# SEDHEAT:

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

**John Holbrook, *Texas Christian University***

**Walter Snyder, *Boise State University***

**David Blackwell, *SMU***

**Joseph Moore, *University of Utah***

**Derek Elsworth *Penn State***

**Herbert Einstein, *MIT***

**Karin Block, *CUNY***

NSF

SEPM

Society for
entary Geology

-71 Particip

# Sustainability Issues Remain at the Forefront


C.O. Tim Killeen

# 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

C.O. Tim Killeen

# 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

**C.O. Tim Killeen**

# Tracking an Energy Elephant

*Geothermal Potential of Sedimentary Basins*

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

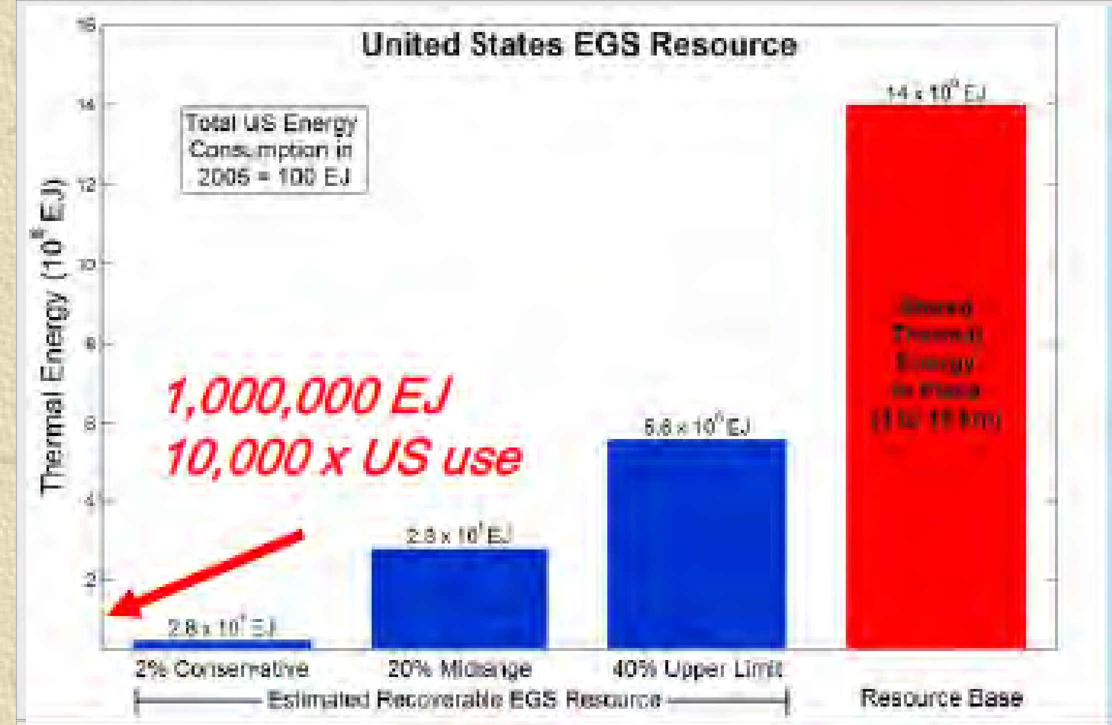
?

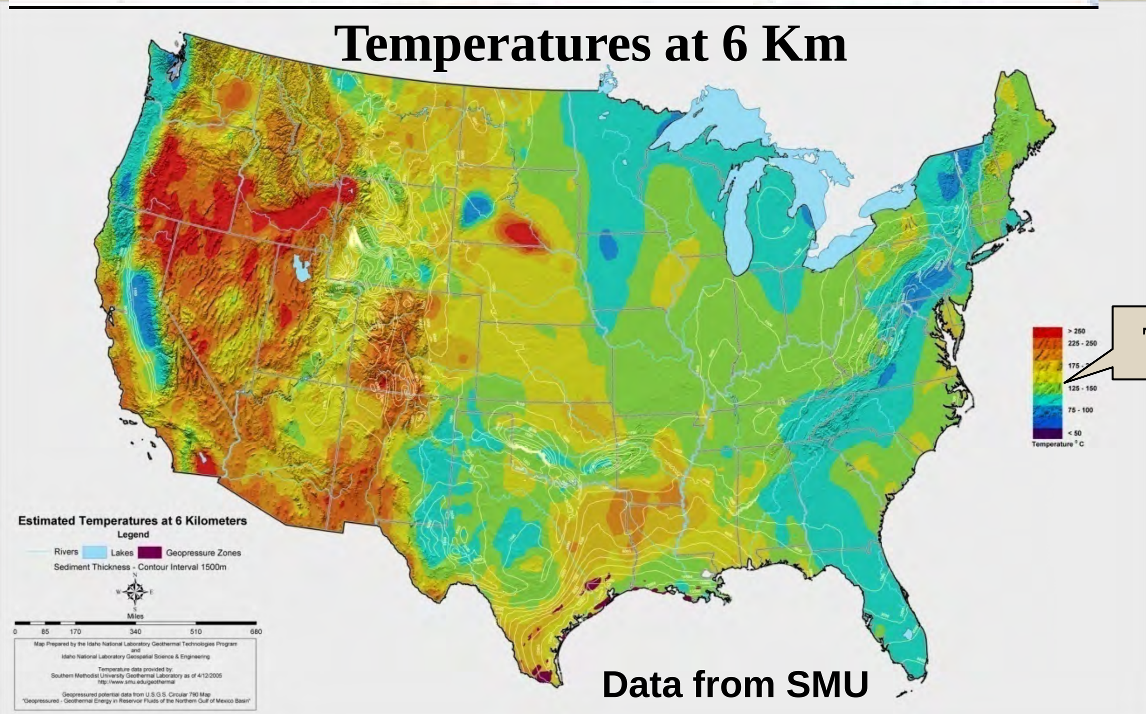
***"What are the basic science and engineering questions that need to be addressed in order to make geothermal energy production from sedimentary basins practical?"***

