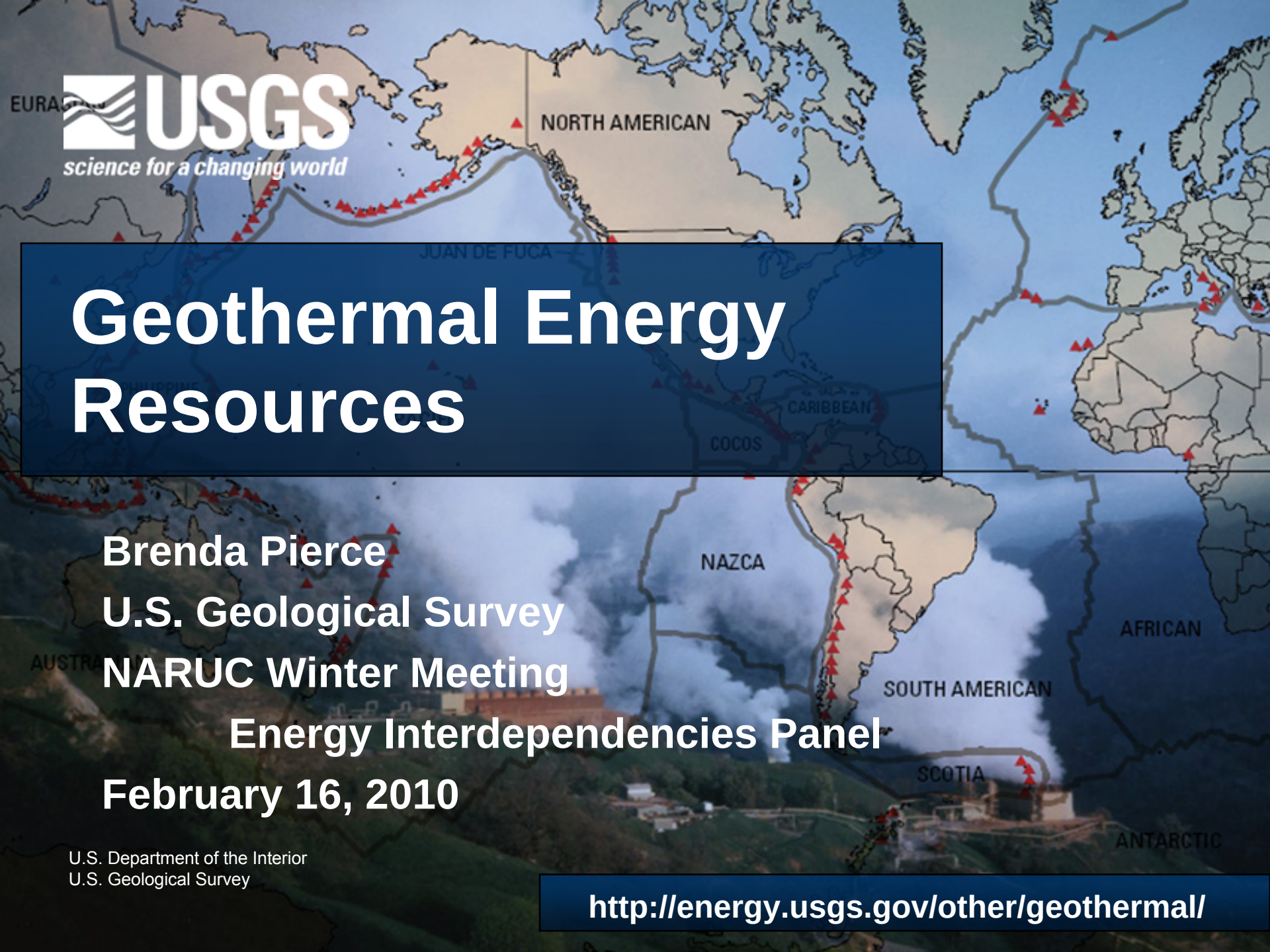

Geothermal Energy Resources

Brenda Pierce
U.S. Geological Survey

NARUC Winter Meeting
Energy Interdependencies Panel
February 16, 2010

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

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

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.***

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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

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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

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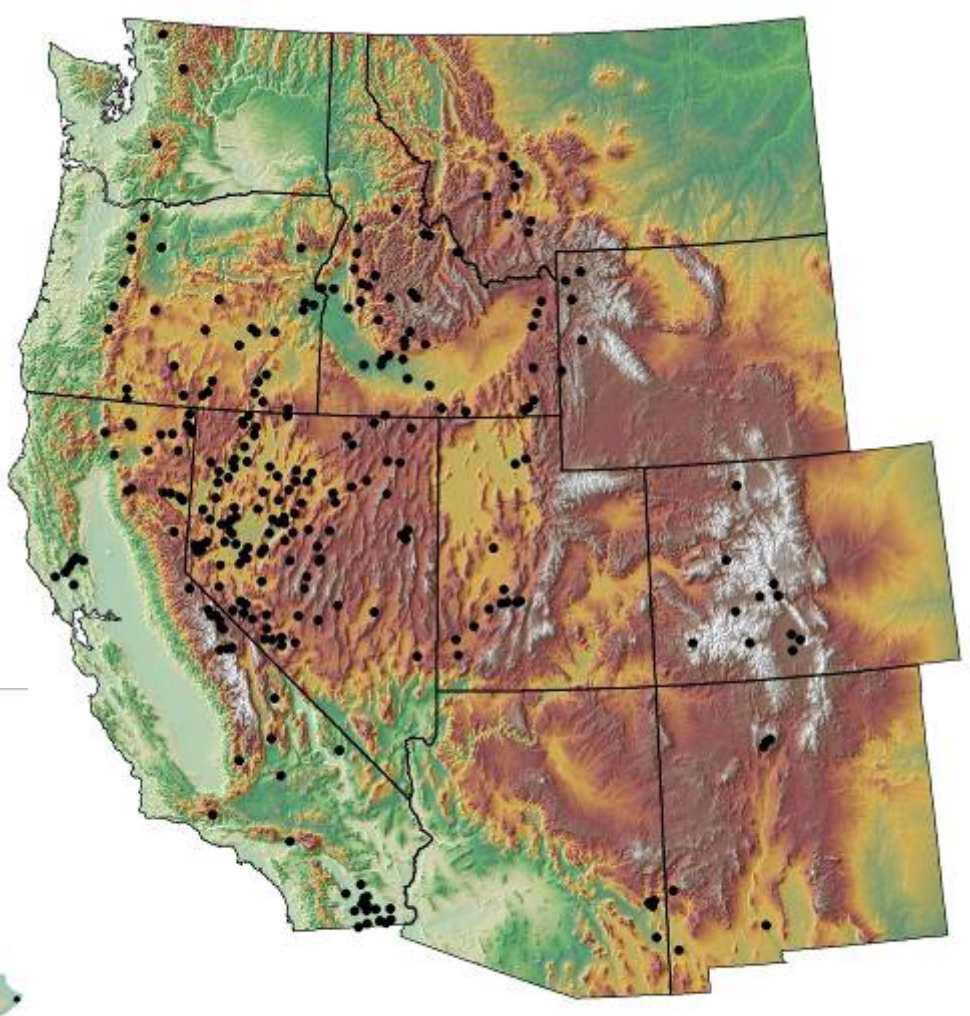
Identified Geothermal Systems



