



Geothermal Energy Resources

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U.S. Geological Survey

**Congress on Assessing America's Renewable
Energy Future, December 2009**

U.S. Department of the Interior
U.S. Geological Survey

<http://energy.usgs.gov/other/geothermal/>

A map of the United States is visible in the background, with a blue banner overlaid at the top containing the title.

Energy Issue – Electric Power

- *The United States needs energy supplies that are secure, uninterrupted, sustainable, and economically and environmentally viable.*
- *Based on current projections, the United States faces the need to increase its electrical power generating capacity by approximately 300,000 Megawatts-electric (MWe) or 30 percent over the next 20 years.*
- *Geothermal energy constitutes one of the United States' largest sources of renewable energy.*
- *A critical question for the near future is the extent to which geothermal resources can help meet the increasing demand for electricity.*



Classification of Geothermal Energy

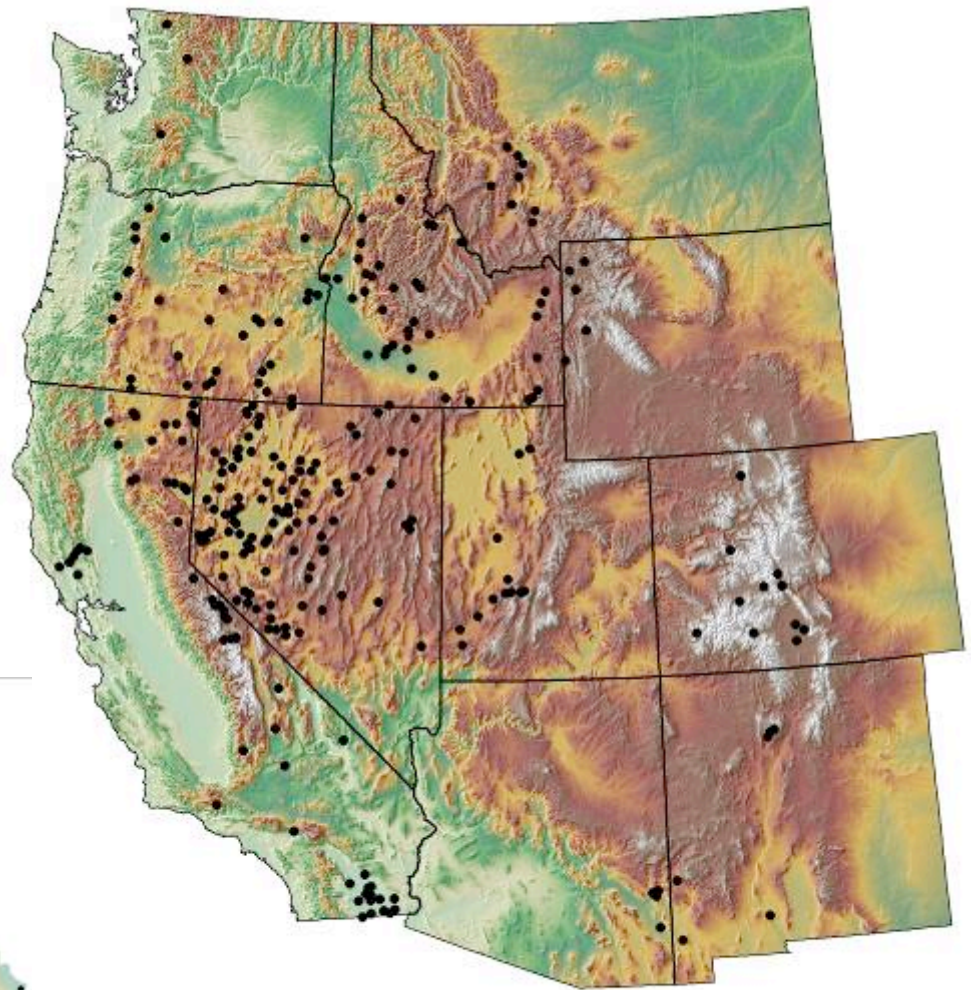
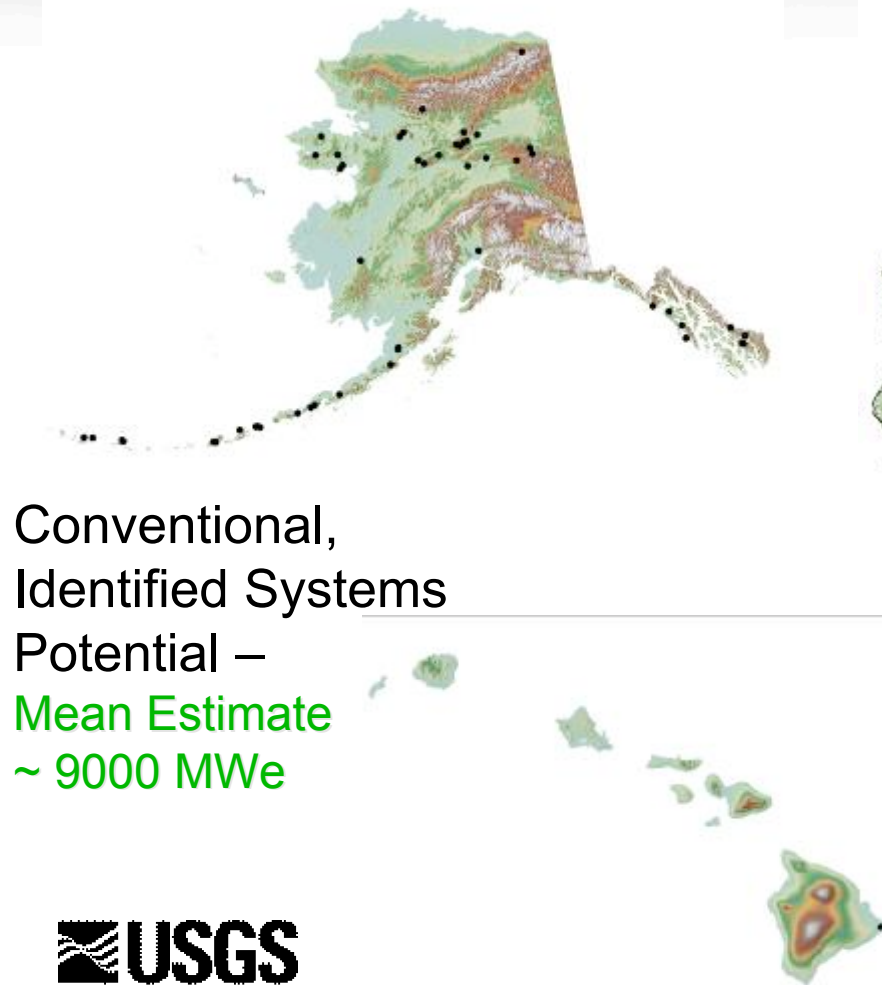
- Conventional Geothermal
 - Direct Use
 - Geothermal Heat Pumps
 - Low-Temperature Systems (<90°C or 194°F)
 - Electric Power Generation and Direct Use
 - High-Temperature Systems (>150°C or 302°F)
 - Moderate-Temperature Systems (90 to 150°C or 194 to 302°F)
- Unconventional Geothermal
 - Enhanced Geothermal Systems (EGS)
 - Deep Sedimentary Basin Resources
 - Geopressured Geothermal
 - Coproduction with Oil&Gas