# Question #1

# Why Bother?

# Geothermal System Resource Base

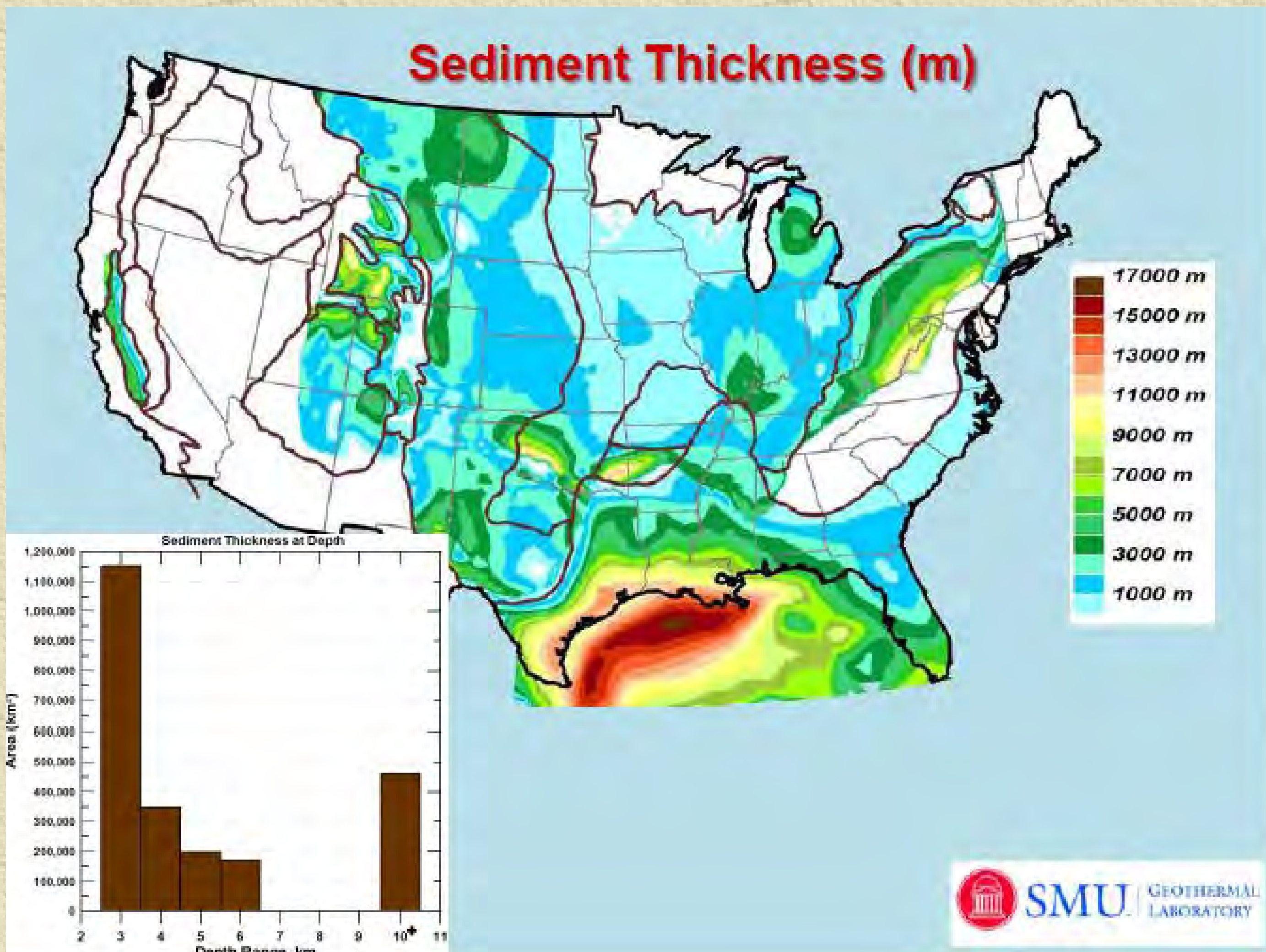


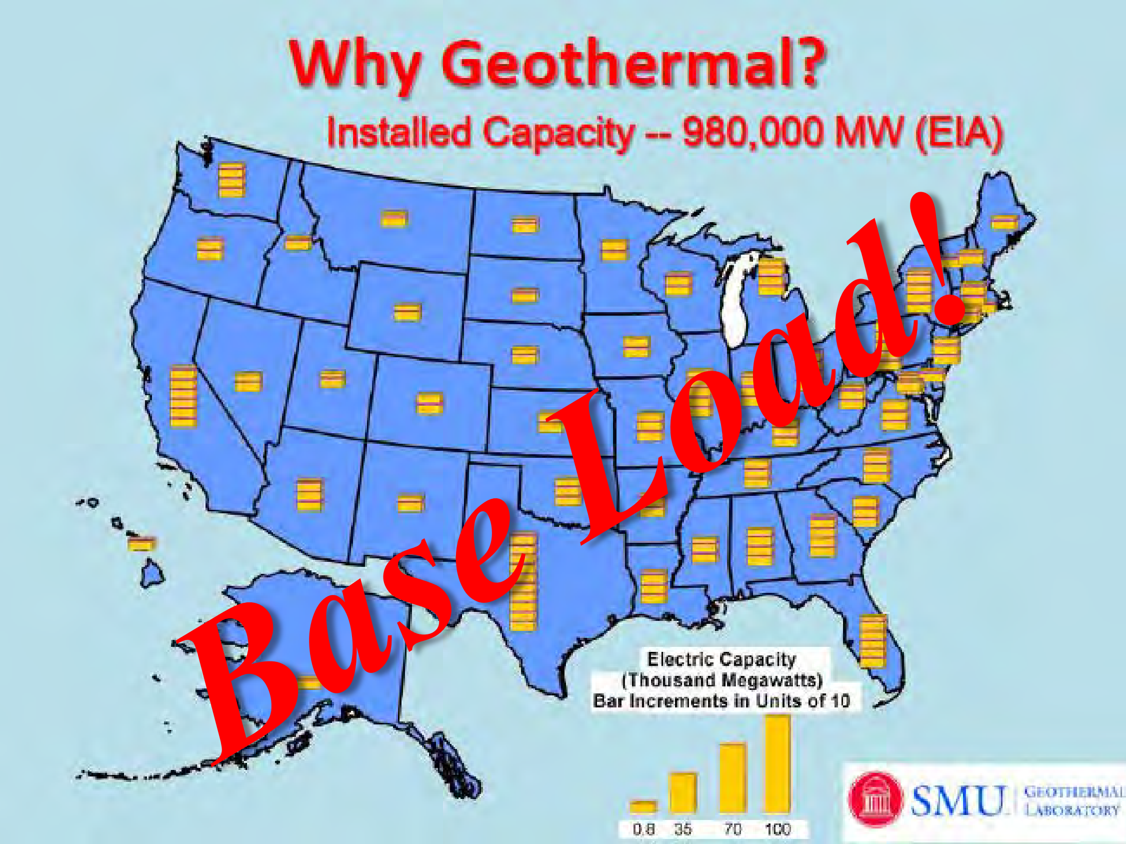



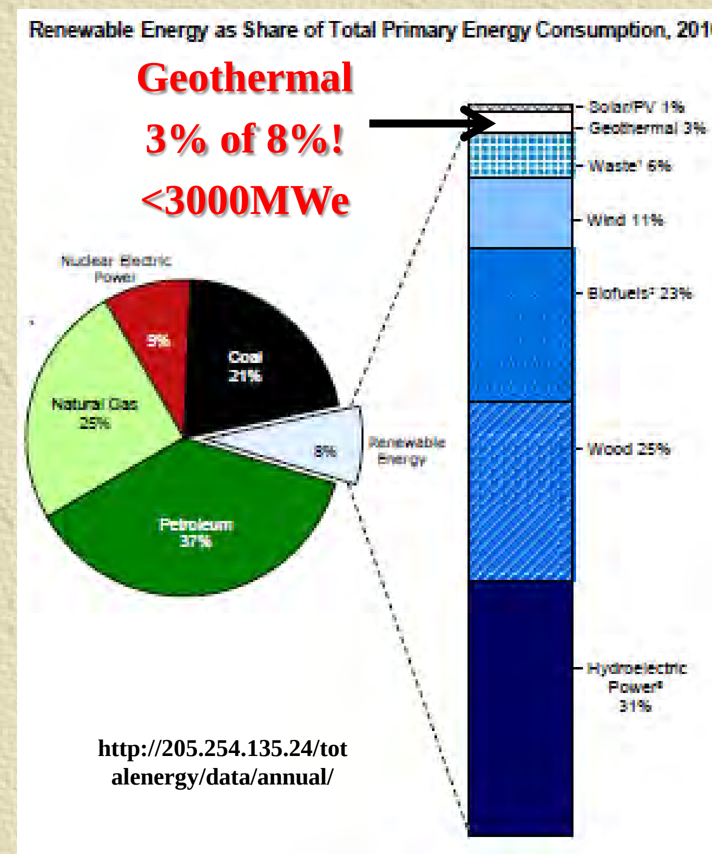

C.O. Joe Moore

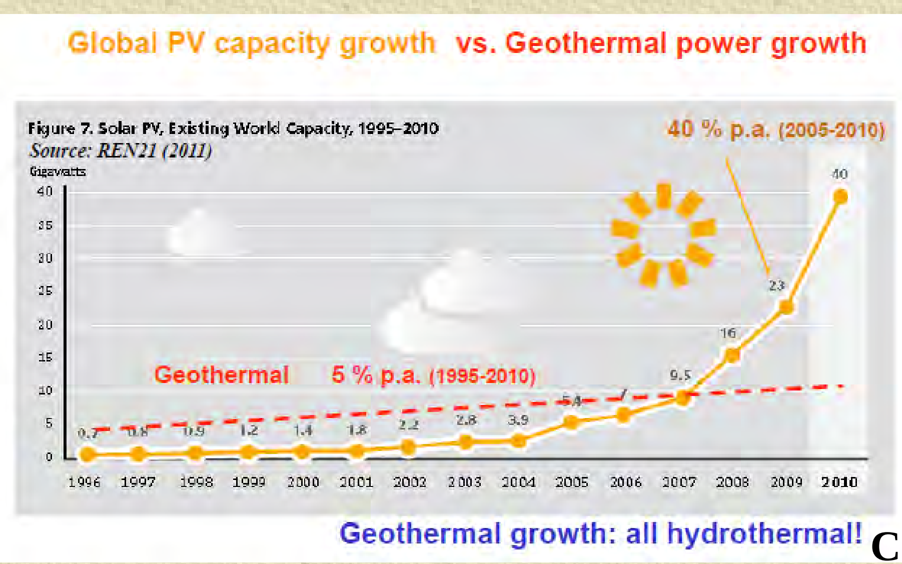
| Category of Resource | Thermal Energy, in Exajoules (1EJ = $10^{18}$J) | Reference |
|---|---|---|
| **Conduction-dominated EGS** | | |
| Sedimentary rock formations | 100,000 | MIT, 2006 |
| Crystalline basement rock formations | 13,300,000 | MIT, 2006 |
| Supercritical Volcanic Systems | 74100 excludes 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 |

