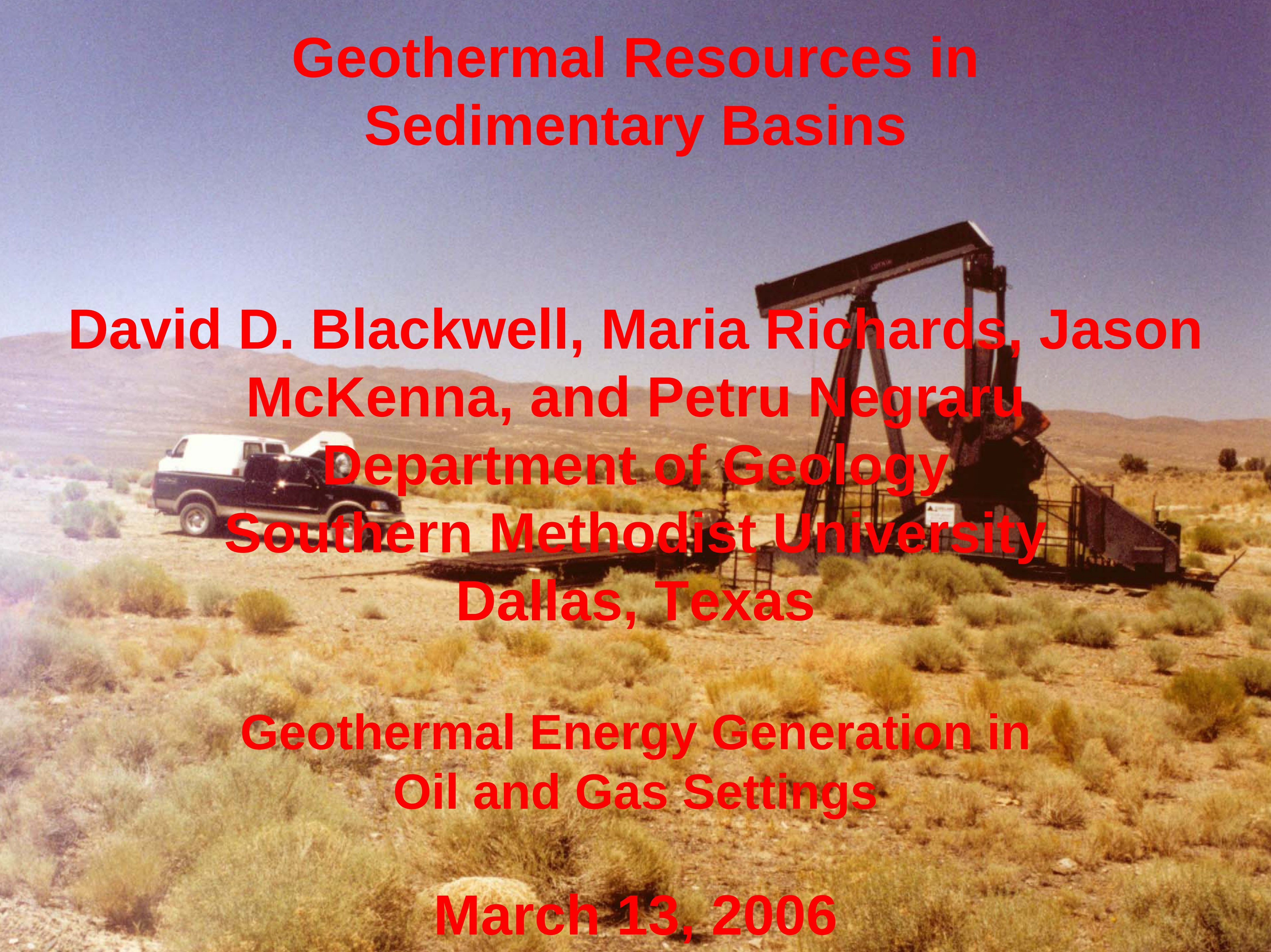

Geothermal Resources in Sedimentary Basins

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