SedHeat: Addressing the Science and Engineering Challenges for Unlocking the Geothermal Potential of Sedimentary Basins*

John Holbrook[1], Walter Snyder[2], Joseph Moore[3], Charles Fairhurst[4], Herbert Einstein[5], Karin Block[6], and Ludmila Adam[2]

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[1]Geology, Texas Christian University, Ft Worth, TX (john.holbrook@tcu.edu)
[2]Department of Geosciences, Boise State University, Boise, ID.
[3]Energy & Geoscience Institute, University of Utah, Salt Lake City, UT.
[4]Dept. Civil Engineering, University of Minnesota, Minneapolis, MN.
[5]Dept. Civil and Environmental Engineering, Massachusetts Institute of Technology, Cambridge, MA.
[6]Department of Earth and Atmospheric Sciences, The City College of New York, New York, NY.

Abstract

SedHeat is a community-based initiative that will address the science and engineering research challenges for realizing the geothermal potential of sedimentary basins. This interdisciplinary effort is being sponsored by the National Science Foundation. The program brings together a diverse group of academic and industry participants. In addition to establishing the research needs of geothermal development in this largely untested geothermal environment, the program places strong emphasis on education, career pathways, data sharing, and cyberinfrastructure.

The ability to translate the geothermal potential of sedimentary basins into productive use lies in the application of basic science and engineering research. Effective use also lies in reducing the economic risk of geothermal exploration and development, which inhibits attracting financial investors to this energy sector. In addition, it is also important to provide federal and state decision makers and agencies with the information they require to make sound decisions about geothermal energy. The long-term vision of this effort is to integrate NSF-sponsored research, education and cyberinfrastructure into a partnership among researchers, industry, and state and federal agencies to insure that geothermal energy can meet its potential as a major and sustainable contributor to our nation's energy grid.

The first workshop for this initiative was held November 7-9, 2011, at the Energy & Geosciences Institute, University of Utah. The overall goal was to define the scope of research needed for this under-studied portion of the renewable energy portfolio and to provide a road map for how NSF's community, through fundamental research, facilities development, data sharing, cyberinfrastructure, and education, can help make the vast geothermal potential of sedimentary basins a significant part of the nation's renewable energy portfolio. The interdisciplinary

nature and the broad range of research needed means that the development of the road map will be an iterative process. Subsequent workshops will be held on more focused topics. The SedHeat.org web site serves as a central communication point for the initiative.

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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***

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

Charles Fairhurst, ***University of Minnesota***

Herbert Einstein, ***MIT***

Karin Block, ***CUNY***

Ludmila Adam, ***Boise State University***

GEOT … ASINS

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

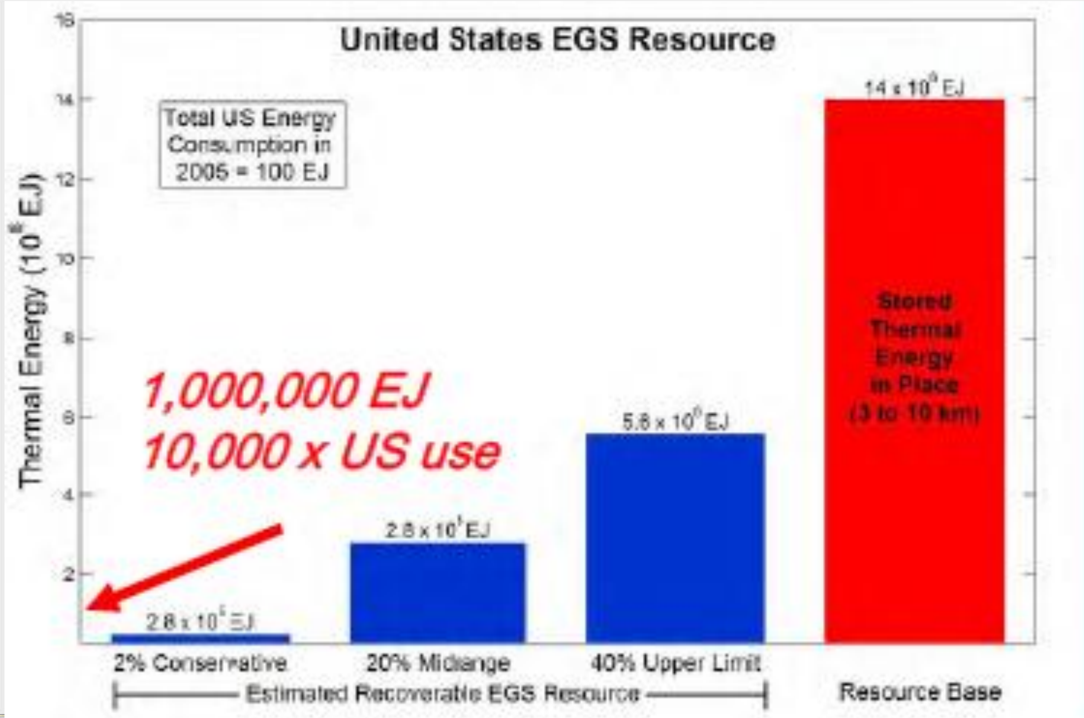
GEOTHERMAL POTENTIAL OF SEDIMENTARY BASINS

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?"

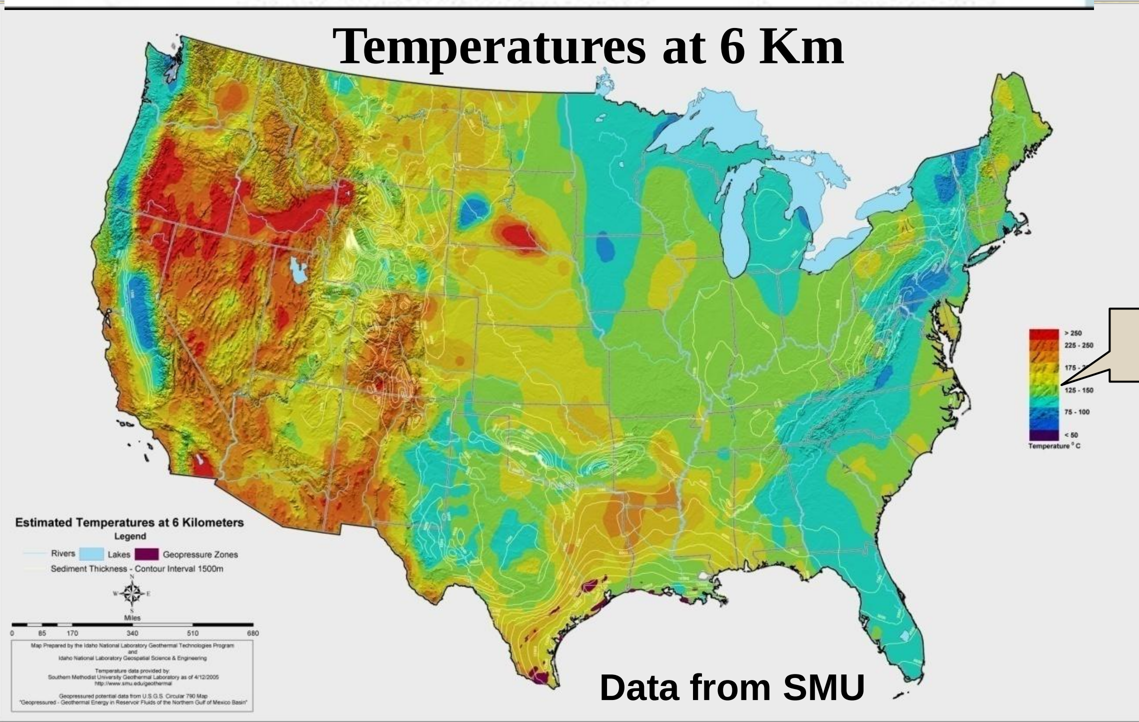
QUESTION #1
WHY BOTHER?



T = 150C

Geothermal System Resource Base

Temperatures at 6 Km



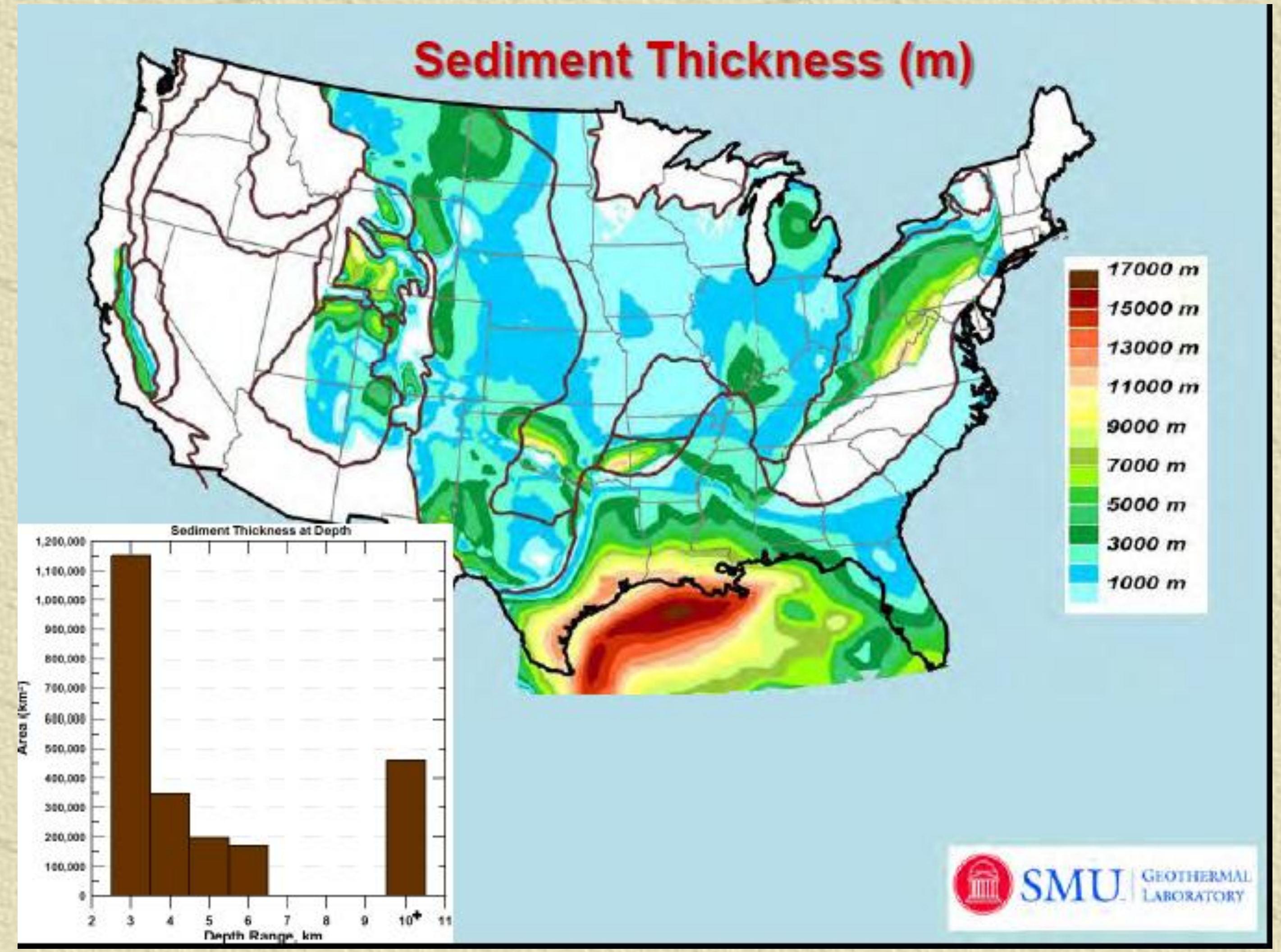
T = 150C

Data from SMU

C.O. Joe Moore

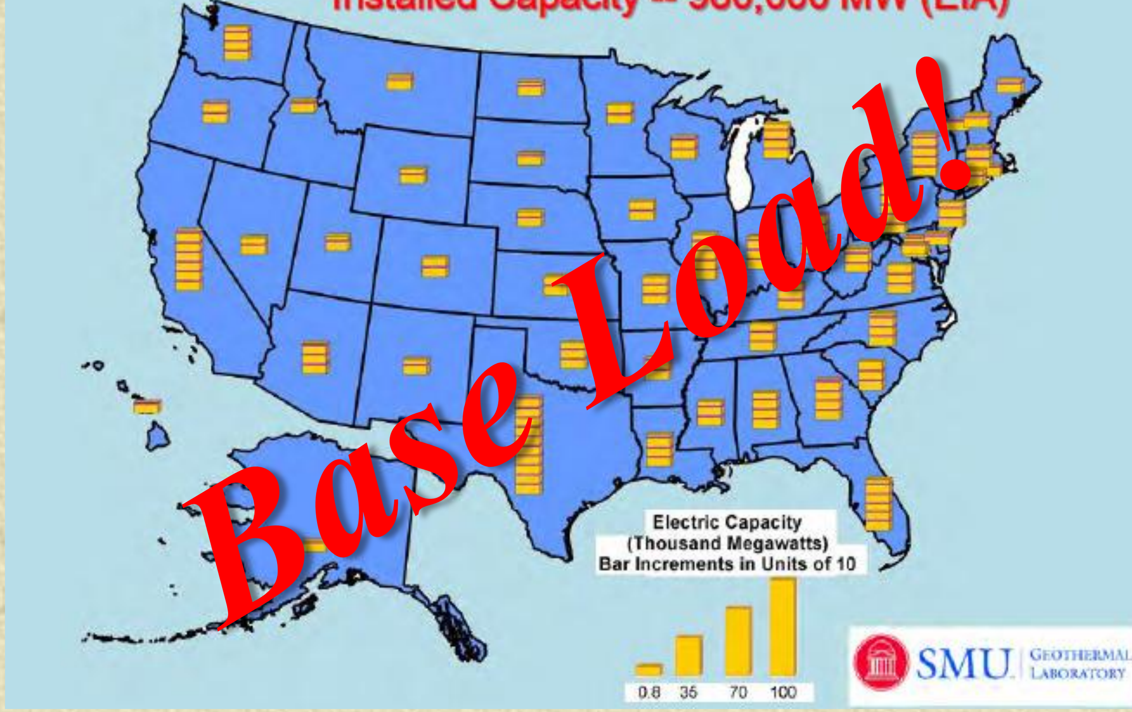
Category of Resource	Thermal Energy, in Exajoules (1EJ = 10^{18}J)	Reference
Conduction-dominated EGS		
Sedimentary rock formations	100,000	MIT, 2006
Crystalline basement rock formations	13,300,000	MIT, 2006
Supercritical Volcanic Systems	74100 excludes Yellowstone NP, Hawaii	USGS Circular 790
Hydrothermal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