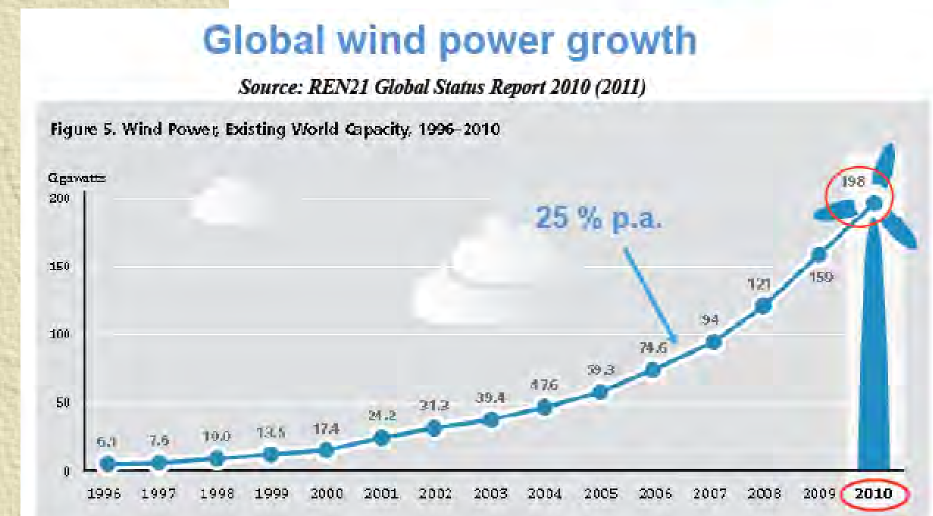
**(C.O. Joe Moore)**





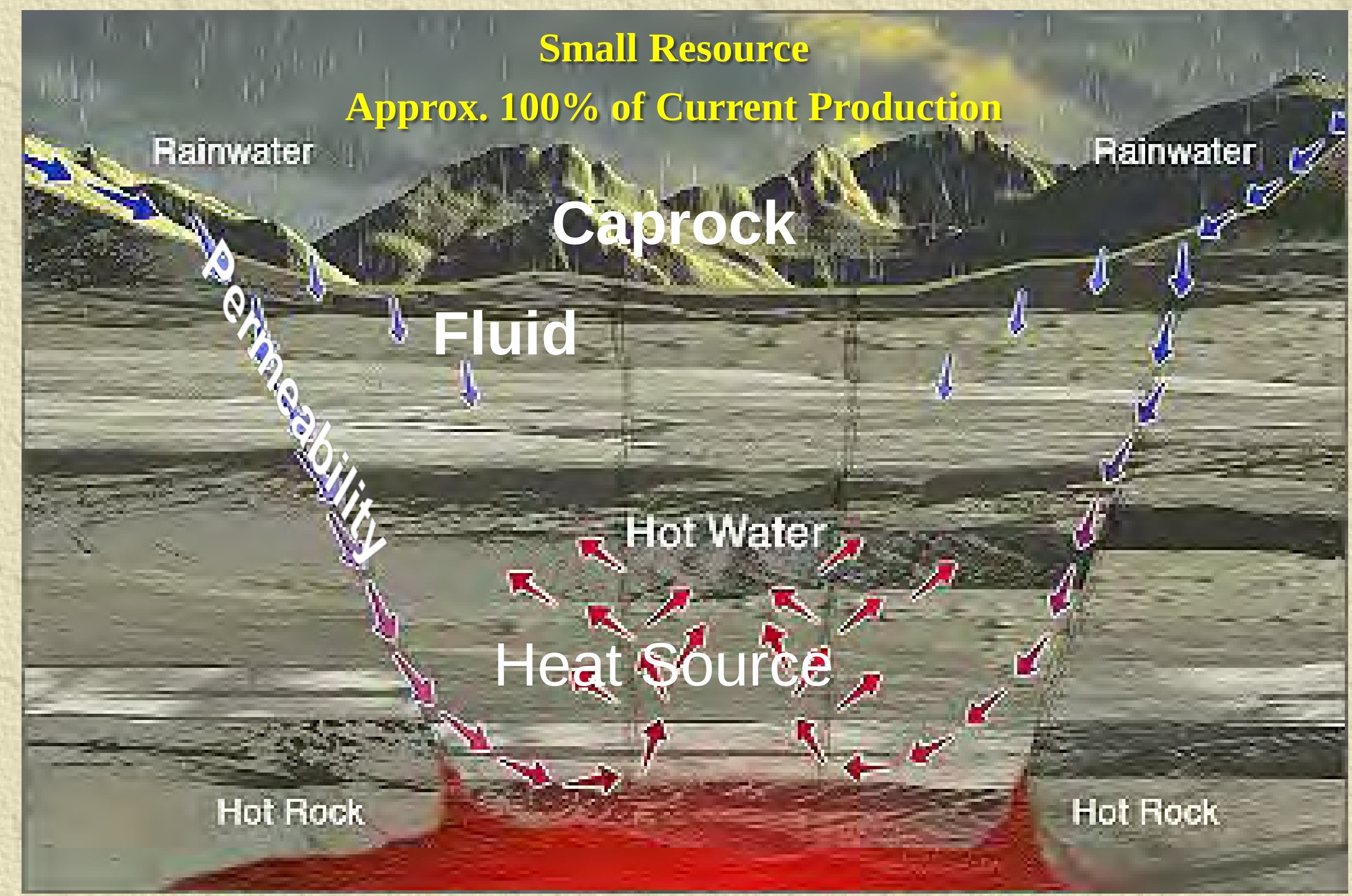




C.O. Ladsi Rybach

Source: REN 21 Global Status Report 2010

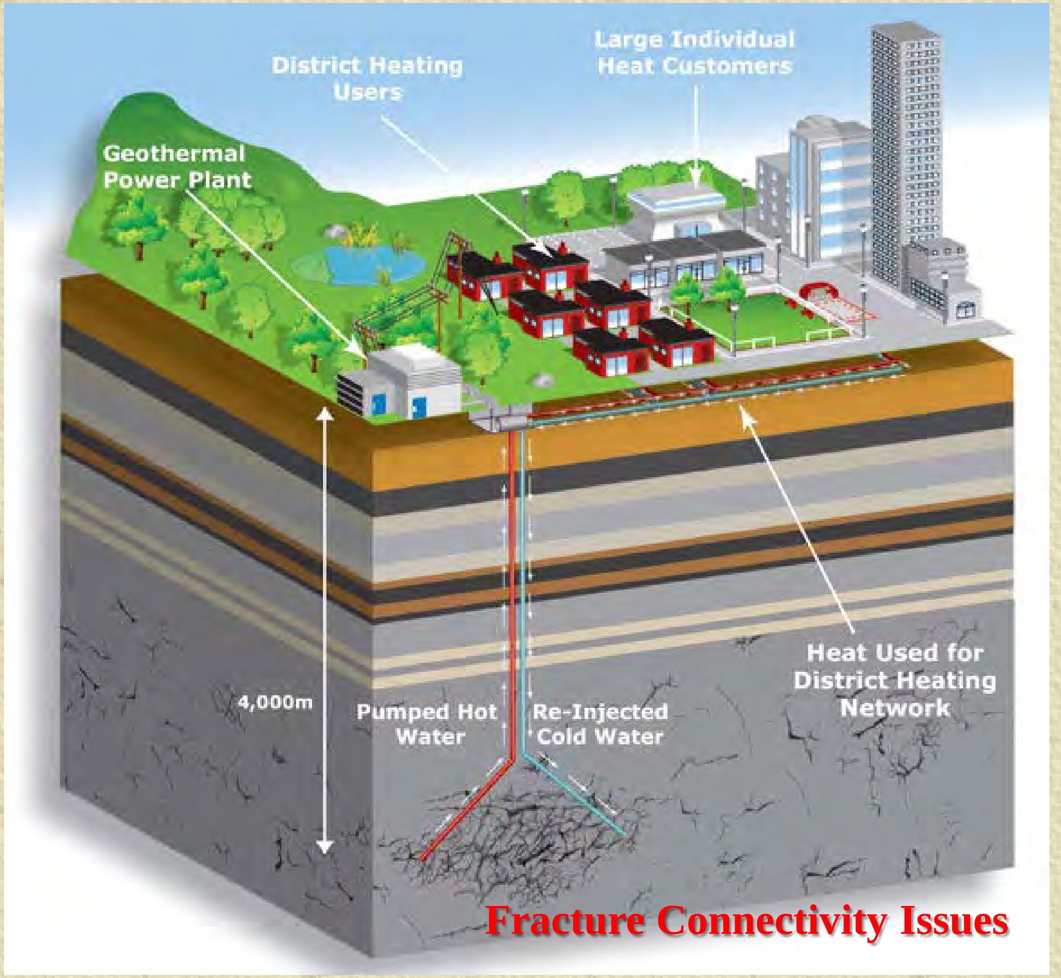
| Category of Resource | Thermal Energy, in Exajoules (1EJ = $10^{18}$J) | Reference |
|---|---|---|
| **Conduction-dominated EGS** | | |
| Sedimentary rock formations | 100,000 | MIT, 2006 |
| Crystalline basement rock formations | 13,300,000 | MIT, 2006 |
| Supercritical Volcanic Systems | 74100 excludes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

# Hydrothermal (Convective) Systems




C.O. Joe Moore

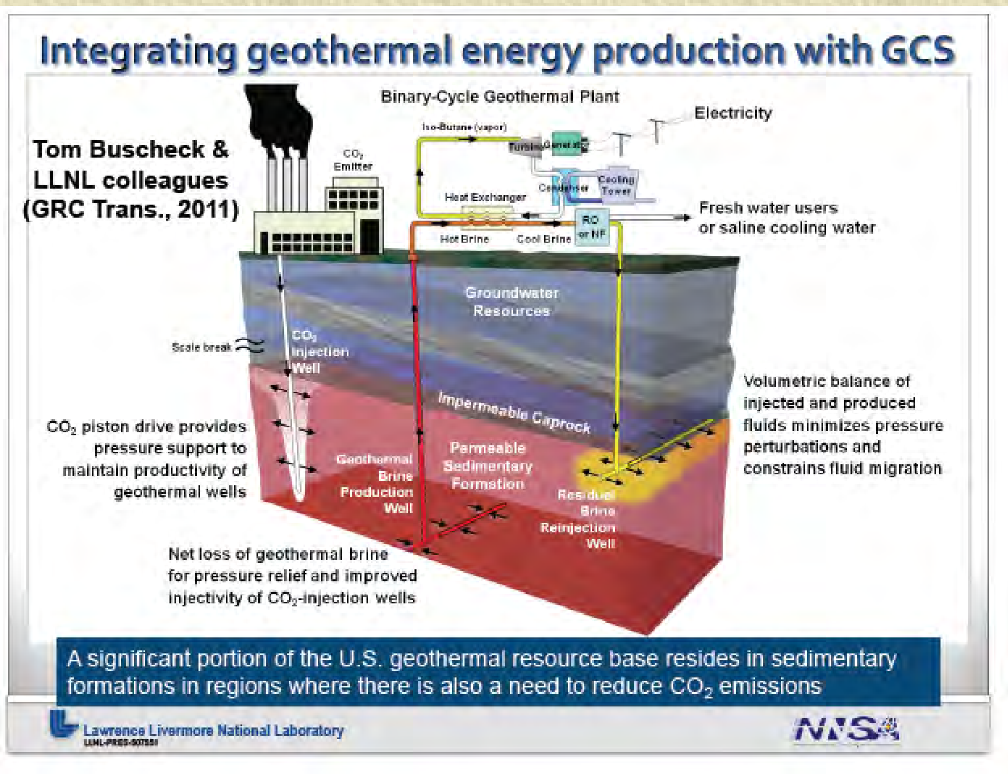
| Category of Resource | Thermal Energy, in Exajoules (1EJ = $10^{18}$J) | Reference |
|---|---|---|
| **Conduction-dominated EGS** | | |
| Sedimentary rock formations | 100,000 | MIT, 2006 |
