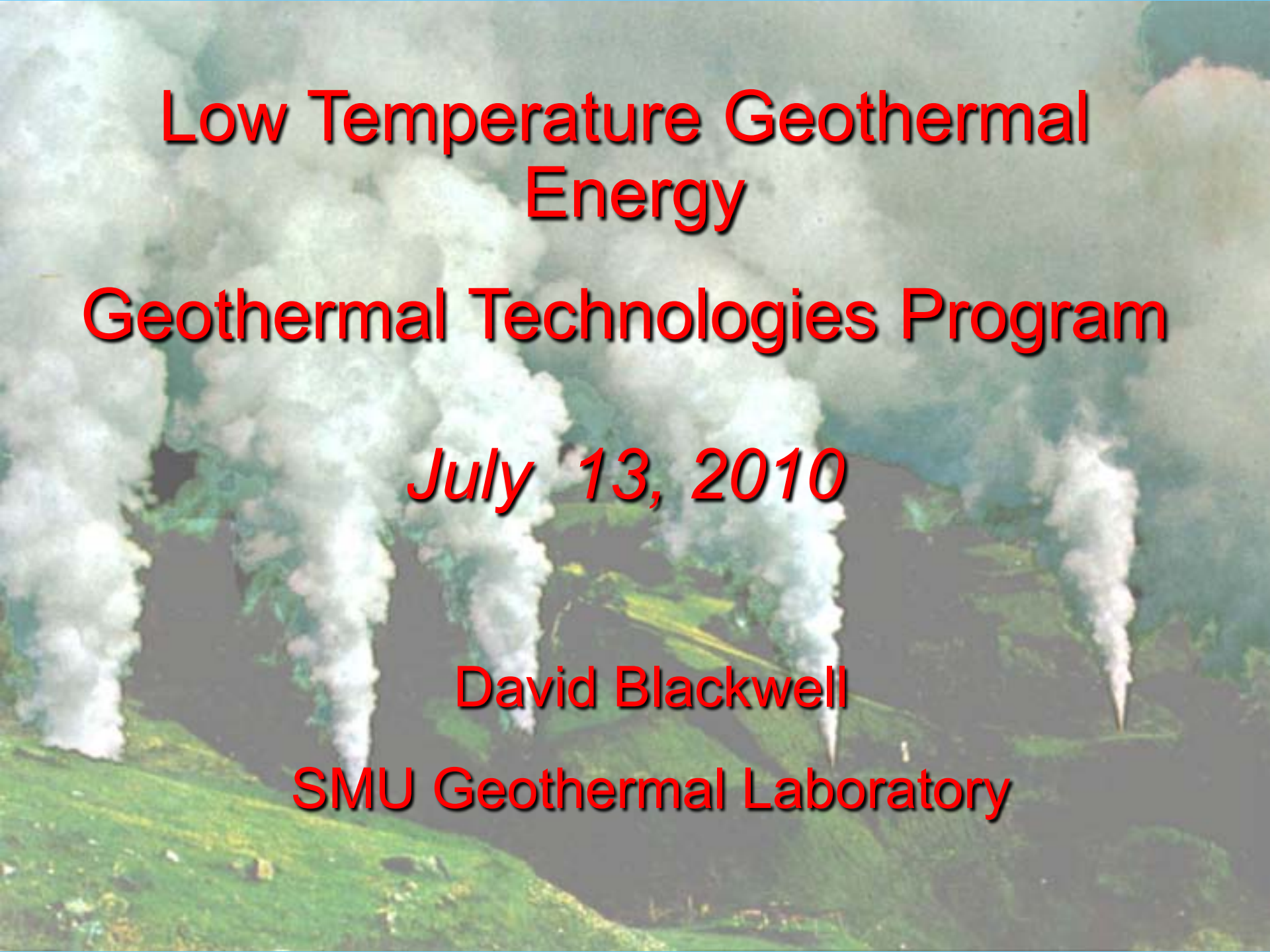


Low Temperature Geothermal Energy

Geothermal Technologies Program

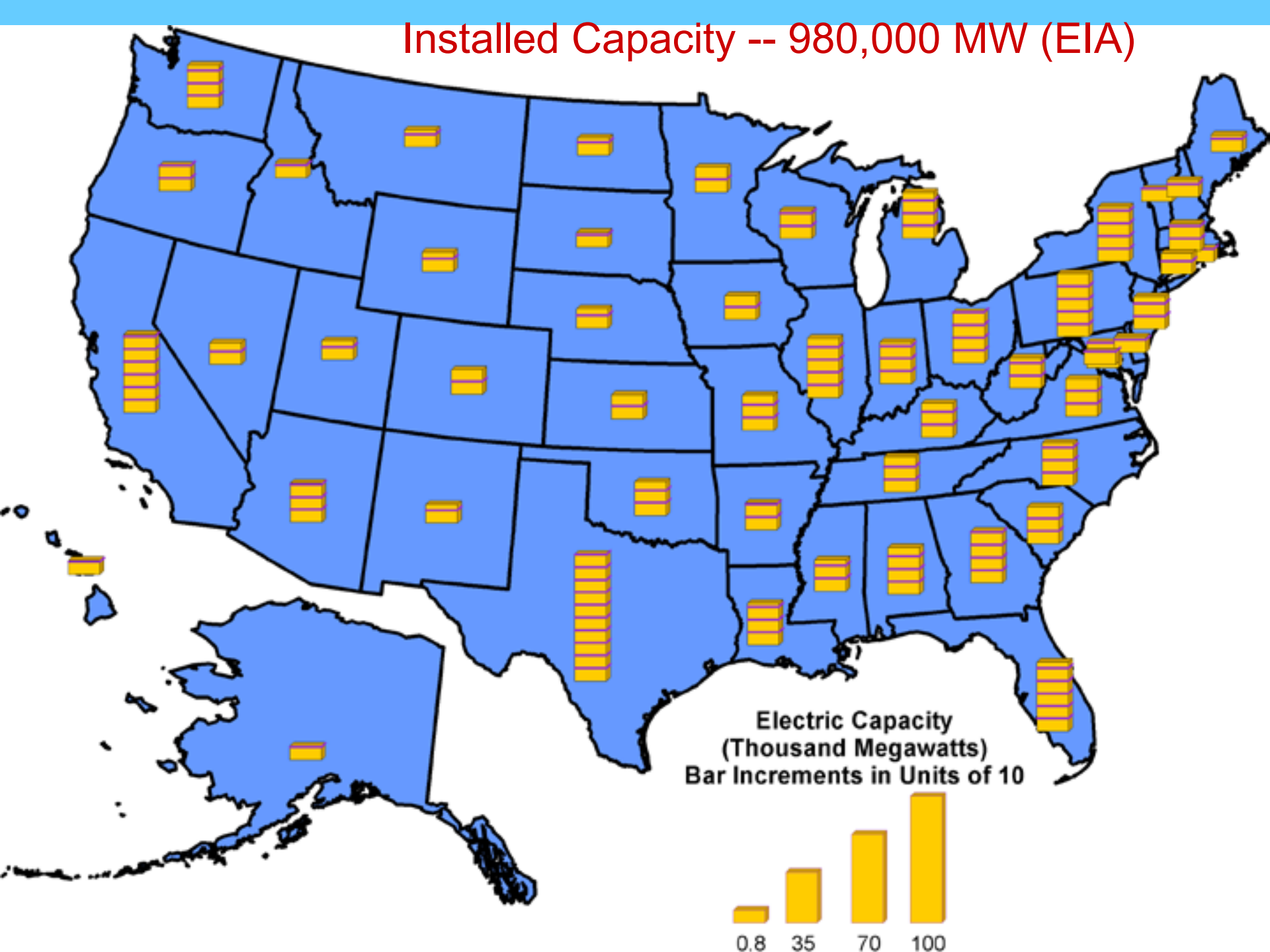
July 13, 2010

David Blackwell

SMU Geothermal Laboratory


GREETINGS, FRIENDS! THIS IS YOUR LUCKY DAY.
WHAT? AN' THIS IS FRIDAY-THE-THIRTEENTH?
1-13
IT'S TUESDAY FRIDAY CAME LAST WEEK... YOU MUST OF SLIPPED A COG IN YOUR ENGINE ROOM.
OH, YEAH? WELL FRIDAY-THE-THIRTEENTH DON'T JEST DISAPPEAR.. ...WE DIN'T HAVE IT YET THIS MONTH... SO IT COMES ON TUESDAY ...THE DAY IS FRAUGHT WITH FATE.
I HAVE JUST THE THING TO FOIL BAD LUCK.
GUARANTEED! A RABBIT'S FOOT..
IF I KNOW HIM YOU BETTER COUNT YOURS.
©1958 WALT KELLY

Installed Capacity -- 980,000 MW (EIA)