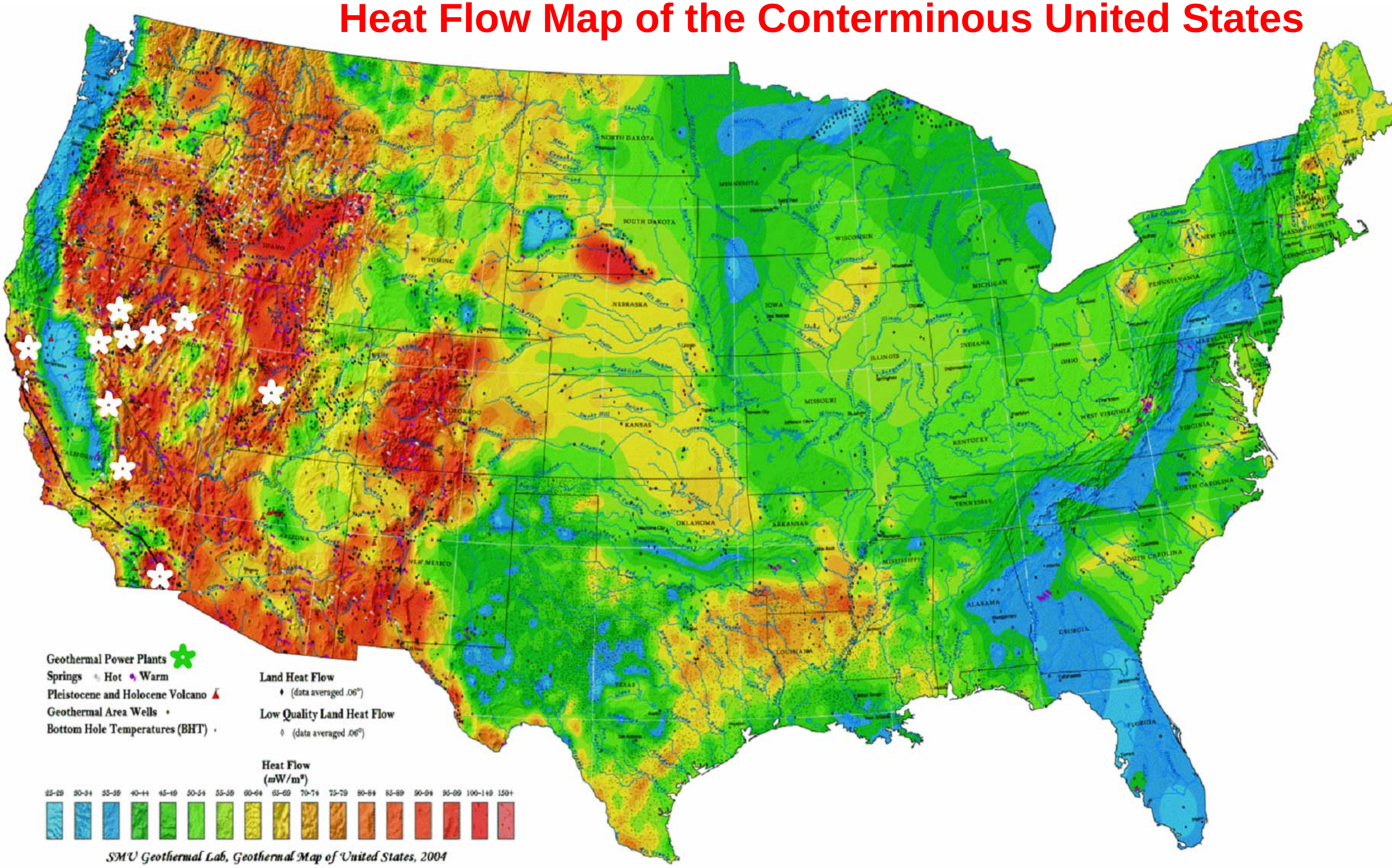
Geothermal Energy Generation in Oil and Gas Settings