| Crystalline basement rock formations | 13,300,000 | MIT, 2006 |
| Supercritical Volcanic Systems | 74100 excludes 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 |

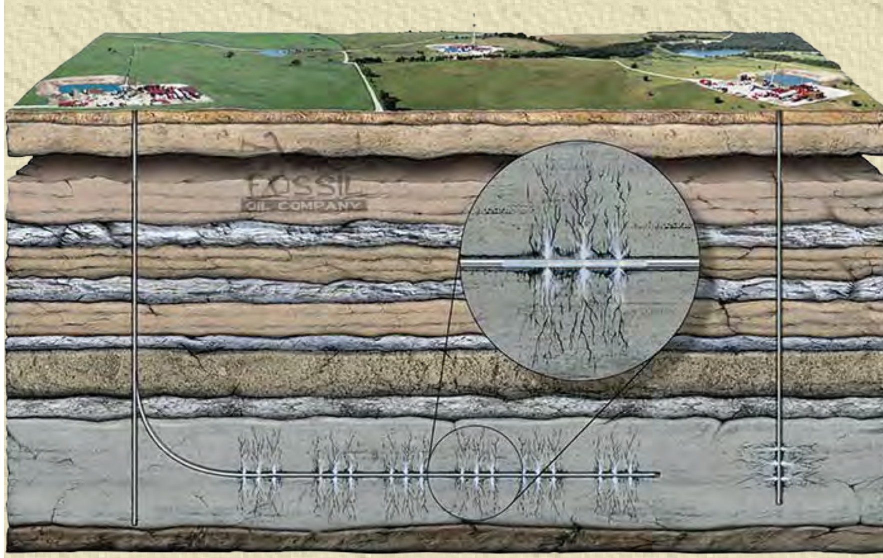



# Enhanced Geothermal Systems

http://www.bing.com/images/search?q=geothermal+energy&qpvt=geothermal+energy&FORM=IGRE#x0y15279

| 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 |




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

# Sedimentary Basins

# Heat Volume and Matrix Permeability

# Challenges!

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

Profit at about .5 Barrels/Sec

| Energy Source | "Good" Well Flow Rate | Energy Flow Rate | Value ($/day per well) |
|---|---|---|---|
| *Geothermal* | 100 kg/s | 100 MW[illegible]0 $MW_e$ | $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 |

