Challenges, Opportunities, and Status of EGS Development in the United States

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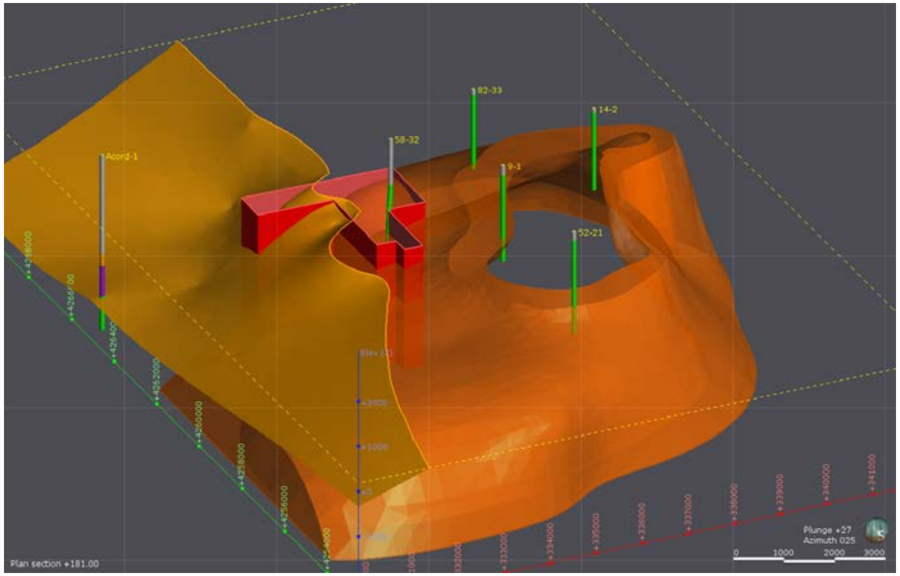
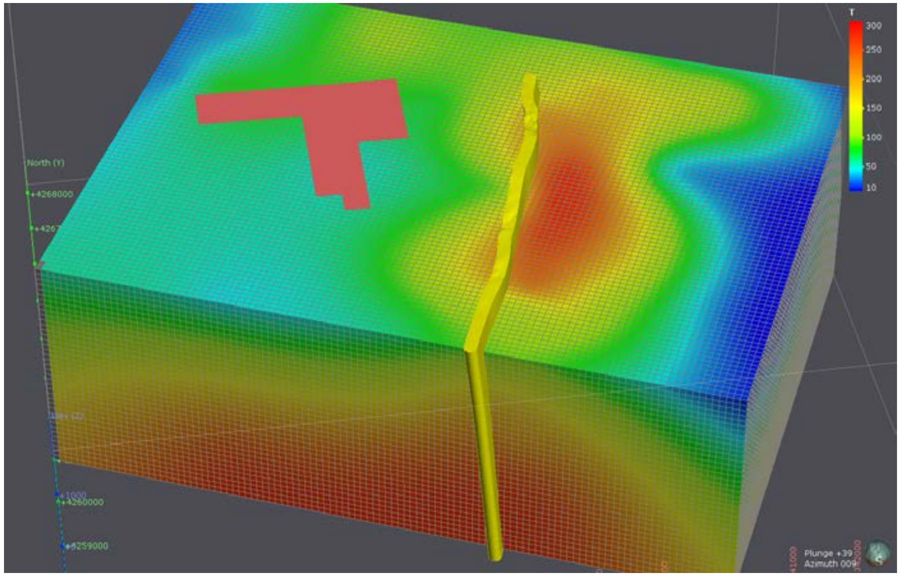
Outline

- Introductions and Acknowledgements
- Why EGS?
- History
- Current Activities
- Summary