Electrical Energy Basics

Texas RPS is based on installed capacity, not produced MW

Load Factor is % of installed capacity delivered on say an annual basis

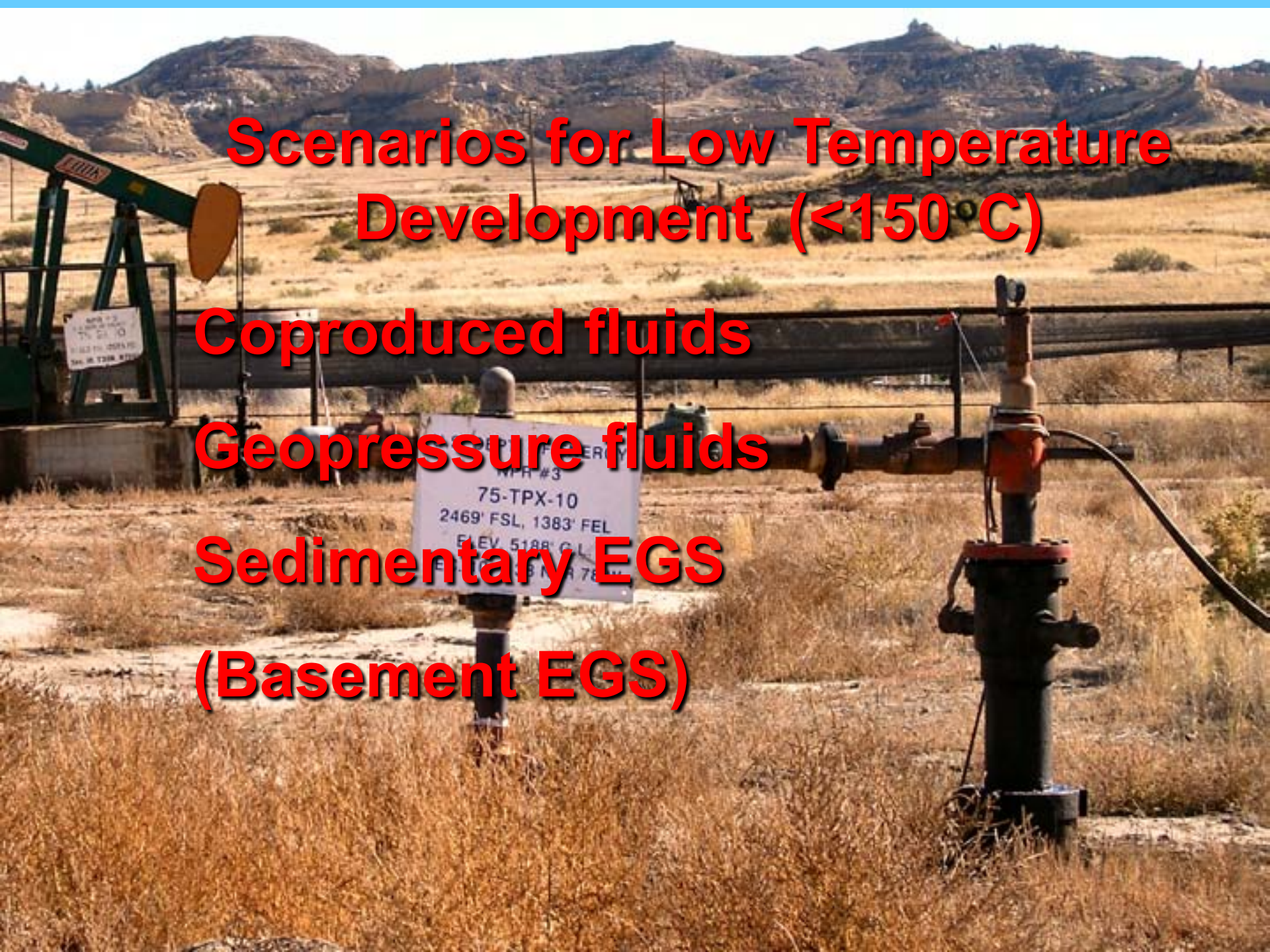
5,000 MW installed wind capacity at 30% load factor is 1,500 MW

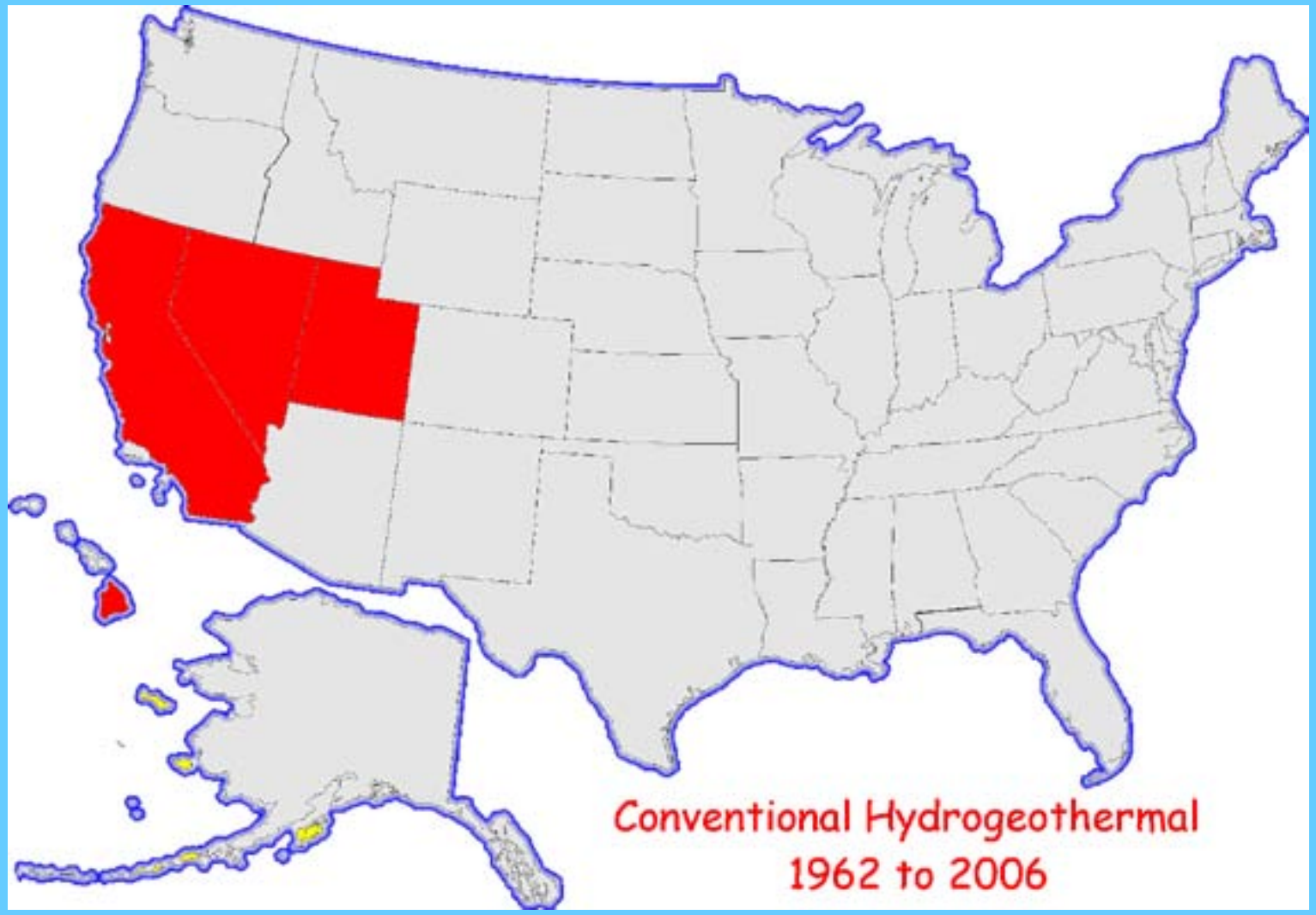
5,000 MW installed at 3% load factor is 150 MW

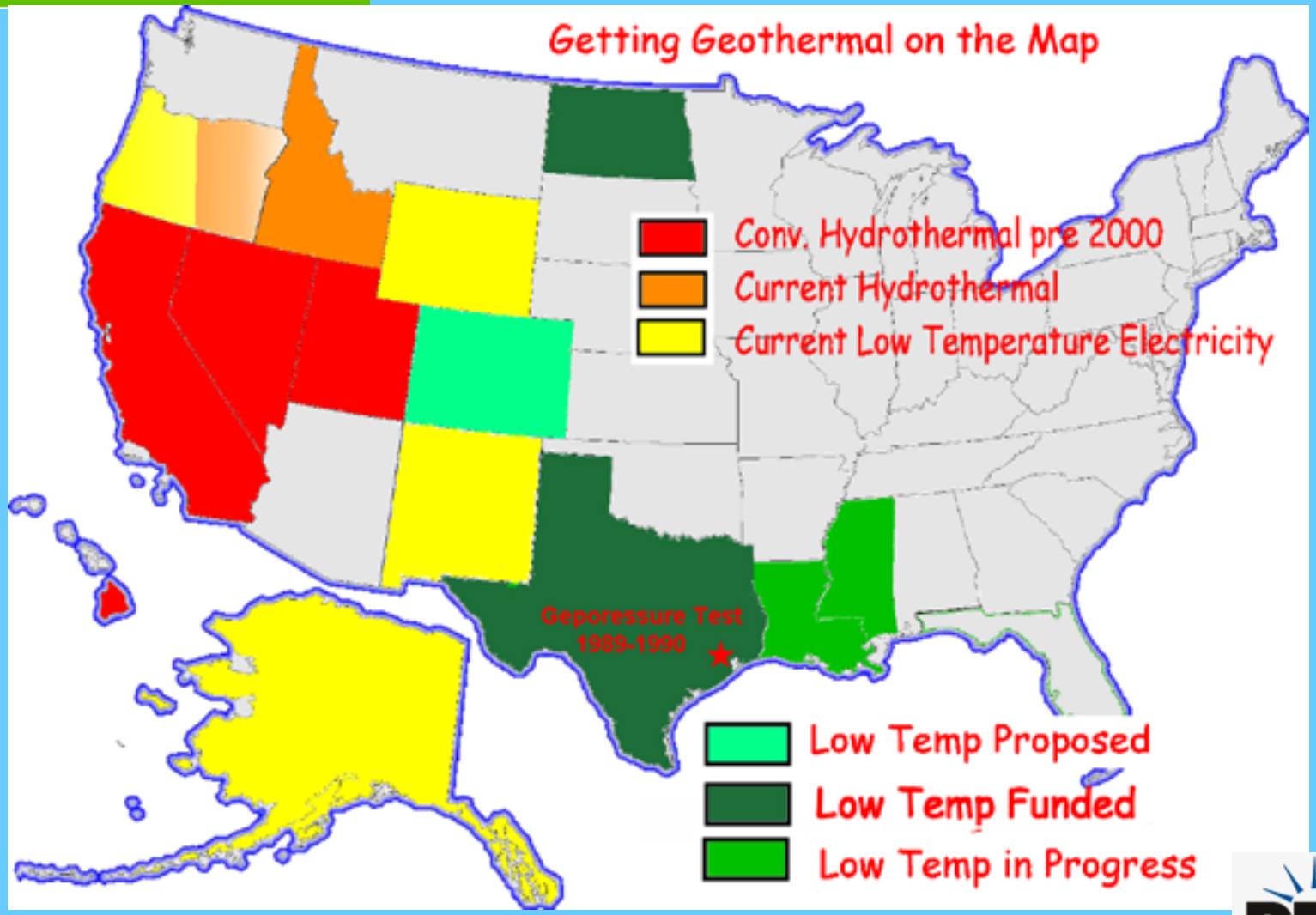
Wind Power is in West Texas, requires power lines to be built, the cost will be $5,000,000,000