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

# Hurdles!


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

Can't Afford to Miss

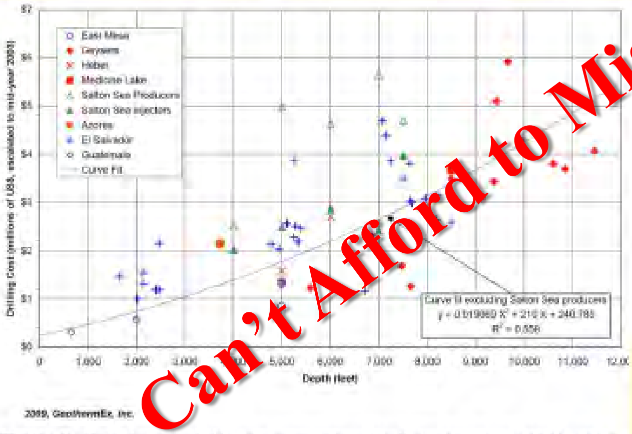



Figure 8. Correlation of drilling cost versus well depth (as of 2003) (from GeothermEx, 2004).

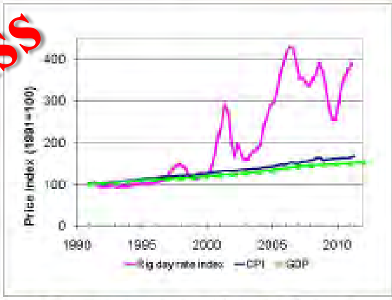



Figure 4. Index of recent rig day rate vs. GDP and CPI. (Note: rig day rate data runs as much as 3 months in arrears.)

Mansure & Blankenship, 2011

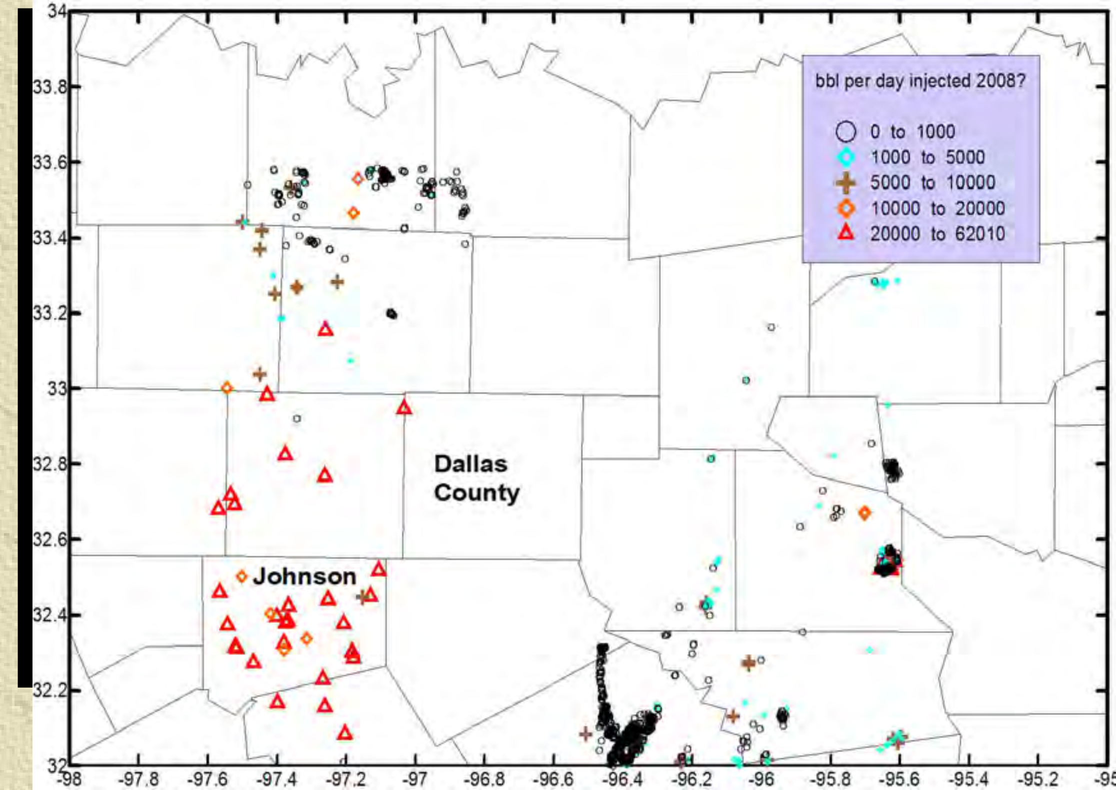
C.O Rick Allis

# *Flow Rates*

## *Economic Sedheat*

## *.5 barrels/sec*

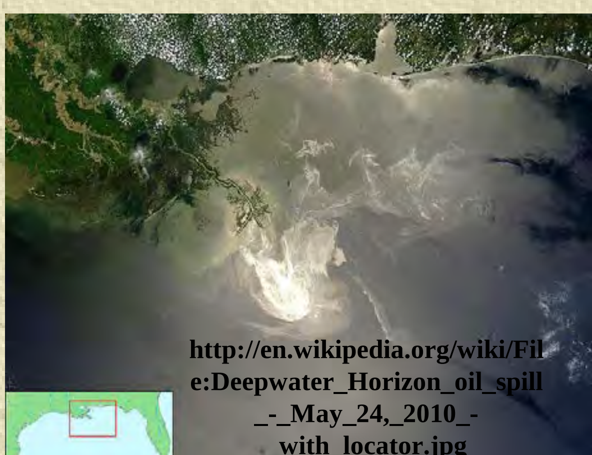
**(80 l/sec at 150C for 5MWe; MIT Panel, 2006)**