Introductions and Acknowledgements





- John Burnell, Jeremy O'Brien, and Paul Siratovich
- Lauren Boyd
- Kennie Tsui and Anya Seward,and IPGT
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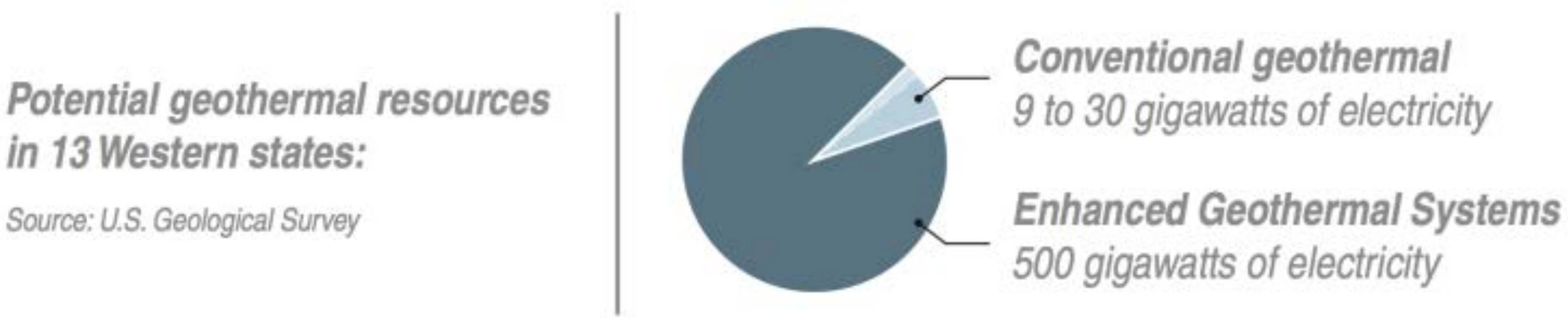
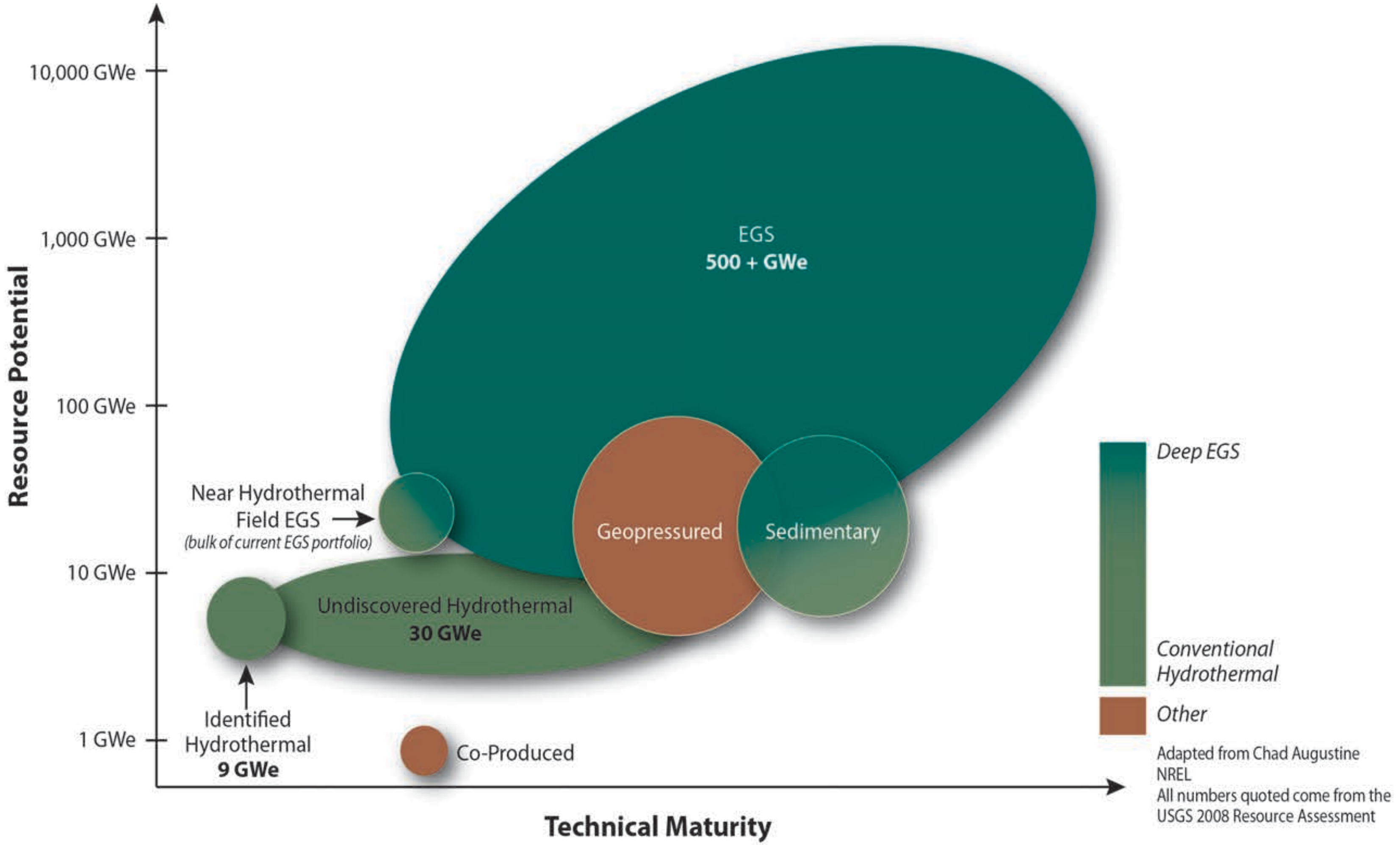
Why EGS?