$5,000,000,000 will build 1,500 to 2,500 MW Geothermal installed

$5,000,000,000 translates to 1,350 to 2,250 MW at 90 % load factor


Scenarios for Low Temperature Development (<150 °C)
Coproduced fluids
Geopressure fluids
Sedimentary EGS
(Basement EGS)
75-TPX-10
2469' FSL, 1383' FEL


Conventional Hydrogeothermal
1962 to 2006


Getting Geothermal on the Map
Conv. Hydrothermal pre 2000
Current Hydrothermal
Current Low Temperature Electricity
Geopressure Test
1989-1990
Low Temp Proposed
Low Temp Funded
Low Temp in Progress

SMU Web site: http://smu.edu/geothermal

Southern Methodist University

Geothermal Laboratory

"Bringing The Earth's Energy Into Your Community"

P.O. Box 750395
Dallas, TX 75275

Voice: 214-768-2749
Fax: 214-768-2701

Site Map

(plus signs for subcategories or words to link)

- + SMU Geothermal Databases
- + Geothermal Heat Pumps
- + Geothermal Resources
- + Informative Links
- + Oil & Gas
- + Publications
- + SMU Geothermal Degree
- + Teacher - Educational Materials
- + Temperature Logs
- + Texas Geothermal Outreach and Networking Program

Conference News

Geothermal Energy Utilization Associated with Oil & Gas Development

June 17-18, 2008

Conference Details

Previous Conferences

Texas Renewables '07

Conference Presentations

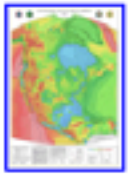
Abilene; November 13-14 2007

Geothermal talks:

Geothermal Energy (GSHP), **Shawn Beard** - *Energy America Geothermal;*

A Ground Source Heat Pump Initiative in the Blue Skyways Collaborative, **James Yarbrough** - *U.S. EPA*

Hot Topics



Geothermal Map of North America

Recent Press

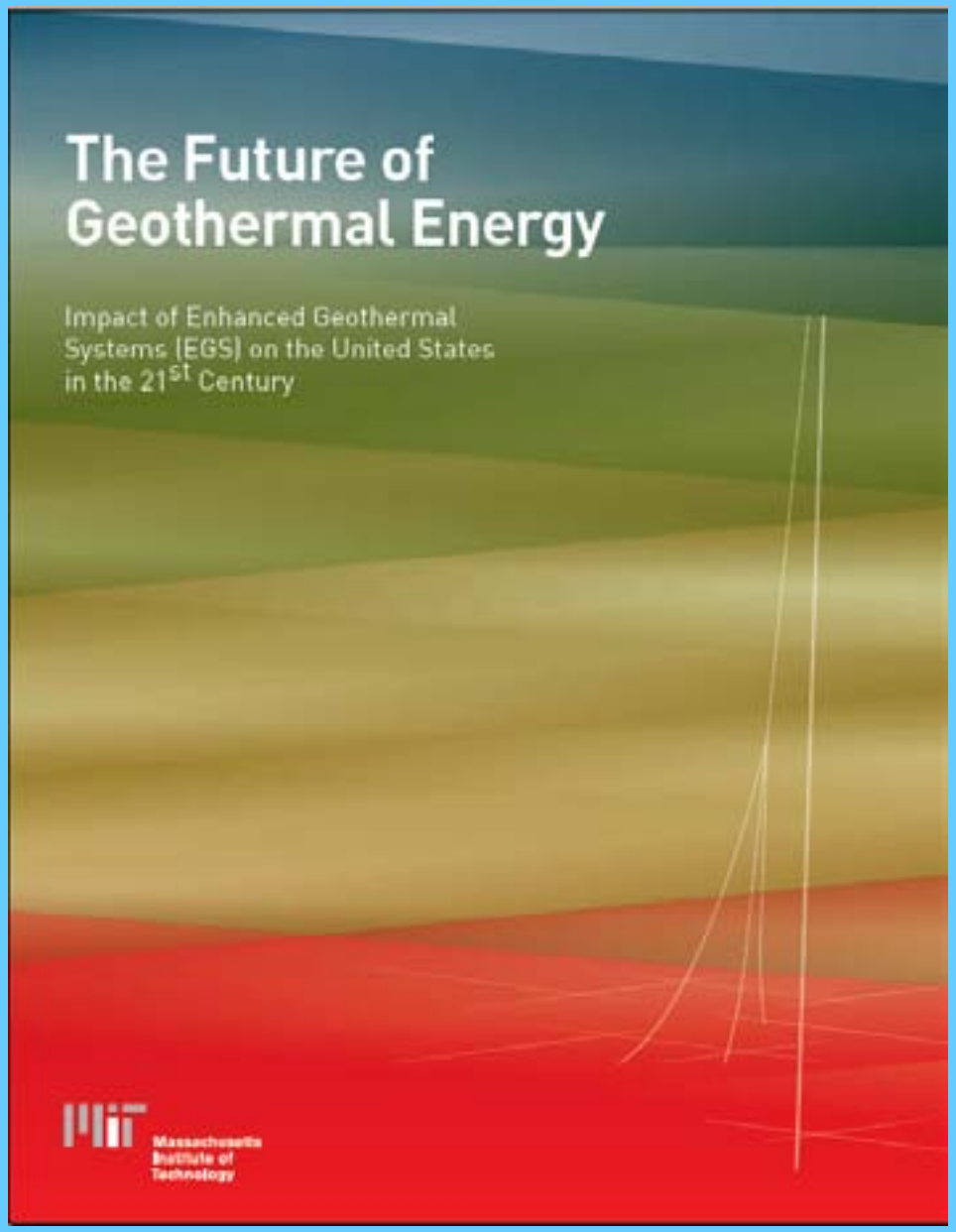
Google to Invest in Geothermal
New York Times 8/19/08

Google.org announcement 8/19/08

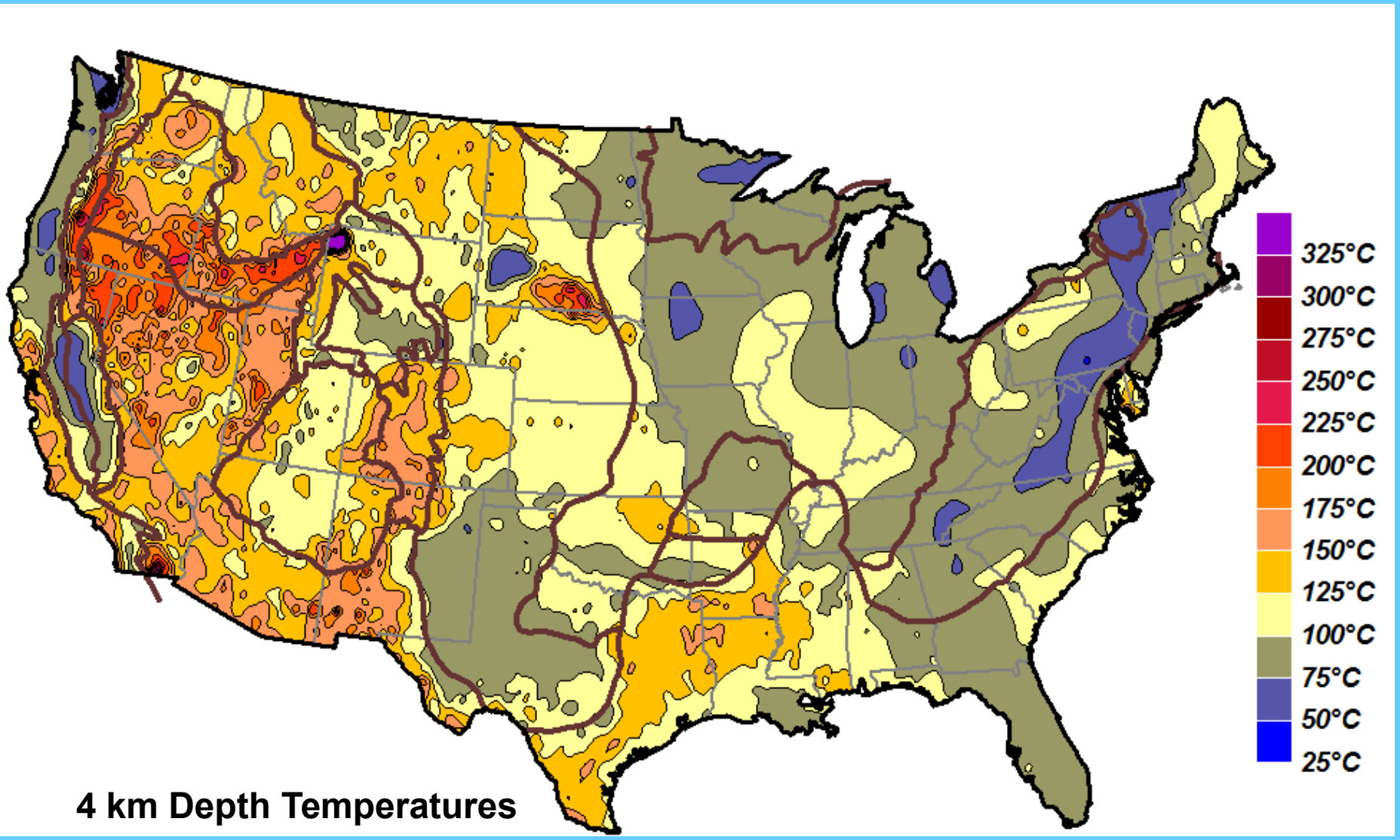
Free to be Green
DFW Chanel 33 News 7/25/08