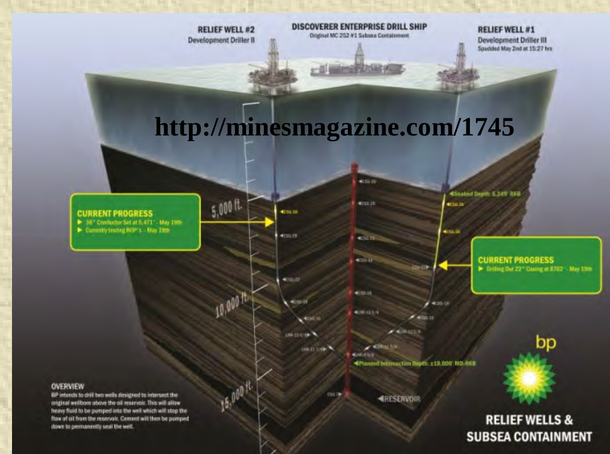

**http://www.rigzone.com/news/article.asp?a_id=94057**

## *.6-.7 barrels/sec*

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



**http://en.wikipedia.org/wiki/File:Deepwater_Horizon_oil_spill_-_May_24,_2010_-_with_locator.jpg**




**http://minesmagazine.com/1745**

**http://topics.nytimes.com/top/reference/timestopics/subjects/o/oil_spills/gulf_of_mexico_2010/index.html**

# Question #3

# What are the questions?

## Topics

**The Native Basin**

**Heat**

**Fluid flow**

**Engineering**

**Drilling**

**Reservoir**

**Geophysics**

**Cyberinfrastructure**

**Education**

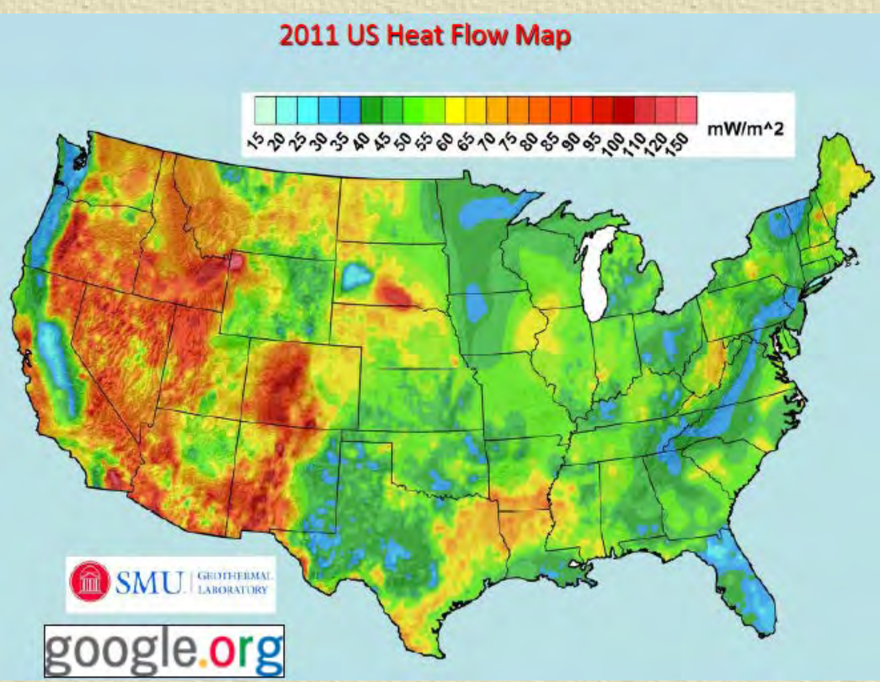
# Topics

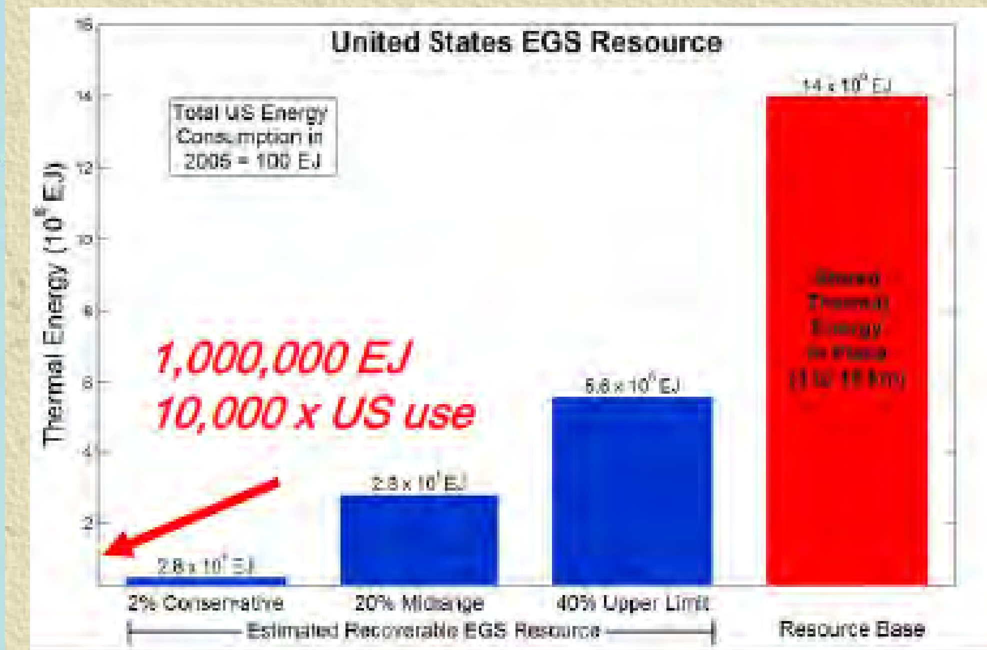
## The Native Basin

### 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?***




**C.O. David Blackwell**

# Topics

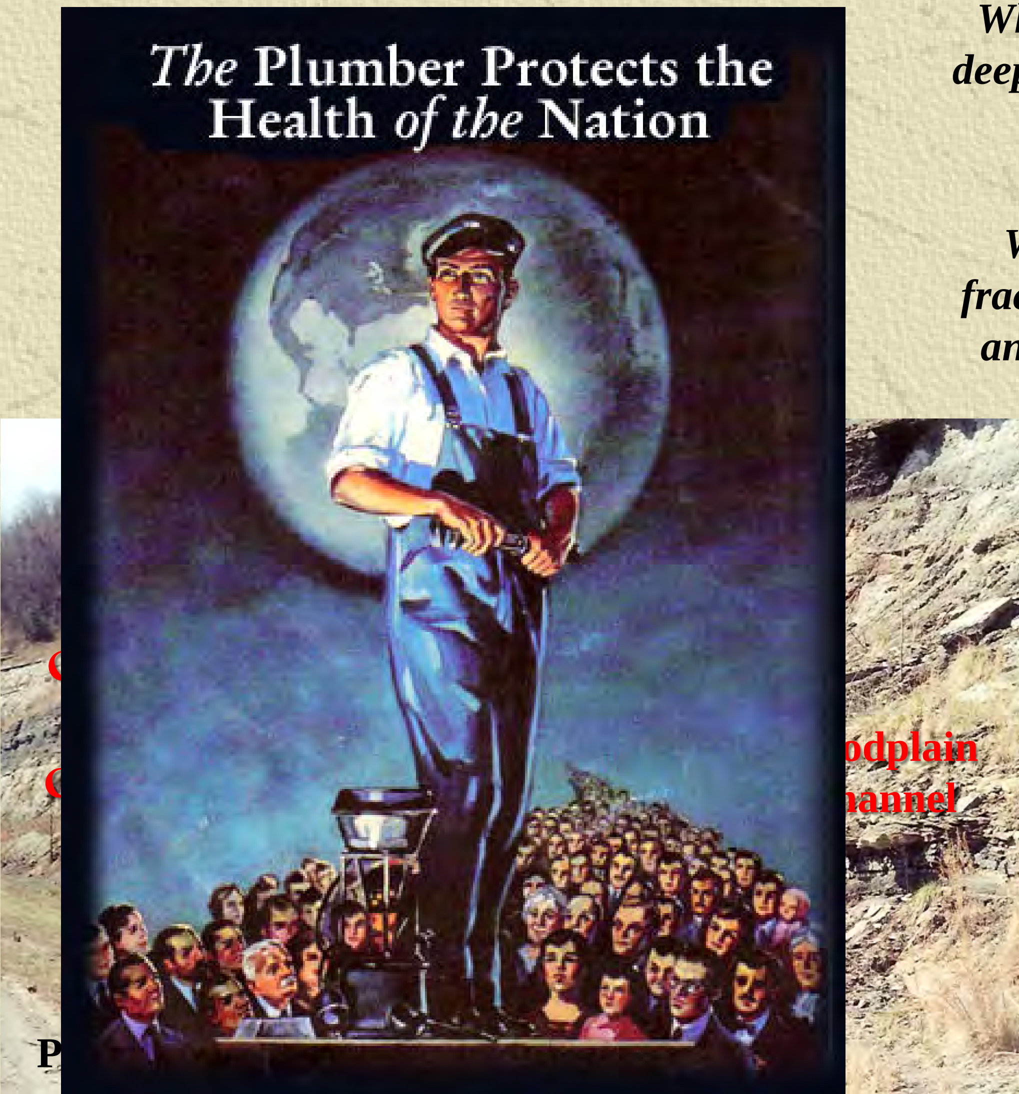
## The Native Basin

### 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 digenetic 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?*