Status of Geothermal Energy

- More than **2500 Megawatts-electric (MWe)** installed Geothermal generation capacity
 - **~15,000 Gigawatt-hours (GWh)** of Geothermal power in 2005
- Approximately 400 Megawatts-thermal (MW_{th}) in direct use applications
- More than 1 million Geothermal Heat Pump installations
- USGS – national assessment of geothermal potential
- USGS, DOE, and other agencies evaluating relative roles of resources, economics, technology and land use in limiting potential development
- DOE Program and ARRA activities
- BLM leasing activities – authorizes geothermal development on BLM and USFS lands

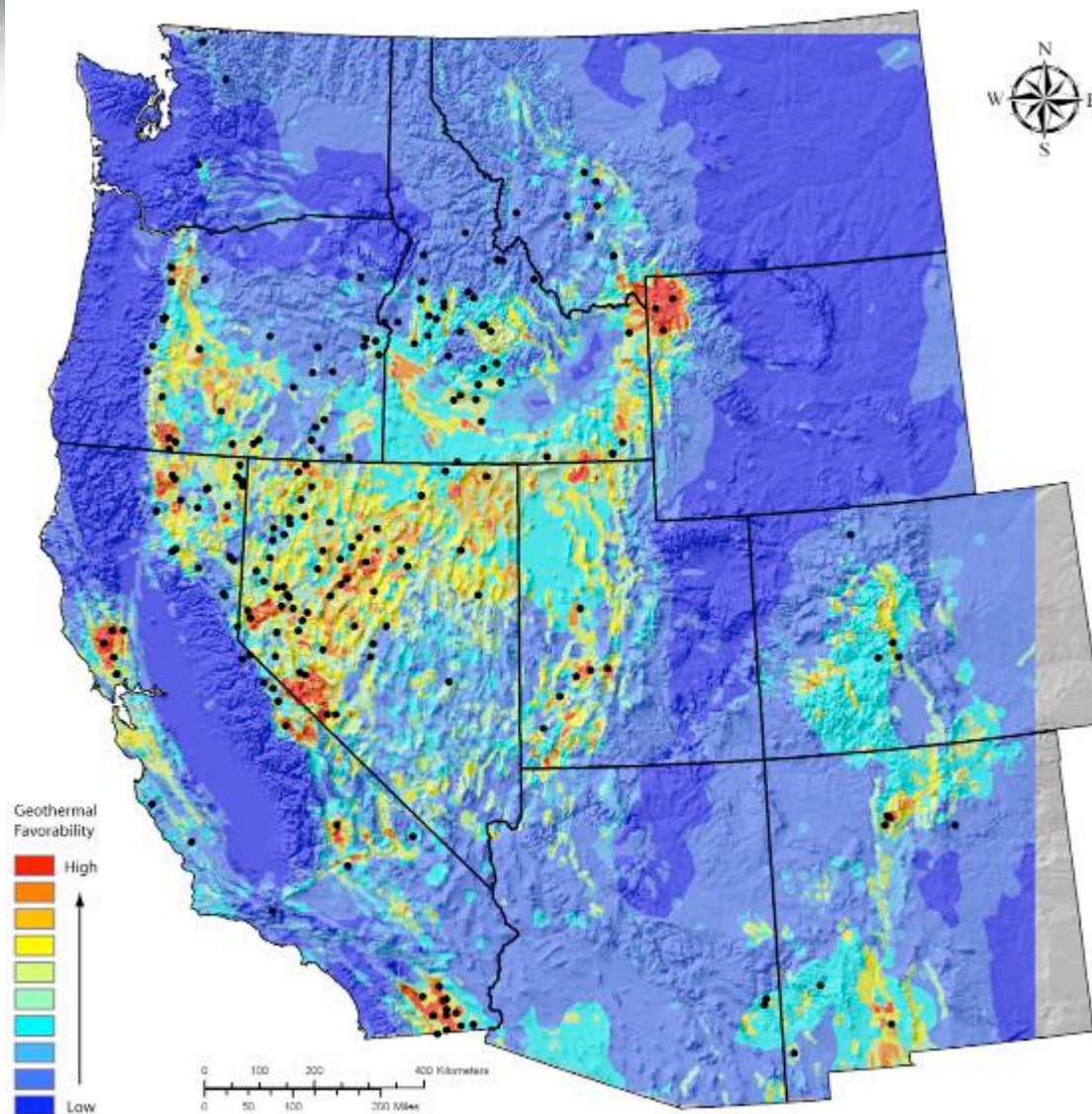
Identified Geothermal Systems



Undiscovered Resources – Geothermal Favorability Maps

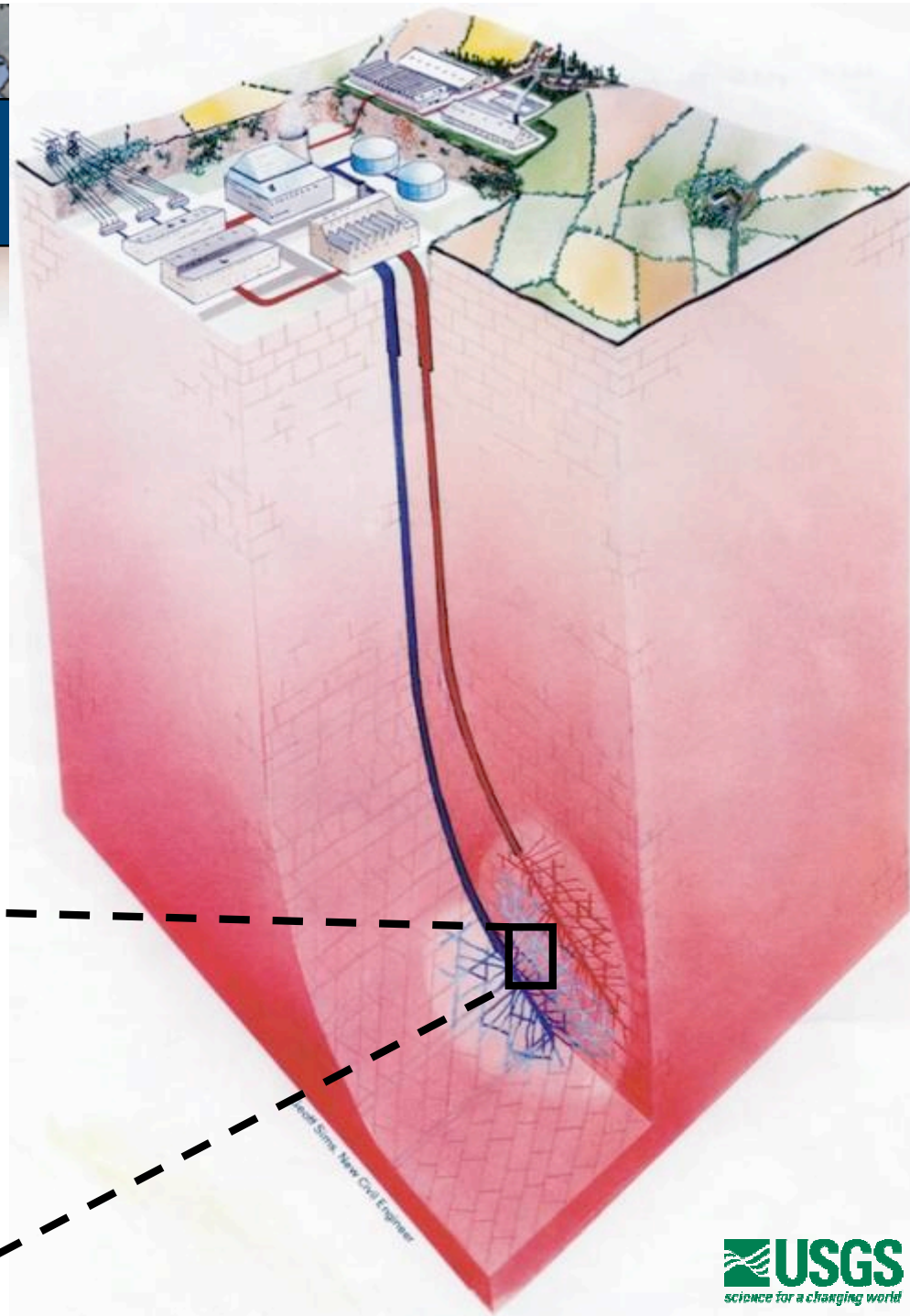
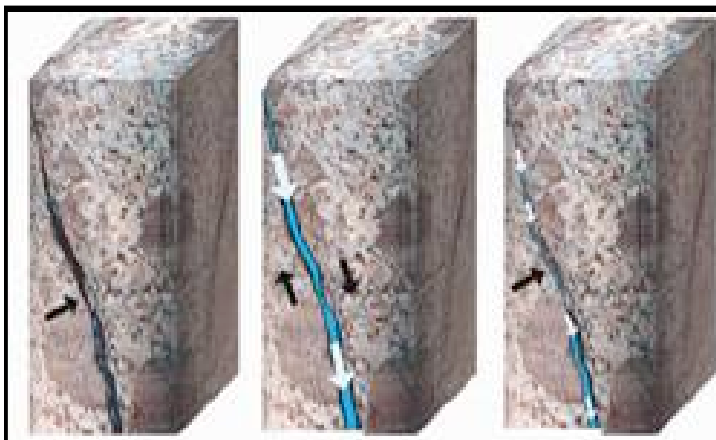
Warmer colors represent higher probability for the presence of geothermal systems.

Conventional, undiscovered:
Mean Estimate ~ 30,000 MWe



Enhanced Geothermal Systems (EGS)

Enhance permeability by causing existing fractures to slip and propagate or creating new tensile cracks by raising fluid pressure



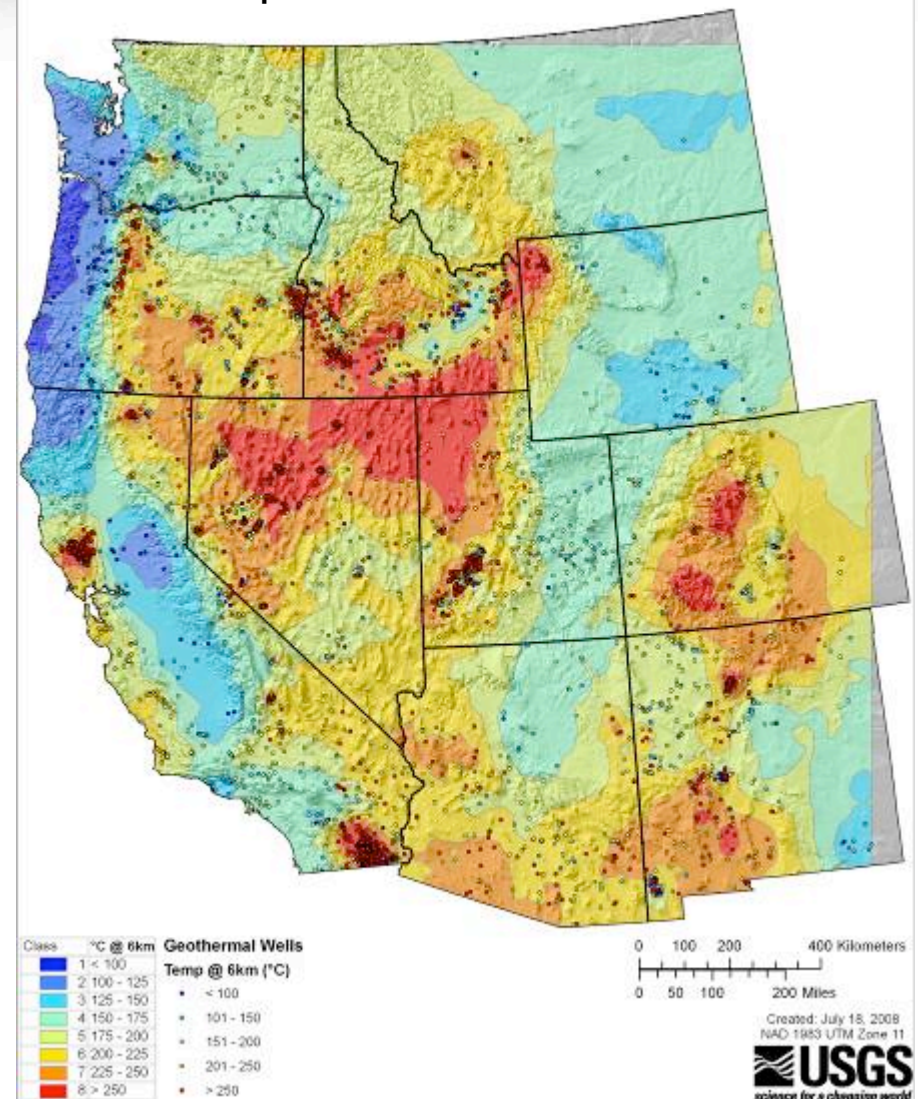
Enhanced Geothermal Systems (EGS) – Temperatures at Depth and Resource Estimates