Conventional,
Identified Systems
Potential –
Mean Estimate
~ 9000 MWe

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Undiscovered Resources – Geothermal Favorability Maps

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

Conventional, undiscovered potential:
Mean Estimate ~ 30,000 MWe

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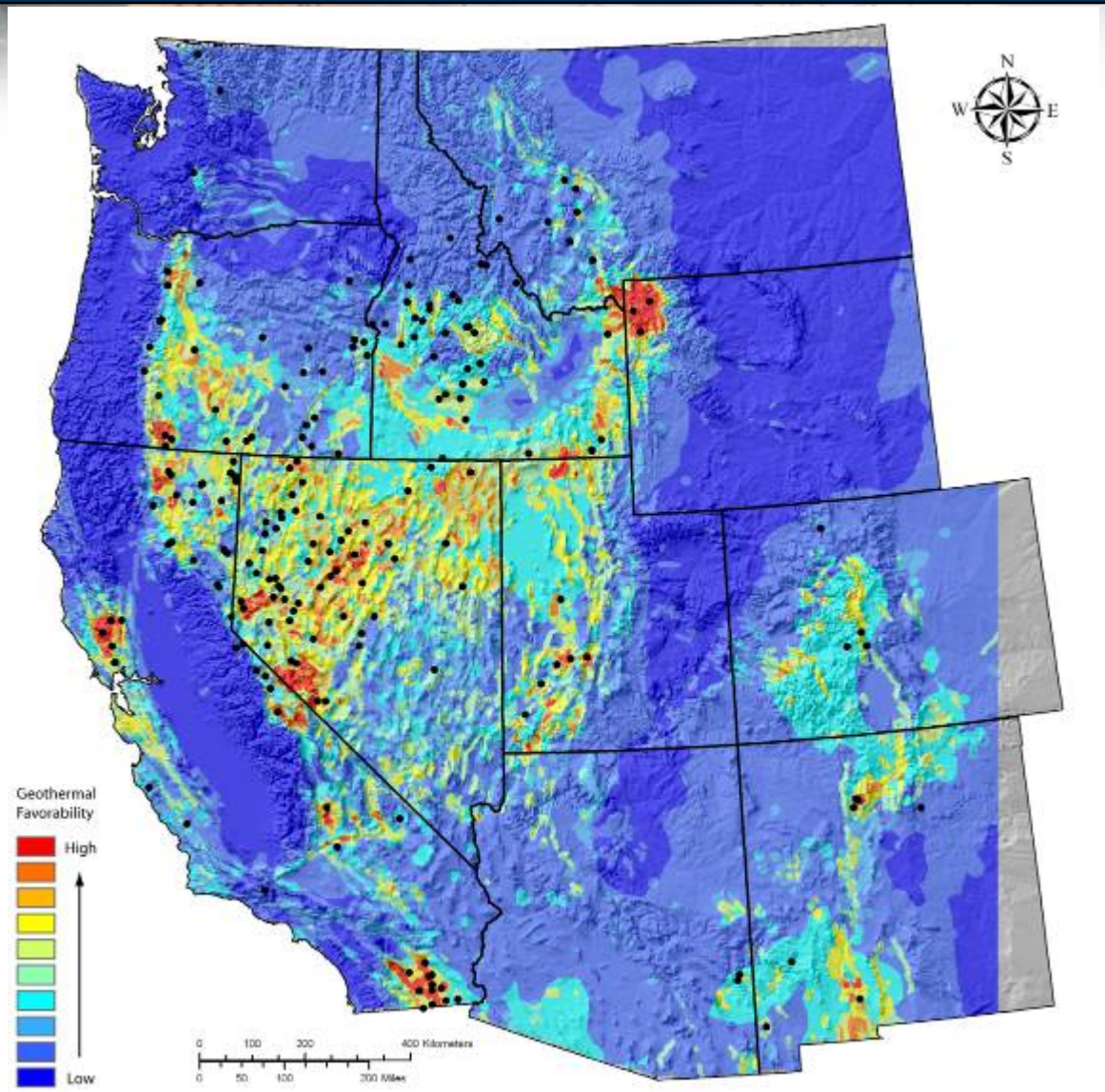
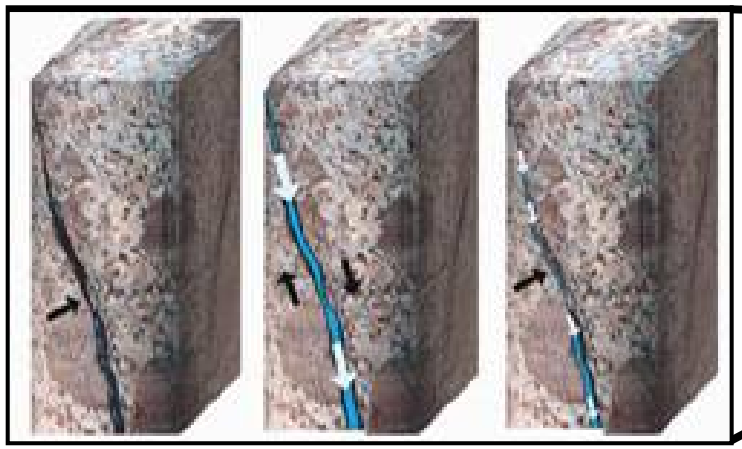
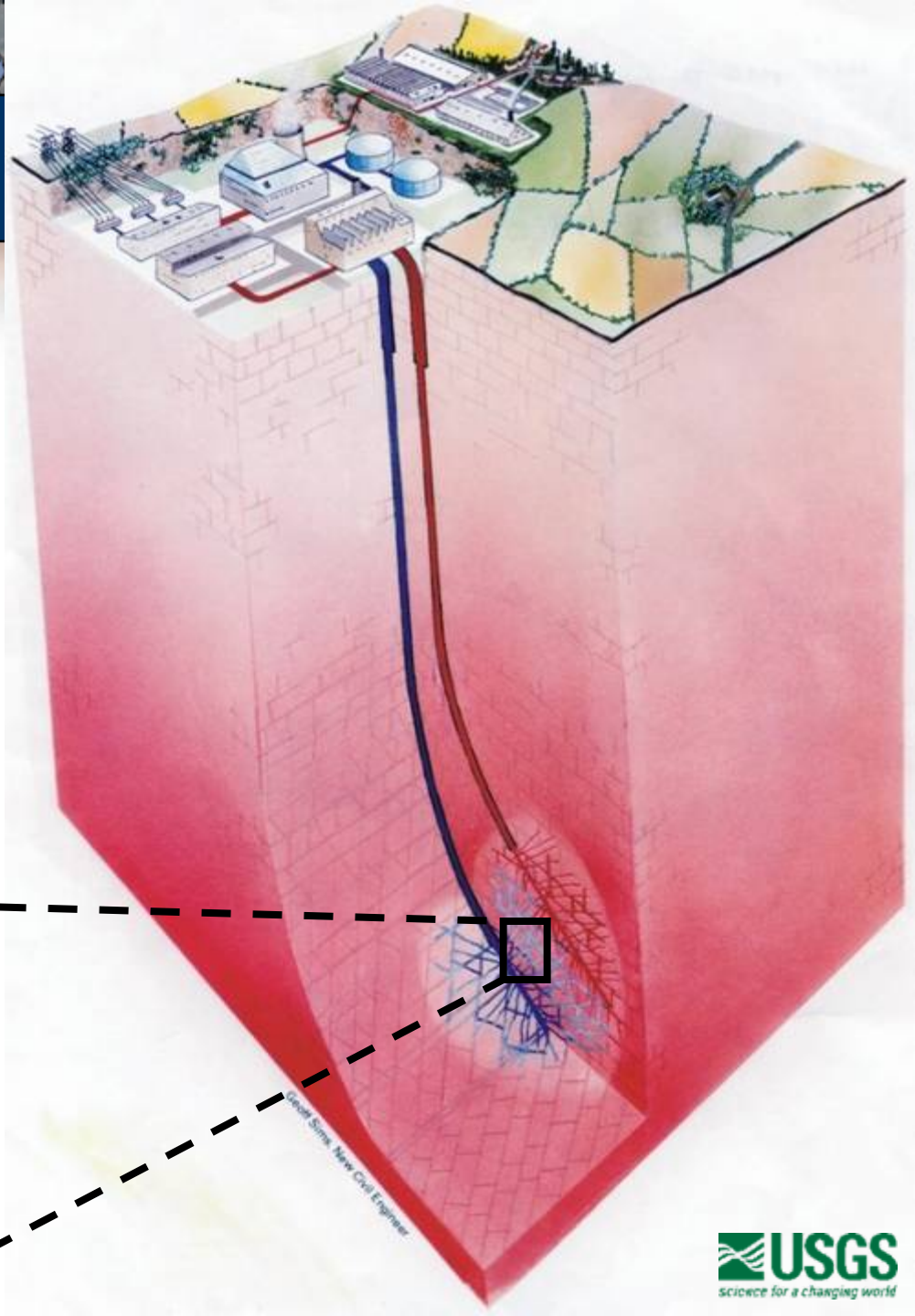