# Topics

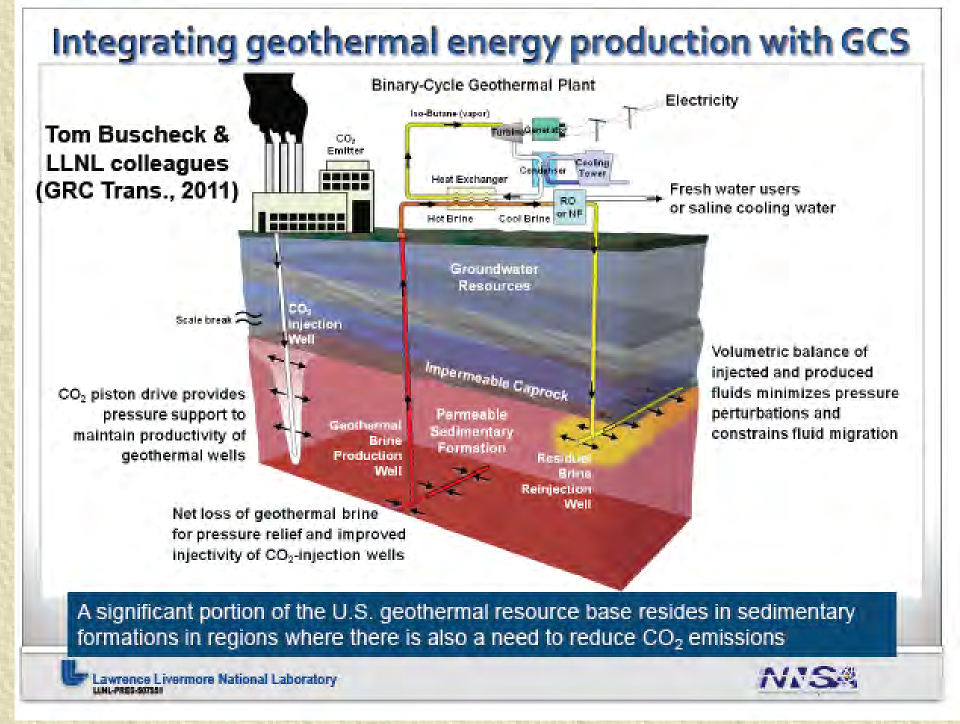
## Engineering

### 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?*


**C.O Rick Allis**



# Topics

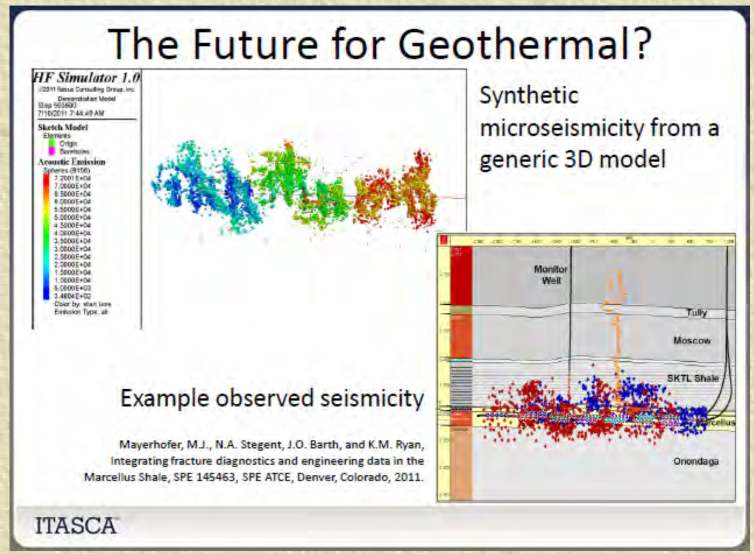
# Engineering

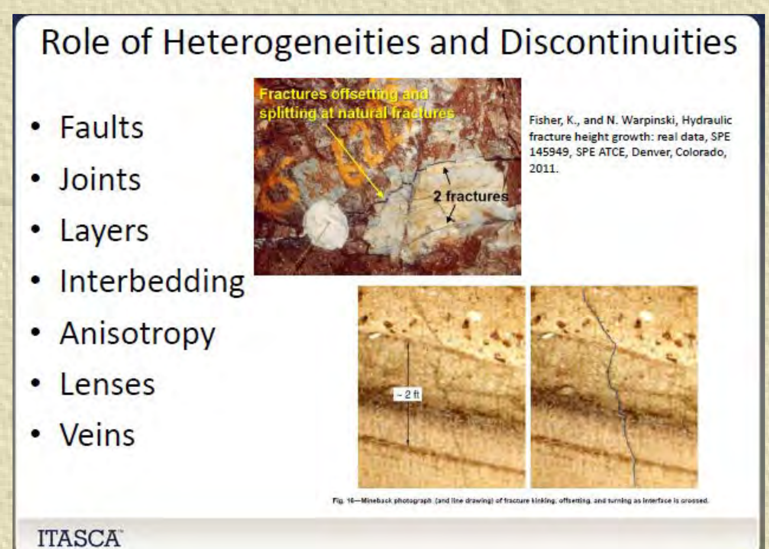
## Reservoir

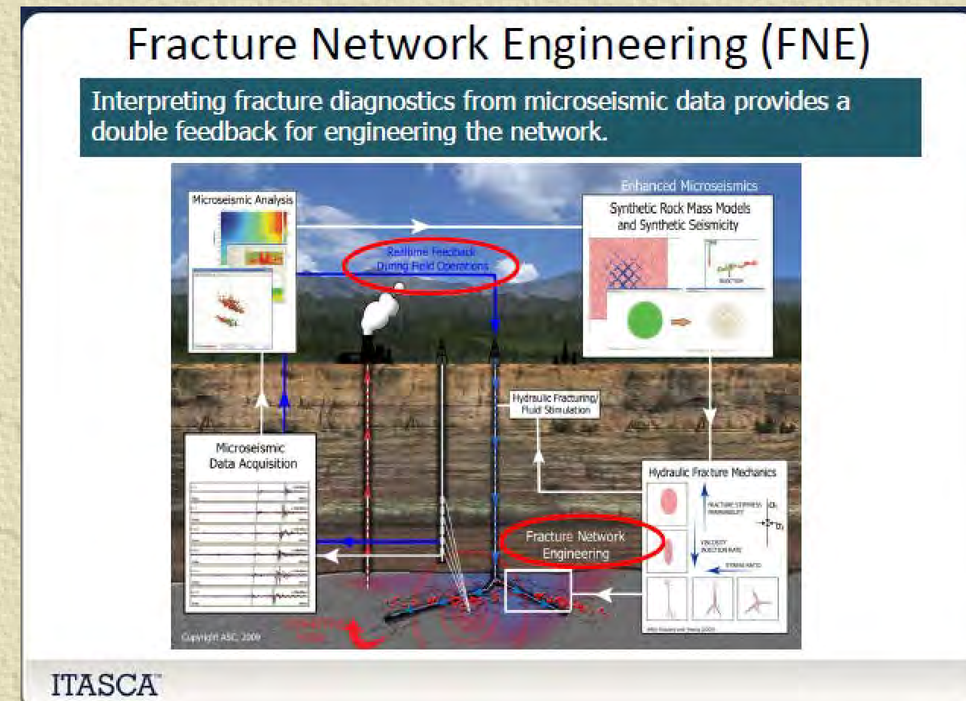
*What new techniques can be defined that permit us to predict, control, and monitor stimulated fracture systems in deep, hot, and heterogeneous media?*