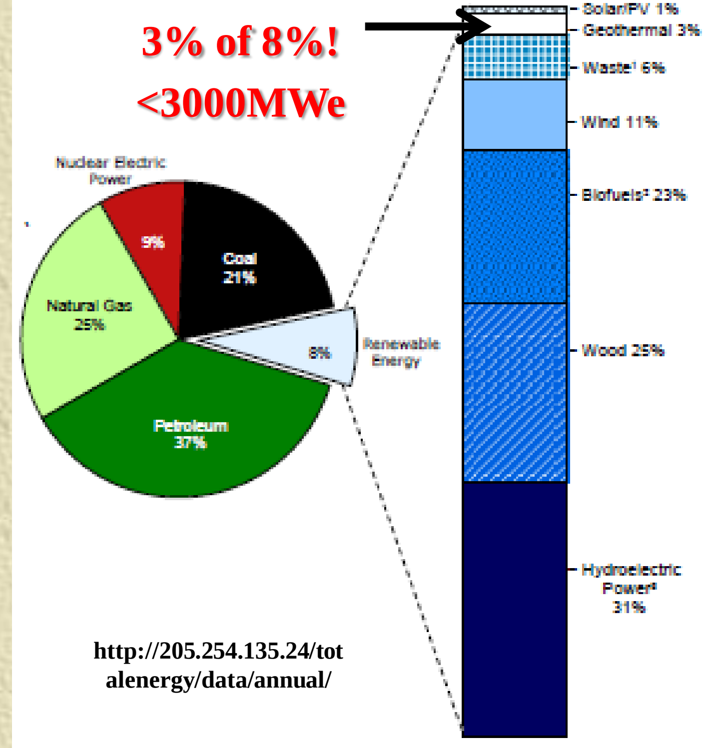
Why Geothermal?

Installed Capacity -- 980,000 MW (EIA)



Renewable Energy as Share of Total Primary Energy Consumption, 2010

Geothermal
3% of 8%!
<3000MWe



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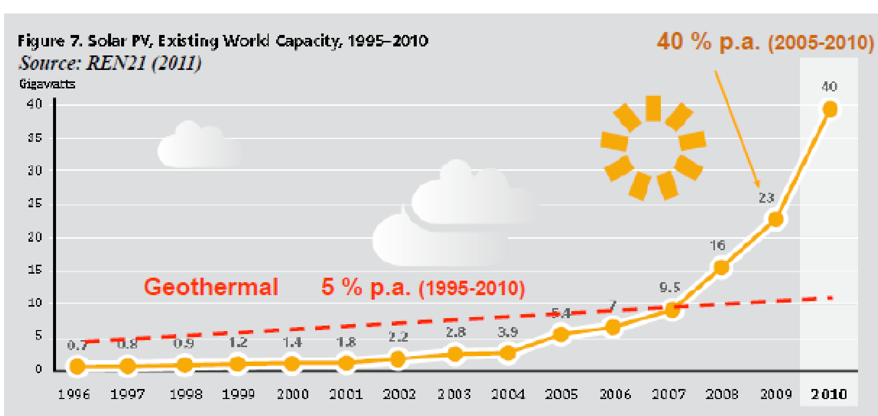
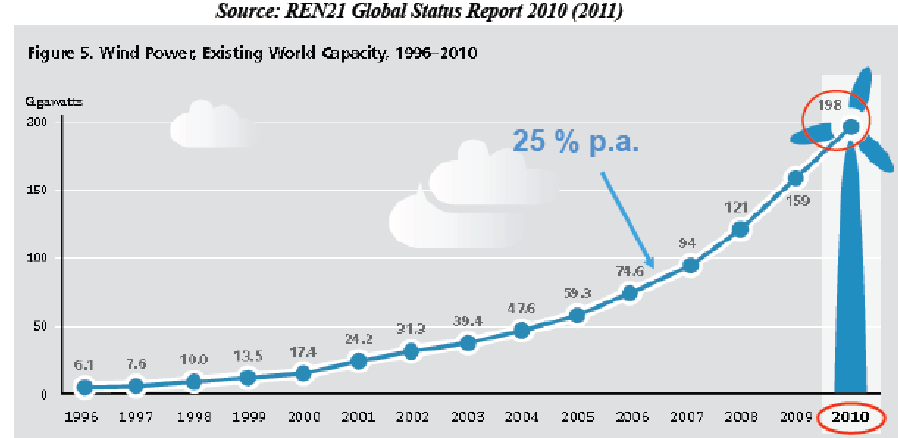
Global PV capacity growth vs. Geothermal power growth



Geothermal growth: all hydrothermal!

Global wind power growth

Source: REN21 Global Status Report 2010 (2011)



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

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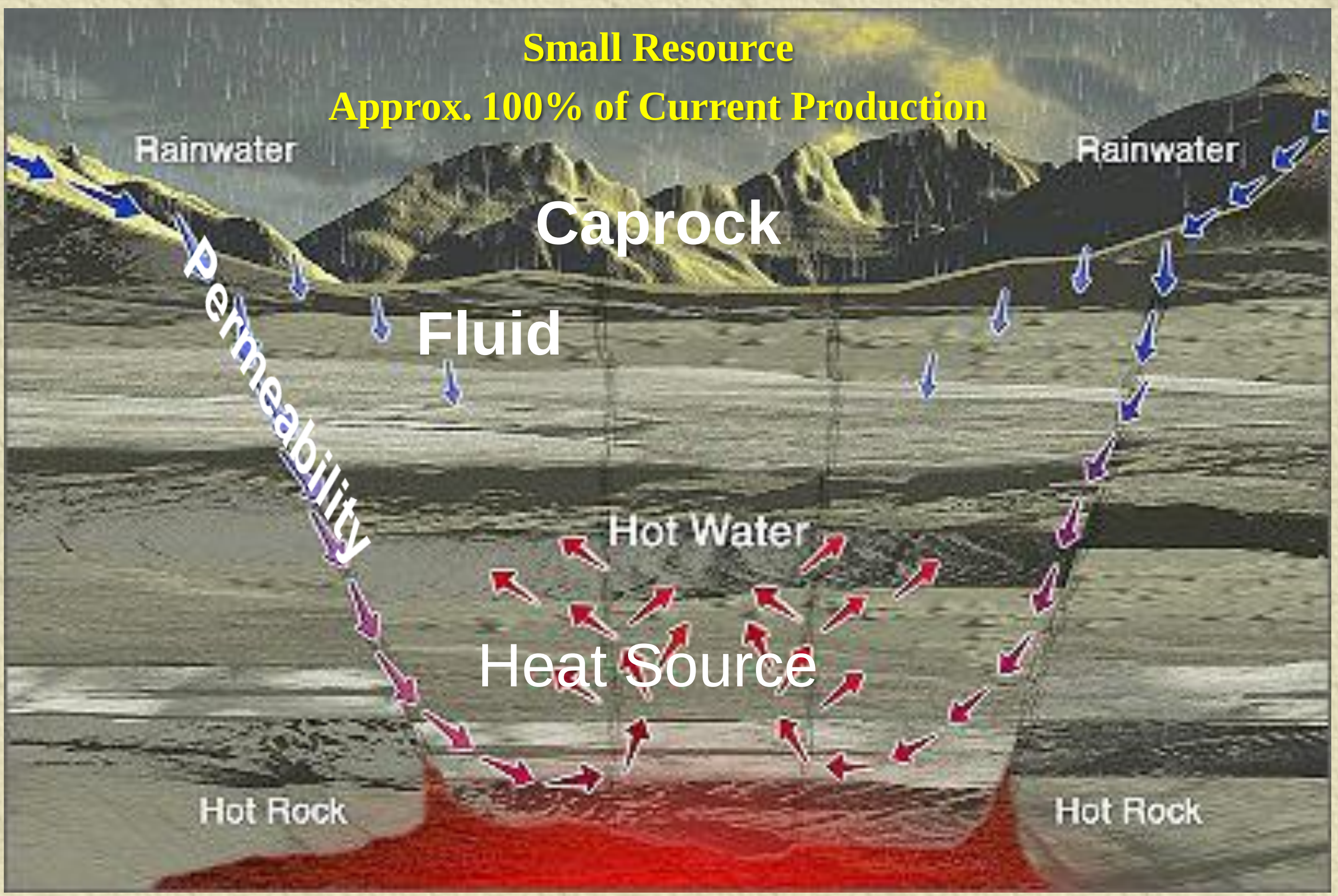
Hydrothermal (Convective) Systems



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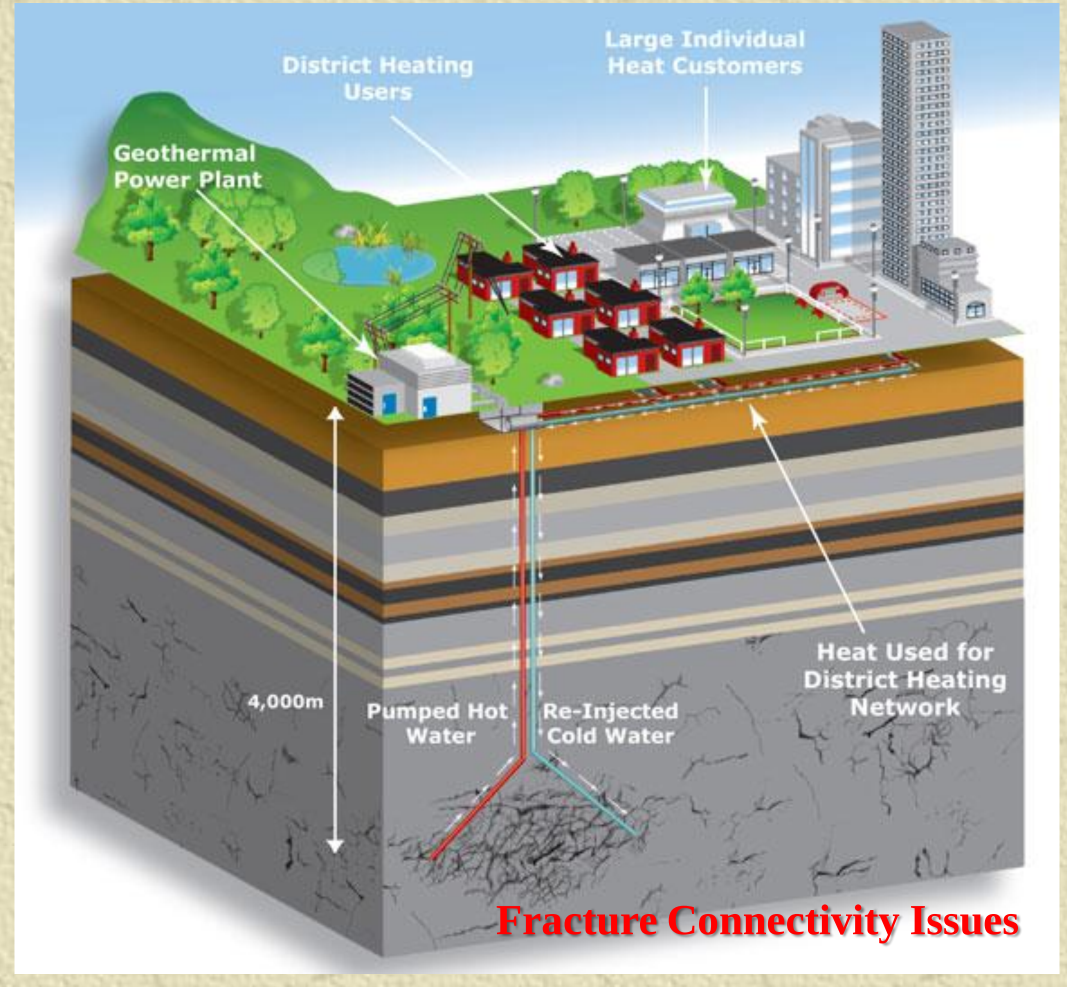
Enhanced Geothermal Systems



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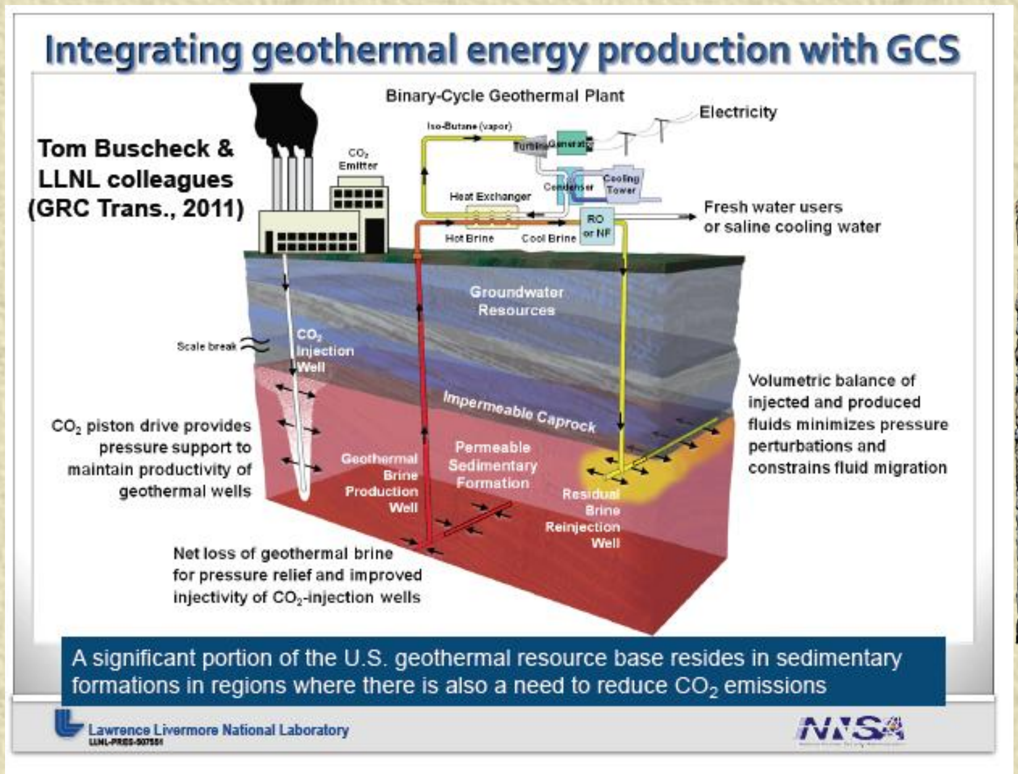