Enhanced Geothermal Systems (EGS)

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





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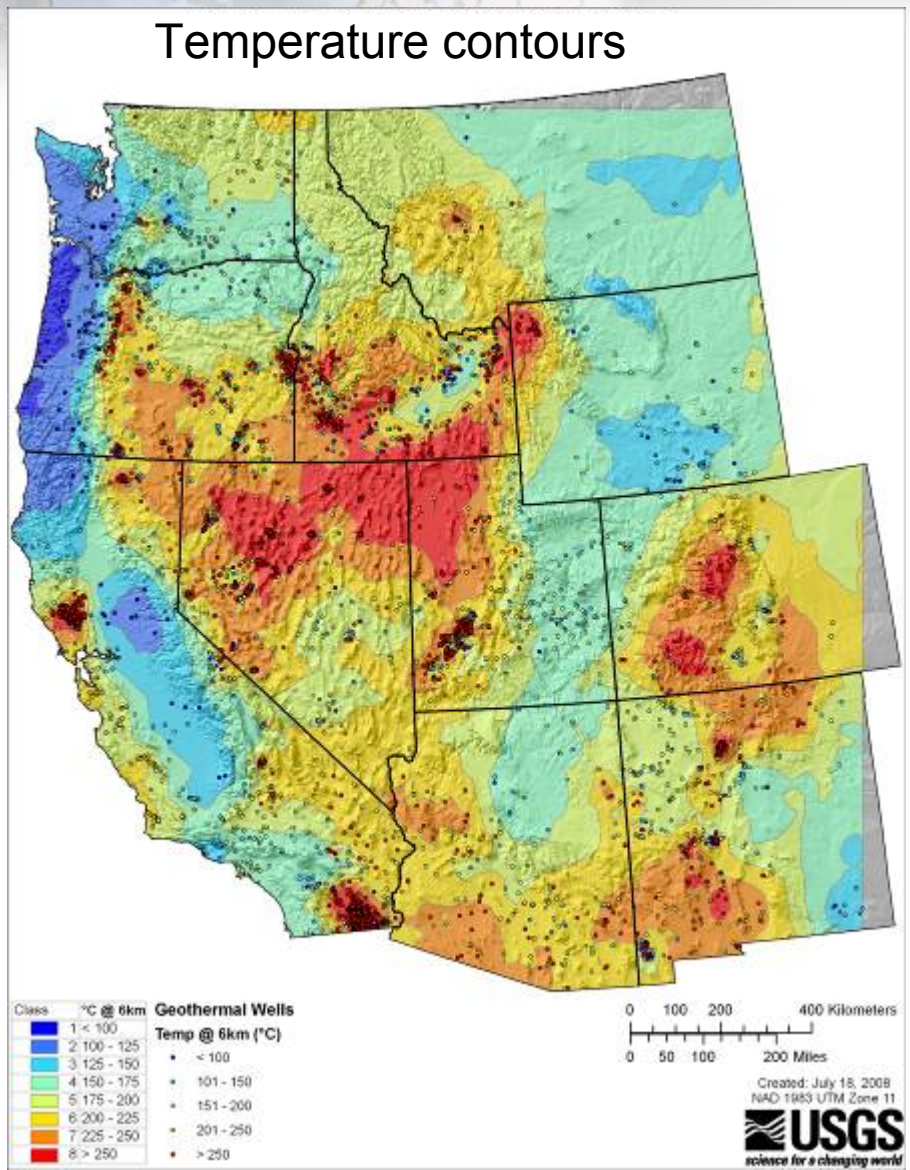
science for a changing world

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

EGS Resource Potential:

Mean Estimate
>500,000 MWe.



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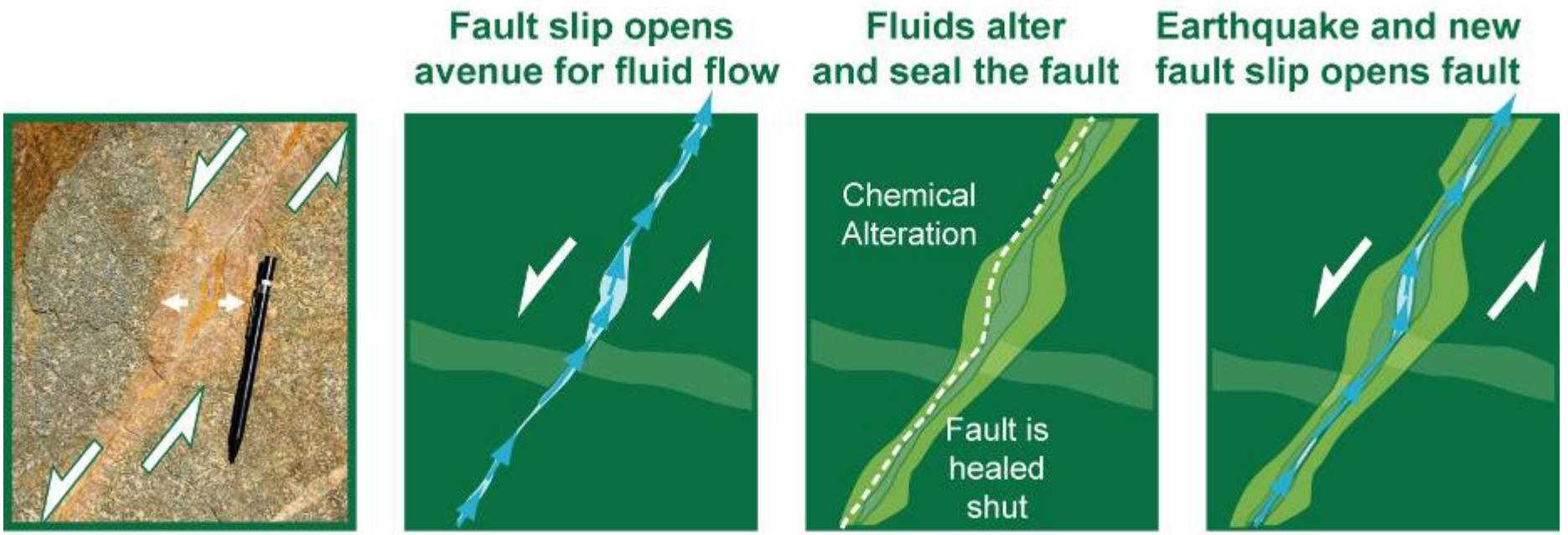
Enhanced Geothermal Systems