*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?*




C.O. Will Pettitt

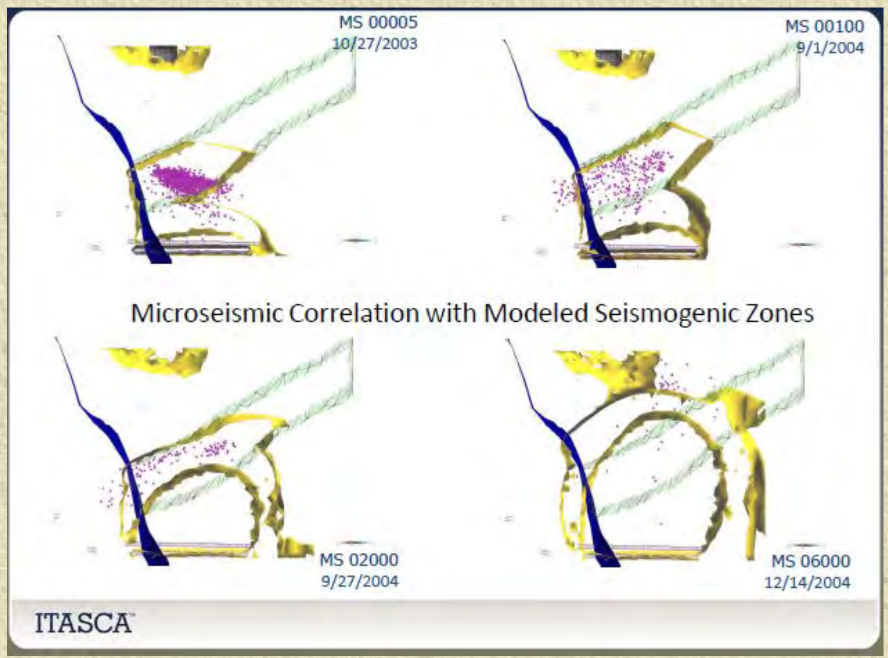
# Topics

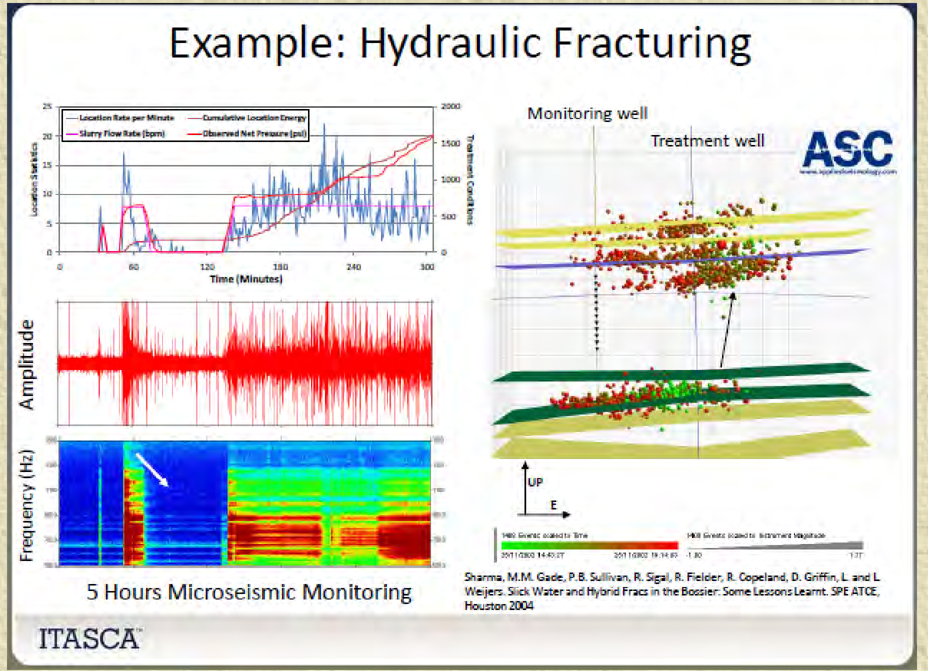
## Geophysics

***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?***




**C.O. Will Pettitt**

# Topics

# Cyberinfrastructure

*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?*



**C.O. Walter Snyder**

# 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, though 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?

SEDHEAT

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 opportunites**

*Lab visits, etc.*

**Education**

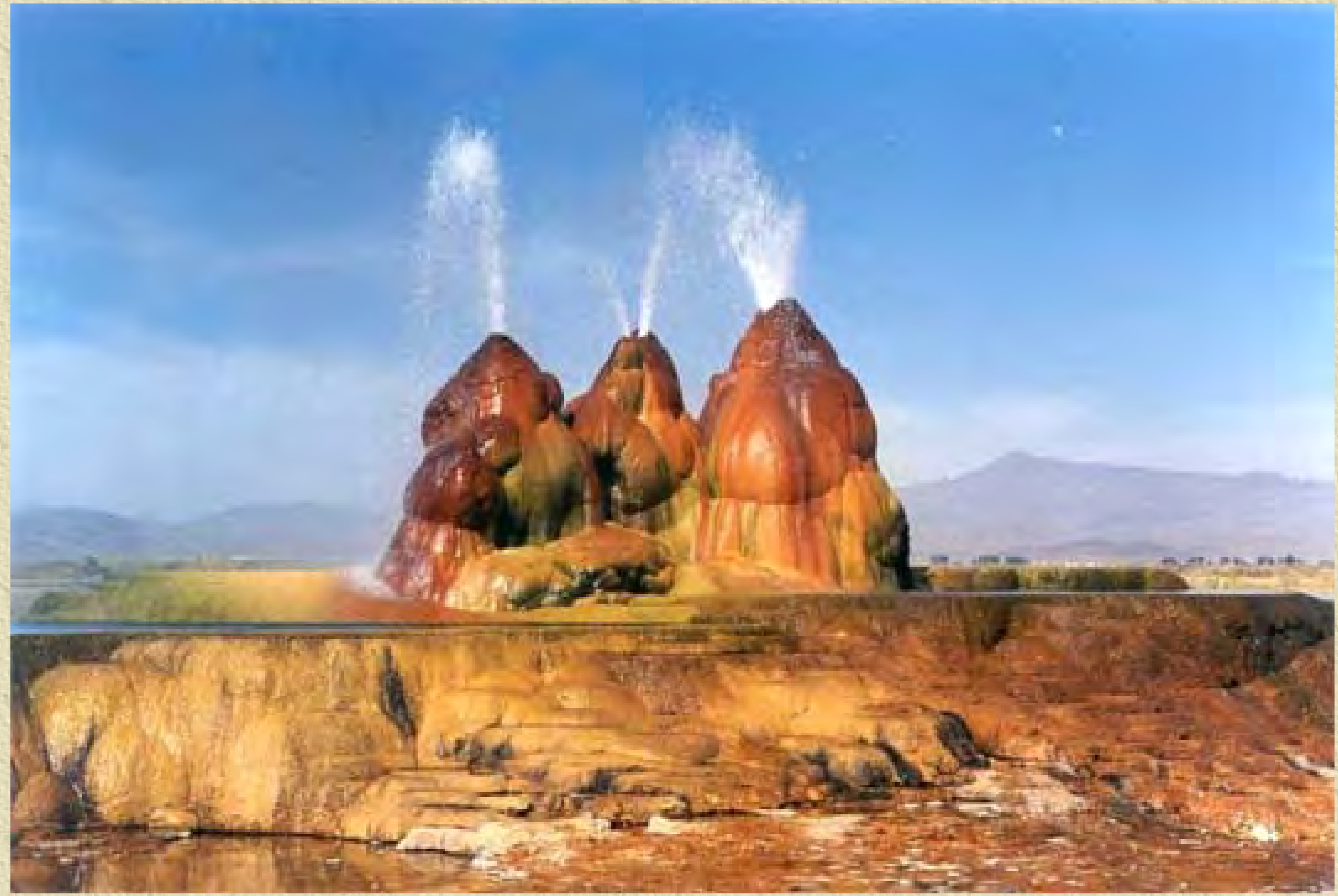
*Short courses, Web Materials*

**Sponsorship**

**Web page** **WWW.SedHeat.org**

# Contact me

John.holbrook@TCU.EDU



C.O. Joe Moore