In the Push for Alternative Energy, What Happened to Geothermal?
US News and World Report 7/21/08

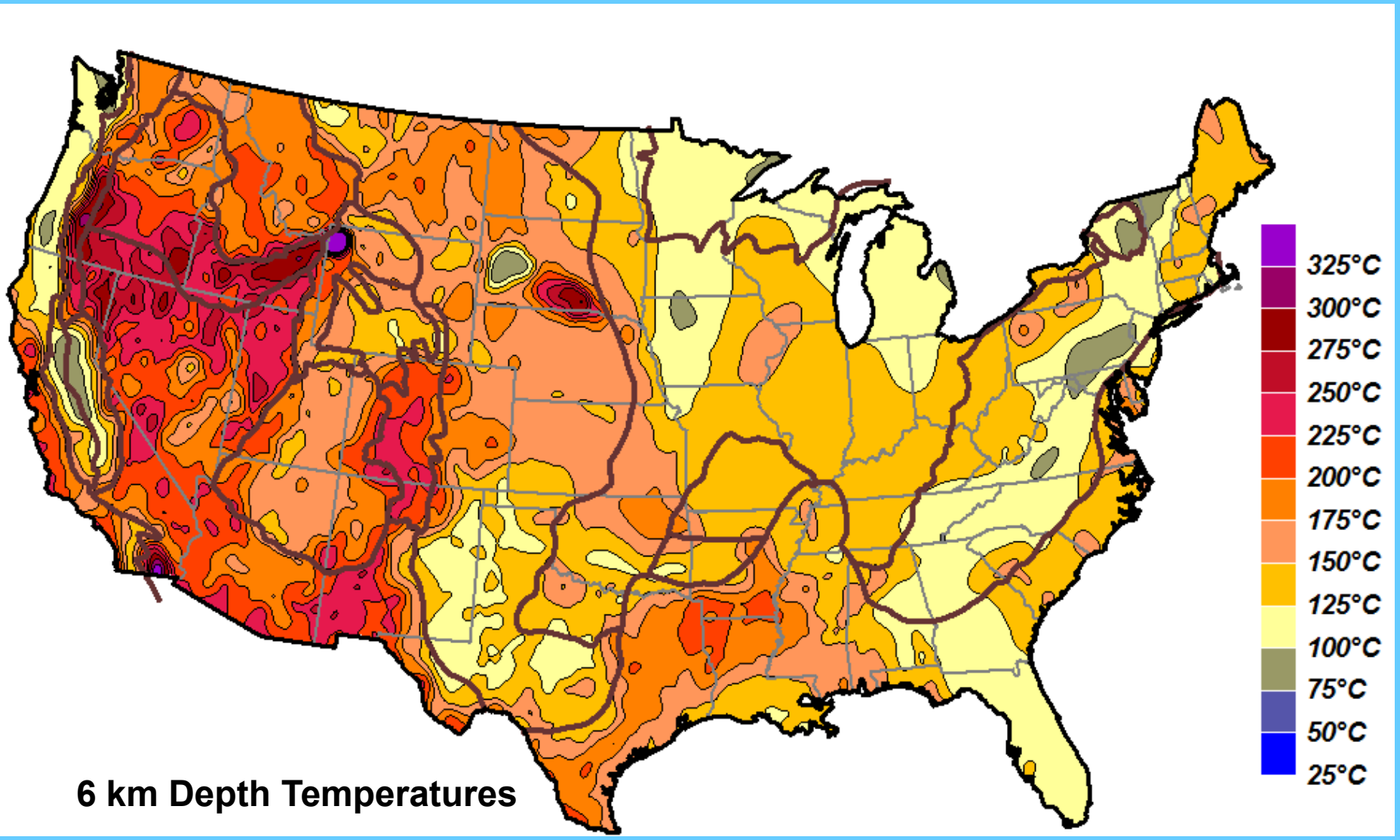
Oil, Gas and Geothermal Energy
SMU Press Release 6/19/08



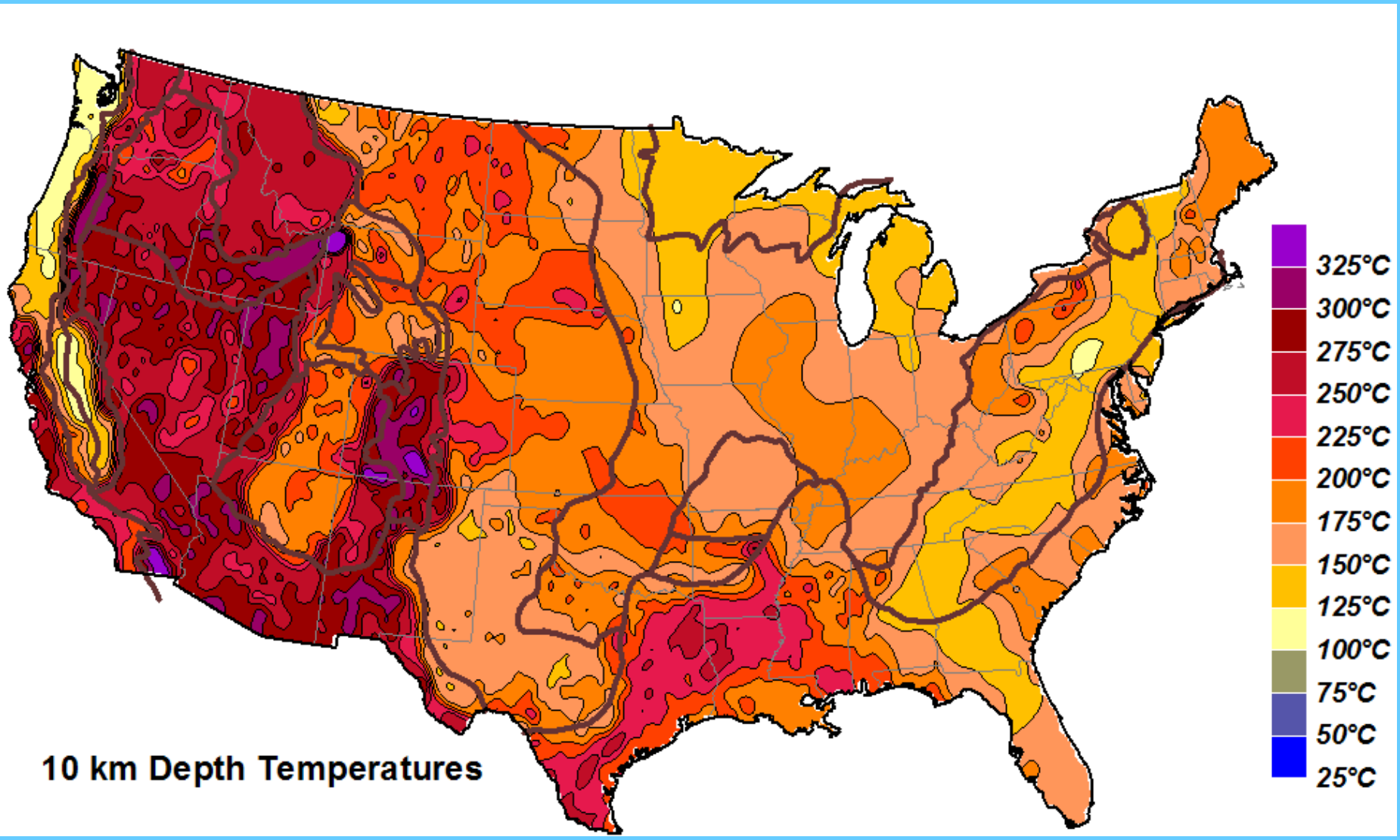
THE EGS SYSTEM
Introduction of water into rock of limited permeability (either tight sediment or basement) in a controlled fracture setting so that this water can be withdrawn in other wells for heat extraction,
i.e. heat mining



