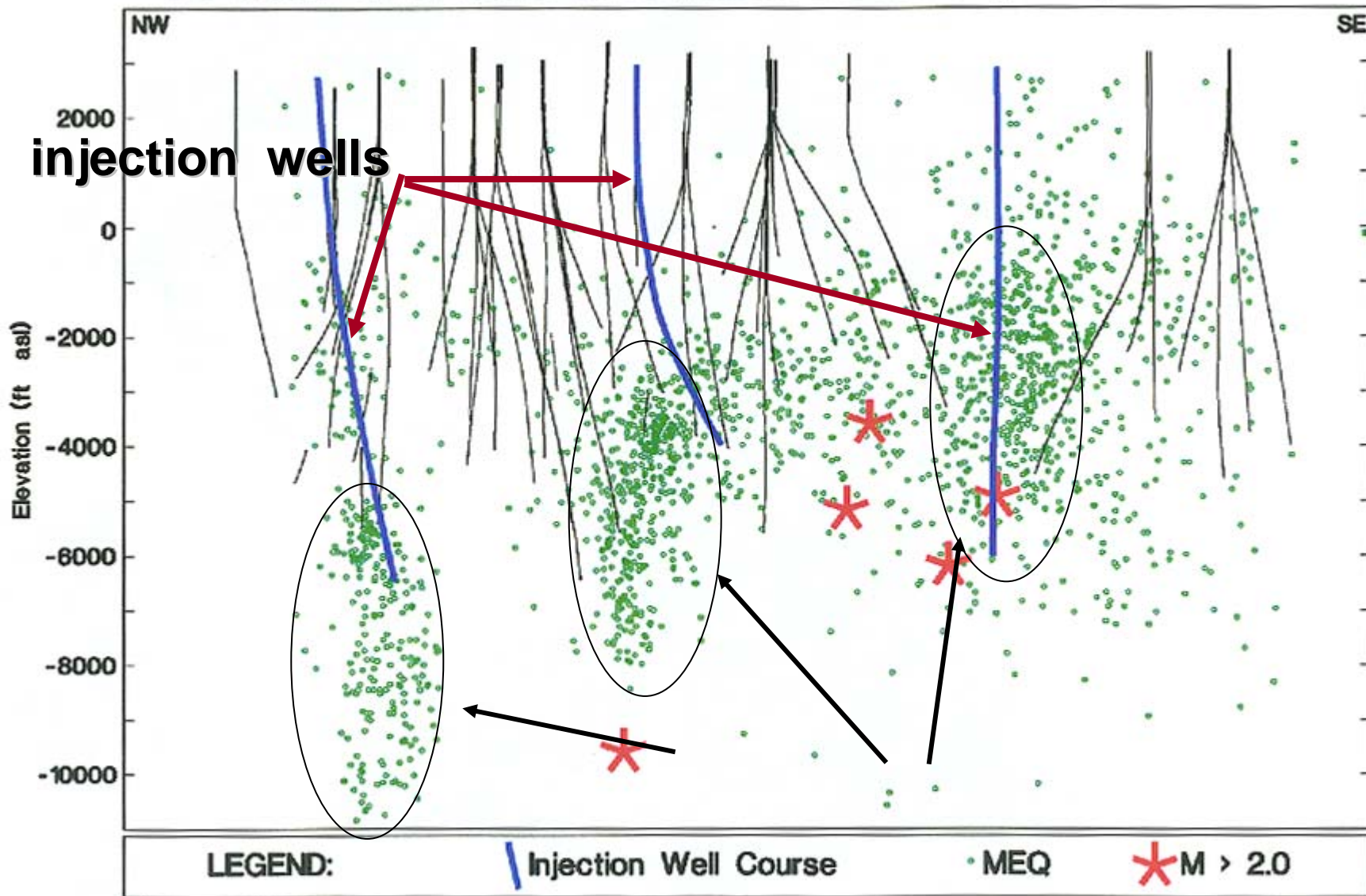
R&D for Exploring and Demonstrating the Feasibility of CO₂-Based EGS

- Need a focused, multi-disciplinary R&D programme that includes mathematical modeling, laboratory experiments, and field studies.
- Reservoir engineering: interplay between fluid flow and heat transfer; tradeoffs between energy extraction and CO₂ storage; design a field demonstration.
- Geochemistry: CO₂-mineral interactions at elevated temperatures, with and without presence of water.
- Power generation engineering: binary cycle vs. feeding CO₂ to the turbines.