- **EGS greatly expands the number of locations that could produce electricity from geothermal resources**
- **Few places of sufficient size have all characteristics for conventional geothermal development and finding them can be difficult and expensive**
- **While EGS is promising, more research is needed to advance the technology so it can be deployed commercially**

Realizing the Full Potential of Geothermal

From Doug Hollett, SGW Keynote 2012



International State of EGS

Table 1
Status of global EGSs and reservoir lithology.
(*Sources:* [17,20–22,69–74,76–81]).

Shyi-Min Lu, In Press (Renewable and Sustainable Energy Reviews)

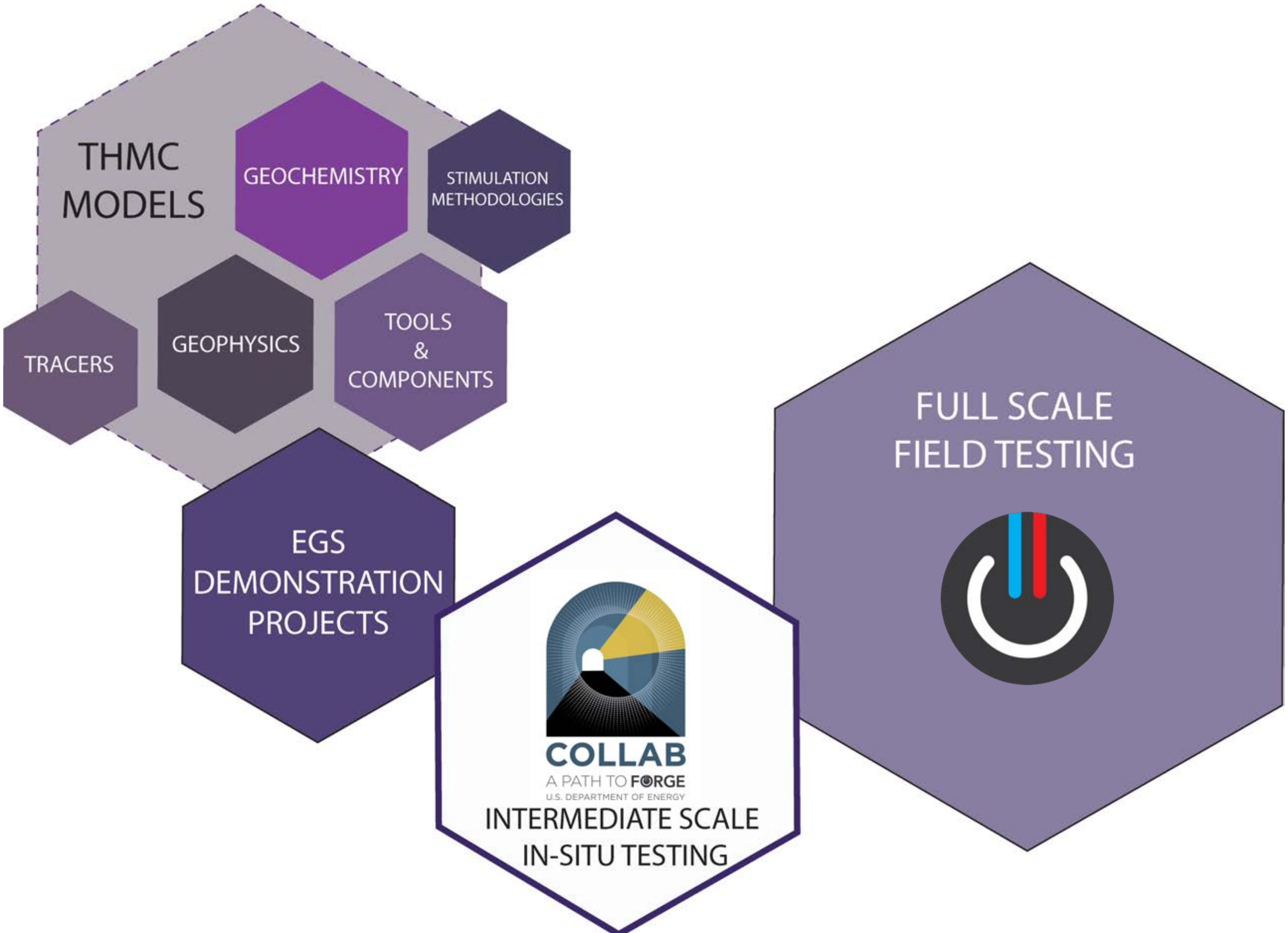
Site name (Development period)	Country	Reservoir lithology	Development attribution	Important feature
Fenton Hill (1974–1995)	United States	Granite	Greenfield	The world's first EGS site, and there were 60 kW binary power system demonstrations.
Rosemanowes (1977–1991)	United Kingdom	Granite	Greenfield	Laid the foundation of EGS development for the followed Eden and Redruth in the United Kingdom.
Hijiori (1981–1986)	Japan	Granodiorite	Greenfield	Japan's first EGS site, and there were 130 kWe binary power system demonstrations.
Fjällbacka (1984–1989)	Sweden	Granite	Greenfield	500 m deep shallow EGS site, applicable as a heat pump greenhouse.
Ogachi (1989–2001)	Japan	Granodiorite	Greenfield	Combined with CO_2 sequestration and CO_2-EGS test.
Basel (2005–2006)	Switzerland	Granite	Greenfield	Tests were suspended due to earthquake, and the EGS relevant specifications were introduced.
Insheim (2008-present)	Germany	Granite	Greenfield	Power plant of 4 MWe is constructed in commercial grade.
Landau (2004-present)	Germany	Granite	Greenfield	2.9 MWe/3 MWt power plant, in commercial grade, and in conjunction with greenhouse.
Groß Schönebeck (2007-present)	Germany	Sandstone/conglomerate	Greenfield	Hydraulic fracturing process is in progress, and three units of a total installed capacity of 1 MWe operated in binary power generation cycles have been built in the site.