- 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

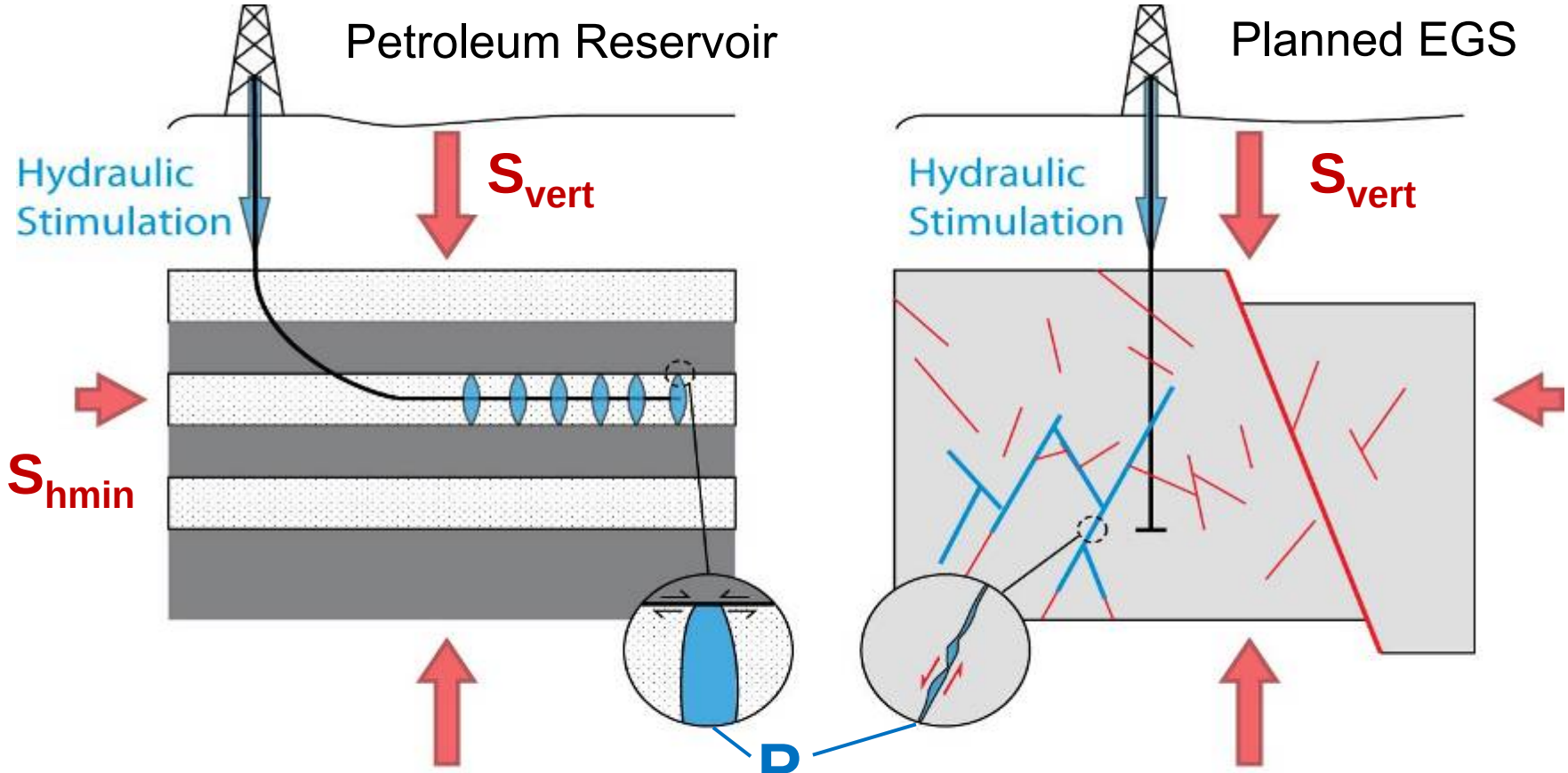
USGS

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*



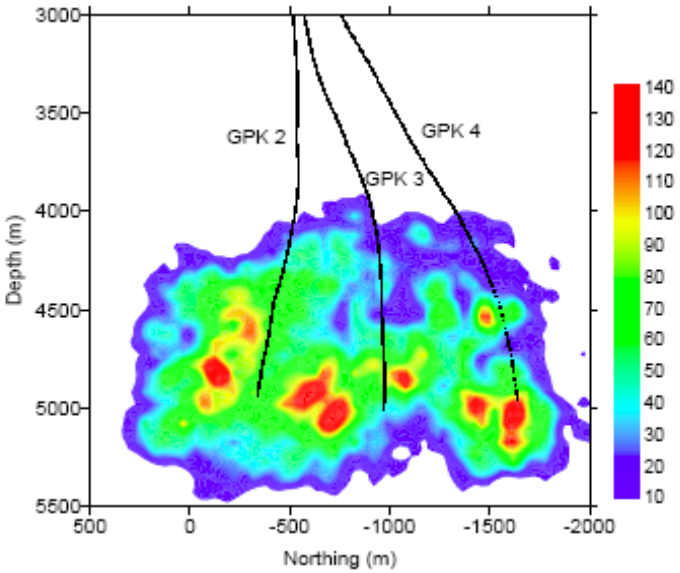
How Do We Open Up Sealed Fractures?
Two Modes of Hydraulic Stimulation