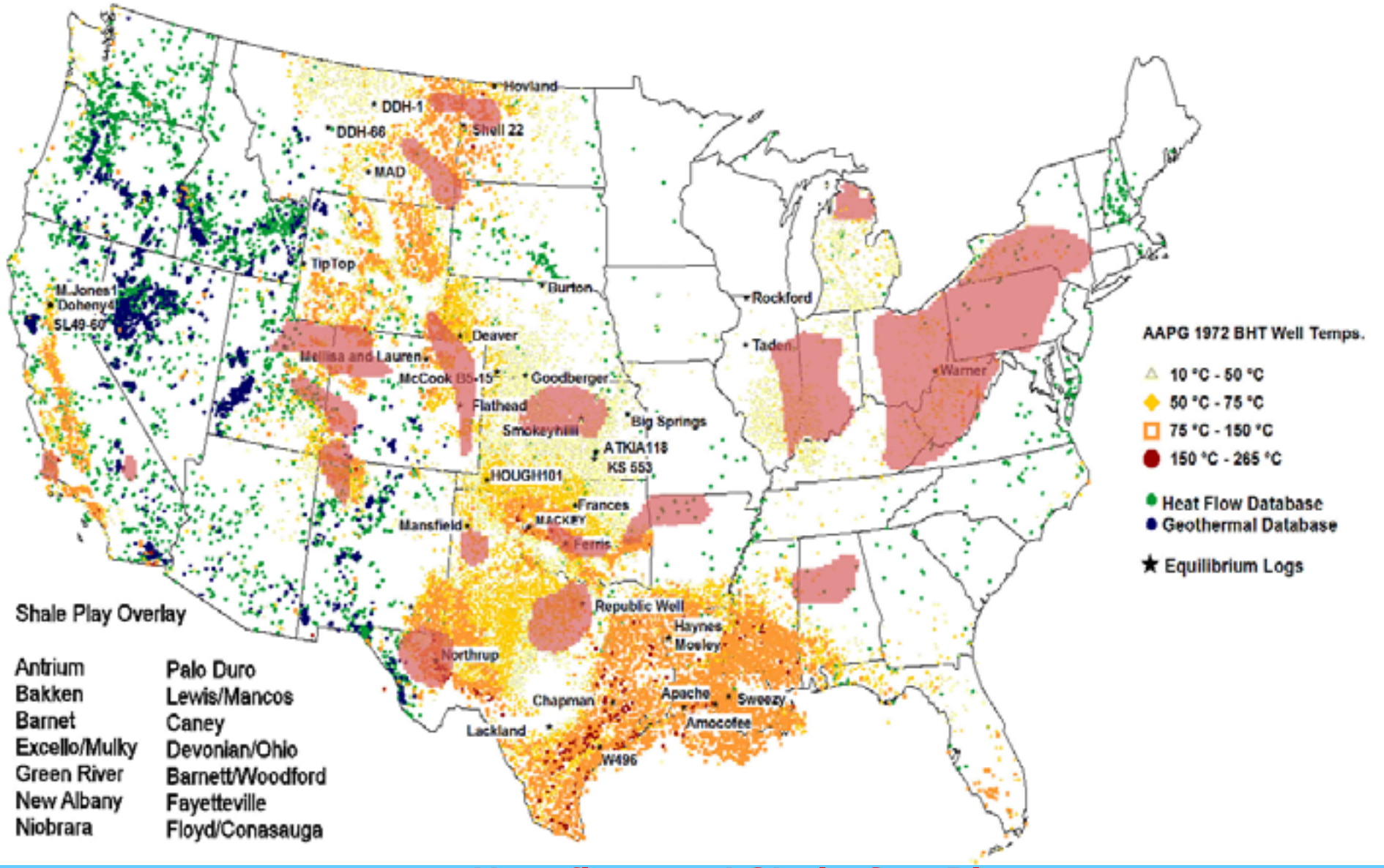
4 km Depth Temperatures



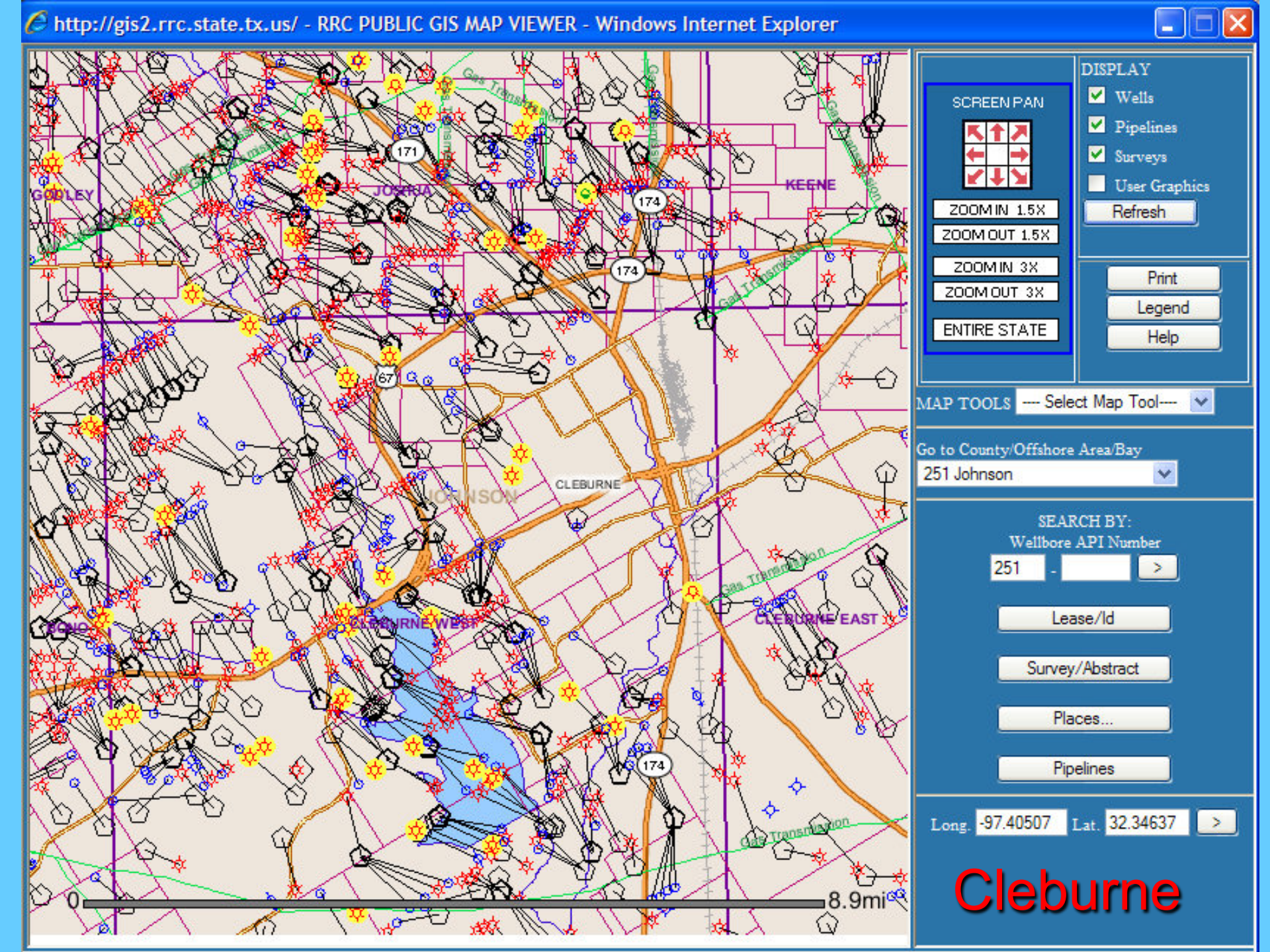
6 km Depth Temperatures

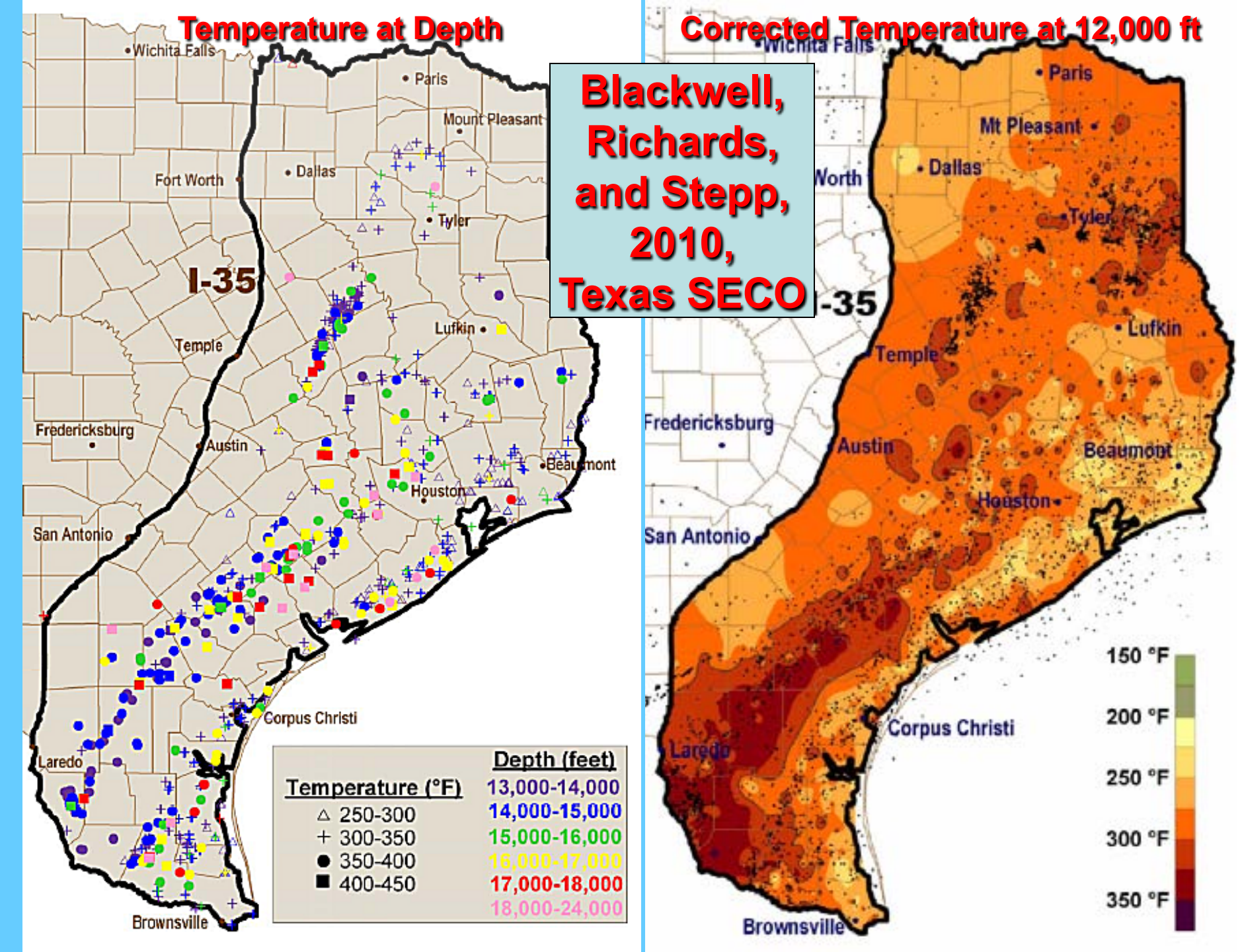

325°C
300°C
275°C
250°C
225°C
200°C
175°C
150°C
125°C
100°C
75°C
50°C
25°C
10 km Depth Temperatures

All data sites for US heat flow map including sites of wells with BHT data in the AAPG data base. BHT symbols are based on depth and temperature. The named wells are the BHT calibration points.

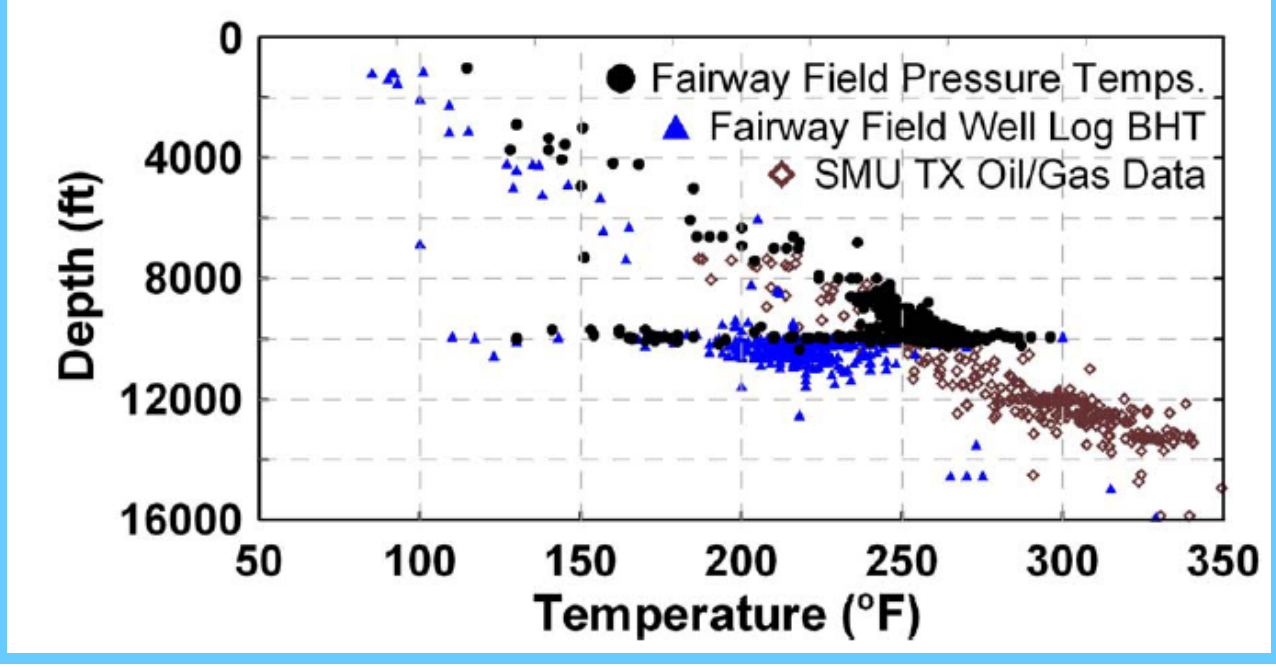


Heat flow, and Shale Gas Plays


http://gis2.rrc.state.tx.us/ - RRC PUBLIC GIS MAP VIEWER - Windows Internet Explorer
SCREEN PAN
ZOOM IN 1.5X
ZOOM OUT 1.5X
ZOOM IN 3X
ZOOM OUT 3X
ENTIRE STATE
DISPLAY
Wells
Pipelines
Surveys
User Graphics
Refresh
Print
Legend
Help
MAP TOOLS
---- Select Map Tool----
Go to County/Offshore Area/Bay
251 Johnson
SEARCH BY:
Wellbore API Number
251
Lease/Id
Survey/Abstract
Places...
Pipelines
Long. -97.40507
Lat. 32.34637
Cleburne
