

SEDHEAT:

Addressing the science and engineering challenges for unlocking the geothermal potential of sedimentary basins

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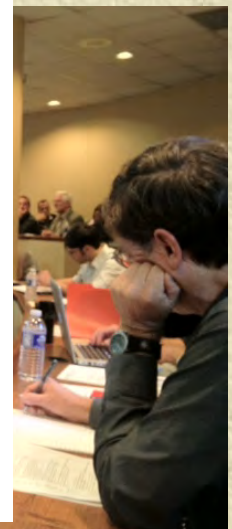
Derek Elsworth *Penn State*

Herbert Einstein, *MIT*

Karin Block, *CUNY*



-71 Partici



Sustainability Issues Remain at the Forefront



Science, Engineering, and Education for Sustainability (SEES)

- Generate discoveries and build capacity to achieve an environmentally and economically sustainable future
- FY 2012 priorities:
 - Advance a clean energy future
 - Nurture the emerging SEES workforce
 - Expand research, education, and knowledge dissemination
 - Engage with global partners
- Environment, energy, and economy nexus



SEES – Geosciences Foci

- Sustainable Energy Pathways
 - characterize and understand existing energy systems and their limitations (e.g. wind, geothermal, hydro)
 - understand risks and stressors associated with new and emerging energy sources (e.g. tidal, clean coal, carbon sequestration)
- Sustainability Research Networks
 - interdisciplinary research and education partnerships involving government, academe, and the private sector
 - address fundamental issues of use in improving policy and practices with regard to energy, the environment, and human well-being

Tracking an Energy Elephant

Geothermal Potential of Sedimentary Basins

Nov 6-9, 2011, Salt Lake City, Utah



“What are the basic science and engineering questions that need to be addressed in order to make geothermal energy production from sedimentary basins practical?”



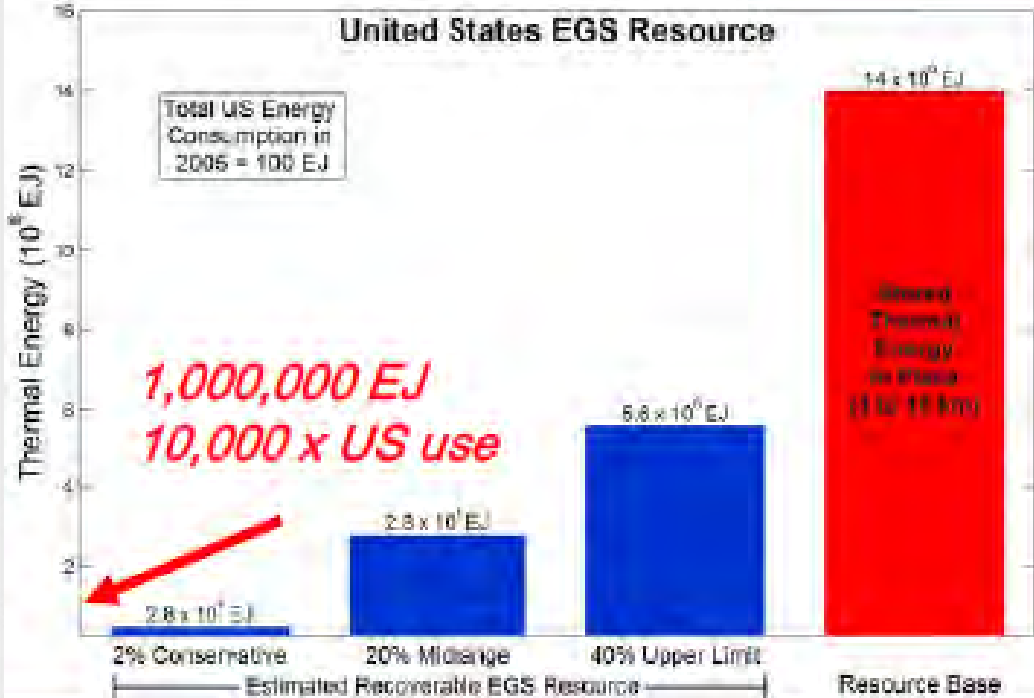
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Question #1

Why Bother?



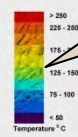
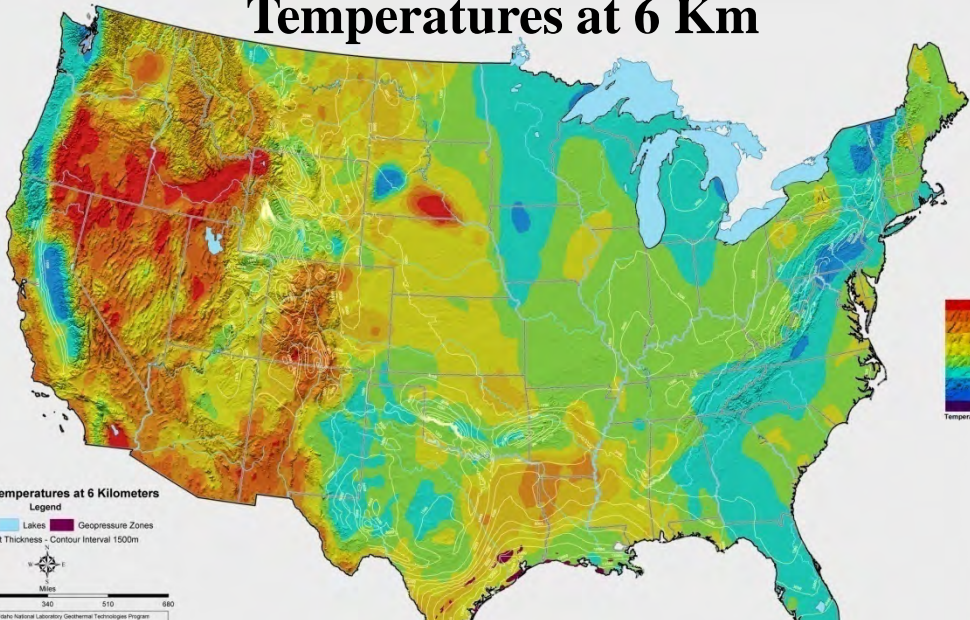
United States EGS Resource