Soultz (1987-present)	France	Granite	Greenfield	The first commercial-scale EGS power plant in France with installed capacity of 1.5 MWe.
KiGam at Pohang (2010-present)	South Korea	Granodiorite	Greenfield	1.5 MWe-targeted demonstration plant, site test in progress.
Habanero (2003-present)	Australia	Granite	Greenfield	1MWe demonstration plant is in operation, targeting for 40 MWe in the first phase, and the overall objective is 450 MWe.
Paralana (2005-present)	Australia	Sedimentary/metamorphic	Greenfield	Targeting for 3.75 MWe power plant, and fluid cycle test in progress.
Newberry (2009-present)	United States	Marl, quartz porphyry, granite	Greenfield	1. Hydraulic fracture and fluid circulation had been completed in 2013. 2. Use of the thermo-degradable zonal isolation materials (TZIM) to shorten the hydraulic fracturing process.
The Geysers (2009-present)	United States	Metasandstone	Near field	1. 5 MW demonstration plant in progress. 2. Urban wastewater reinjection to the reservoir to increase capacity. 3. Use the method of cold crack to create fractures in the surrounding of wells.
Raft River (2009-present)	United States	Granite	Near field	1. 5 MWe EGS demonstrated plants are targeted by 2020, and the flow rate is at least 20 kg/s per well. 2. The method of cold crack is used to create fractures in the surrounding of wells.
Bradys Hot Spring (2008-present)	United States	Rhyolite, metamorphic substrate	In field	Use of the existing geothermal wells to increase capacity, and the establishment of 2–3 MWe EGS power plant in commercial-scale is targeted.
Desert Peak (2002-present)	United States	Metamorphic tuff	In field	1. The establishment of a 1.7 MWe power plant in commercial-scale was scheduled at end of 2013. 2. Mix the cold cracking, shear, chemical and other hydraulic fracturing technologies.