GODLEY
JOSHUA
KEENE
CLEBURNE
JOHNSON
CLEBURNE WEST
CLEBURNE EAST
TOGO
171
174
67
0
8.9mi


Temperature at Depth
Corrected Temperature at 12,000 ft
Blackwell, Richards, and Stepp, 2010, Texas SECO
Wichita Falls
Paris
Mount Pleasant
Mt Pleasant
Fort Worth
Dallas
Tyler
I-35
Lufkin
Temple
Fredericksburg
Austin
Beaumont
Houston
San Antonio
Corpus Christi
Laredo
Brownsville
Temperature (°F)
△ 250-300
+ 300-350
● 350-400
■ 400-450
Depth (feet)
13,000-14,000
14,000-15,000
15,000-16,000
16,000-17,000
17,000-18,000
18,000-24,000
150 °F
200 °F
250 °F
300 °F
350 °F

Blackwell, Richards, and Stepp, 2010, Texas SECO



Depth Range Feet	Number of Wells	Average Uncorrected Temperature °F	Average Corrected Temperature °F	Maximum Corrected Temperature °F
12,000 - 13,000	879	263	299	363
13,000 - 14,000	628	283	320	430
14,000 - 15,000	330	304	340	423
15,000 - 16,000	159	306	349	420
16,000 - 17,000	107	319	361	422
17,000 - 18,000	60	319	358	454
18,000 - 24,000	46	362	402	544