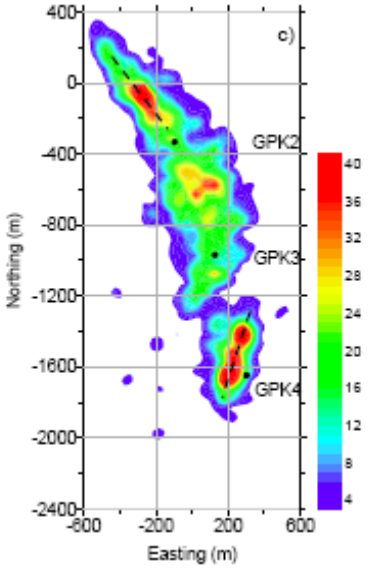


Hydro-Fracture:
- P_{fluid} greater than S_{hmin}
- Tensile failure induced

Hydro-Shearing:
- P_{fluid} less than S_{hmin}
- Shear failure induced

Enhanced Geothermal Systems – Experimental Success





Maps of microearthquake density from reservoir stimulation

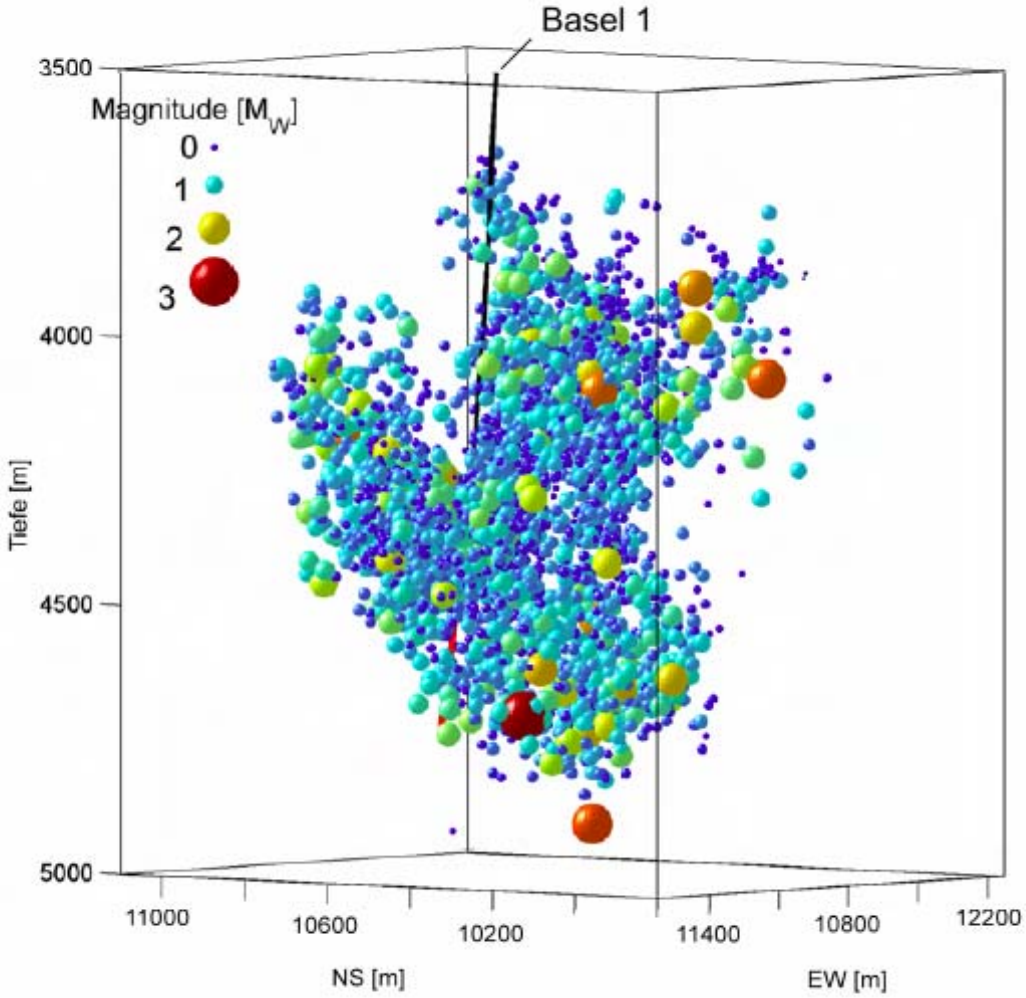
Soultz-sous-Forets, France

- Stimulated Volume ~6-8 km^3
- Temperature ~200°C
- Potential Generation ~1.5MWe

(Tischner et al., 2007)

USGS

Triggered Earthquakes in Basel



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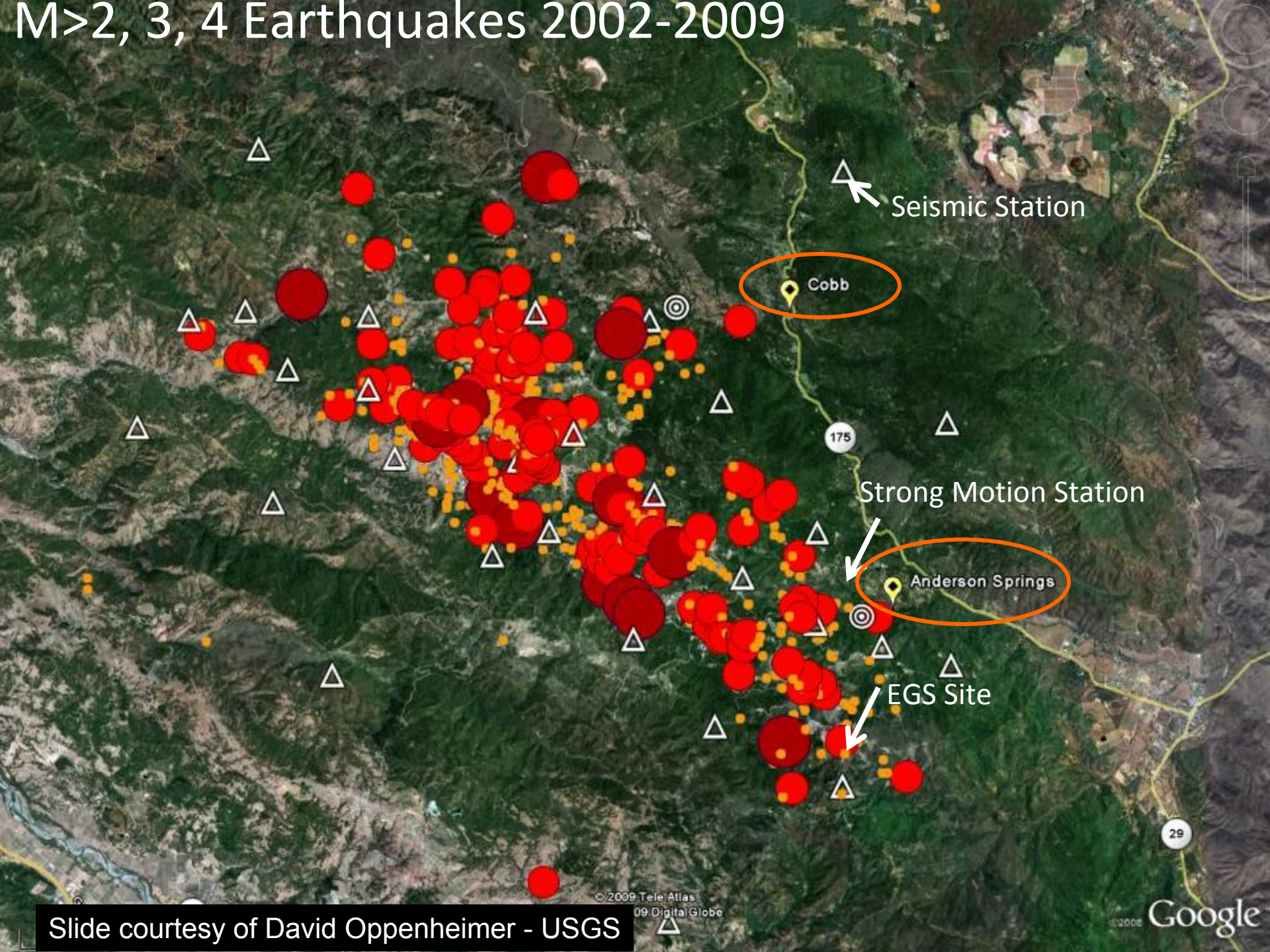
The Geysers Geothermal Field, Northern CA