T = 150C

Geothermal System Resource Base

Temperatures at 6 Km



T = 150C

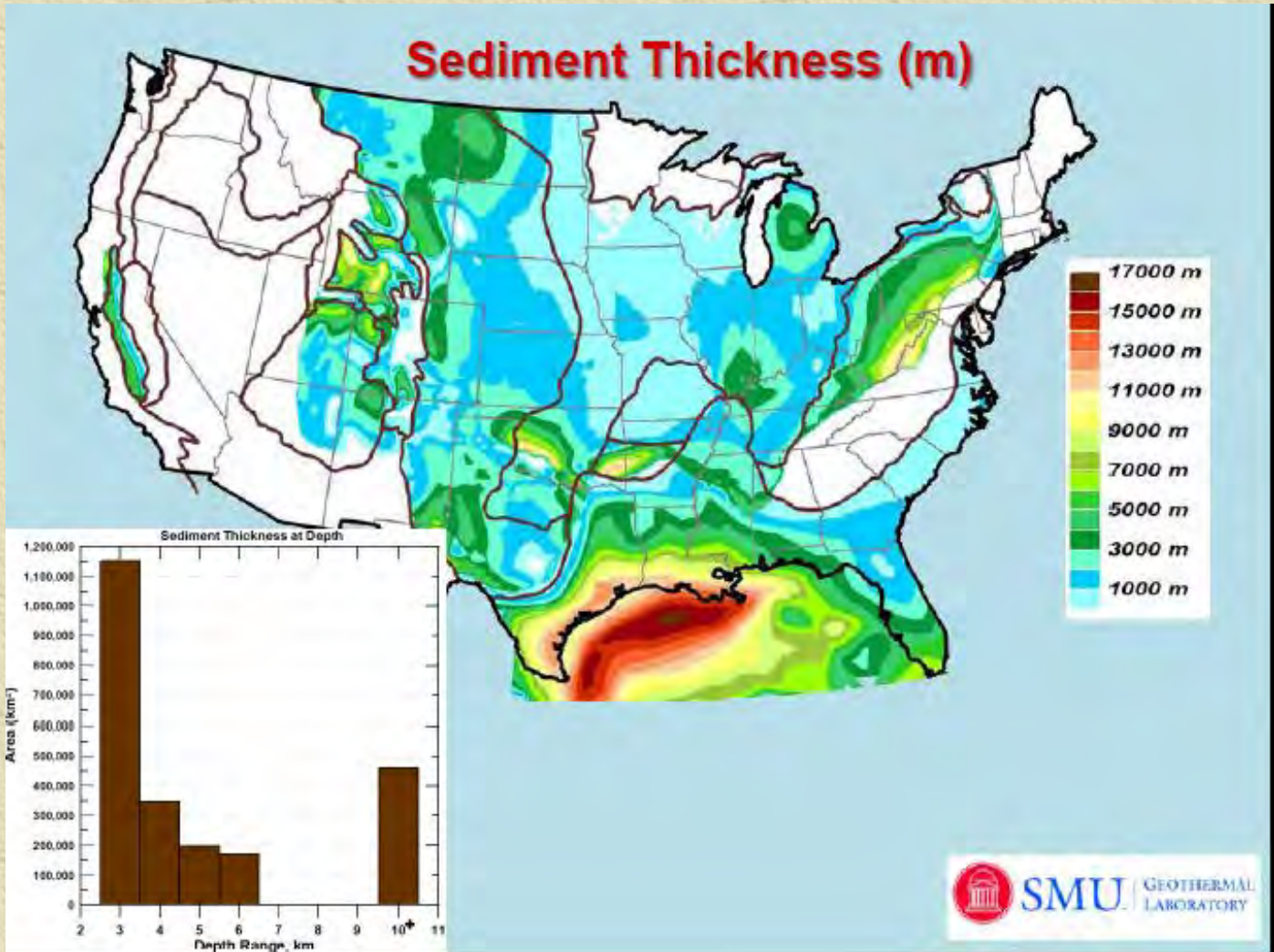
Estimated Temperatures at 6 Kilometers
 Legend
 Rivers Lakes Geopressure Zones
 Sediment Thickness - Contour Interval 1500m
 0 85 170 340 610 680 Miles
 Map Prepared by the Idaho National Laboratory Geothermal Technology Program
 Idaho National Laboratory Geothermal Science & Engineering
 "Temperature data provided by Southern Methodist University Geothermal Laboratory as of 4/12/2005
 (http://www.earth.geol.smu.edu/)
 "Depressured potential data from U.S.G.S. Circular 780 Map
 "Geopressures: Geothermal Energy in Reservoir Fluids of the Western Gulf of Mexico Basin"

Data from SMU

C.O. Joe Moore

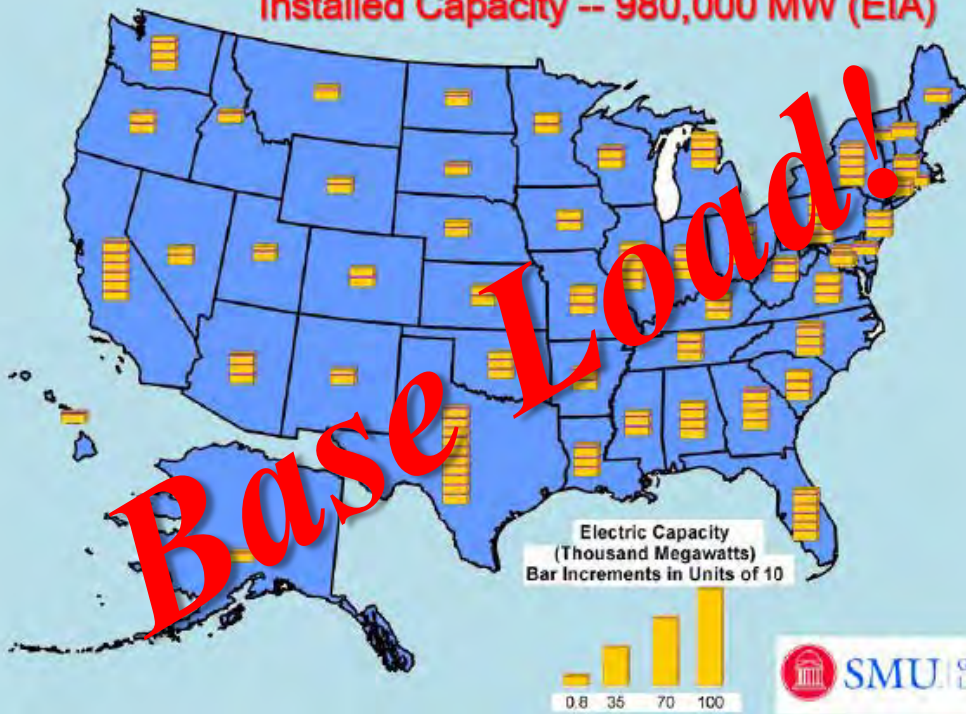
Category of Resource	Thermal Energy, in Exajoules (1EJ = 10 ¹⁸ J)	Reference
Conduction-dominated EGS		
Sedimentary rock formations	100,000	MIT, 2006
Crystalline basement rock formations	13,300,000	MIT, 2006
Supercritical Volcanic Systems	74100 excludes Yellowstone NP, Hawaii	USGS Circular 790
Hydrothermal	2,400 – 9,600	USGS Circular 726 and 790
Coproduced (oil field) fluids	0,0944 – 0,4510	McKenna, et al. (2005)
Geopressured systems	71,000 – 170,000 (includes methane)	USGS Circular 726 and 790

(C.O. Joe Moore)



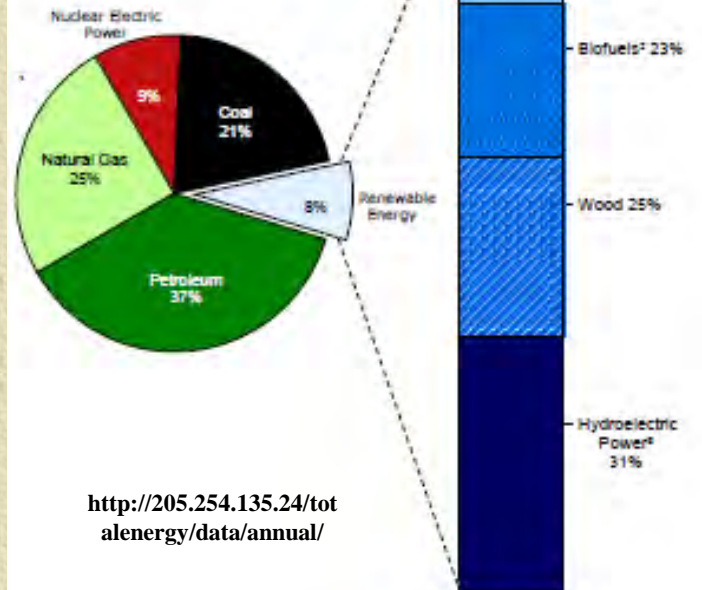
Why Geothermal?