FORGE DESTRESS DEEPEGS GEOTHERMAL

GeoLaB - A geoscientific perspective for Germany

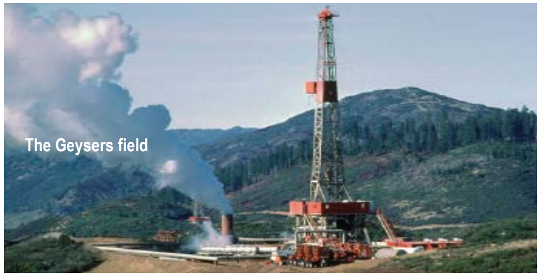
GeoWell

EGS Program Strategy



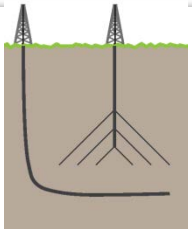
EGS Demonstration Portfolio

- **Desert Peak, NV.** First to generate 1.7 MW commercial electricity to the grid, by providing an additional at the existing well field.
- **The Geysers, CA.** First sustained EGS project at commercial scale in the U.S., with the potential to produce 5MW.
- **Newberry Volcano, OR.** First-of-its-kind achievement to demonstrate multiple stimulation zones using diverter technology within a single well. ***Seismic data indicates that the stimulated extended 250m around wellbore.***
- **Raft River, ID.** Thermal stimulation initiated in May 2013 complemented by full wellbore temperature monitoring using a Distributed Temperature Sensor array. ***Stimulation activities throughout 2015/2016 led to successful reservoir creation- well placed into commercial operation in 2016***
- **Brady, NV.** Multi-phase stimulation completed in April 2013, followed by large-volume stimulation in September 2013. ***Recently submitted final report and shutting down project***

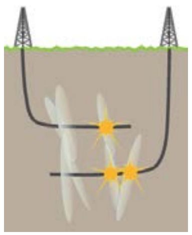


Challenges to EGS Development

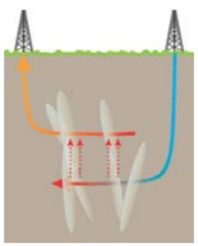
Technology Barriers | ***Potential Solution Set*** | ***Goal***



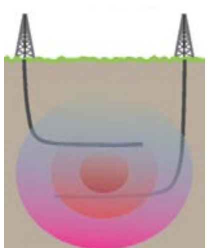
Reservoir Access
New well geometries and concepts, optimized drilling



Reservoir Creation
Characterize local stress, zonal isolation, novel fracturing methods, increase fractured volume per well



Productivity
Increase flow rates without excessive pressure needs or flow localization



Sustainability
Maintain productivity with minimal thermal drawdown and water losses

Hard/Hot-rock drilling, completion technologies

Horizontal wells

Rotary steering

Stress-field diagnostics

Smart tracers

Zonal Isolation

High-T sensors

Cross-well monitoring

Diverter and Zonal Isolation Technologies

EGS Success

Intermediate Scale: EGS Collab

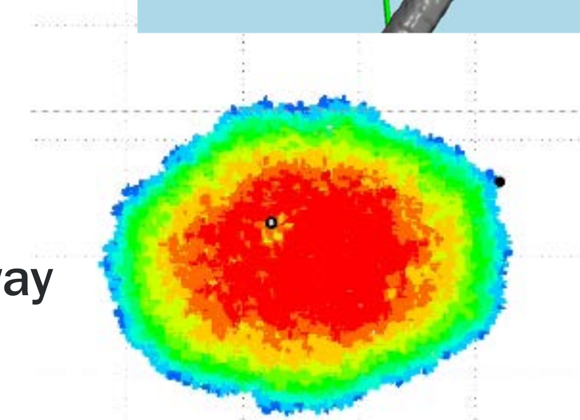
- **Understand constitutive behaviors of crystalline rock masses** under pressure and temperature;
- **Improve subsurface stress measurement and seismic processing**
- Advance predictive algorithms and **assess the relationship and impacts on permeability enhancement;**
- **Improve coupled THMC processes** in fractured crystalline rocks

COLLAB
A PATH TO FORGE
U.S. DEPARTMENT OF ENERGY

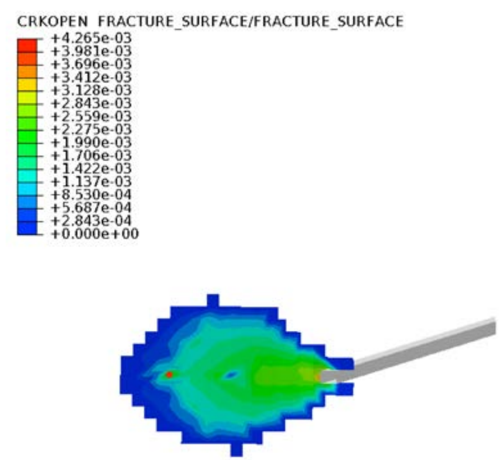
EGS Collab Status

- Sanford Underground Research Facility (SURF) in South Dakota
- Currently working at the 4850 level in the mine
- Cored 8 testing and monitoring wells
- Heavily instrumented
- Recently completed first (of potentially 3) stimulation experiments
- Flow and tracer tests underway

Leapfrog 3-D image (looking down at 75º due north) of EGS Collab Experiment 1 test bed with mapped fractures in boreholes from televiewer logs. Grey feature is West Drift. Red disks represent foliation, green disks are open quartz-lined fractures, black disks are closed quartz veins, and open flowing fractures are purple disks. The green line is the injection borehole, the red line is the production borehole, and the yellow lines depict the monitoring boreholes. Orange lines and blue disks represent kISMET holes and stimulation fractures, respectively.