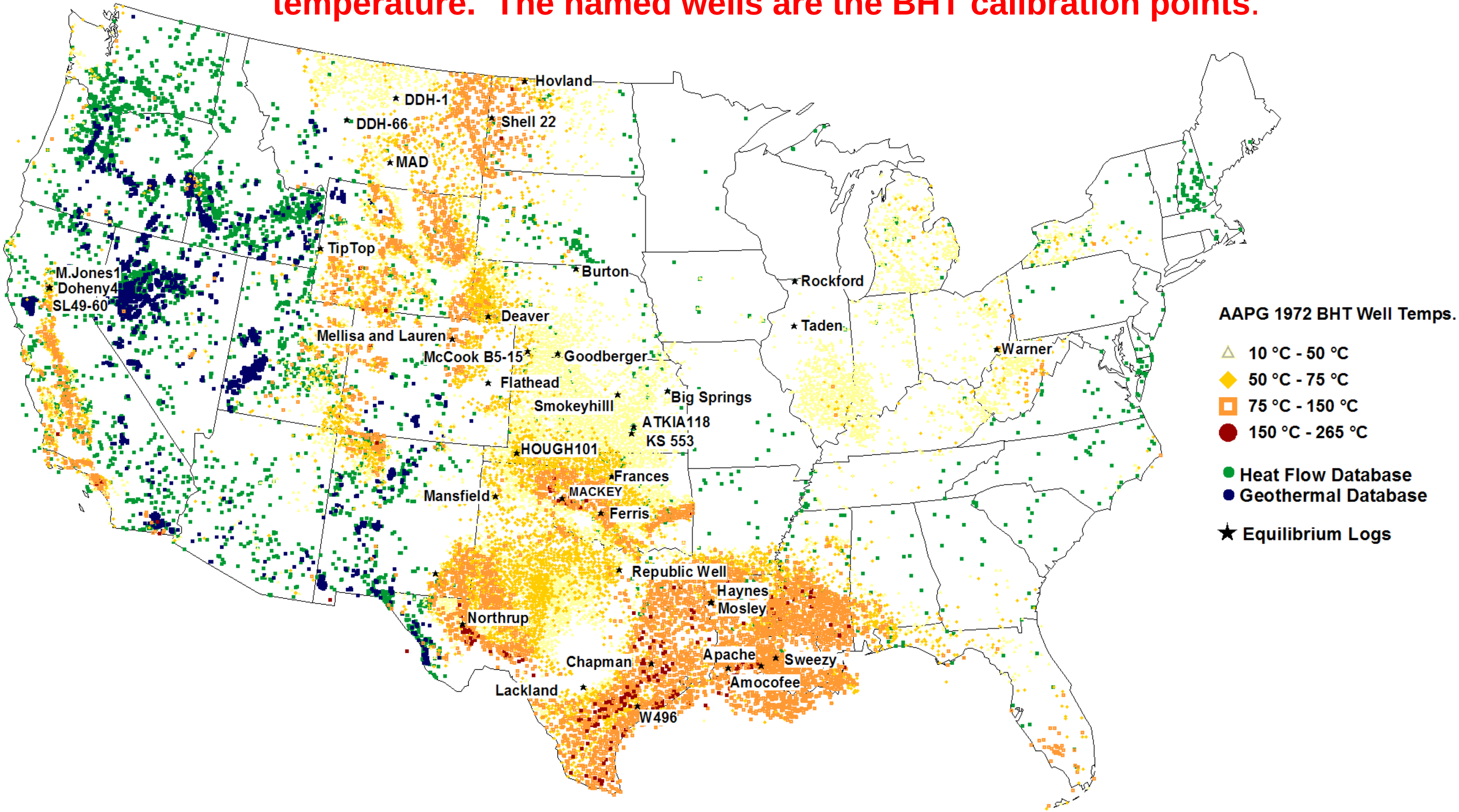
March 13, 2006

Heat Flow Map of the Conterminous United States



Subset of the Geothermal map of North America (Blackwell and Richards, 2004), current geothermal power plants are shown as white stars.