Installed Capacity -- 980,000 MW (EIA)



Renewable Energy as Share of Total Primary Energy Consumption, 2010

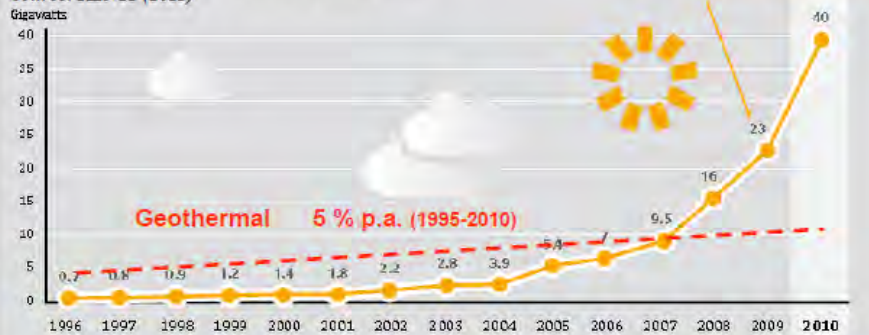
**Geothermal
3% of 8%!
<3000MWe**



Global PV capacity growth vs. Geothermal power growth

Figure 7. Solar PV, Existing World Capacity, 1995-2010

Source: REN21 (2011)



Geothermal growth: all hydrothermal!

Global wind power growth

Source: REN21 Global Status Report 2010 (2011)

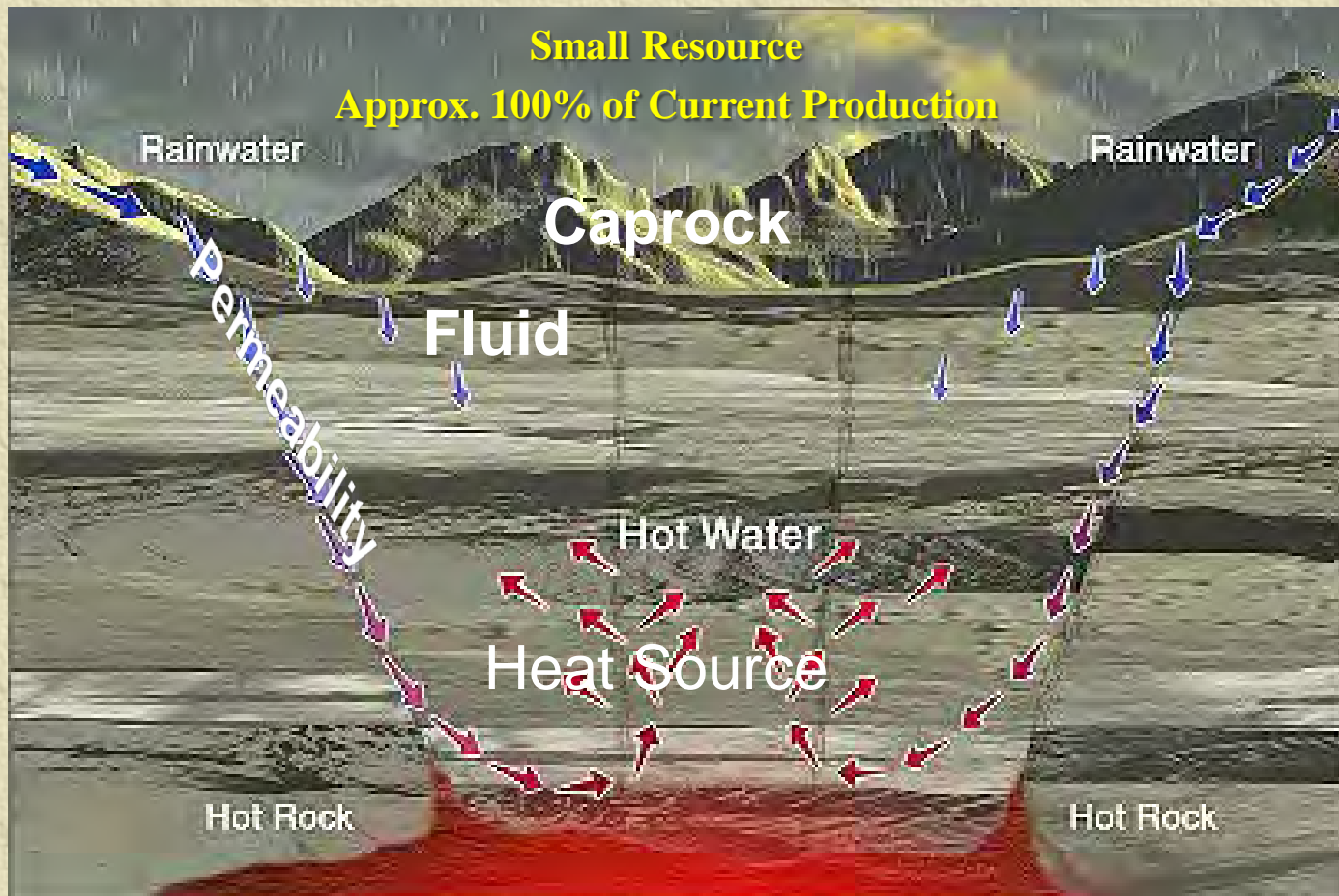
Figure 5. Wind Power, Existing World Capacity, 1996-2010