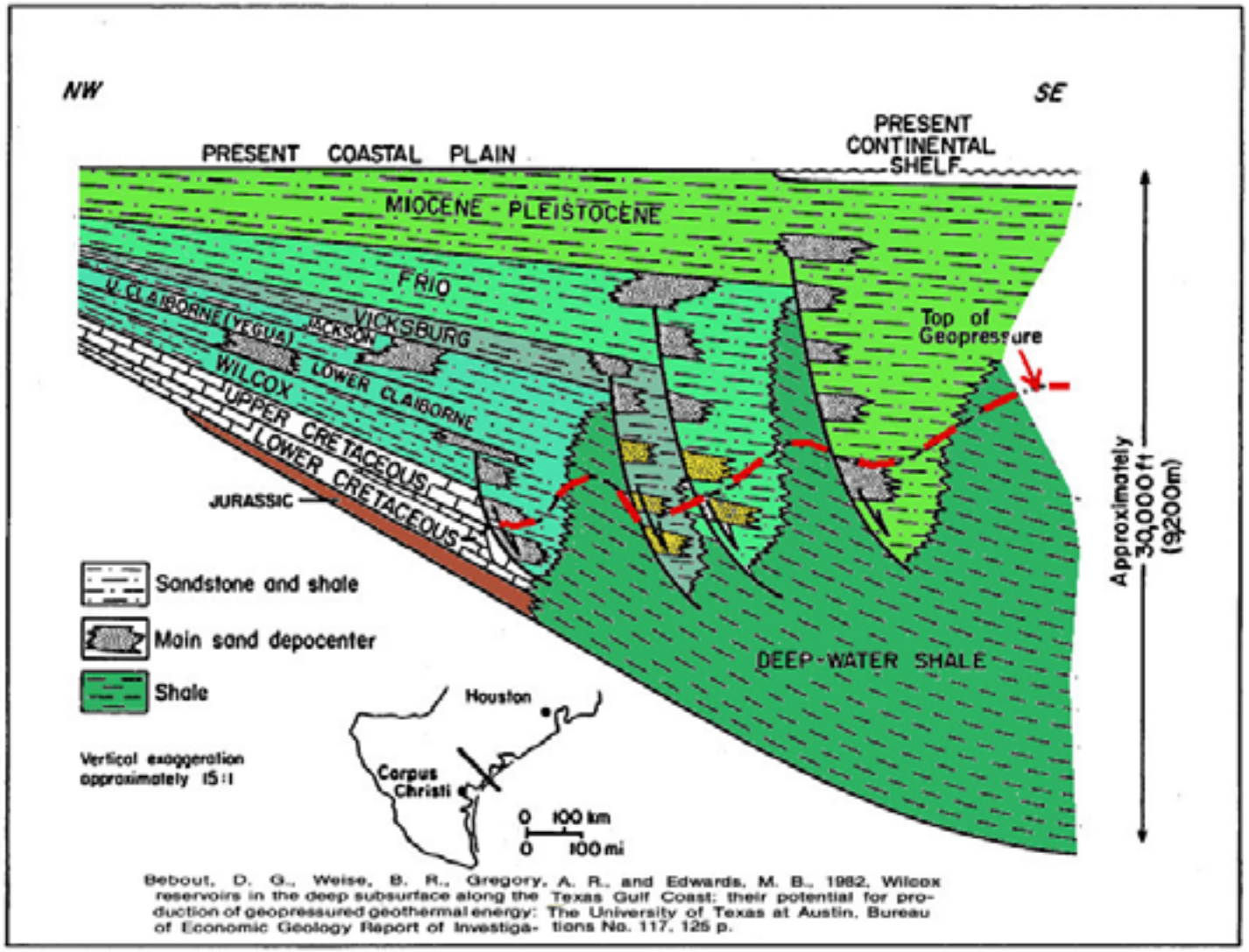
GEOPRESSURED GEOTHERMAL ENERGY

- A Geopressured Geothermal resource is an over-pressured body of hot water, saturated with methane gas, which flows to the surface and can be re-injected under its own power
- The resource has two sources of energy – geothermal heat and natural gas. Both can be separated from the water and converted into usable energy using a hybrid Geothermal plant
- Each Geopressured Well/installation is capable of producing 2-5MW. These individual wells can be part of a cluster capable of producing 20-50MW each. Hundreds of oil and gas fields with requisite formation pressure, temperature and thousand of previously drilled wells exist in Texas alone
- The power potential of a Geopressured Geothermal resource has been successfully demonstrated by the DoE at a commercial pilot scale: a 1MW Hybrid Plant was operated on a Geopressured Well at Pleasant Bayou in Texas between 1989-90
- A recent evaluation of this technology (Griggs et al, 2004) concluded that "the commercial production of Geopressuzied Geothermal aquifers is now feasible under reasonable assumptions of natural gas and electricity prices" (i.e. natural gas prices of $4.50 Mscf and wholesale electricity prices of $0.03 kWh). The current price of natural gas is approximately $9.89 Mscf and wholesale electricity prices of $0.058 kWh

Geopressured Resource, US

Geopressured Resource, Worldwide

Pleasant Bayou, Texas



Schematic cross section, central Texas Gulf Coast, showing relationship among major growth faults, expansion of section, sand depocenters, and top of geopressure (after Bebout and others, 1982).

Gulf Coast Geology and Geopressure Geothermal Resource Setting: USGS (1979) estimates 70 to 170 MW resource potential (gas & heat)

Geopressure Power Plant

- Pleasant Bayou, Brazoria, Texas 1989-1990

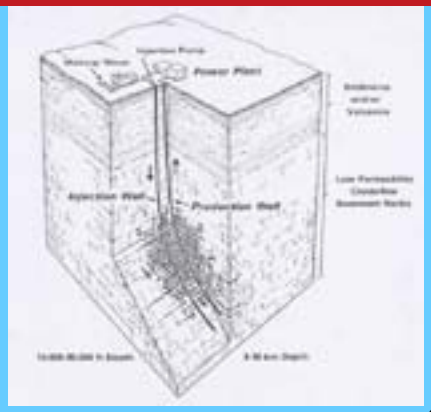
SEDIMENTARY ENGINEERED GEOTHERMAL SYSTEMS (EGS)

- Sedimentary EGS targets hot, tight sedimentary rock with limited permeability. Controlled fracturing is applied such that heat can be transferred to water which is withdrawn for heat extraction.
- Sedimentary EGS can be developed as a "field" and can produce 25-250MW of power per field
- East and West Texas, N. Louisiana, Montana, N. Dakota, Colorado and Utah have favorable areas where low permeability tight formations with temperatures as high as 400 F are currently being exploited as tight gas systems
- The Grosse Schönebeck project near Potsdam is a typical sedimentary EGS project and is now successfully being tested
- The major advantages of Sedimentary EGS in Oil and Gas Setting are:
  - Many wells with BHT's over 300 F at 15,000 ft or less and reservoir is already fractured
  - Water is easily available from well or adjoining wells in fields
  - In-place infrastructure of power lines, roads, pipelines, etc.
  - Possible continued stripping of O&G in otherwise non-economic wells

Worldwide Sedimentary Basins

Gross Schönebeck, Germany

EGS Schematic



CO-PRODUCED GEOFLUIDS

- Hot water is a co-product of Oil and Gas development– where it is considered a ‘waste product’ and typically passed to a central collection facility (for hydrocarbon separation and water cooling/ disposal).
- In mature fields, the Water/ Oil cut can be as high as 95%-98% (e.g., 97% in Texas)
- It is feasible to ‘piggyback’ a small-scale Geothermal Plant onto existing infrastructure to recover energy from this ‘waste water’ stream. There are minimal plant development costs (no drilling or well development) and recent innovations in low temperature Binary Plant technology (e.g., UTC Purecycle) have led to a significant reduction in capital equipment costs (e.g., Chena Hot Springs Resort in Alaska)
- Estimates for the Geothermal resource from existing Hydrocarbon production facilities in Texas alone range from 420MW-2,300 MW (depending on inlet temperature and production flow rates)

Co-Produced Energy Potential Across Selected States

UTC PureCycle

Chena Resort, AL

DOE Stimulus Funding: Geothermal $338,000,000

2) Coproduced, Geopressured, and Low Temperature Projects				
Universal GeoPower LLC	$1,499,288	Liberty County	TX	Universal GeoPower LLC will utilize a modular low temperature binary unit to produce power from oil and gas wells in Liberty County, Texas.
University of North Dakota	$1,733,864	Williston Basin, (Bowman County)	ND	The University of North Dakota will utilize a low temperature binary unit to produce power from oil and gas wells in Bowman County, North Dakota.
Louisiana Tank, Inc.	$5,000,000	Cameron Parish	LA	Louisiana Tank, Inc. will demonstrate the feasibility of a geopressured power plant in Cameron Parish, Louisiana.
University of North Dakota	$1,733,864	Williston Basin, (Bowman County)	ND	The University of North Dakota will construct a low temperature power plant in Bowman County, ND.

Wind Power Grants: Texas

- Bull Creek: $ 91,390,497
- Pyron Farm: $121,903,906
- Penascal: $114,071,646
- Barton Chapel: $ 72,573,627

Geothermal Energy from Oil and Gas Fields

- Base Load
- Green, no emissions
- Located in industrialized areas
- Financing by long term loans
- Lowers cost of production
- Multibillion dollar market in Texas alone
- Large scale gas resources developed with geopressure
- PTS and Severance Tax Avoidance

Economics of EGS in Oil Fields

- Scenario 1 – Wells of opportunity assumptions
  - Depleted oil field with 1000 psi overpressure
  - Wells 12,000 ft deep with 5” completion
  - Temperature 300 F
  - Build 50 MW plant -$110,000,000
  - Need 117 wells!
  - Competed above primary hot water reservoir
  - Pumped with 700 HP motor
  - Maximum flow rate - 450 gpm
  - Cost of Power – 8.91 ¢/kWh

Economics of EGS in Oil Fields

- Scenario 2 – Drill new wells assumptions
  - Dry holes in area of soft geopressure ~1000 psi overpressure
  - Wells 12,000 ft deep with 9 5/8” completion
  - Temperature 300 F
  - Build 200 MW capacity – 30 wells for $190,000,000
  - 200 MW binary plant for $220,000,000
  - Drill and complete with screen and gravel pre-pack
  - Stimulate to achieve higher flow rates
  - Pumped with 700 HP motor
  - Maximum flow rate - 1500 gpm
  - Cost of Power – 8.07 ¢/kWh

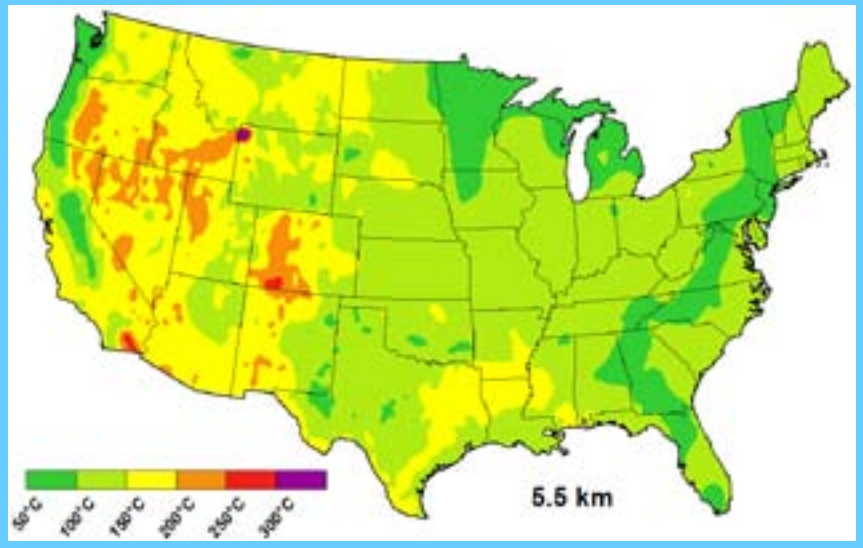
Reality Check EGS

What would need to happen to make EGS a reality?