EGS Resource Potential:

Mean Estimate
>500,000 MWe.



Temperature contours



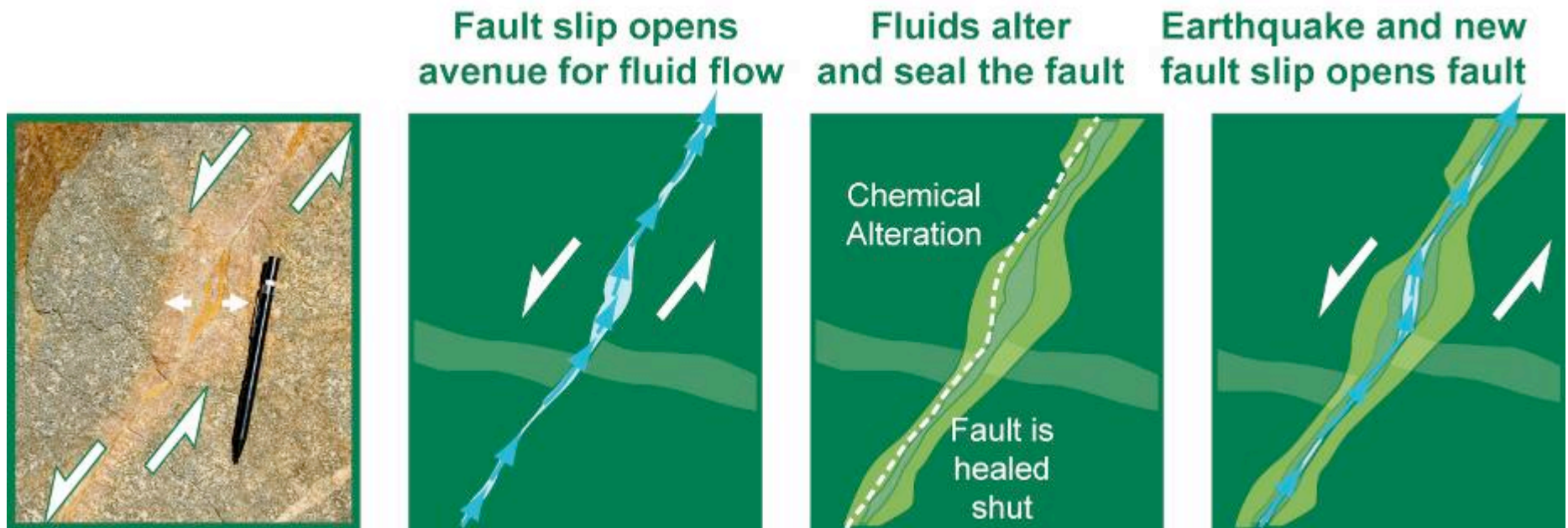


Enhanced Geothermal Systems

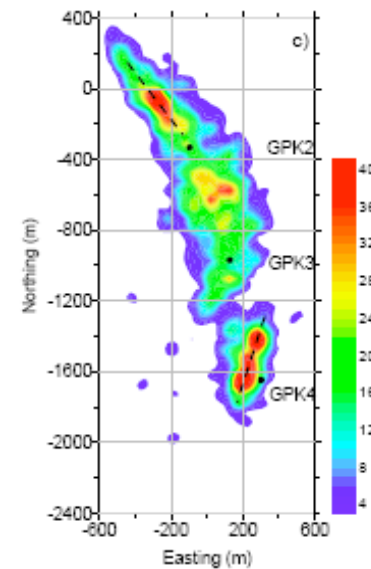
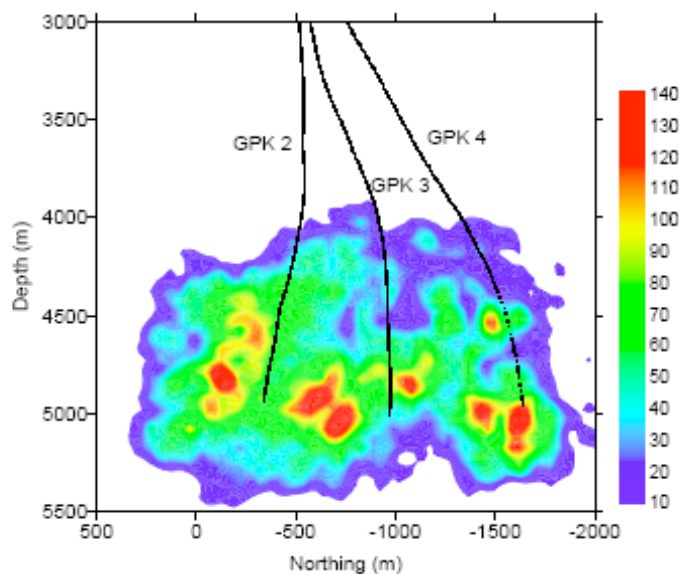
- Large regions of the western U.S. with high temperatures at depths less than 6 km.
- Thermal energy in these regions many orders of magnitude greater than thermal energy in conventional hydrothermal systems
- High permeability required over large volume for effective thermal energy sweep
- Rock stress at depth, rock type, temperature, fluid chemistry, structure determine viability of EGS projects but roles poorly understood