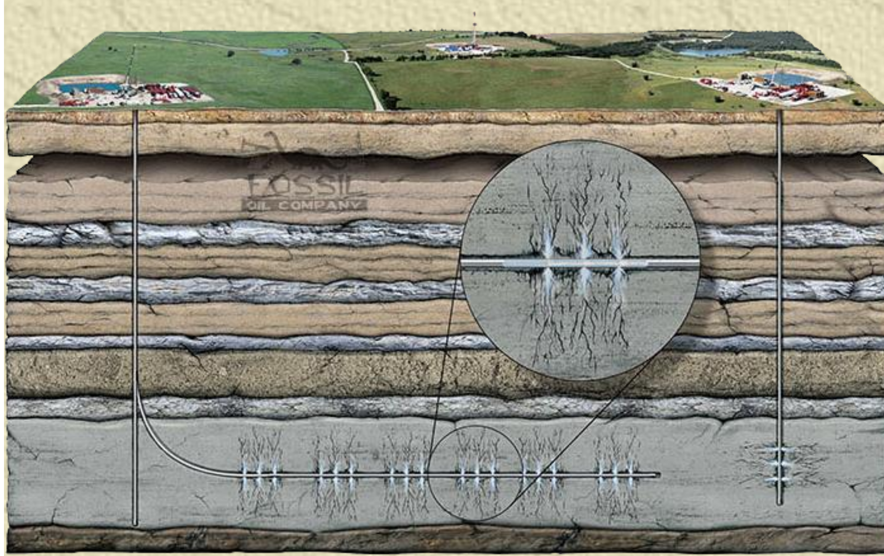

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Sedimentary Basins

Heat Volume and Matrix Permeability

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

Energy Source	"Good" Well Flow Rate	Energy Flow Rate	Value ($/day per well)
Geothermal	100 kg/s	100 MW$_{th}$, 10 MW$_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

Profit at about .5 Barrels/Sec

C.O Rick Allis

Challenges!

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

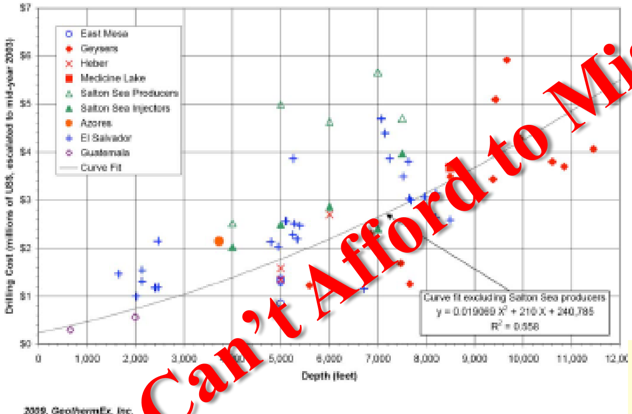


Figure 8. Correlation of drilling cost versus well depth (as of 2003) (from GeothermEx, 2004).

Can't Afford to Miss

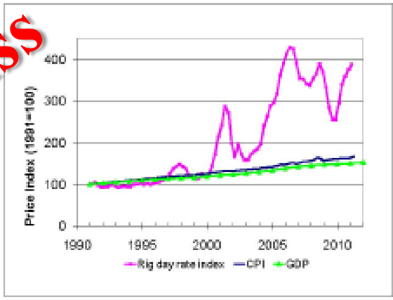


Figure 4. Index of recent rig day rate vs. GDP and CPI. (Note: rig day rate data runs as much as 3 months in arrears.)

Mansure & Blankenship, 2011

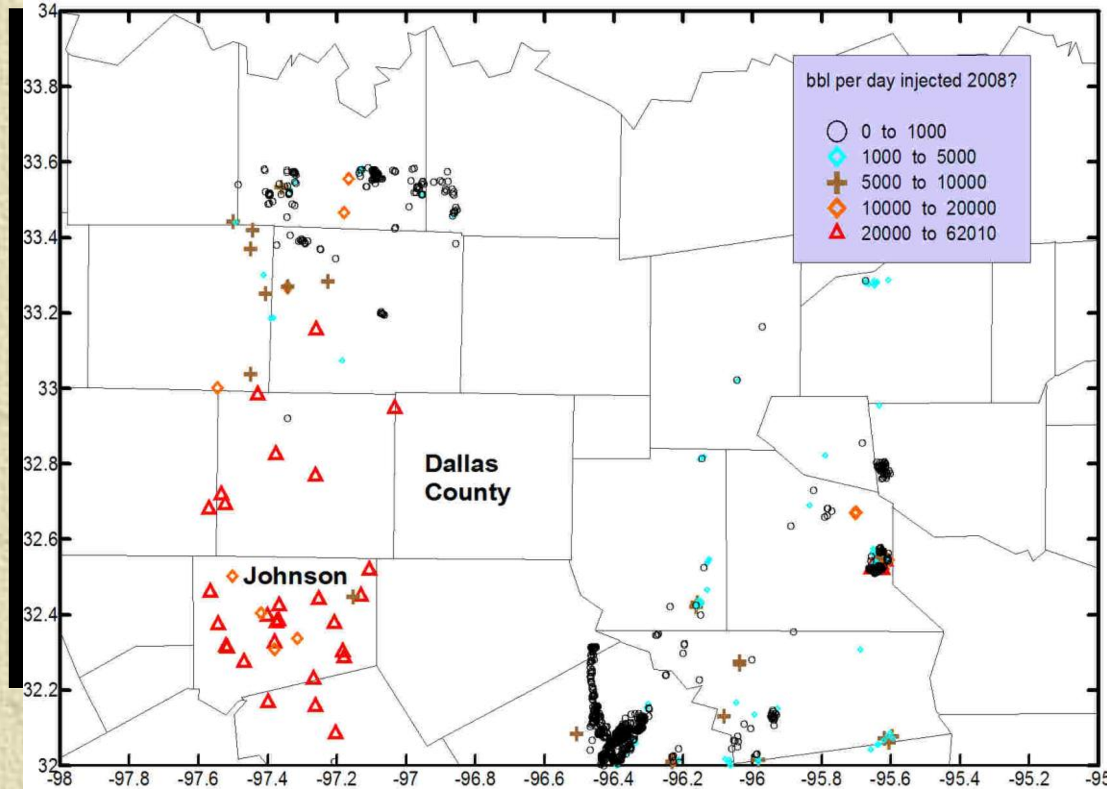
C.O Rick Allis

Flow Rates

Economic Sedheat

.5 barrels/sec

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



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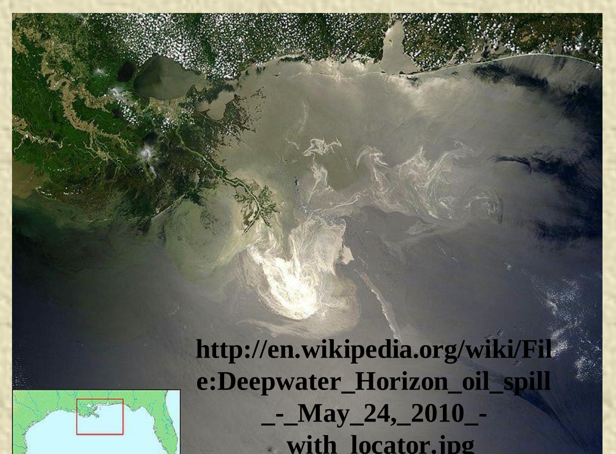
.6-.7 barrels/sec

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



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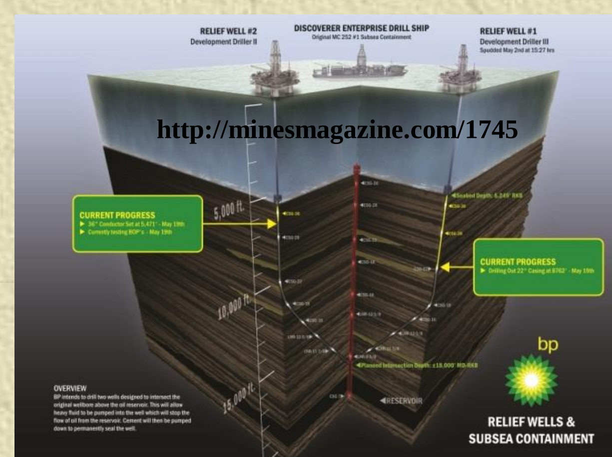