Fracture aperture prior to intersecting production well



Field Scale: FORGE

DIVERSE & TRANSFORMATIONAL

research in subsurface engineering and geoscience

WORLD-CLASS LABORATORY

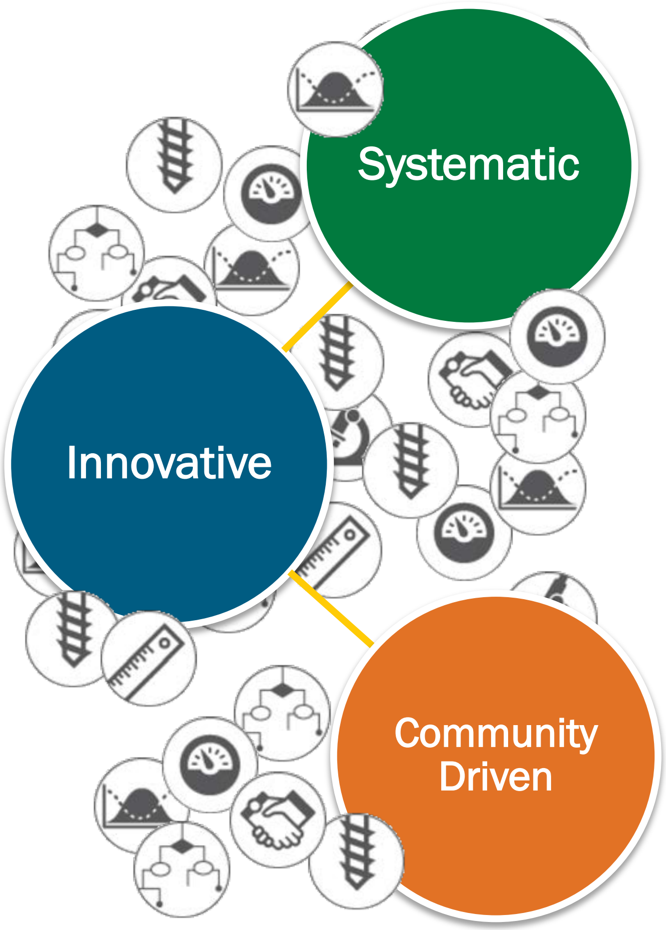
Opportunity for the community to take advantage of a world-class, fully characterized & controlled environment