In Low-Porosity (“Tight”) Rock Fractures Carry Most of the Water

- In viable geothermal reservoirs, many of these fractures are open to rapid water flow (**permeable**).
- In most low-porosity rocks, these fractures are sealed with precipitated minerals as part of a cycle of opening and sealing driven by natural fault slip.
- EGS reservoir stimulation replicates the natural fracture opening process



Enhanced Geothermal Systems – Experimental Success



Maps of
microearthquake
density from
reservoir
stimulation

Soultz-sous-Forêts, France

Stimulated Volume $\sim 6-8 \text{ km}^3$

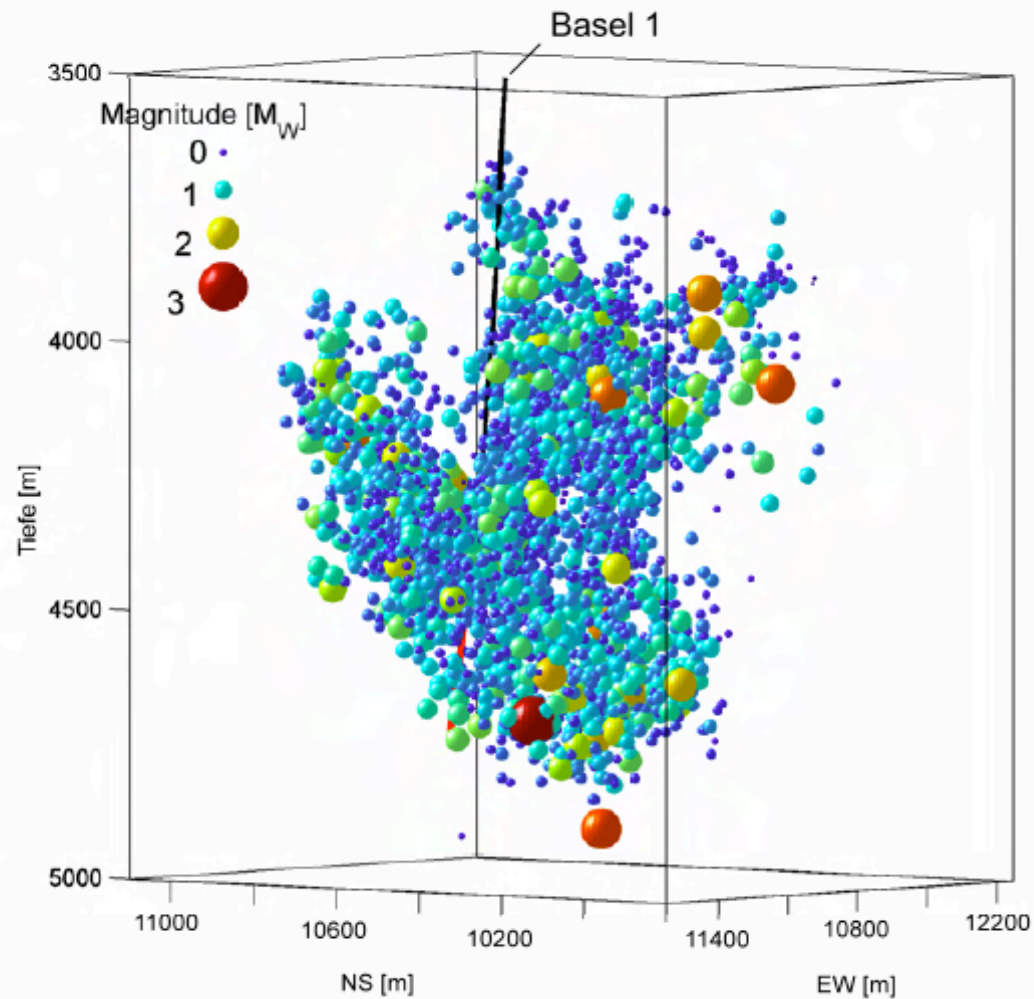
Temperature $\sim 200^\circ\text{C}$

Potential Generation $\sim 1.5 \text{ MWe}$

(Tischner et al., 2007)