http://minesmagazine.com/1745

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

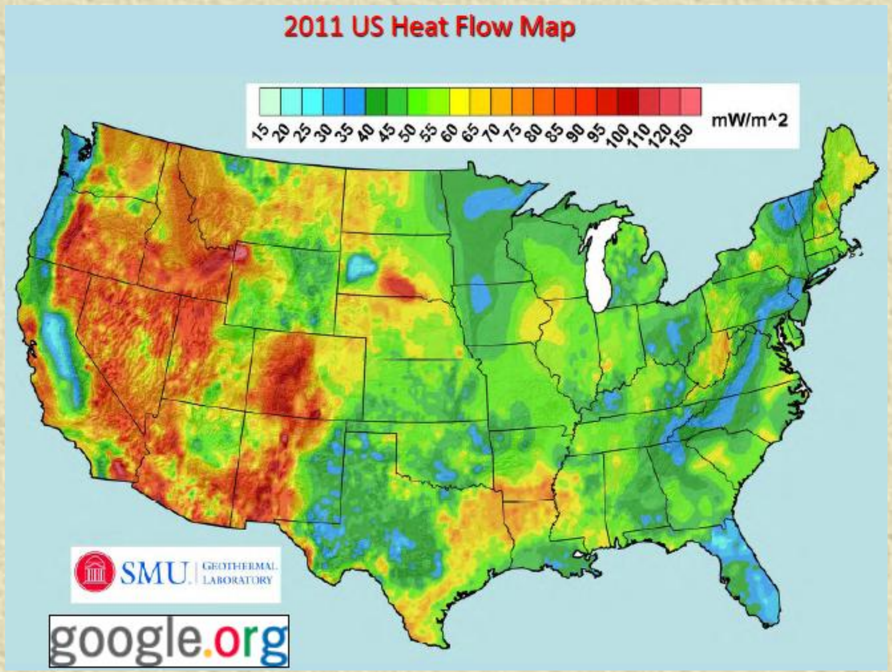
Topics

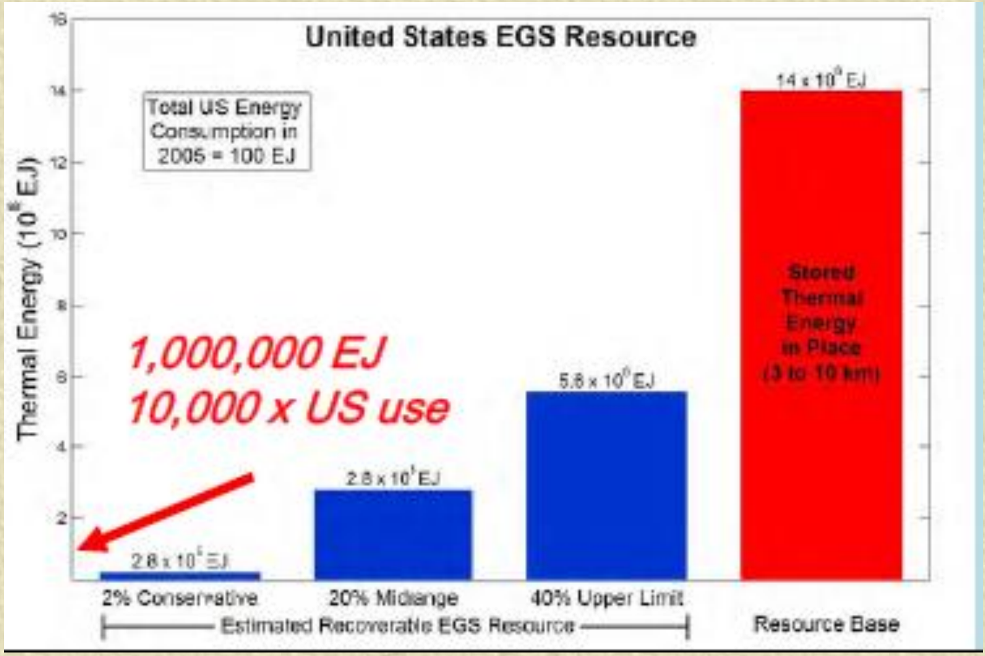
The Native Basin

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

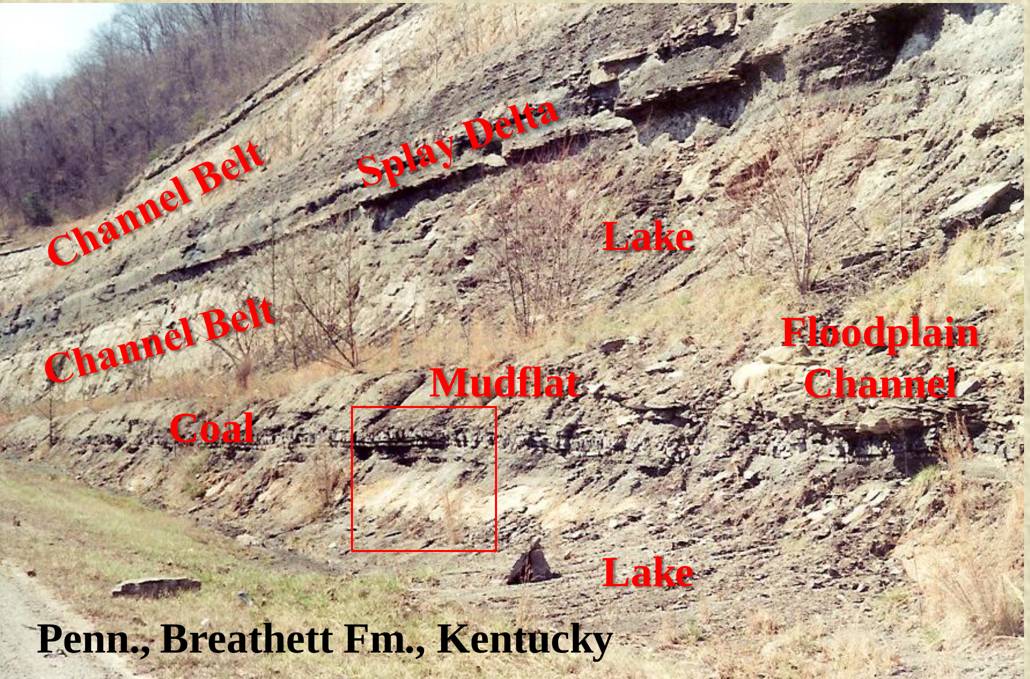
The Native Basin

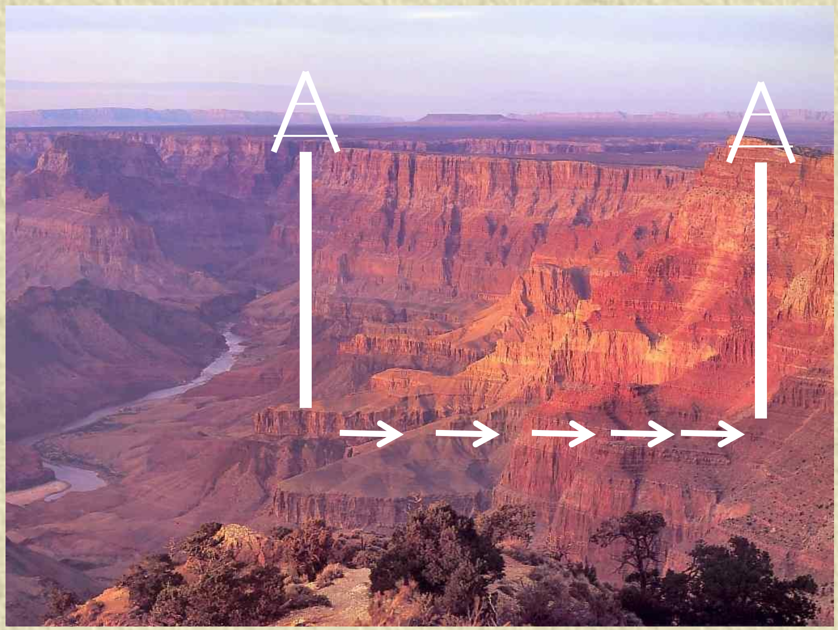
Fluid flow

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

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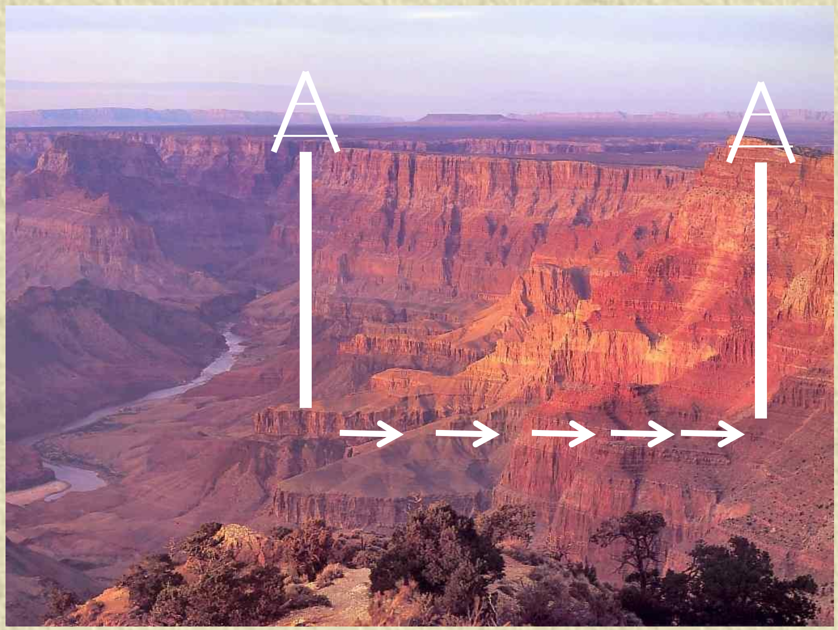


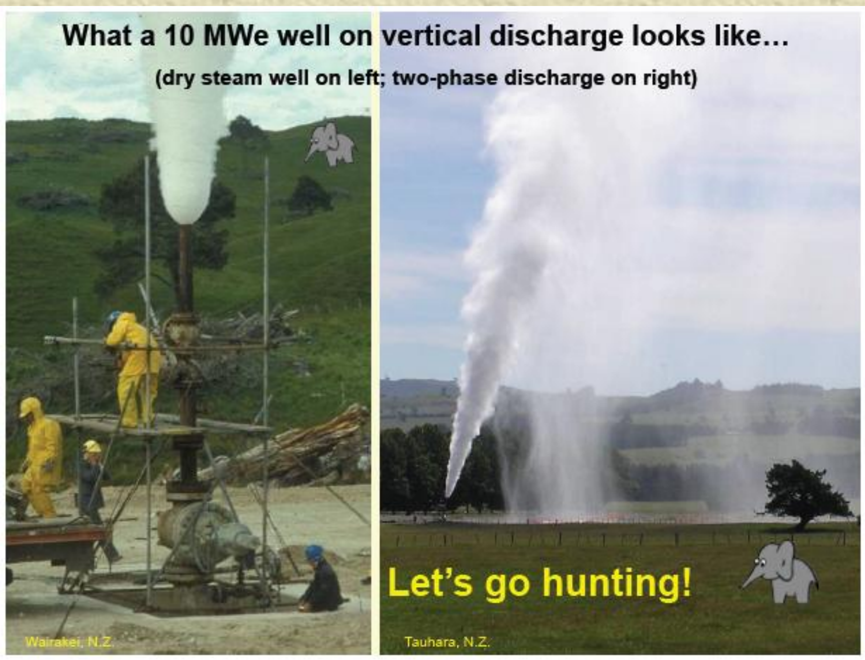
Topics

Engineering

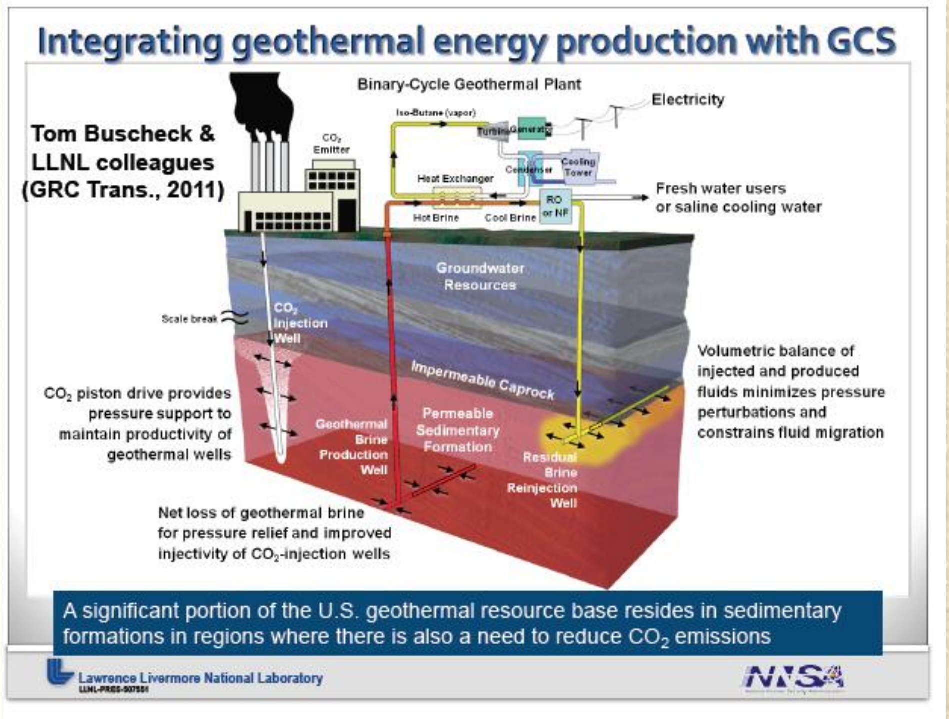
Drilling

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?



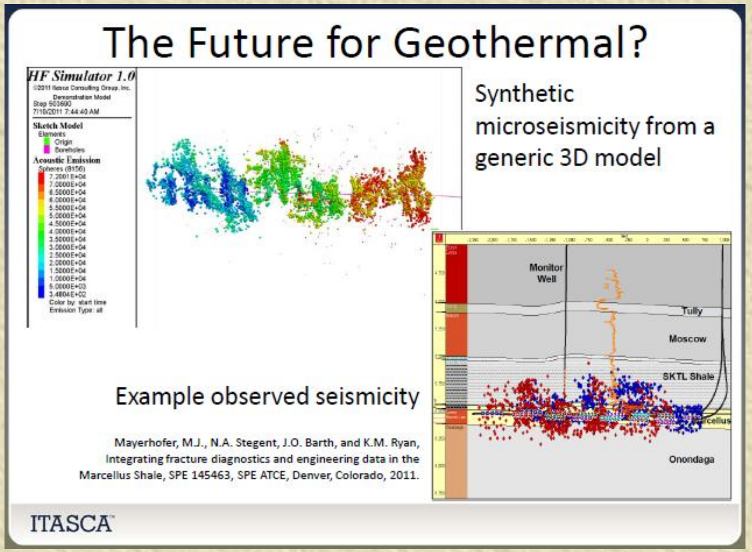
C.O Rick Allis

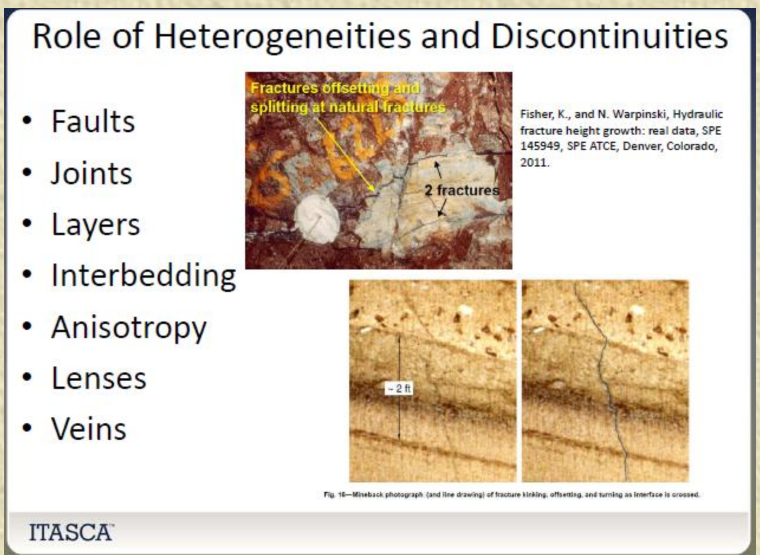


Topics

Engineering

Reservoir

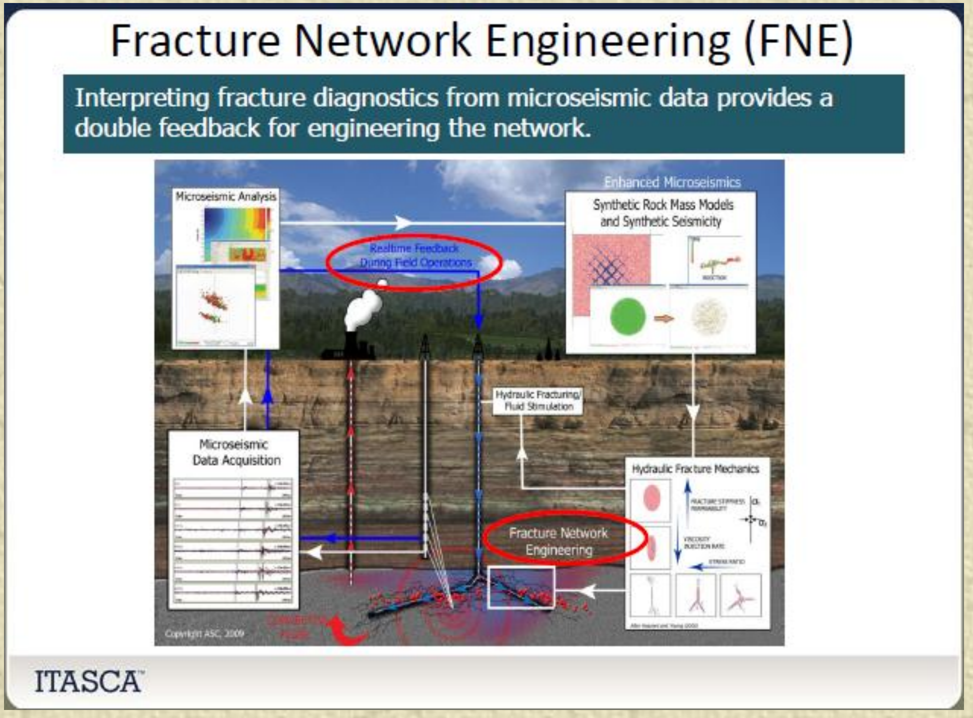




What new techniques can be defined that permit us to predict, control, and monitor stimulated fracture systems in deep, hot, and heterogeneous media?