SHARE, COMMUNICATE, EDUCATE

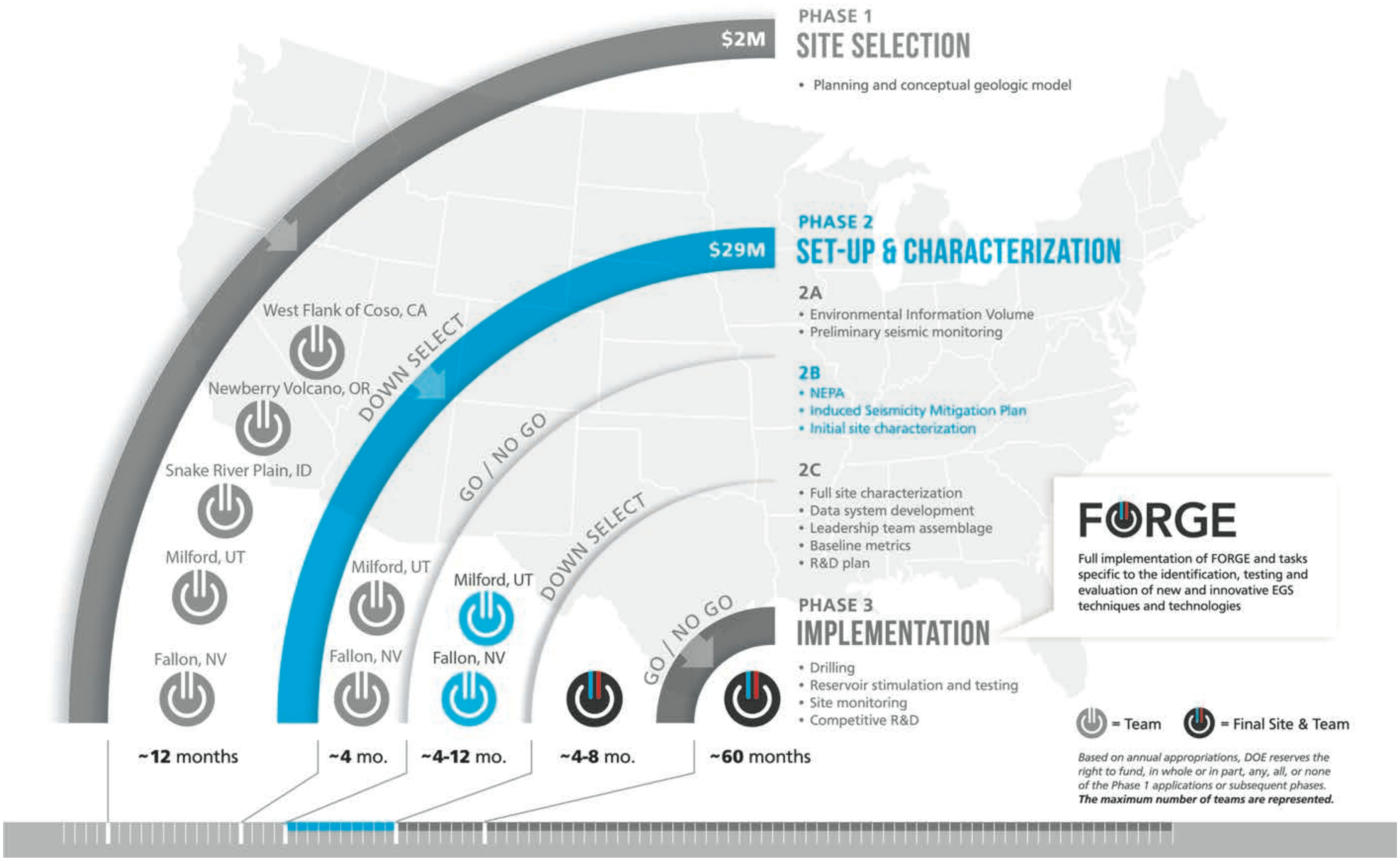
Data and findings to the broader technical and non-technical community

FORGE Principles

- Gain fundamental understanding of the **key mechanisms controlling Enhanced Geothermal System (EGS) success**.
- Develop, test, and improve new **technologies and techniques** in an ideal EGS environment.
- Make integrated **comparison of technologies and tools** in a controlled environment.
- Rapidly **disseminate technical data and communicate** to the research community, developers, and other interested parties