C.O. Ladsy Rybach Source: REN 21 Global Status Report 2010

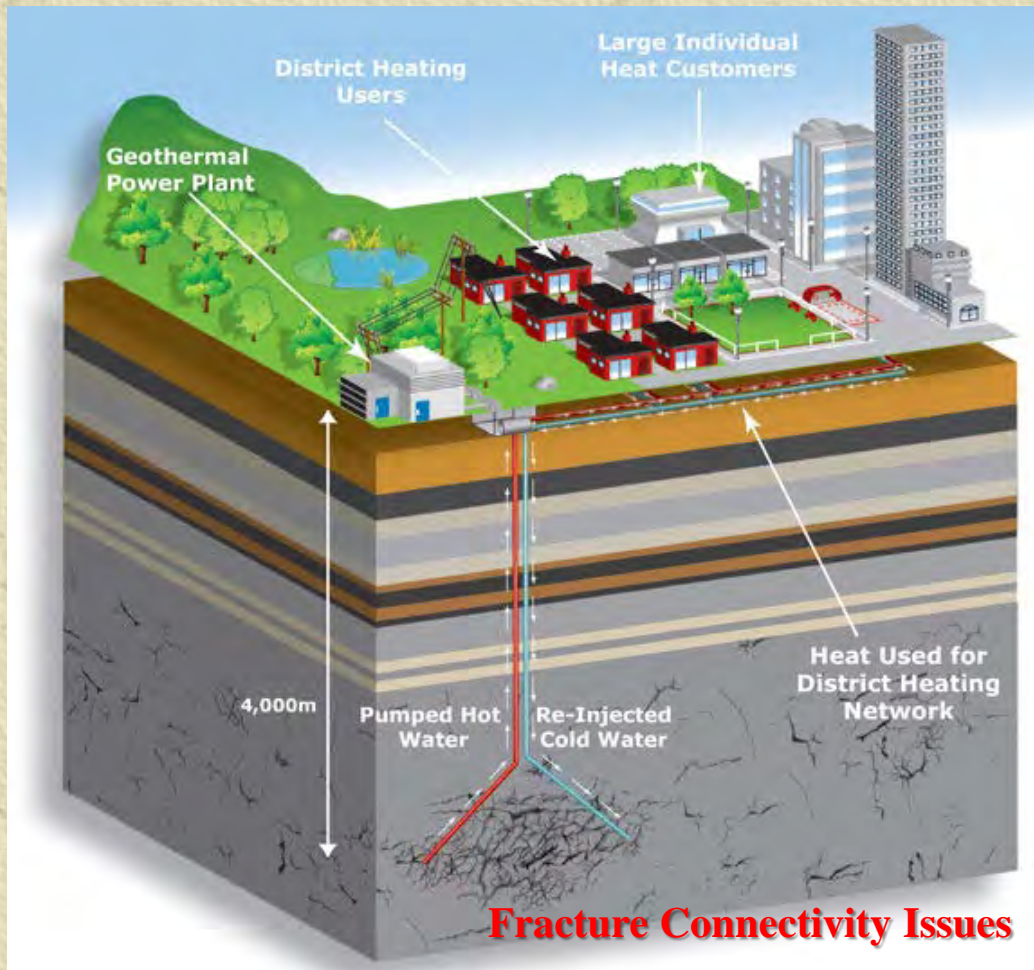
Category of Resource	Thermal Energy, in Exajoules (1EJ = 10^{18} J)	Reference
Conduction-dominated EGS		
Sedimentary rock formations	100,000	MIT, 2006
Crystalline basement rock formations	13,300,000	MIT, 2006
Supercritical Volcanic Systems	74100 excludes Yellowstone NP, Hawaii	USGS Circular 790
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Hydrothermal (Convective) Systems



C.O. Joe
Moore

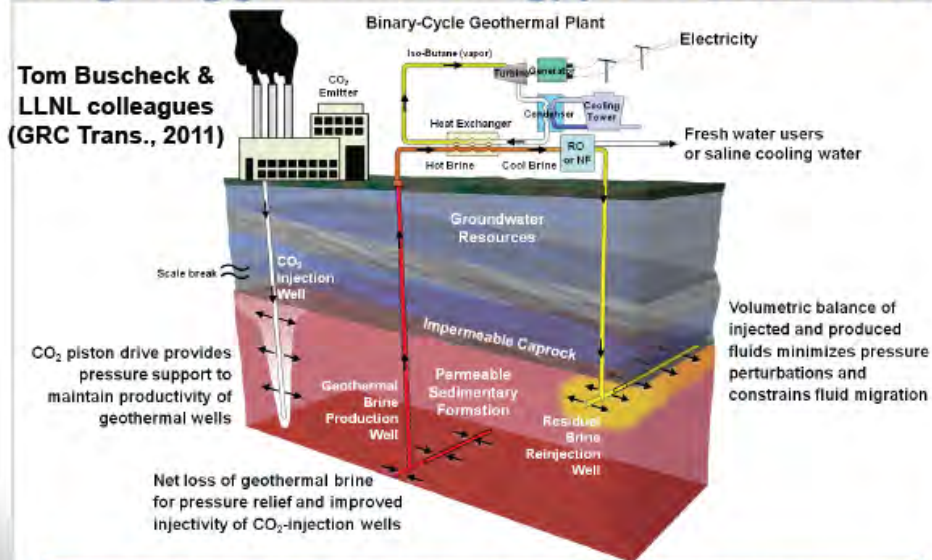
Category of Resource	Thermal Energy, in Exajoules (1EJ = 10 ¹⁸ J)	Reference
Conduction-dominated EGS Sedimentary rock formations Crystalline basement rock formations Supercritical Volcanic Systems	100,000 13,300,000 74100 excludes Yellowstone NP, Hawaii	MIT, 2006 MIT, 2006 USGS Circular 790
Hydrothermal	2,400 – 9,600	USGS Circular 726 and 790
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Enhanced Geothermal Systems

Category of Resource	Thermal Energy, in Exajoules (1EJ = 10 ¹⁸ J)	Reference
Conduction-dominated EGS Sedimentary rock formations Crystalline basement rock formations Supercritical Volcanic Systems	100,000 13,300,000 74100 excludes Yellowstone NP, Hawaii	MIT, 2006 MIT, 2006 USGS Circular 790
Hydrothermal	2,400 – 9,600	USGS Circular 726 and 790
Coproduced (oil field) fluids	0,0944 – 0,4510	McKenna, et al. (2005)
Geopressured systems	71,000 – 170,000 (includes methane)	USGS Circular 726 and 790

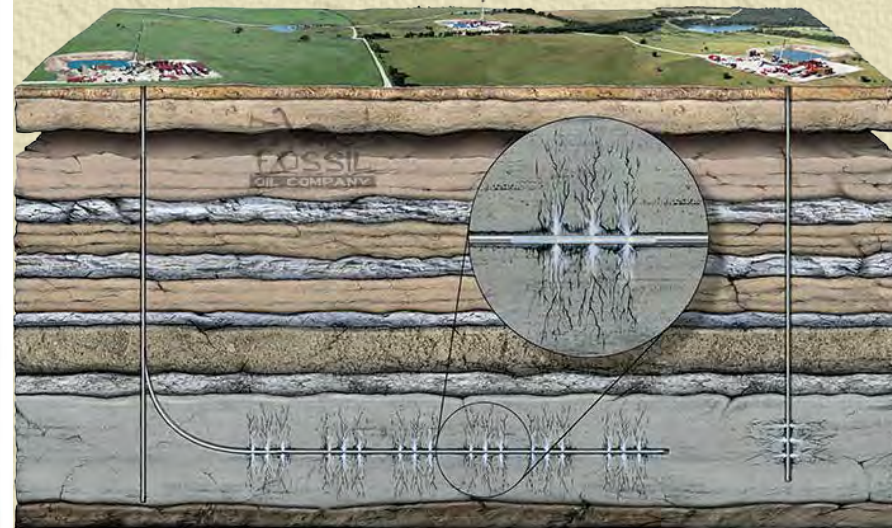
Integrating geothermal energy production with GCS



A significant portion of the U.S. geothermal resource base resides in sedimentary formations in regions where there is also a need to reduce CO₂ emissions

Lawrence Livermore National Laboratory
LLNL-PRDS-007551

NIS



<http://www.bing.com/images/search?q=oil+drilling&qpvt=oil+drilling&FORM=IQFRML#x0y6408>

Sedimentary Basins

Heat Volume and Matrix Permeability

Reality #1: geothermal water is a relatively low-enthalpy, low-value product compared to oil and gas

Challenges!