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?

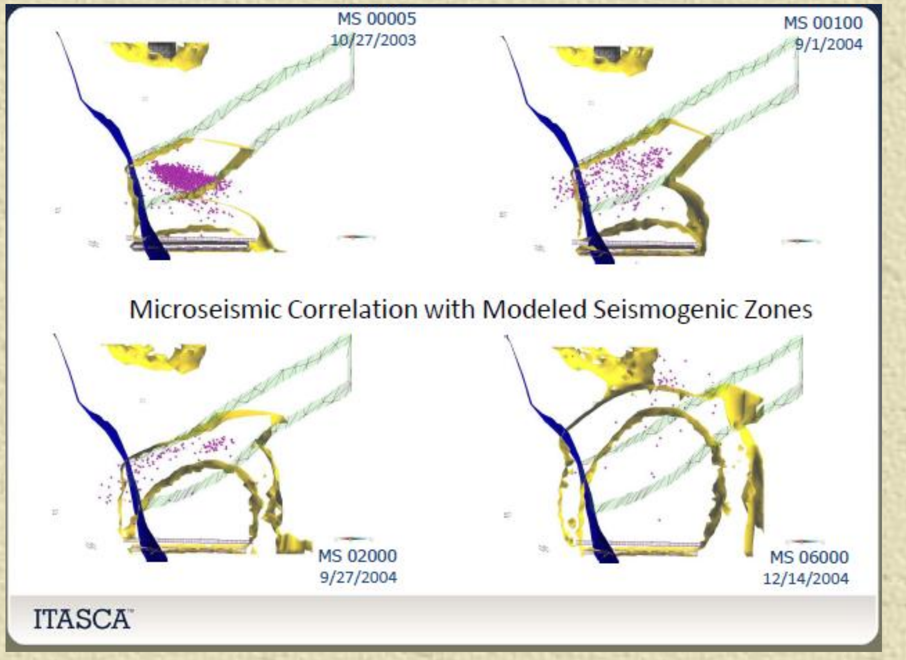


C.O. Will Pettitt

<u>Topics</u>

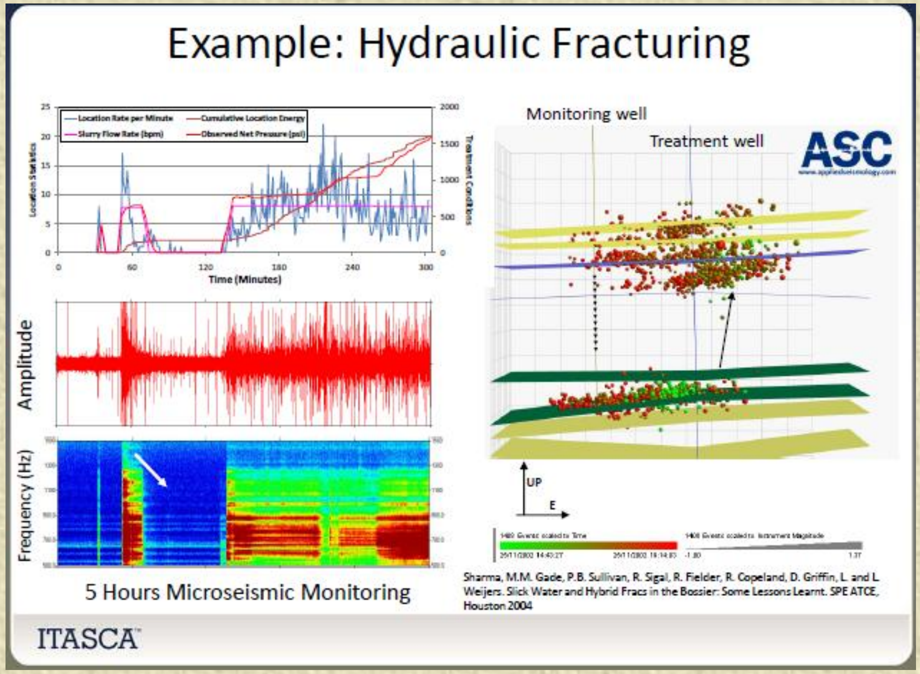
Geophysics

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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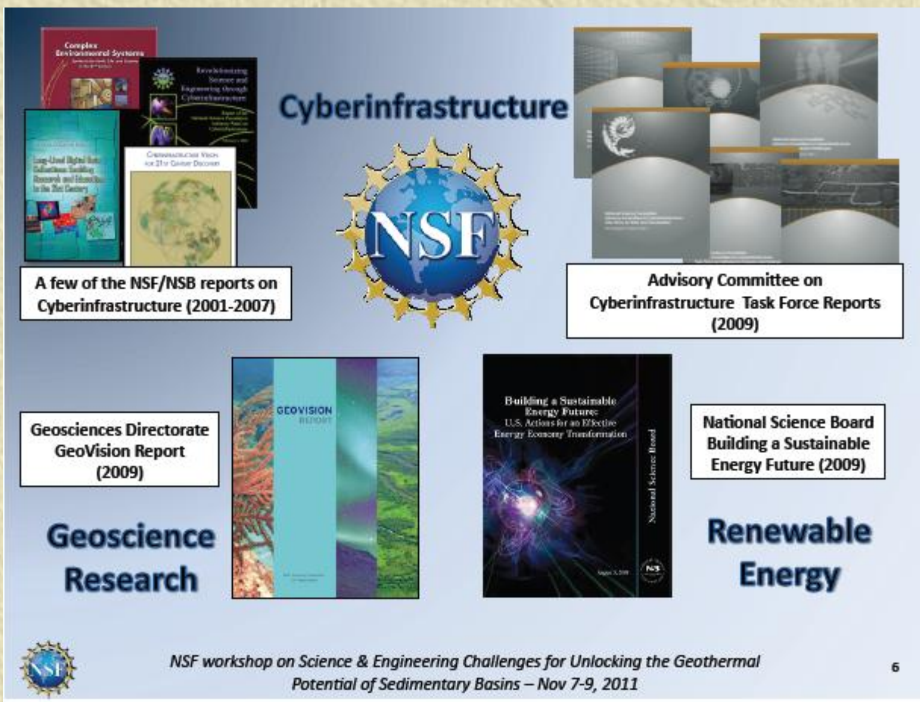
Topics

Cyberinfrastructure

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

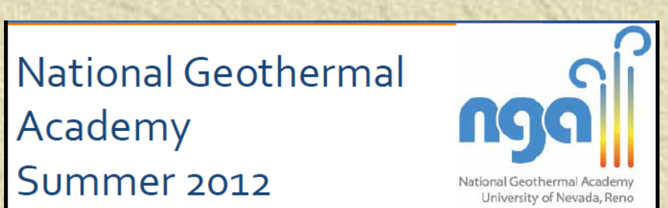
What data-sharing systems are most likely to be both effective and organically grow?



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 minds 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?