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

USGS



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

USGS

Water and Geothermal Energy Production

- Depending on the resource T, the rate of water flow through a geothermal power plant ranges from ~100 (high T) to 2500 (low T) acre-ft per year for each MWe generated. (1 acre-ft ~ 326,000 gallons)
- In general, no water is lost in the operation of the binary power plants typically used for lower temperature (≤175°C) resources. All of the produced water is re-injected into the reservoir.
- From 5 to 35% of the produced water may be lost through cooling towers associated with the steam flash power plants used for higher temperature (≥175°C) resources.
- In order to maintain reservoir pressure, geothermal operators make up for these water losses by injecting non-potable water from other sources (e.g. treated wastewater).
    - Development of 500,000 MWe of EGS resource in the western U.S. could require as much as 20 million acre-ft of water (non-potable) for reservoir creation. This is roughly equivalent to the amount of water that flows through the Colorado River in a single year.

USGS

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.

USGS

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?

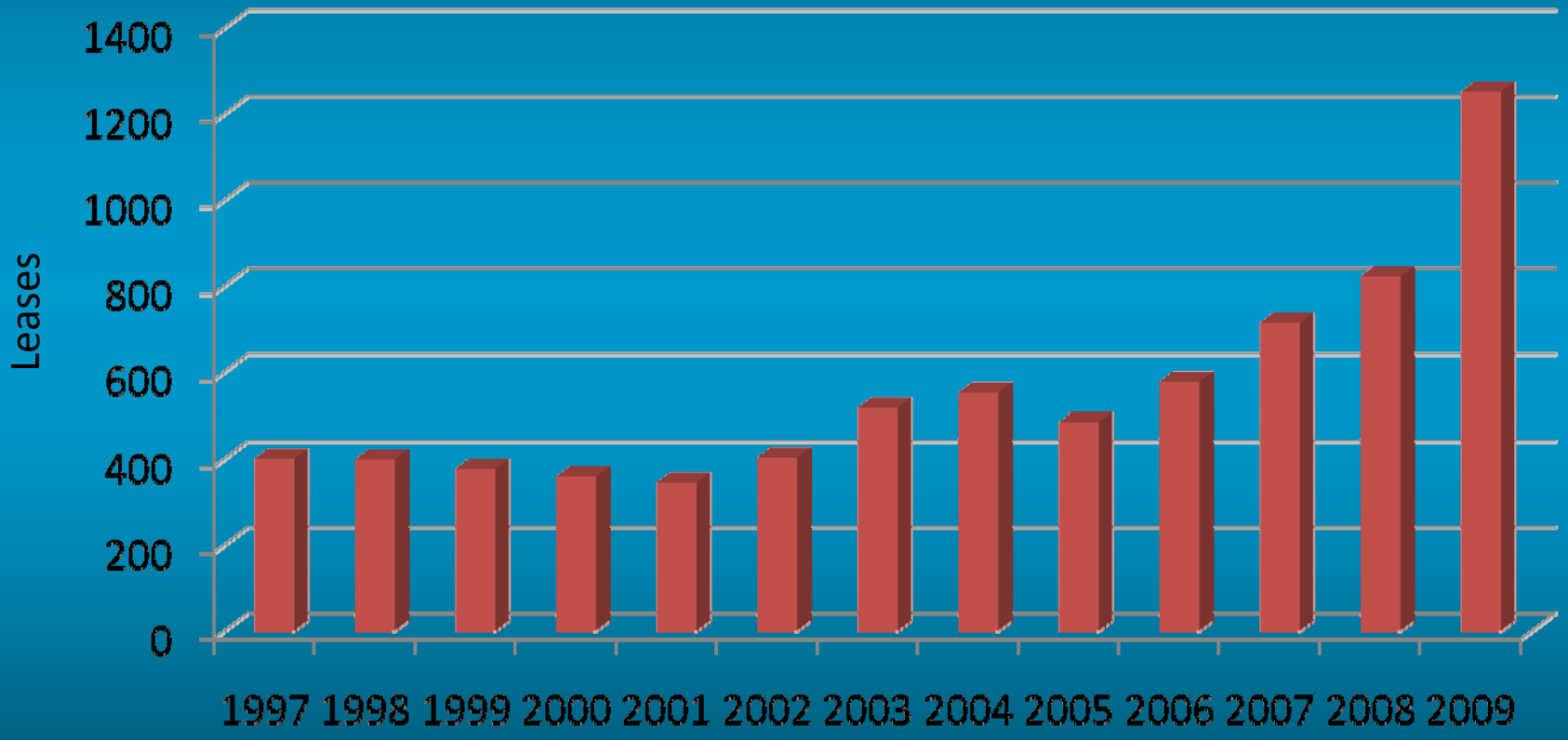
USGS

BLM GEOTHERMAL – Status

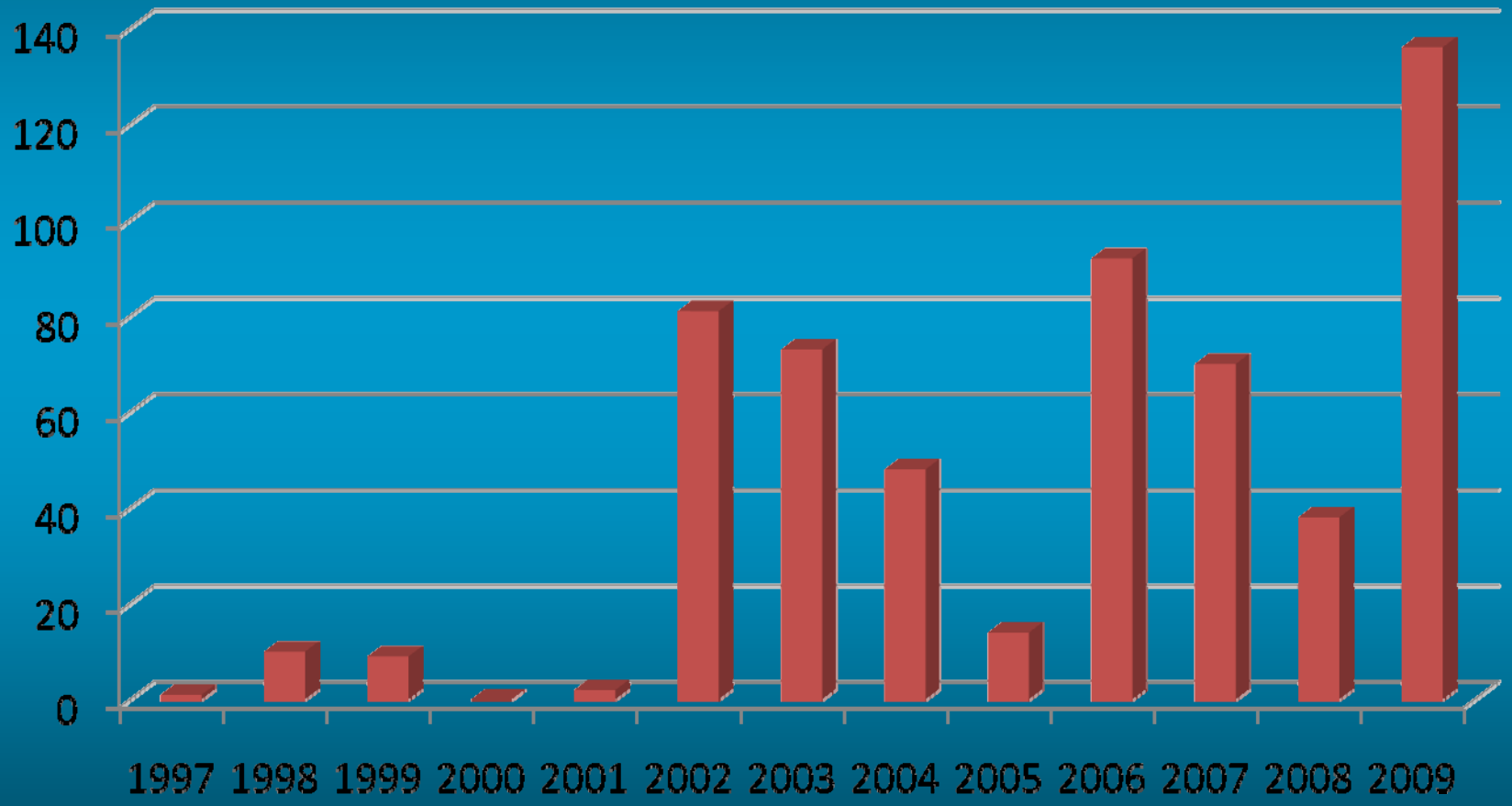
Status
- Programmatic EIS completed
  - Conducted 30 Implementation workshops
- Lease sales (June 2007, Aug 2007, Aug 2008, Dec 2008, July 2009)
- 248 parcels/$71.5 million
- 666 geothermal leases (9/30/2009)
- 59 leases in producing status
- Generating about 1,300 MW
- 22 pending development plans (761MWs)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

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

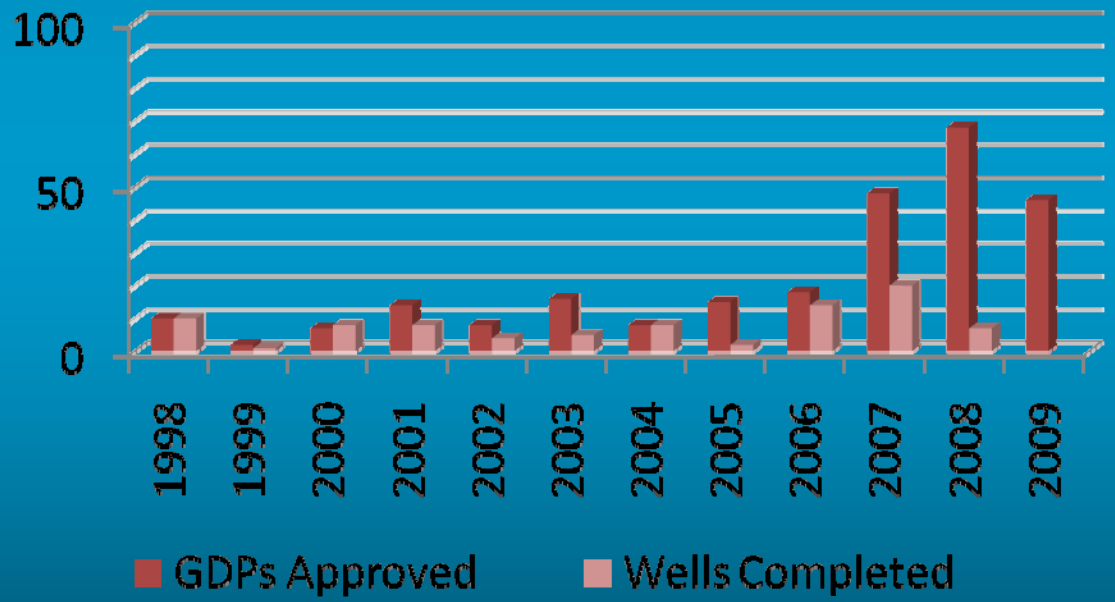
GEOTHERMAL LEASE ACREAGE IN EFFECT FY 1997 - 2009



Geothermal Leases Issued
FY 1997-2009



Geothermal Drilling Permits Approved and Wells Completed



Since FY2005, 130 GDPs have been approved: 8 in CA, 1 in OR, 12 in UT and 109 in NV.

Thank You

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

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Photo by J. Donnelly-Nolan, USGS