Energy Source	"Good" Well Flow Rate	Energy Flow Rate	Value (\$/day per well)
Geothermal	100 kg/s	100 MW _{th} = 9 MW _e	\$24k @ 10c/kWh
Ground Water	2000 gpm (130 kg/s)	pump needed	\$3k @ \$1/1000 gal
Oil	5,000 bbl/d (16 kg/s)	320 MW _{th}	\$400k @ \$80/bbl
Natural Gas	20,000 mcf/d	250 MW _{th}	\$80k @ \$4/mcf

Profit at about .5 Barrels/Sec

More than half of all wells being drilled today in U.S. are for oil and they have horizontal legs and multi-stage "frac" completions – the fracking costs ~ \$5 million on top of drilling costs

C.O Rick Allis



Reality #2: the risk-reward equation is challenging when thinking of deep wells (3 – 5 km for high temperature stratigraphic targets); and geothermal developments need both injection and production wells. Note Mansure (2011 GRC) recommends using multiplier of 2 to correct from 2003 to 2010.

Wells > 3 km deep probably cost ~ \$7 – 10 million each

Hurdles!



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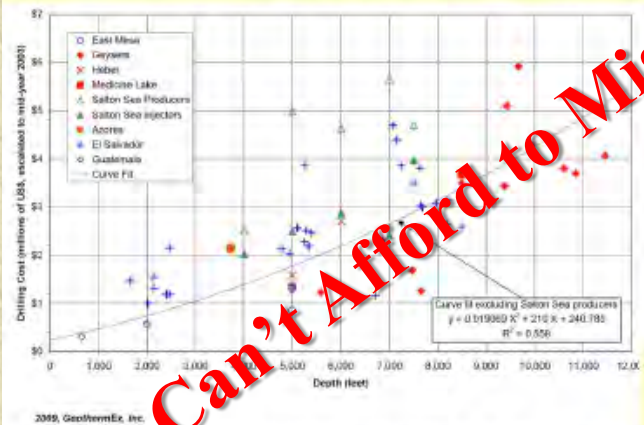


Figure 8. Correlation of drilling cost versus well depth (as of 2003) (from GeothermEx, 2004).

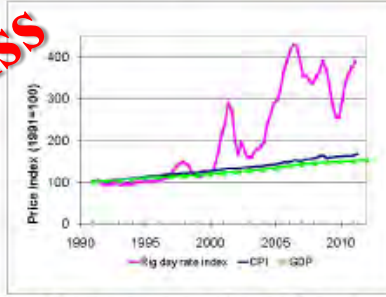


Figure 4. Index of recent rig day rate vs. CDP and CPI. (Note: rig day rate data runs as much as 3 months in arrears.)

Mansure & Blankenship, 2011

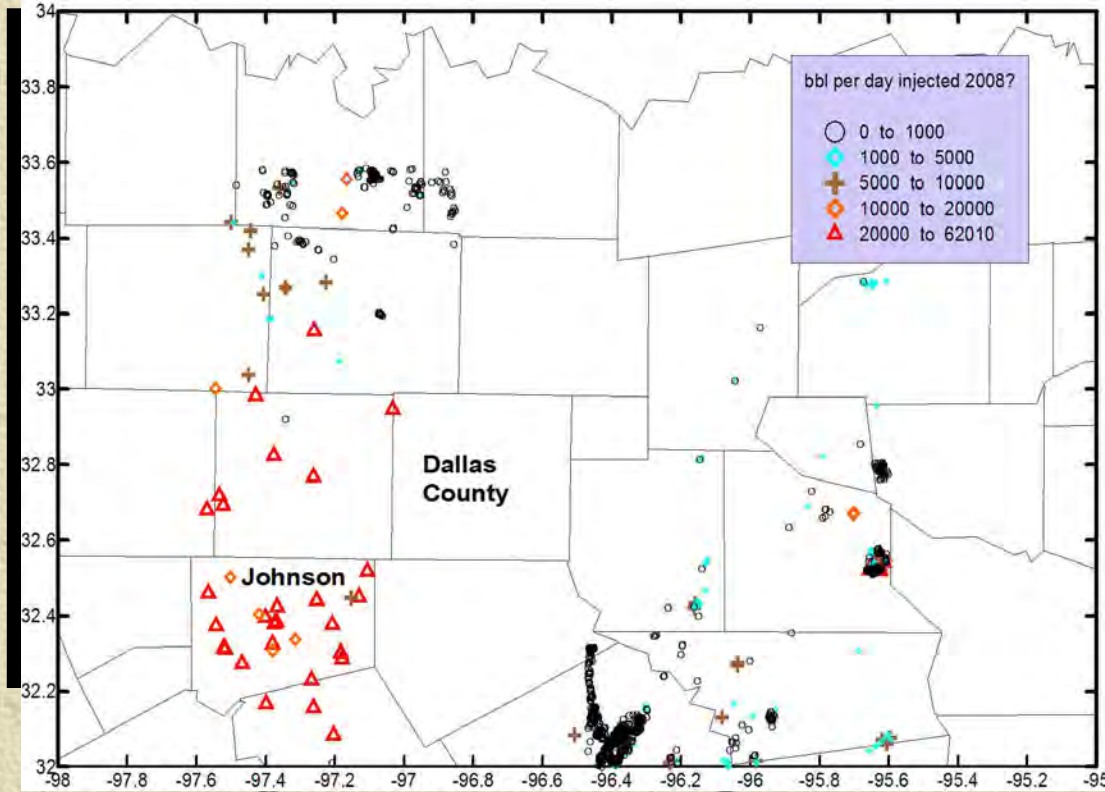
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Flow Rates

Economic Sedheat

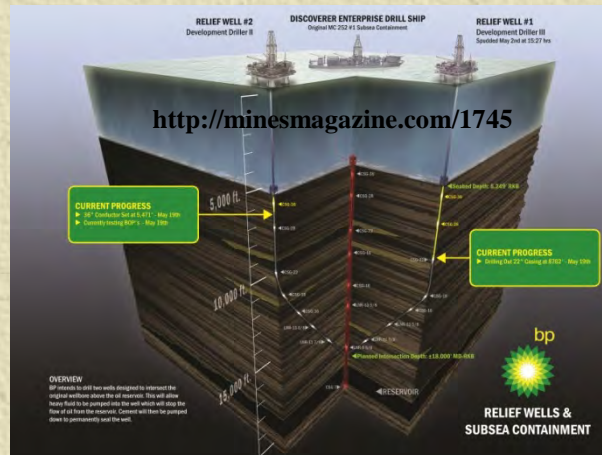
.5 barrels/sec

(80 l/sec at 150C for 5MWe;
MIT Panel, 2006)



.6-.7 barrels/sec

(62k-53k bpd; Flow Rate Technical Group 2010)



Question #3

What are the questions?