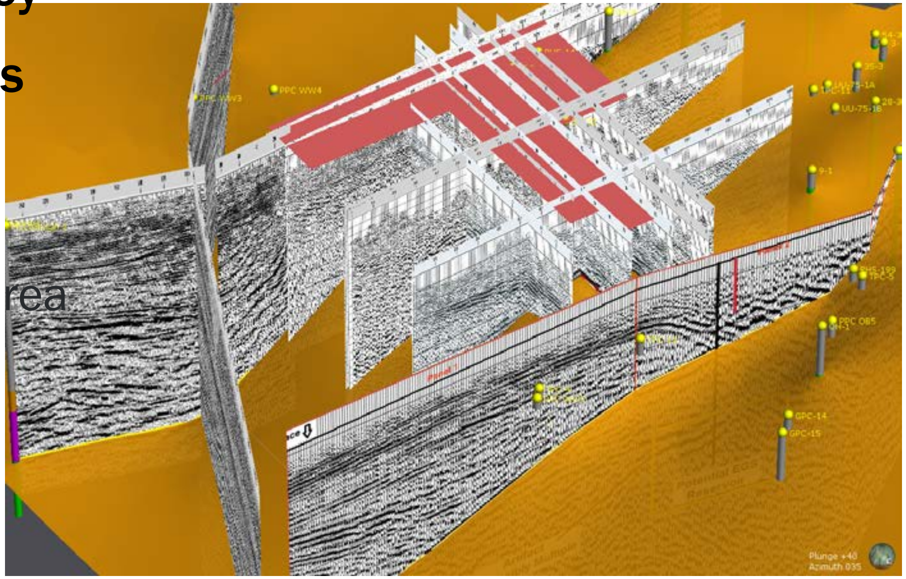


FORGE Timeline and Process



Utah FORGE

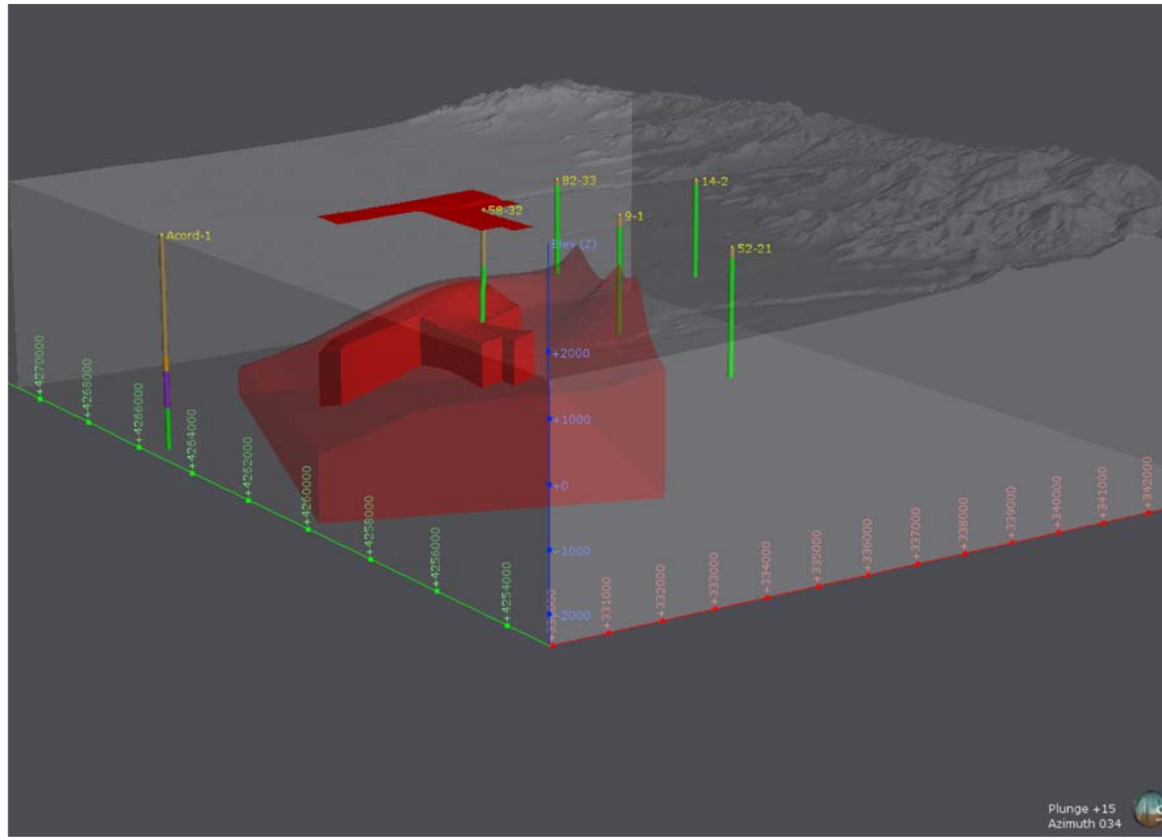
- **Site near Milford Utah**
- **Drilled, completed and tested exploration well to 7536 ft**
  - **Cored two intervals within the reservoir section**
  - **Performed a minifrac test**
- **Full suite of geophysical and image logs, 3D seismic survey, gravity survey**
- **Detailed earth and numerical models**
  - The geologic model footprint is approximately 14km by 18km
  - The base geologic model covers an area of approximately 252 km^2, with elevations ranging from 2700m to -2500m



Utah FORGE Target Reservoir Summary

- **4.6 km^3 of granitic rocks between 175^{o}C and 225^{o}C under FORGE footprint** and above 4 km depth

- **93.71 km^3 of granitic rocks** above 175^{o}C and above 4 km depth in Utah FORGE area, max estimated T = 270^{o}C



Path Forward

Collab

- Experiments are on-going, data to become available soon
- Team at ARMA this week, strong presence at GRC in Reno
- PI-Tim Kneafsey at LBNL, tjkneafsey@lbl.gov

FORGE

- Phase 2C initiating, building out site infrastructure
- Forming an Science and Technical Advisory Team (TEAM)
- Planning workshop being planned
- Managing PI-Joe Moore at EGI, jmoore@egi.utah.edu