Induced Seismicity

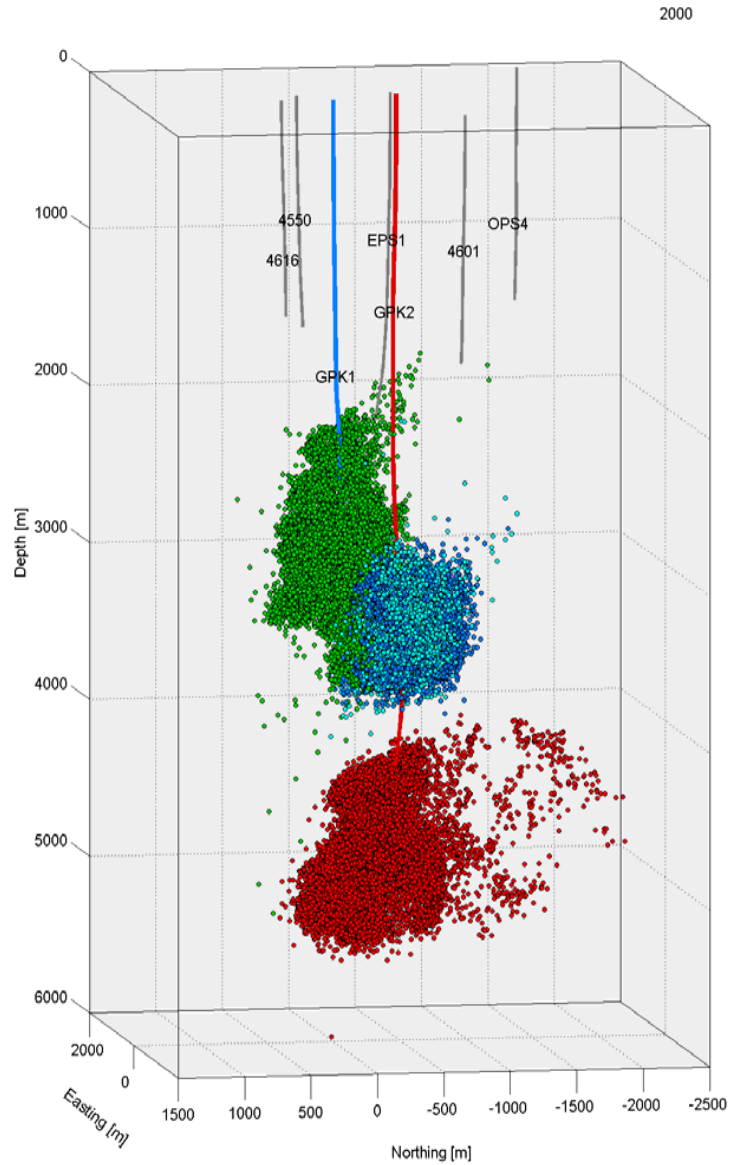
- Induced seismicity has been studied and dealt with in many other applications (dams, waste disposal, mining, oil and gas, etc.)
- Seismicity has delayed or blocked several EGS projects, addressing this issue now is required for EGS to be successful
- Seismicity is being used as an important reservoir monitoring tool in geothermal applications
- Critical gaps in knowledge on EGS induced seismicity need to be addressed
 - Mitigation
 - Reservoir management
- Need to establish a consensus opinion of mitigation and monitoring protocols

SE Geysers cross-section showing MEQ's and active injectors, 11/95 - 10/97



(Stark, 1999)

Soultz, France, (Hydrofracture)



Technical Issues

- Is it possible to mitigate seismicity and optimise production at the same time?
- Does the reservoir reach an equilibrium?
- What are the critical parameters necessary to estimate the seismicity hazard?
- What measurements and data are lacking, and if additional data are needed, how much and how long should monitoring continue?
- What can we learn from other induced seismicity cases? general seismicity?
- Are there experiments that can be performed which will shed light on key mechanisms causing EGS seismicity?
- How does induced seismicity differ in naturally fractured systems versus hydrofracturing environments?

Conclusions

- Technical basis for understanding and controlling EGS induced seismicity has been established.
 - White paper and draft protocol finished
- Issues are similar to other induced seismicity cases which have been successfully addressed
- Issues are both technical and non-technical
 - Technical issues remain on fully utilizing seismicity as a reservoir management tool
- Induced seismicity should not be an impediment to EGS development