<u>An RCN</u>

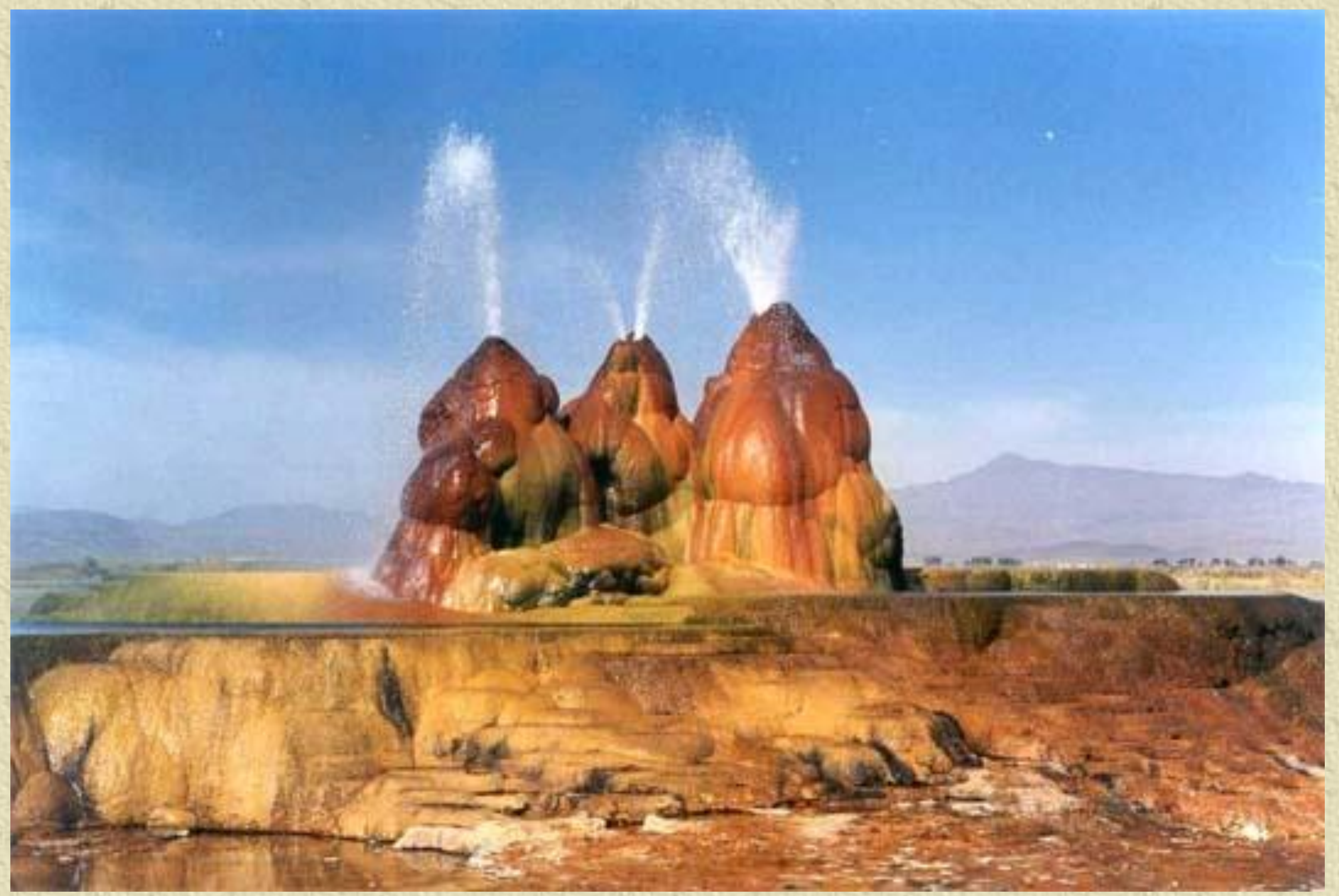
<u>A Report</u>

<u>A Bunch of Proposals</u>

WWW.SedHeat.org

SEDHEAT

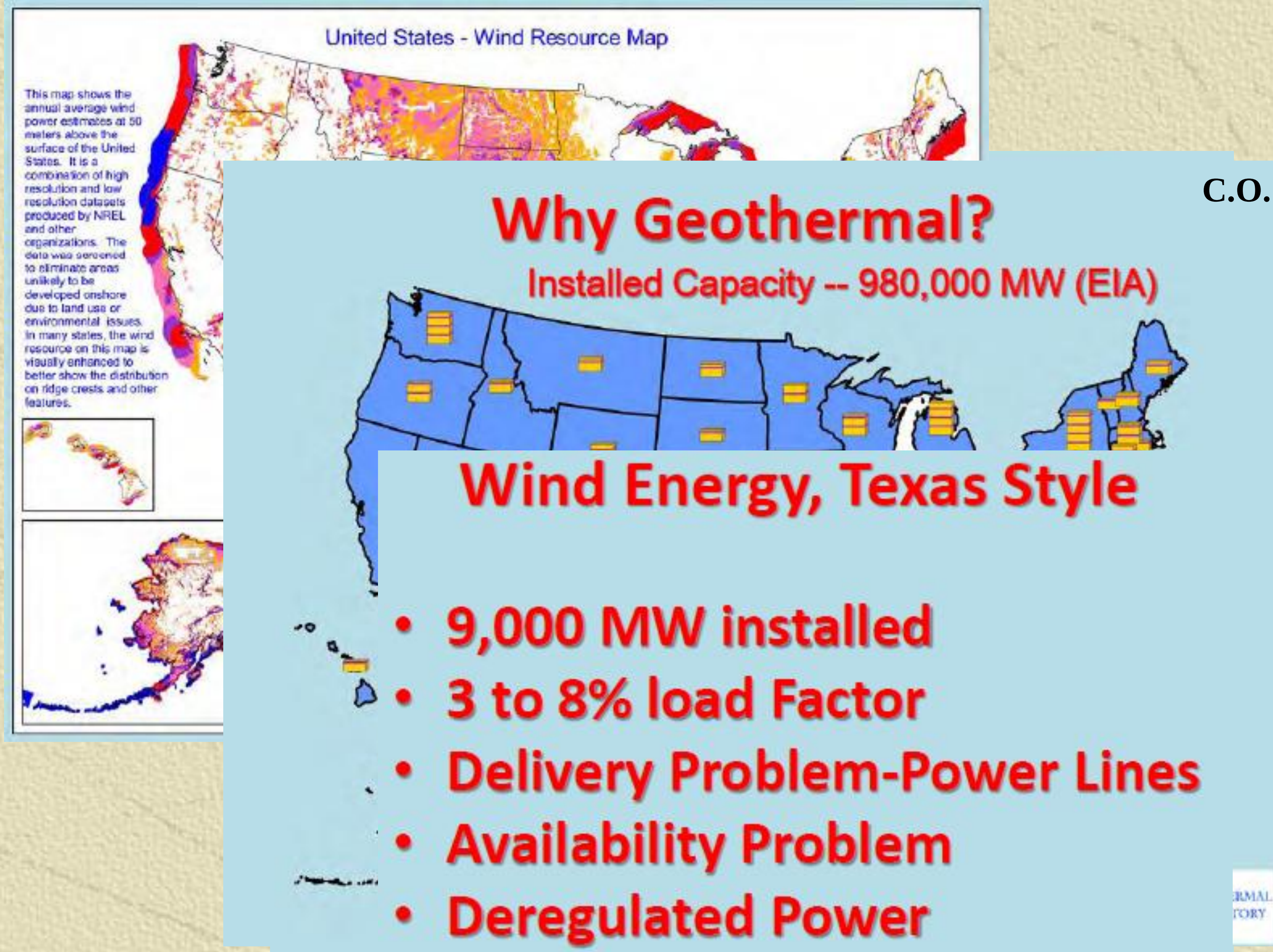
THANK YOU FOR YOUR ATTENTION



C.O. Joe Moore

Addenda

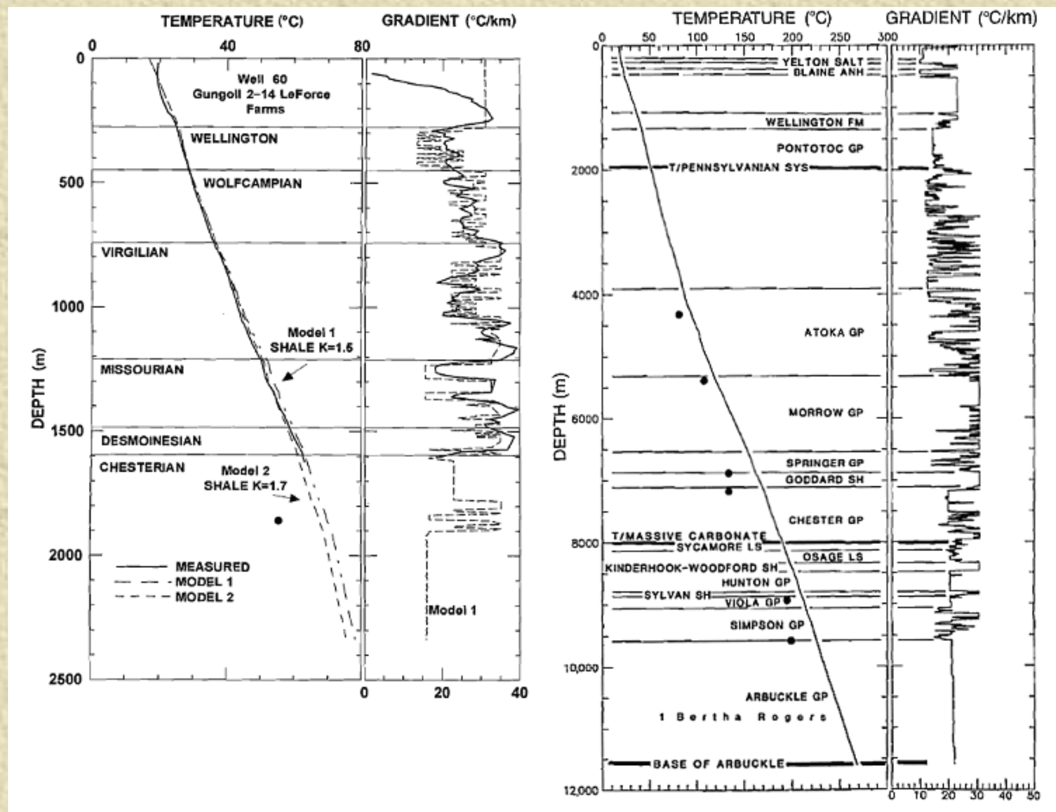
C.O. David Blackwell



Wind Energy, Texas Style

- 9,000 MW installed
- 3 to 8% load Factor
- Delivery Problem-Power Lines
- Availability Problem
- Deregulated Power
- Ownership and Construction
- Energy Density

Electric generation of Co-produced Fluids



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Ormat binary plant (~250 kW; 90ºC water) at RMOTC, WY

Electric generation depends on depth (temperature), water flow rate, and proximity of favorable wells for combining flows for the particular application

Regional development geothermal power capacity 2020-2030-2050 (GW_e)

	Africa and Middle East	Developing Asia	India and China	OECD Pacific	OECD Europe	OECD North America	Other	World
2020	1	5	0	2	3	7	2	**22**
2030	2	14	2	3	5	13	7	**46**
2050	12	64	15	11	14	49	35	**200**

From IEA Geothermal Road Map (2011)

C.O. Ladsi Rybach

National Geoth
Academy
Summer 2012

University of Nevada, Reno

- Over 50 attendees from around the world…
  ….gathered in Reno, Nevada!
- Attracted students, professors, and industrialists
  backgrounds and expertise

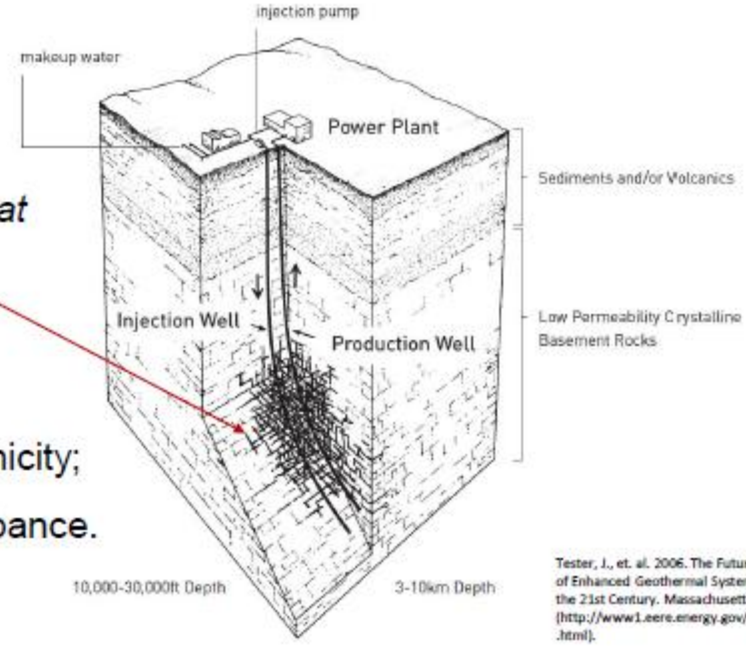
Natio
U

C.O. Will Pettitt

EGS Reservoir Development and Operation

Underground Heat Exchanger:

- ❑ Efficiency;
- ❑ Longevity;
- ❑ Mitigate Seismicity;
- ❑ Aquifer Disturbance.



Tester, J., et. al. 2006. The Future of Geothermal Energy: Impact of Enhanced Geothermal Systems (EGS) on the United States in the 21st Century. Massachusetts Institute of Technology (http://www1.eere.energy.gov/geothermal/future_geothermal.html).

ITASCA

nal in Sedimentary

Estimated Temperatures at Specific Depths

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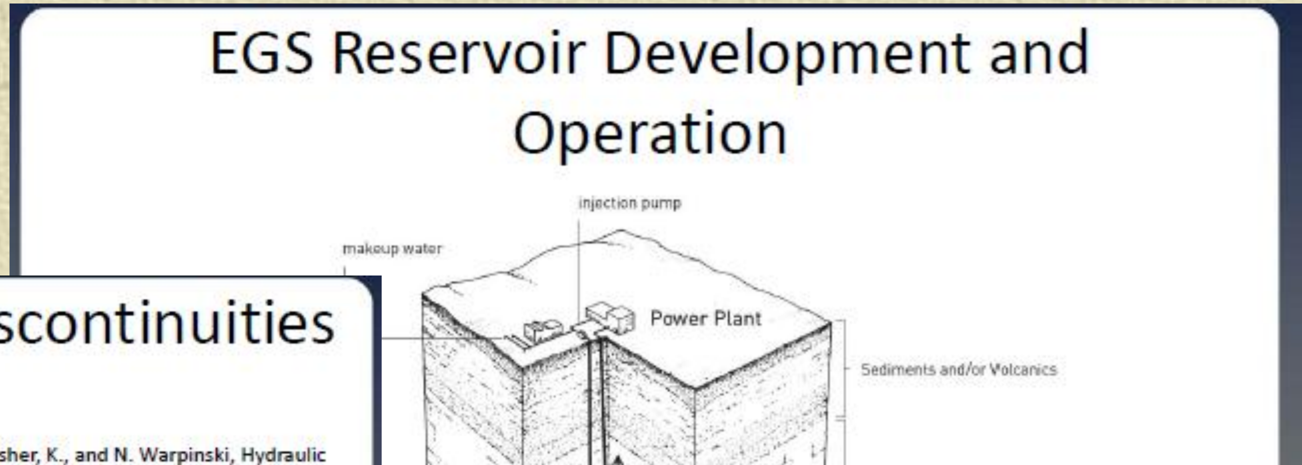