Triggered Earthquakes in Basel

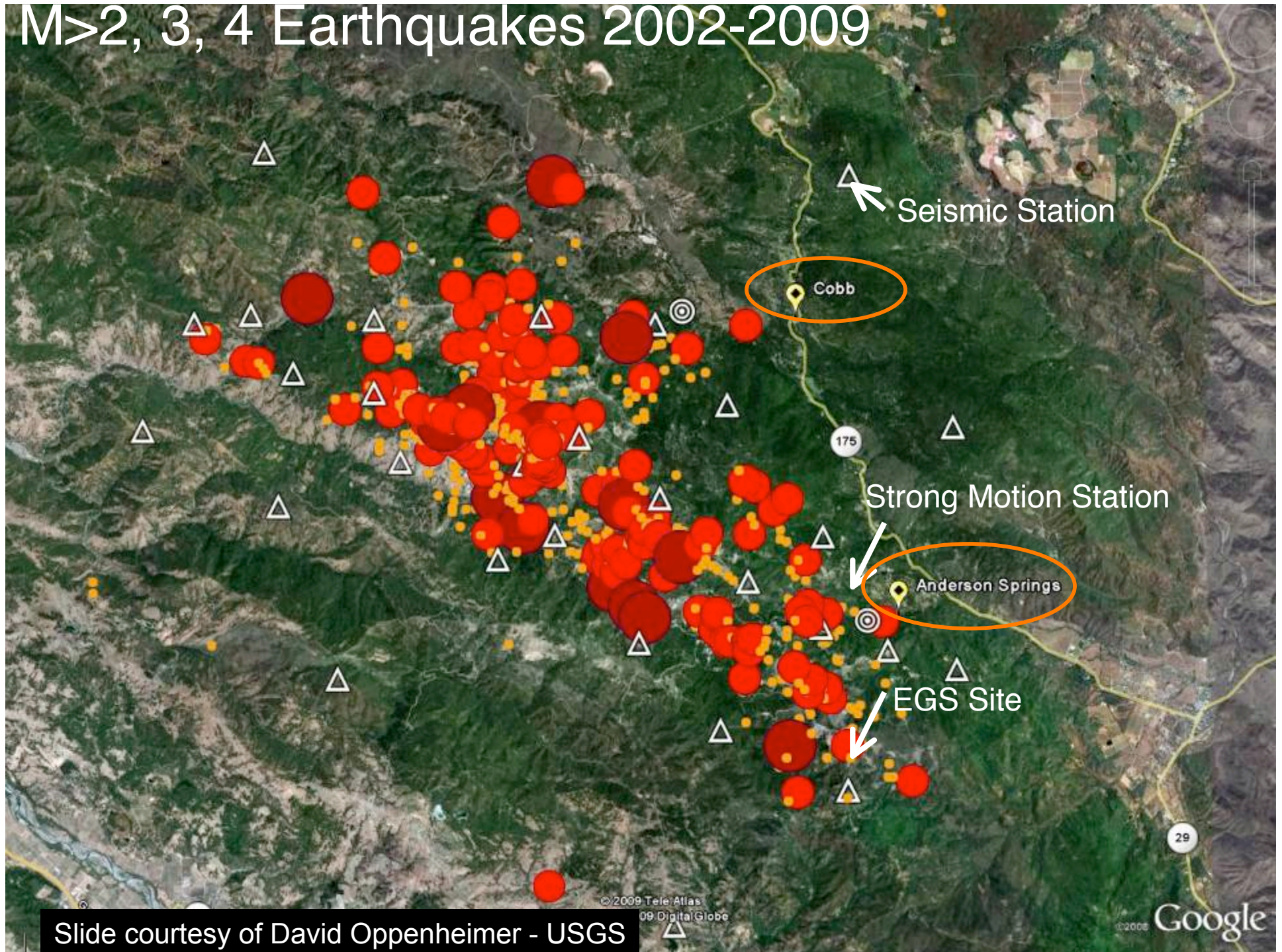


The Geysers Geothermal Field, Northern CA

DOE had funded AltaRock Energy to test EGS technology in low perm rock below The Geysers reservoir. Now funded in Oregon



M>2, 3, 4 Earthquakes 2002-2009



Slide courtesy of David Oppenheimer - USGS



The Press Highlights the Issue

LAKE COUNTY NEWS

New geothermal project raises questions, concern

Written by Elizabeth Larson

Monday, 29 June 2009

The New York Times

June 24, 2009

Deep in Bedrock, Clean Energy and Quake Fears

By James Glanz

THE SACRAMENTO BEE



Small town fears quakes from
geothermal energy project

By Jim Downing

Monday, July 13, 2009





Directions for Future USGS Work

- Build on Current Assessment Results
- Improve Enhanced Geothermal Systems Assessment Methodology
- Address EGS Issues
 - Water Availability
 - Induced Seismicity
- Assess Other Unconventional Geothermal Resources
 - Geopressured Geothermal
 - Co-produced Geothermal with Oil&Gas



Co-produced Geothermal and Oil&Gas

At the Rocky Mt. Oil Test Center in Wyoming, electricity is being produced from hot water that is brought up with petroleum.



Hot water from oil wells at RMOTC (Johnson and Schochet, 2007)

Major Sedimentary Basins – North America

Billions of bbl
of water
produced from
oil fields, some
of it hot enough
to be used for
geothermal.
Question is how
much can
actually be
utilized?





Geothermal Energy

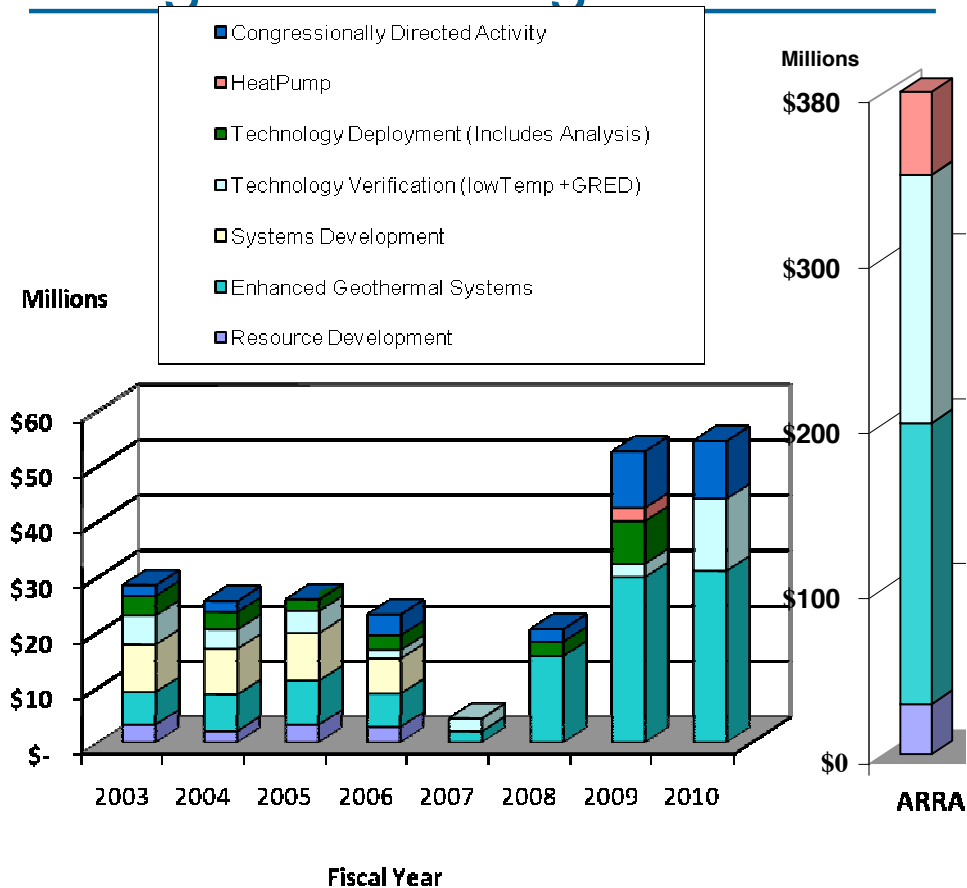
- Emphasis on EGS while supporting hydrothermal
- Investigate co-produced geothermal fluids from oil and gas wells
- Remove institutional barriers for all geothermal resources
 - National Geothermal Database
 - Workforce Development and Education
- Cost-shared step-out approach to Field Projects