Topics

The Native Basin

Heat

Fluid flow

Engineering

Drilling

Reservoir

Geophysics

Cyberinfrastructure

Education



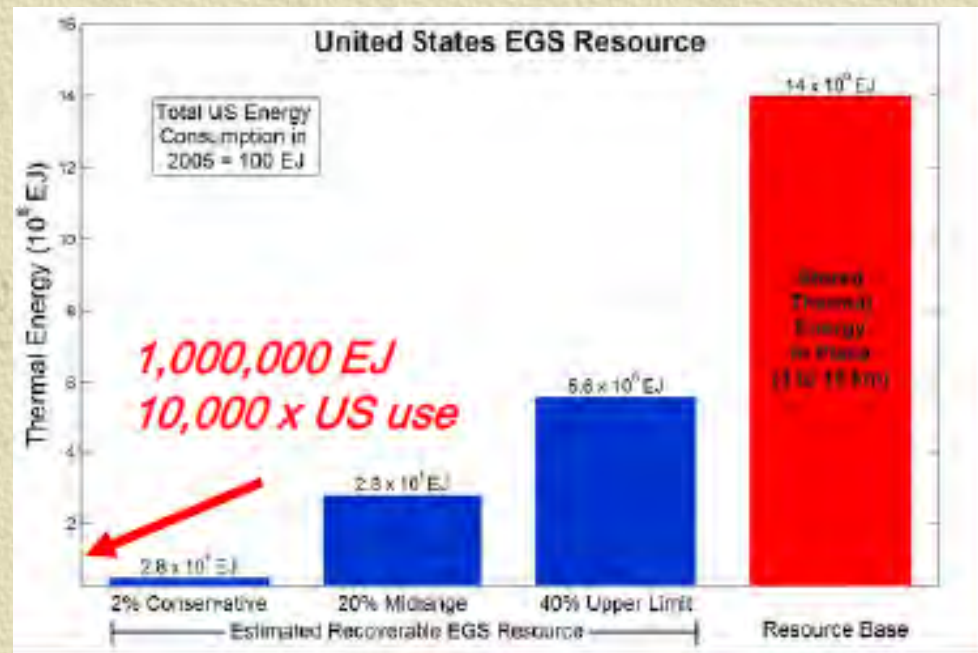
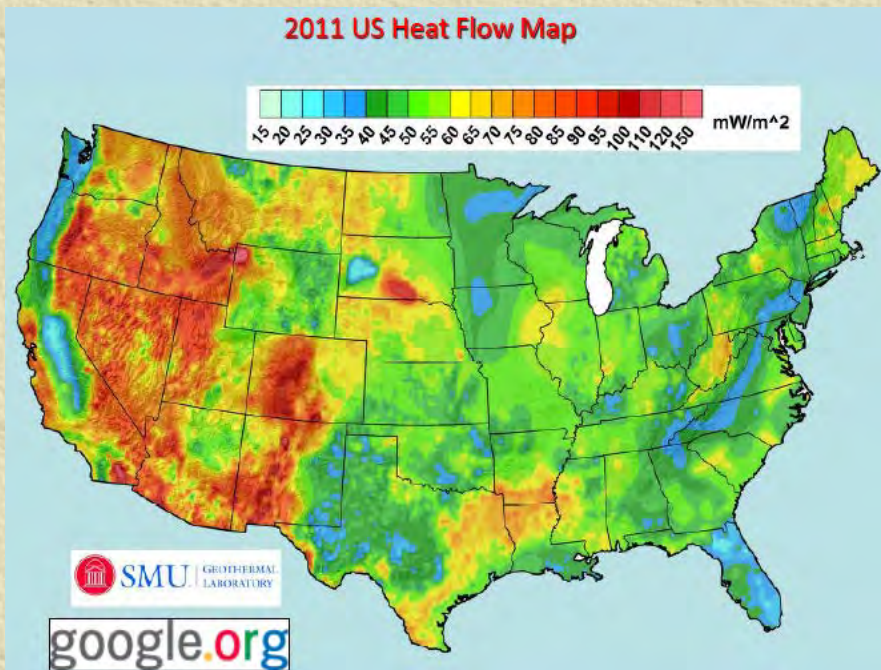
Topics

The Native Basin

Heat

How does heat move within sedimentary basins at large scales and how does this impact the renewability of the resource?

How is heat stored and released on the local and micro scales and how does this impact efficiency of heat sweep?



Topics

The Native Basin

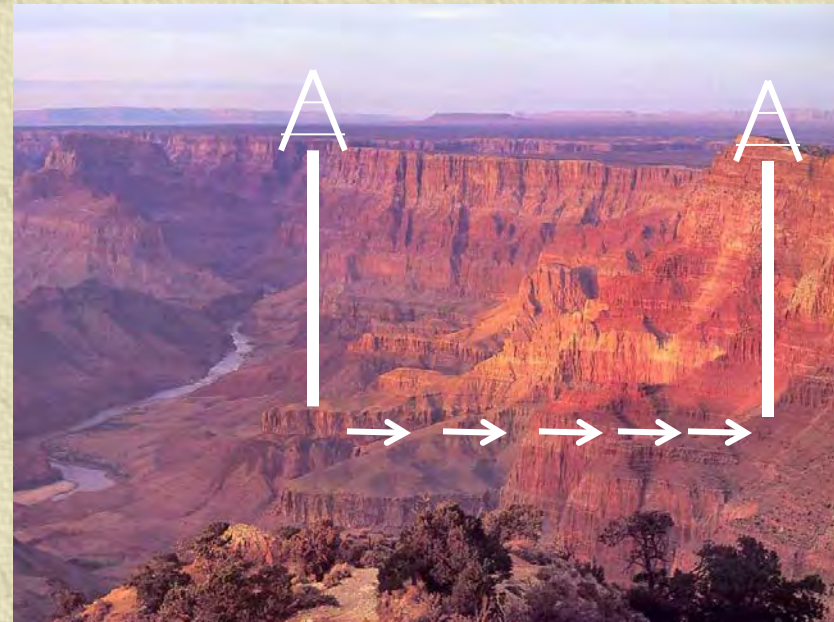
Fluid flow

What are the fundamental sedimentary processes that control the filling of sedimentary basins across all scales, and how do they impact permeability, connectivity, and heterogeneity of deep-basin flow paths?

What are the diagenetic processes that operate in deep sedimentary basins and how do they augment or deduct permeability as they evolve?

What controls the natural processes whereby fractures form and evolve within basin sediments, and what is the impact of these fractures on the transmission of fluid flow?