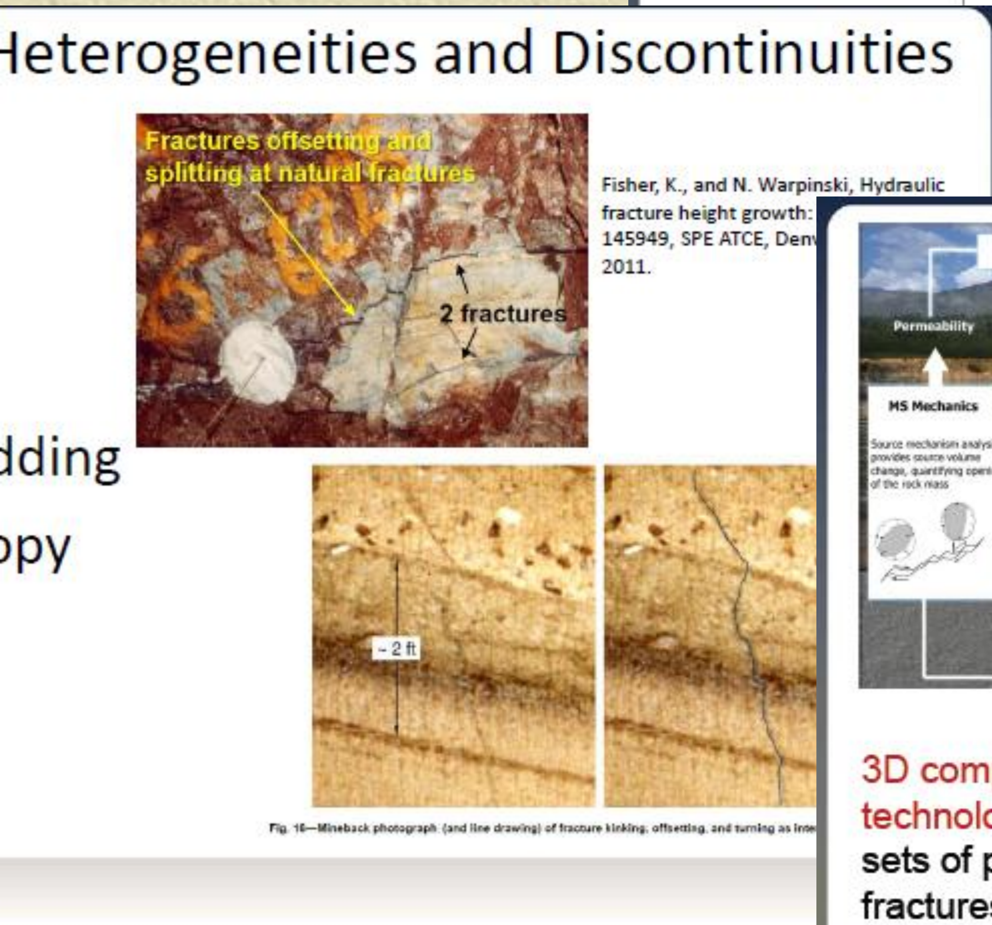

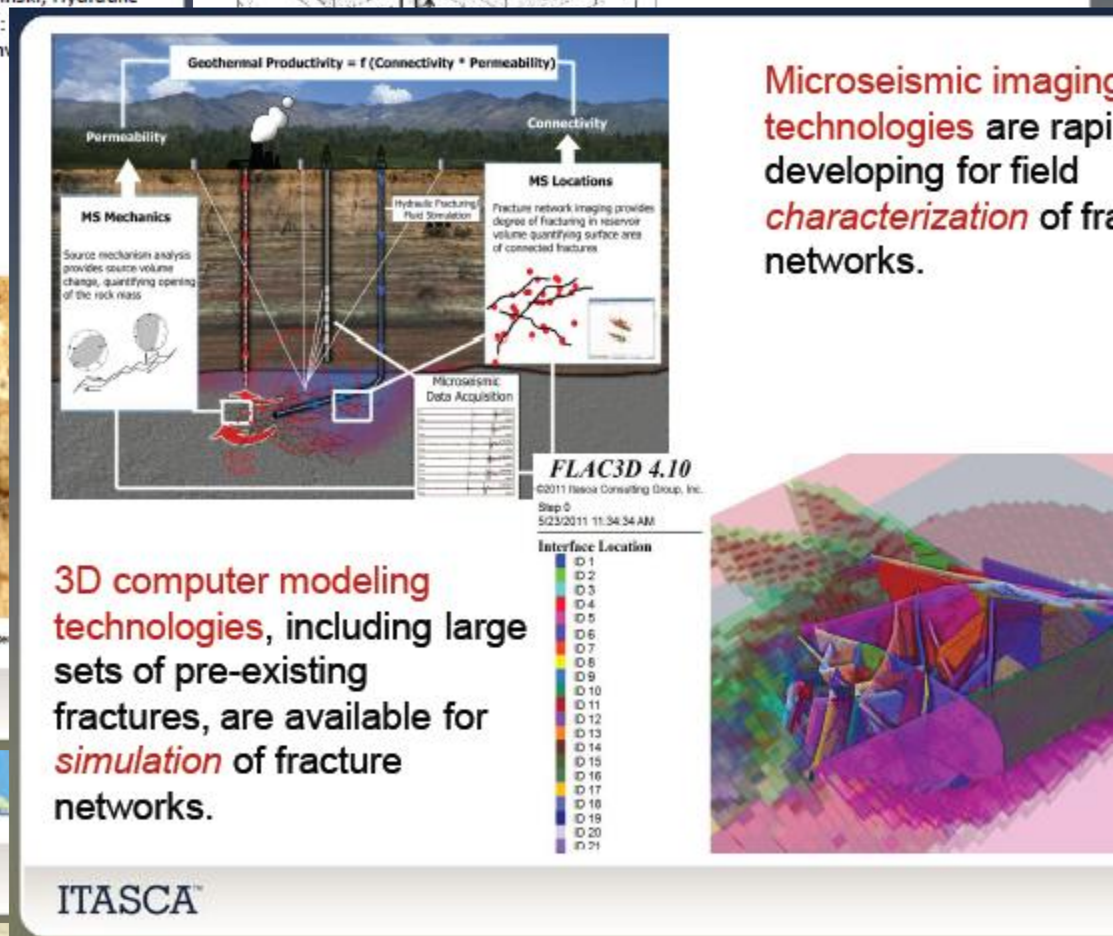

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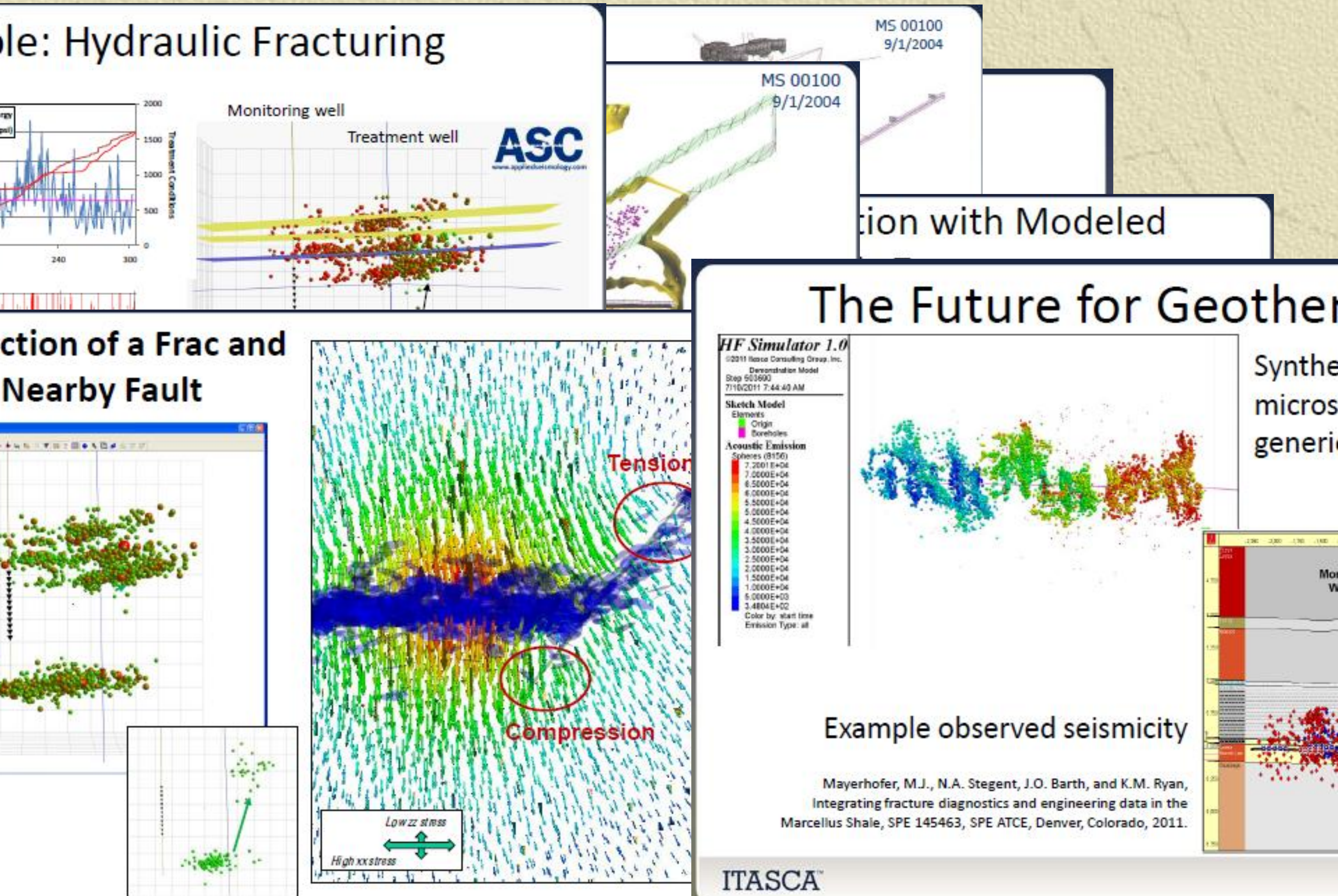


C.O Rick Allis

Chasing the Geothermal Elephants in Sediments (*i.e. Stratigraphic Reservoirs*)

Rick Allis, Utah Geological Survey
Nov. 6 – 8, SLC, UT

The motivation:

Geothermal resource estimates are massive:

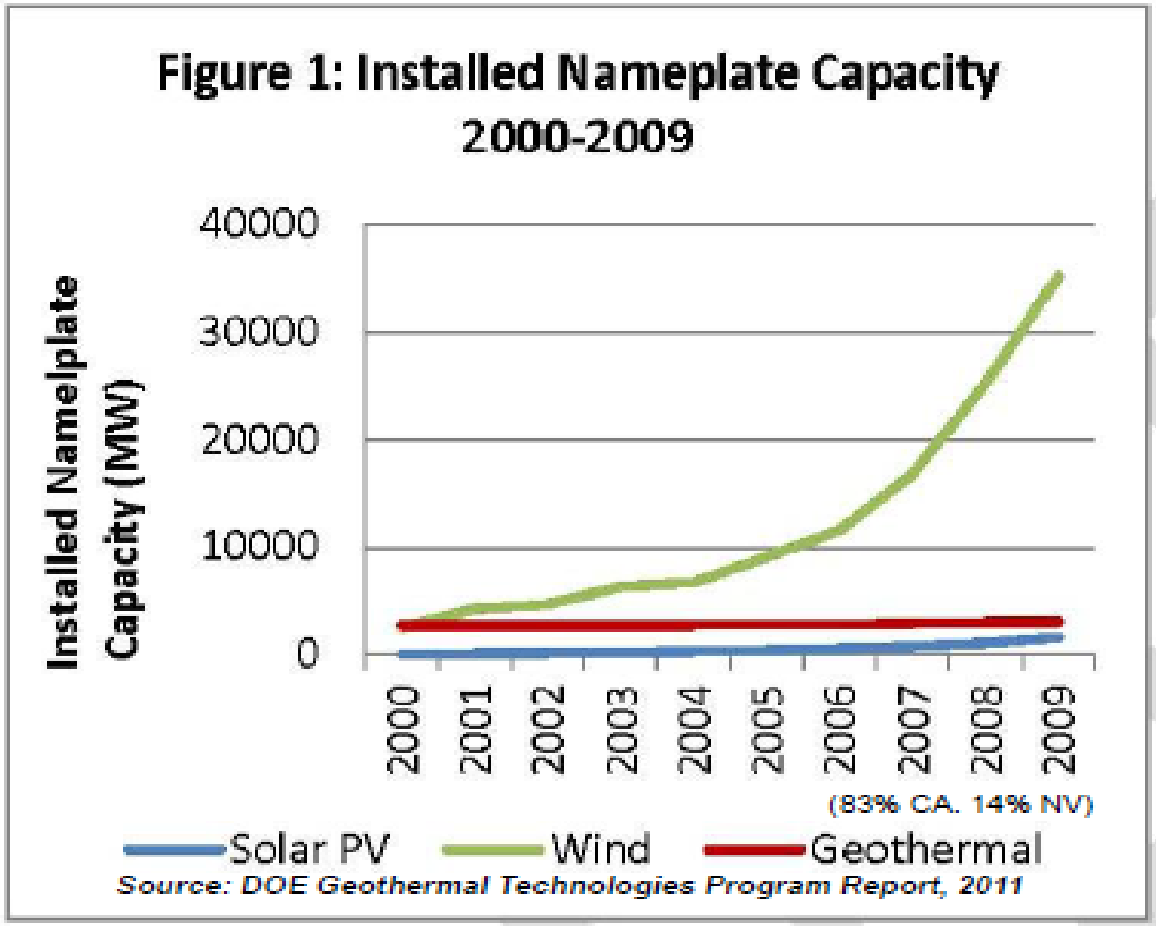
~ 100 GWe for EGS,

~ 10 GWe for co-produced basin fluids (MIT, 2006)

~ 10 - 30 GWe from the western U.S. (USGS, 2008)

The Challenge:

Geothermal development track record is lagging other renewables – we need GWes of development during next decade to have credibility



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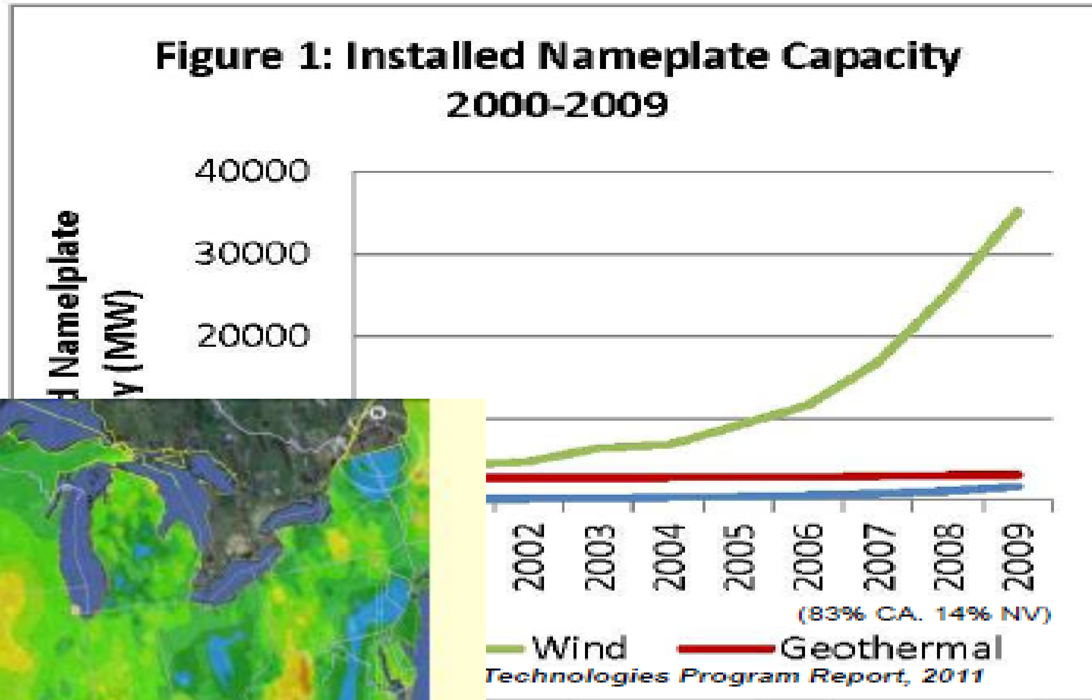
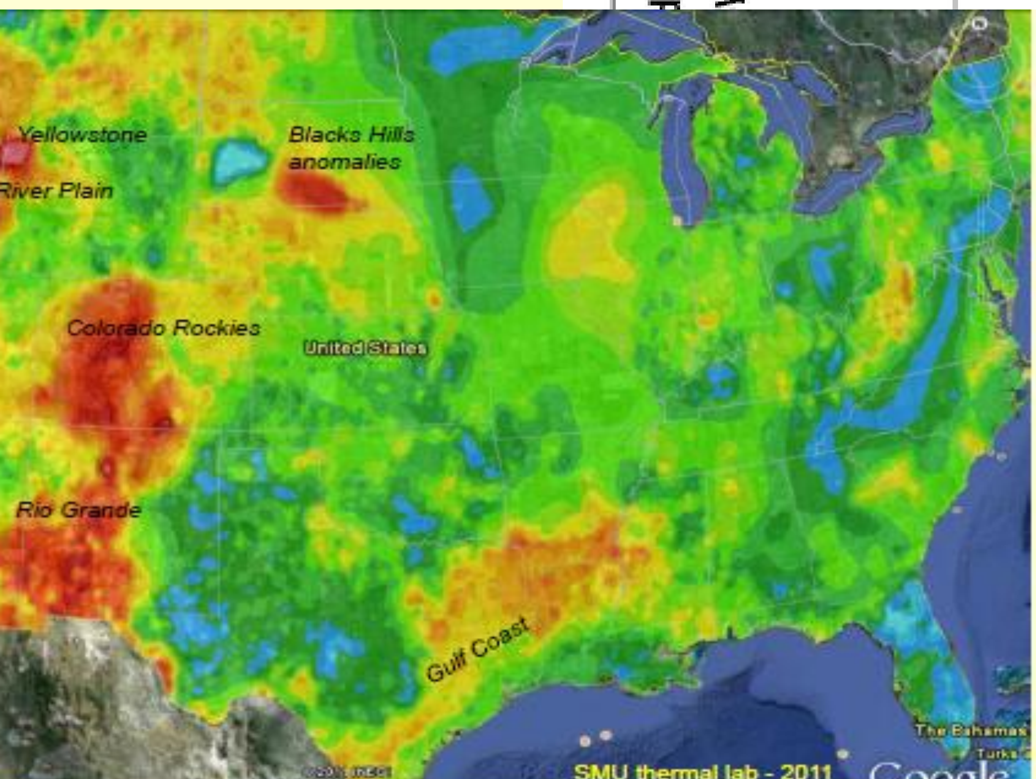
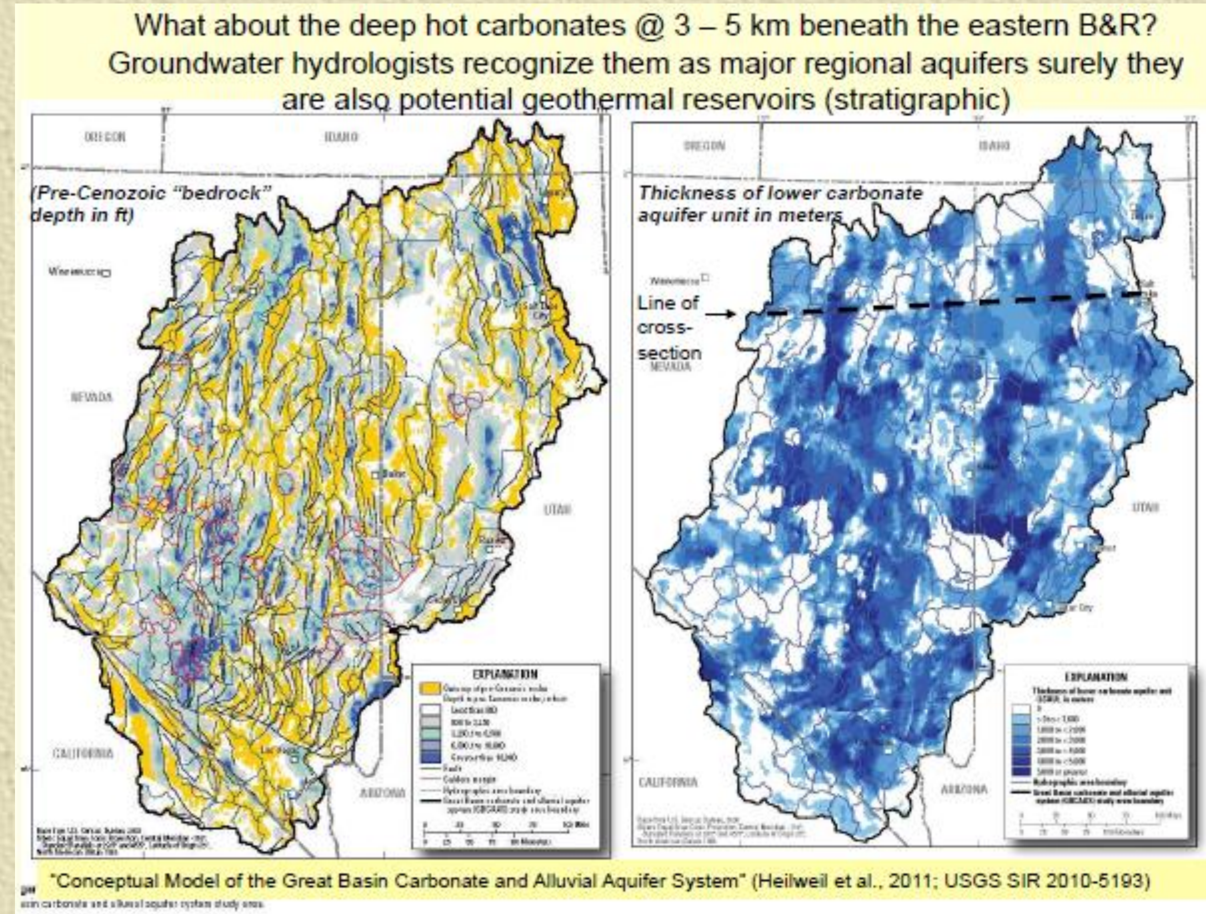