The U.S. generates more geothermal electricity than any other country in the world





Budget and Program Goals



Program Goal:

Demonstrate the ability to
create a 5MW EGS reservoir
by 2015

Find & develop 30 GW of
undiscovered hydrothermal
by 2030

Lower development risk by completing
comprehensive resource assessment for
hydrothermal, low-temperature geothermal
and EGS across the 50 states

Develop EGS tools & techniques to enable
working fluid flow of 60 kg/sec by 2015

Demonstrate ground source heat pumps in
variety of buildings and locations to enable
their widespread deployment

BLM GEOTHERMAL – Status



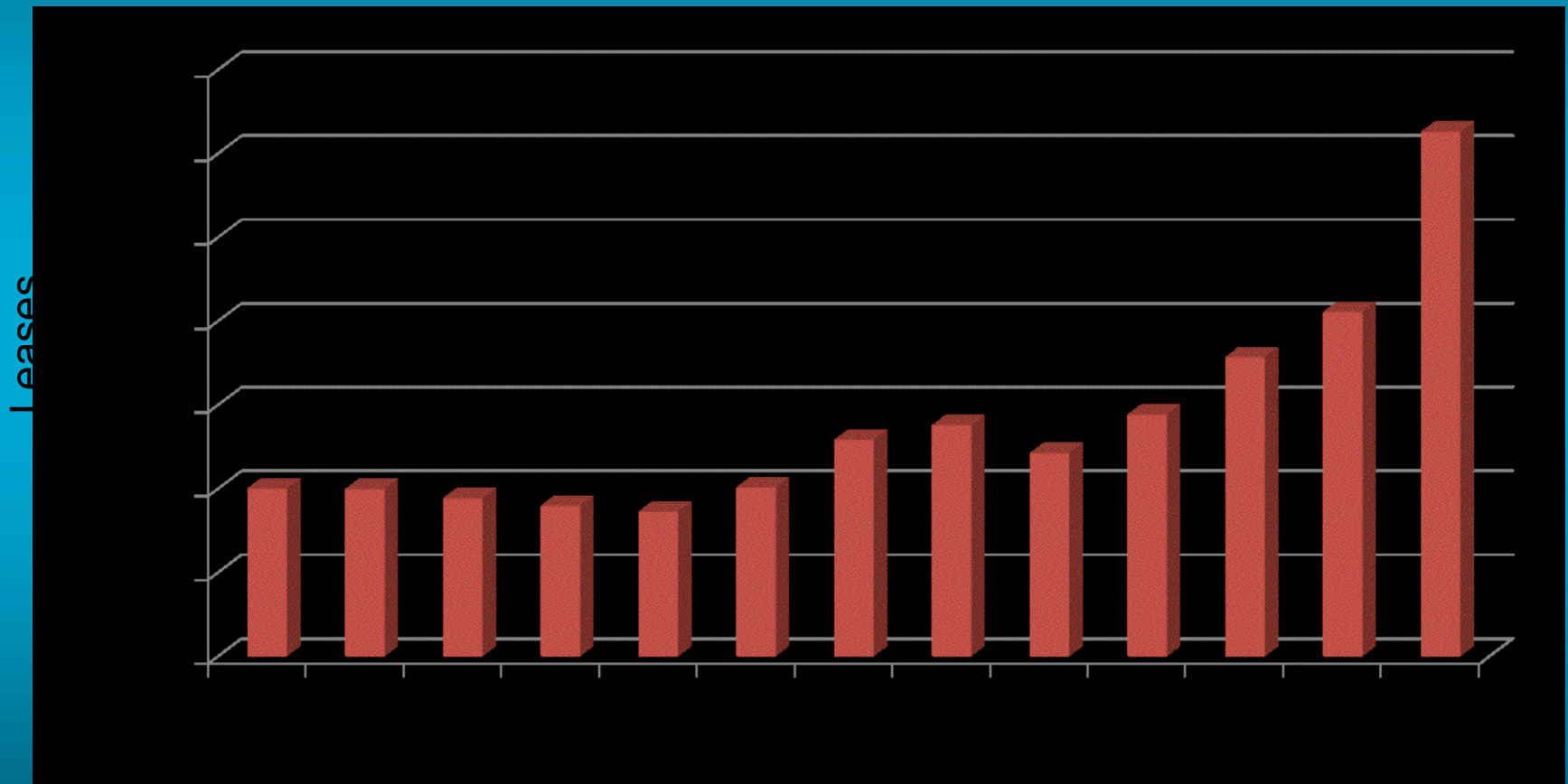
Status

- Programmatic EIS completed
 - Conducted 30 Implementation workshops
- Lease sales (June 2007, Aug 2007, Aug 2008, Dec 2008, July 2009)
- 248 parcels/\$71.5 million
- 666 geothermal leases (9/30/2009)
- 59 leases in producing status
- Generating about 1,300 MW
- 22 pending development plans (761MWs)
 - 3 Fast Track projects (100 MWs)