The Plumber Protects the Health of the Nation



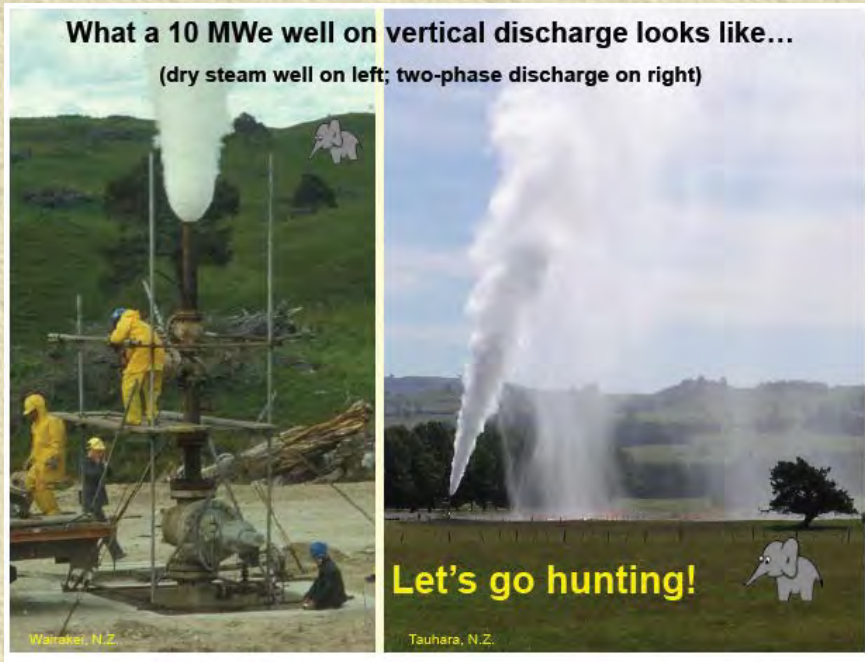
Topics

Engineering

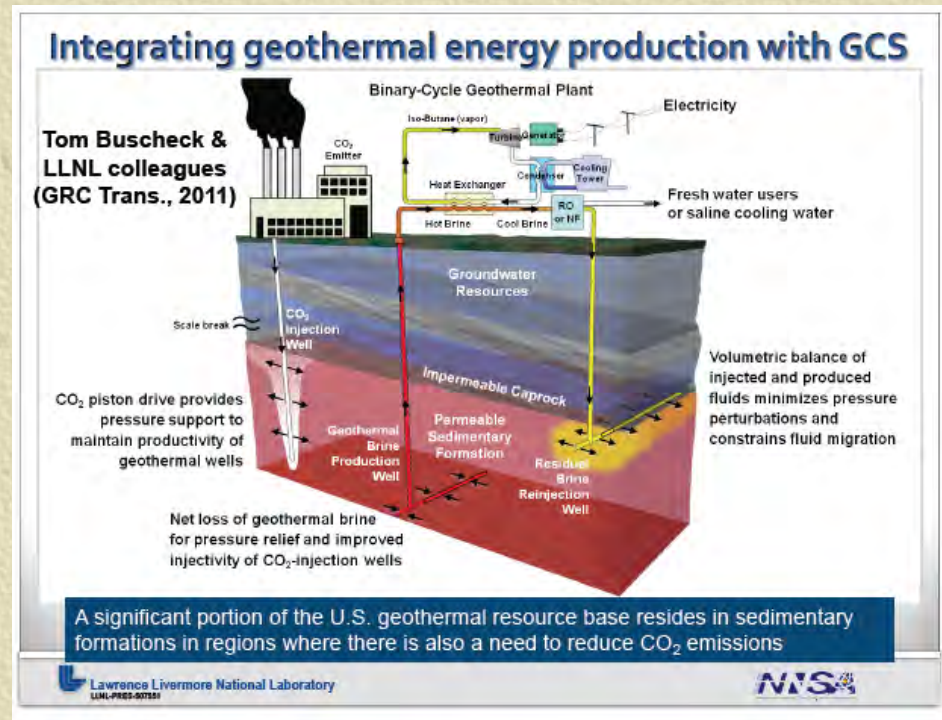
Drilling

What new or improved well technologies can make drilling and developing large boreholes possible and practical at very high temperatures?

Can numerical decision models be generated that effectively predict geothermal operational risk?



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Topics

Engineering

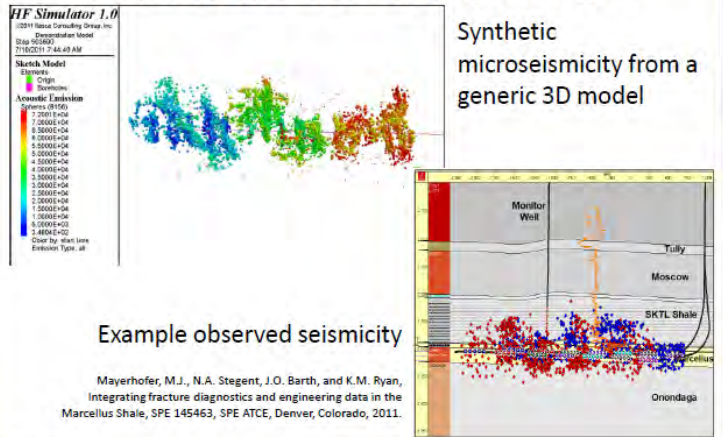
Reservoir

What new techniques can be defined that permit us to predict, control, and monitor stimulated fracture systems in deep, hot, and heterogeneous media?

How can we effectively monitor the evolution of fractures, heat regime, and stress conditions induced by geothermal extraction?

What are the relationships and thresholds between modified fluid pressures and induced seismicity?

The Future for Geothermal?



ITASCA

Role of Heterogeneities and Discontinuities

- Faults
- Joints
- Layers
- Interbedding
- Anisotropy
- Lenses
- Veins

Fractures offsetting and splitting at natural fractures

2 fractures

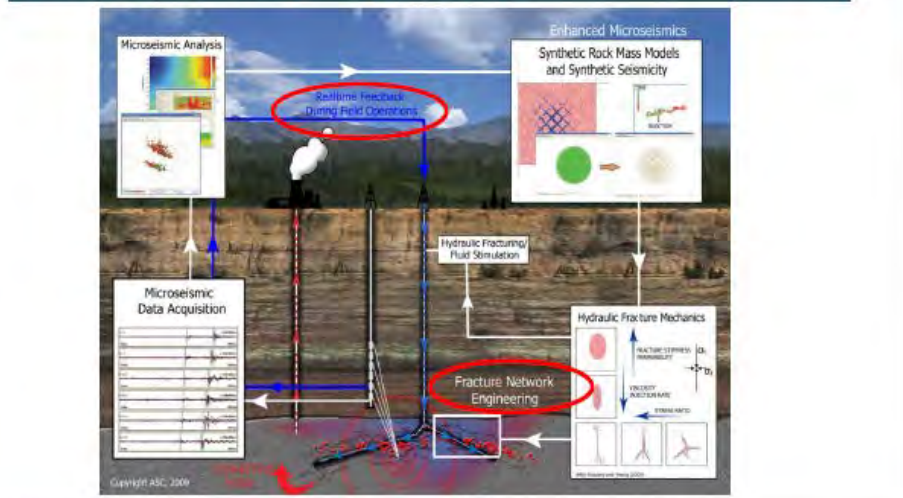
~ 2 ft

Fisher, K., and N. Warpinski, Hydraulic fracture height growth: real data, SPE 145949, SPE ATCE, Denver, Colorado, 2011.