^{6} km^2 of high heat flow terrain in the west (> 90 mW/m^2) and a major n of sedimentary successions with the potential for stratigraphic nperatures are ~ 200°C @ > 3 – 5 km

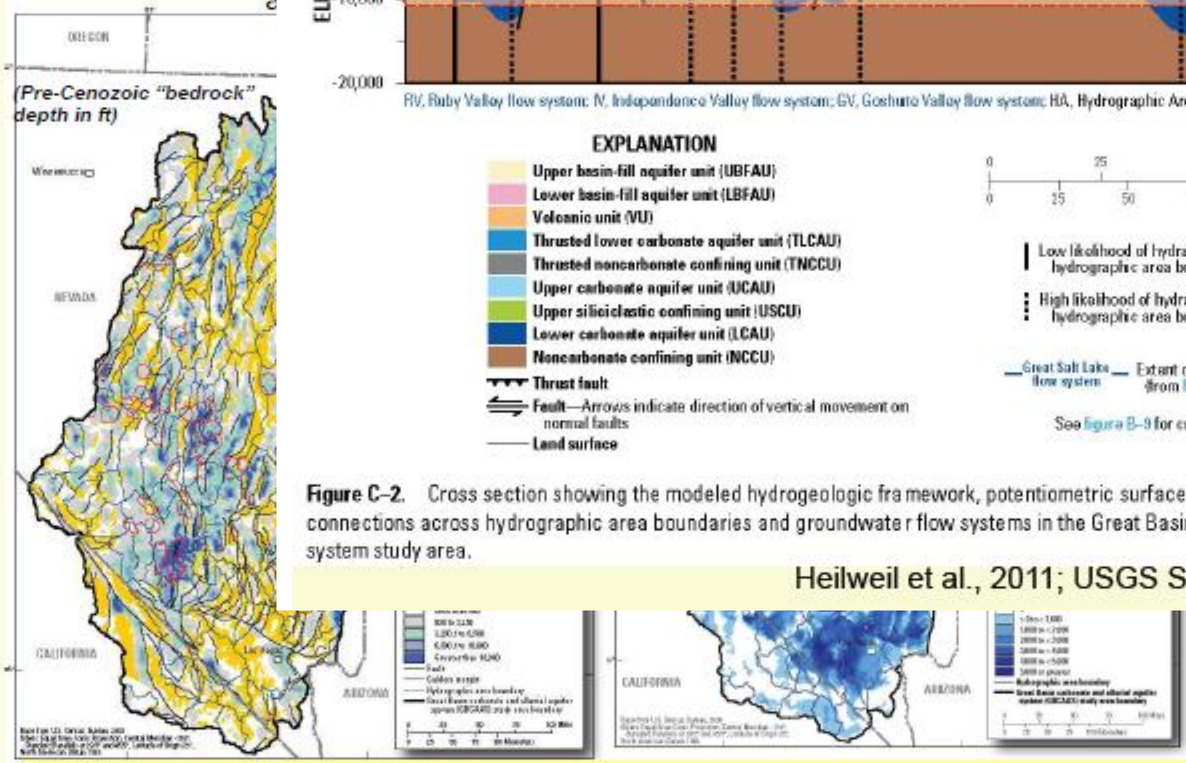
C.O Rick Allis



C.O Rick Allis

What about

Groundwater



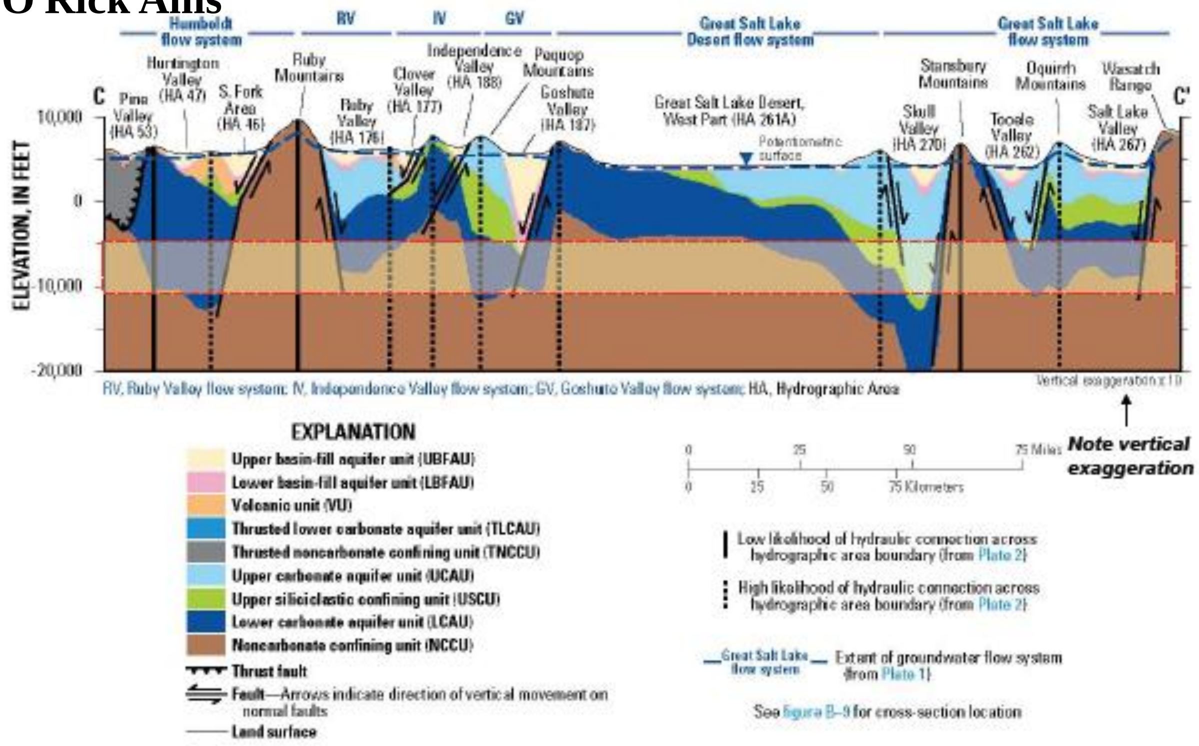
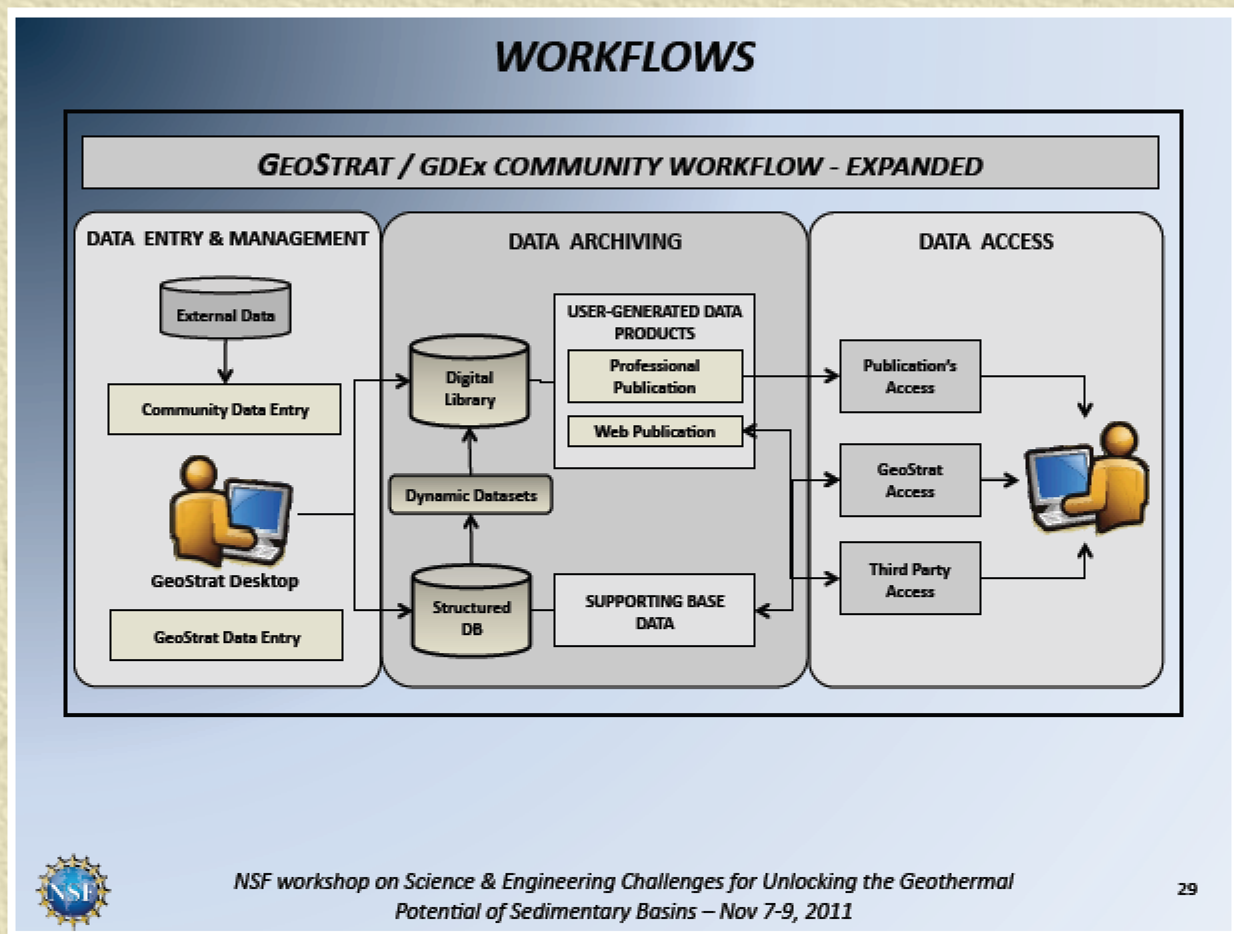


Figure C–2. Cross section showing the modeled hydrogeologic framework, potentiometric surface, and likelihood of hydraulic connections across hydrographic area boundaries and groundwater flow systems in the Great Basin carbonate and alluvial aquifer system study area.

Heilweil et al., 2011; USGS SIR 2010-5193

"Conceptual Model of the Great Basin Carbonate and Alluvial Aquifer System" (Heilweil et al., 2011; USGS SIR 2010-5193)

C.O. Walter Snyder



C.O. Walter Snyder