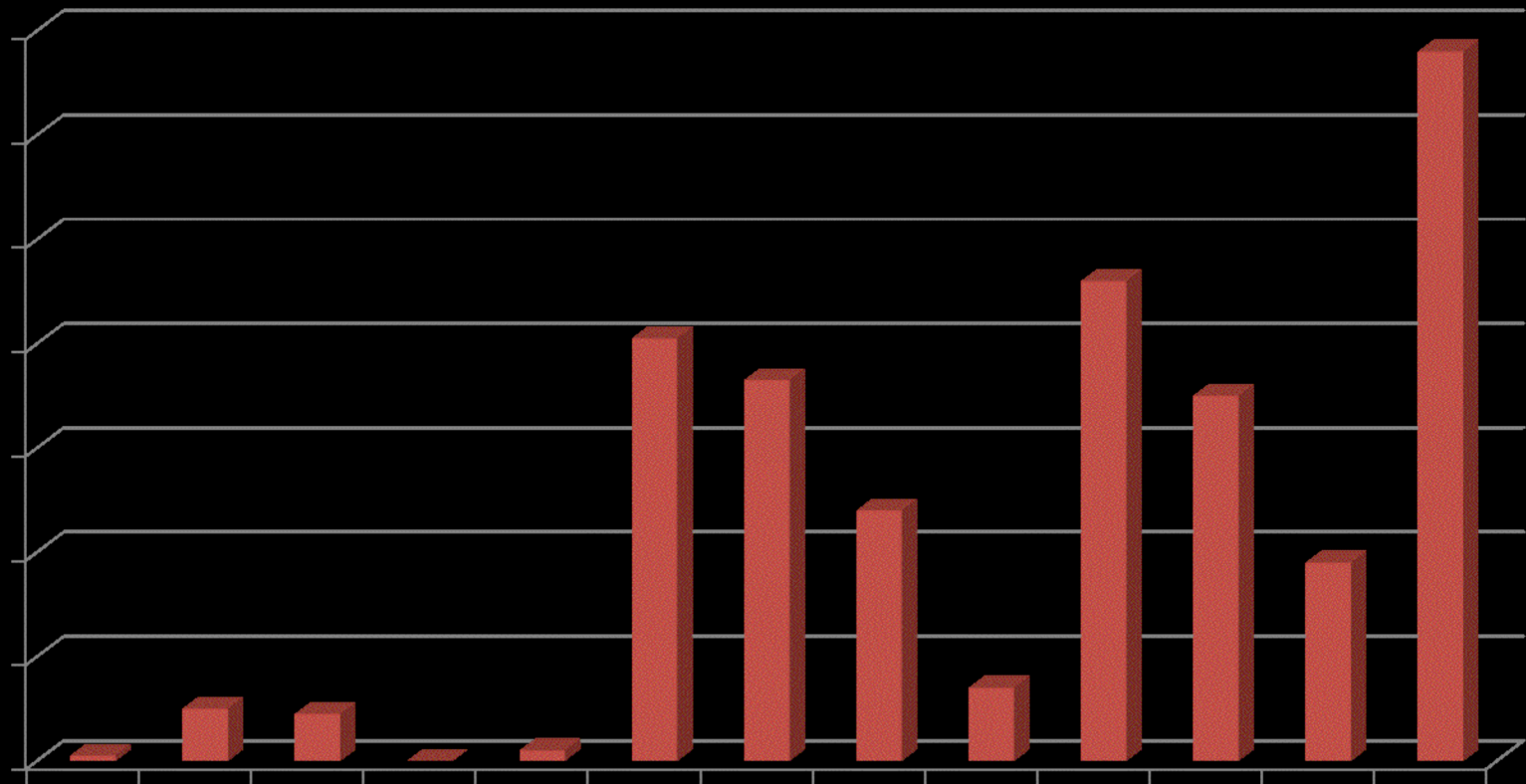
Challenges

- Geothermal Fund expires 2010
- NEPA
- Surface Use conflicts
- Co-Production limitations
- Litigation

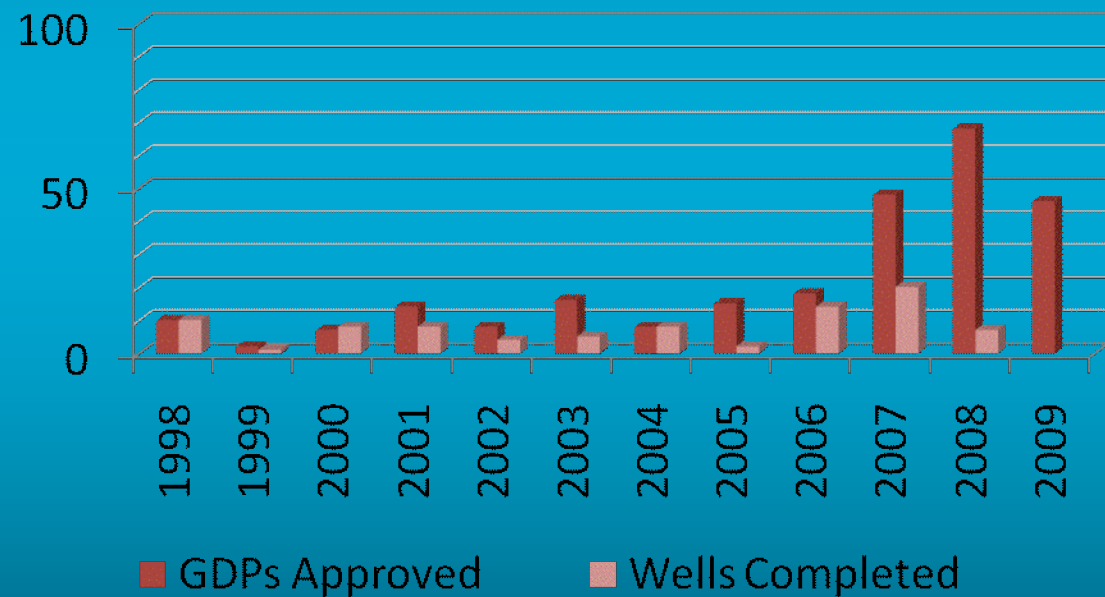
GEOHERMAL LEASE ACREAGE IN EFFECT FY 1997 - 2009



Geothermal Leases Issued FY 1997-2009



Geothermal Drilling Permits Approved and Wells Completed





Information Needs and Technical Challenges for Geothermal Resource Studies – EGS and Conventional

- Continent-scale maps of regional variations in thermal regime, rock type and the orientations and magnitudes of tectonic stresses at depths targeted for EGS.
- Improved models for the physics and chemistry of permeability creation and destruction in potential reservoir rocks, including effects of mineralogy, physical properties, fluid chemistry, temperature and state of stress.
- Identification of active faults and evaluation of potential for reservoir stimulation and production to trigger significant earthquakes.
- Requirements for and availability of water for reservoir creation and operation.
- Maps of fault intersections, other geologic boundaries, and heat flow at a local scale for evaluation of exploration targets.



Information Needs and Technical Challenges for Geothermal Resource Studies – Unconventional

- Improved databases of water chemistry and flow properties for shallow thermal aquifers.
- Detailed information on in situ and surface temperatures, flow rates, wellhead spacing, and produced fluid characteristics for oil wells.
- Three-dimensional geospatial databases with information on the temperature, permeability, fluid composition and stratigraphic character of geopressured formations in deep sedimentary basins.

Thank You



Photo by J. Donnelly-Nolan, USGS