ITASCA

Fracture Network Engineering (FNE)

Interpreting fracture diagnostics from microseismic data provides a double feedback for engineering the network.



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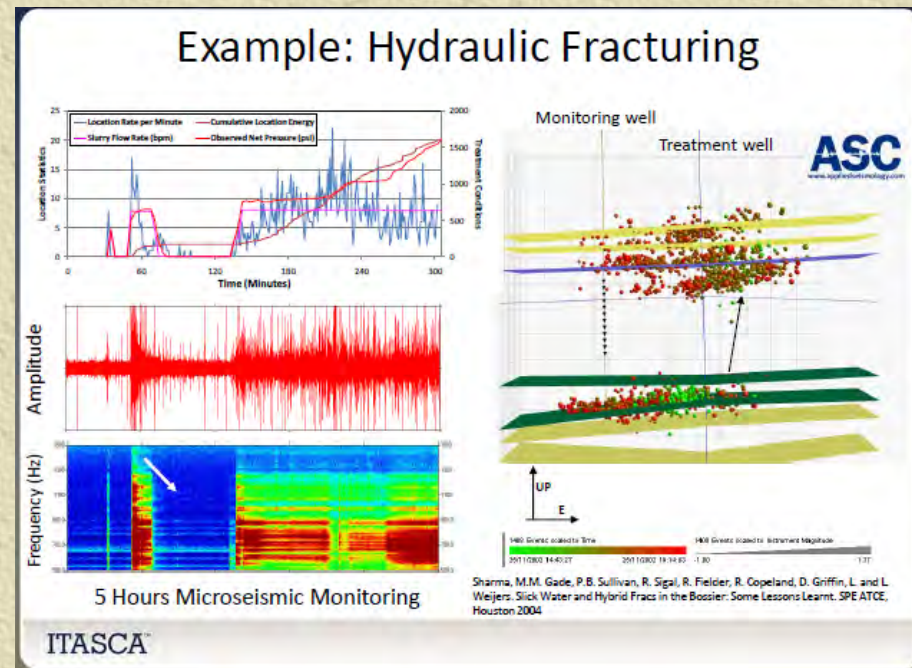
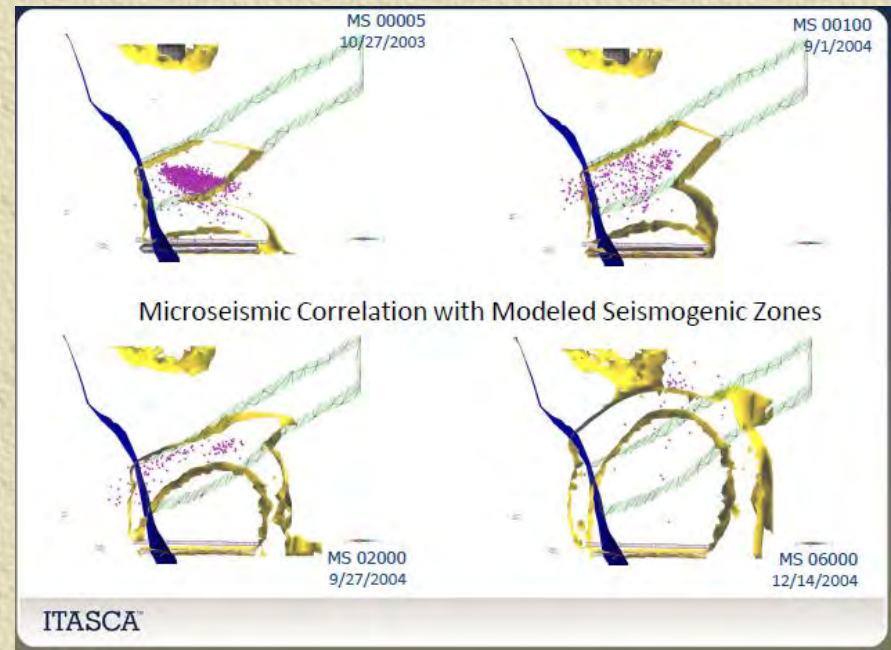
Topics

Geophysics

How can discrete geophysical methods be integrated to identify basin properties critical to geothermal development (e.g. permeability pipes, thermal distribution, etc)?

What are the critical advances needed to better predict and measure thermal properties of fluids and solids in deep-Earth settings?

How can geophysical aspects of deep-Earth settings be effectively simulated within the lab?



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Topics

Cyberinfrastructure

Cyberinfrastructure

NSF

A few of the NSF/NSB reports on Cyberinfrastructure (2001-2007)

Complex Earth-systems Systems
Evolving Systems and Engineering Through Global Research
Long-Term Higher Education: Developing Research and Innovation in the 21st Century
Cyberinfrastructure Vision for 21st Century Research

Advisory Committee on Cyberinfrastructure Task Force Reports (2009)

Geosciences Directorate
GeoVision Report (2009)

Geoscience Research

Building a Sustainable Energy Future: U.S. Actions for an Effective Energy Economy Transformation
National Science Board
Building a Sustainable Energy Future (2009)

Renewable Energy

NSF workshop on Science & Engineering Challenges for Unlocking the Geothermal Potential of Sedimentary Basins – Nov 7-9, 2011

6

C.O. Walter Snyder

What partnerships best serve research advancement and industrial success of sedimentary basin geothermal systems and how are they most effectively linked?

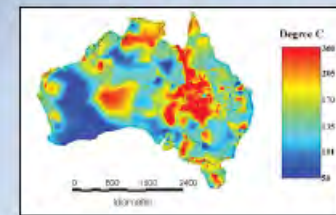
What data sharing systems are most likely to be both effective and organically grow?

SOME SOCIAL/POLITICAL/CULTURAL ISSUES

International collaboration and cooperation

Working with the international geothermal community on:

- Developing common approaches, standards and protocols to data
- Sharing data modeling approaches and software



Topics

Education

What short-term and long-term efforts will prove most effective toward tempering workforce shortages expected of an emerging geothermal industry?

What efforts would prove most effective at raising the current low profile of geothermal energy in the mind of the public and policy makers?

What are the positive and negative feedbacks tied to relationships between the geothermal and oil and gas industries as it relates to perceptions, workforce development, and educational infrastructure?

What are the most effective forms of cyberinfrastructure that may be used to promote sharing of data and education materials in order to foster more offerings of geothermal curricula?

What are the best vehicles for fostering cross-disciplinary education and scholarship between engineering and science disciplines?

What are the best processes for building an educational and workforce pipeline from K-12, through undergraduate, to graduate, to professional in the geothermal sciences, and how can we best assure that women and minorities are not leaked from this system?




Question #4

The Next Steps?

SEDHE  T



SEDHEAT



-NSF Research Coordination Network (RCN)

Build a research community for geothermal energy from sedimentary basins

-What Do We Do?

Workshops

GSA Penrose: Predicting and Detecting Natural and Induced Flow Paths for Geothermal Fluids in Deep Sedimentary Basins

Student opportunities

Lab visits, etc.

Education

Short courses, Web Materials

Sponsorship

Web page

WWW.SedHeat.org

Contact me

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