- Reduce the cost of power through technology improvement and learning by doing
  - Increase flow rate per producer by improving stimulation methods
  - Reduce drilling cost by reducing number of casing intervals, improving rate of penetration and reducing risk
  - Improve conversion efficiency
- Identify high temperature oil fields with potential for high volume water production
- Develop a commercial project with DOE/industry in at least two areas with different geology

Reaching the Goal

- To get 1000 MW of EGS power on line we need:
  - 1 well in 3 months, average 5 MW per well
  - 16 rigs drilling for three years
  - 4 sites with 250 MW potential
  - Identify fields with declining production and large numbers of wells that can be recompleted.
  - Identify large areas of uniform hot rock at reasonable depth from O&G drilling data
  - Use hot oil/gas fields to get data and starting points for projects



Susan Petty & Bill Livesay

From Hot Water to Hydrogen

Bringing Geothermal Power to Alaska

Presented by: **Bernie Karl**

SMU Geothermal Conference June 12th, 2007


Hot Water Storage Tank, 195°F
250 kW Turbine and Generator
Spent Water, 170°F
to cooling tank


Seperators, oil (1%) and water (99%) enter and are seperated, ~200°F
Cooling Tank
Hot Water Tank
RMOTC, Tea Pot Dome, Casper, Wyoming

Chena Mobile Power System

Denbury Resources - Gulf Coast Green Energy

RPSEA.org Demonstration Project

Mississippi Summerland Field

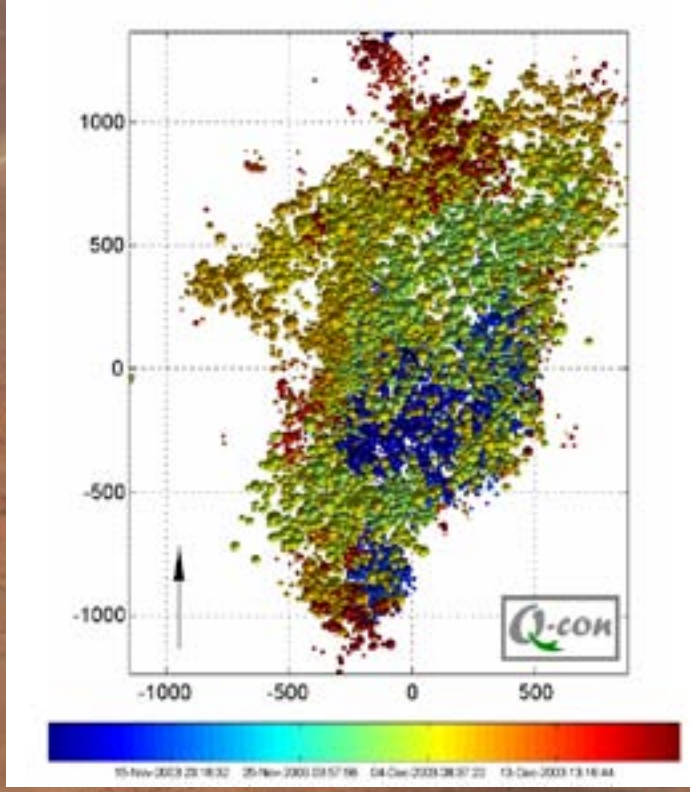
190 F current surface temperature

Raser Thermo, Utah 12.5 MW Geothermal Development- Cascaded UTC 250kW Units

Aerial view of the 50-unit power generation network.

A panorama from the day of the ribbion cutting ceremony.

GeoDynamics Ltd
South Australia Project



Geothermal Drilling & Geophysical Surveys to YE 09

Geodynamics/Origin/Tata Power/Sentient-SunSuper (HR)
- 2003-5: Proved flow of geothermal energy with Habanero 1 & 2
- 2007-9: Habanero 1 - 3 closed loop flow, Jolokia 1 & Savina 1 drilled.
- Next: Two more deep wells, 1 MW deployment. Decision to upscale 2010/11

Petratherm/Beach Petroleum/TRUenergy (HR)
- 2005-7: Drilled Yerila and Paralana, deepened Paralana & recorded MT + seismic
- Next: Now drilling Paralana 2 to 4000m. Then Paralana 3

Geothermal Resources (HR)
2007-9: drilled 8 Frome area wells up to 1809m depth
- Next: Drill deep wells in the Frome area

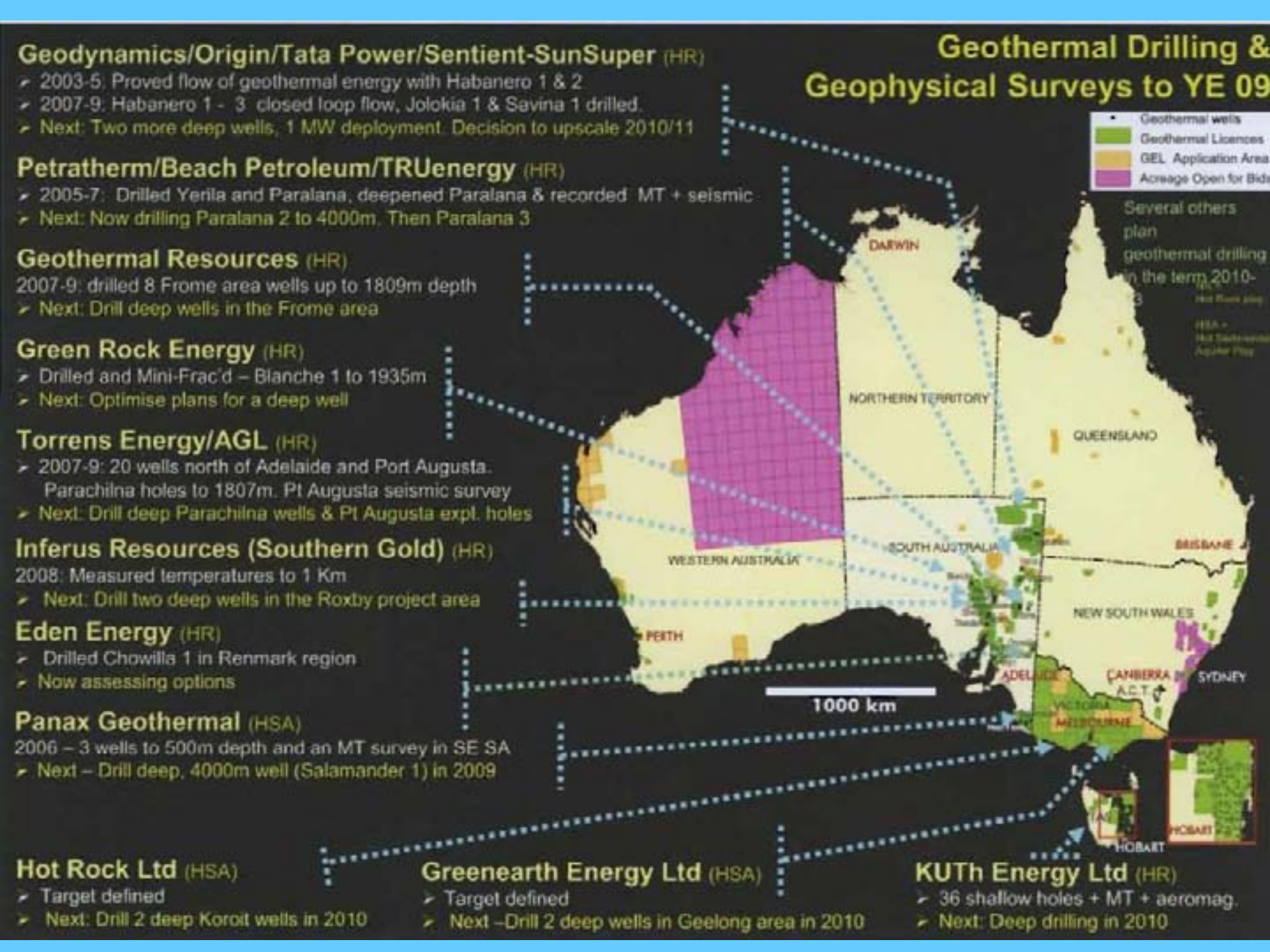
Green Rock Energy (HR)
- Drilled and Mini-Frac'd – Blanche 1 to 1935m
- Next: Optimise plans for a deep well

Torrens Energy/AGL (HR)
- 2007-9: 20 wells north of Adelaide and Port Augusta. Parachilna holes to 1807m. Pt Augusta seismic survey
- Next: Drill deep Parachilna wells & Pt Augusta expt. holes

Inferus Resources (Southern Gold) (HR)
2008: Measured temperatures to 1 Km
- Next: Drill two deep wells in the Roxby project area

Eden Energy (HR)
- Drilled Chowilla 1 in Renmark region
- Now assessing options

Panax Geothermal (HSA)
2006 – 3 wells to 500m depth and an MT survey in SE SA
- Next – Drill deep, 4000m well (Salamander 1) in 2009



Hot Rock Ltd (HSA)
- Target defined
- Next: Drill 2 deep Koroit wells in 2010

Greenearth Energy Ltd (HSA)
- Target defined
- Next –Drill 2 deep wells in Geelong area in 2010

KUTh Energy Ltd (HR)
- 36 shallow holes + MT + aeromag.
- Next: Deep drilling in 2010

Geothermal Incentives and Financing

Texas H.B. 4433 Hydrocarbon Tax Exemption from Geothermal Wells (effective September 1, 2009)

"Exempts from severance taxes oil and gas incidentally produced in association with the production of geothermal energy."

Severance Taxes *Exemption* if produced with Geothermal Energy

- **Gas (7.5%)**
- **Oil (4.6%)**

ITEMS TO CONSIDER FOR DEVELOPMENT

-Assess Resources

Geopressure

Public Information

Legal Regulations

Power Plant Eng.
-Turbine
-Cooling Methods

Gov/Private Leases

Economics

RECs/ Tax Credits

Transmission Lines

Oil & Gas Wells Producing Water

Injection Wells

Abandoned Wells

If Life Gives You Hot Water

Make Ice!