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 BHT sites

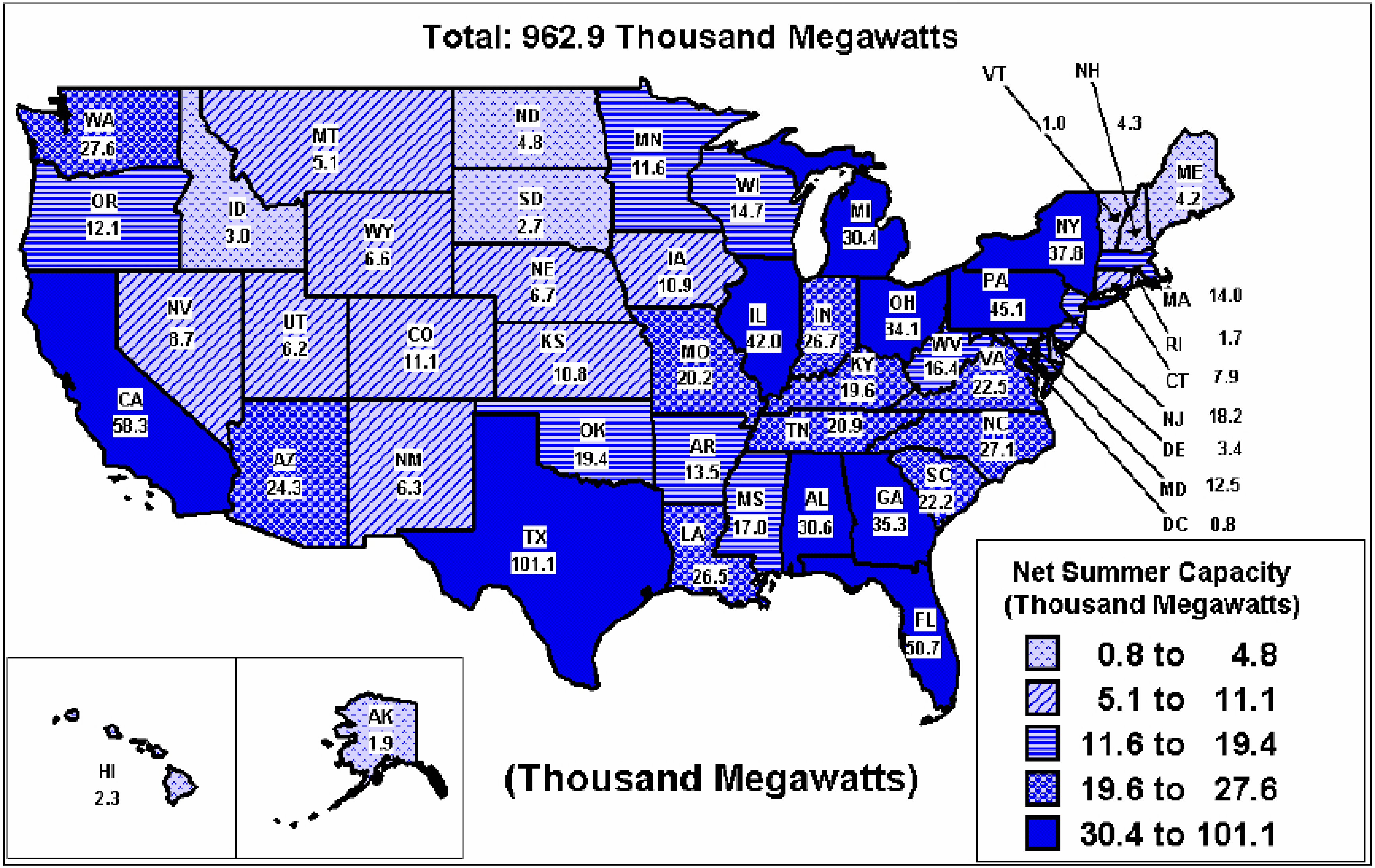
Scenarios for Development in Sedimentary Basins

Coproduced fluids
Geopressure fluids
Sedimentary EGS

These are briefly described, resource base discussed, and examples of development given for each category

The resource base for these 3 types of geothermal development is briefly summarized: HUGE!

U.S. Electric Power Industry Existing Net Summer Capacity by State, 2004



Source: Energy Information Administration, Form EIA-860, "Annual Electric Generator Report."

Geothermal Resource Base Summary, Conterminous US

Category	Thermal Energy ExoJoules (10^{18})	Methane 10^{12} ft^3	Total Energy ExoJoules
Geopressure			
Papadoulopous et al. (1975)	46,000	669	71,000
Wallace et al. (1979)	107,000	59	170,000

Sedimentary EGS >

Basement EGS (4-8 km) 12.9×10^6 ExoJoules

Coproduced Resources 2,500-12,000 MWe (100°C – 150°C water)

Gulf Coast Resources

Present US installed electricity 1.0×10^6 MW

The EGS resource base for Texas alone (at temperature above 150°C (300°F) and depths less than 7 km (23,000 ft)) is 255,000 EJ, or $4.1x10^8$ MWsecs-20yrs.

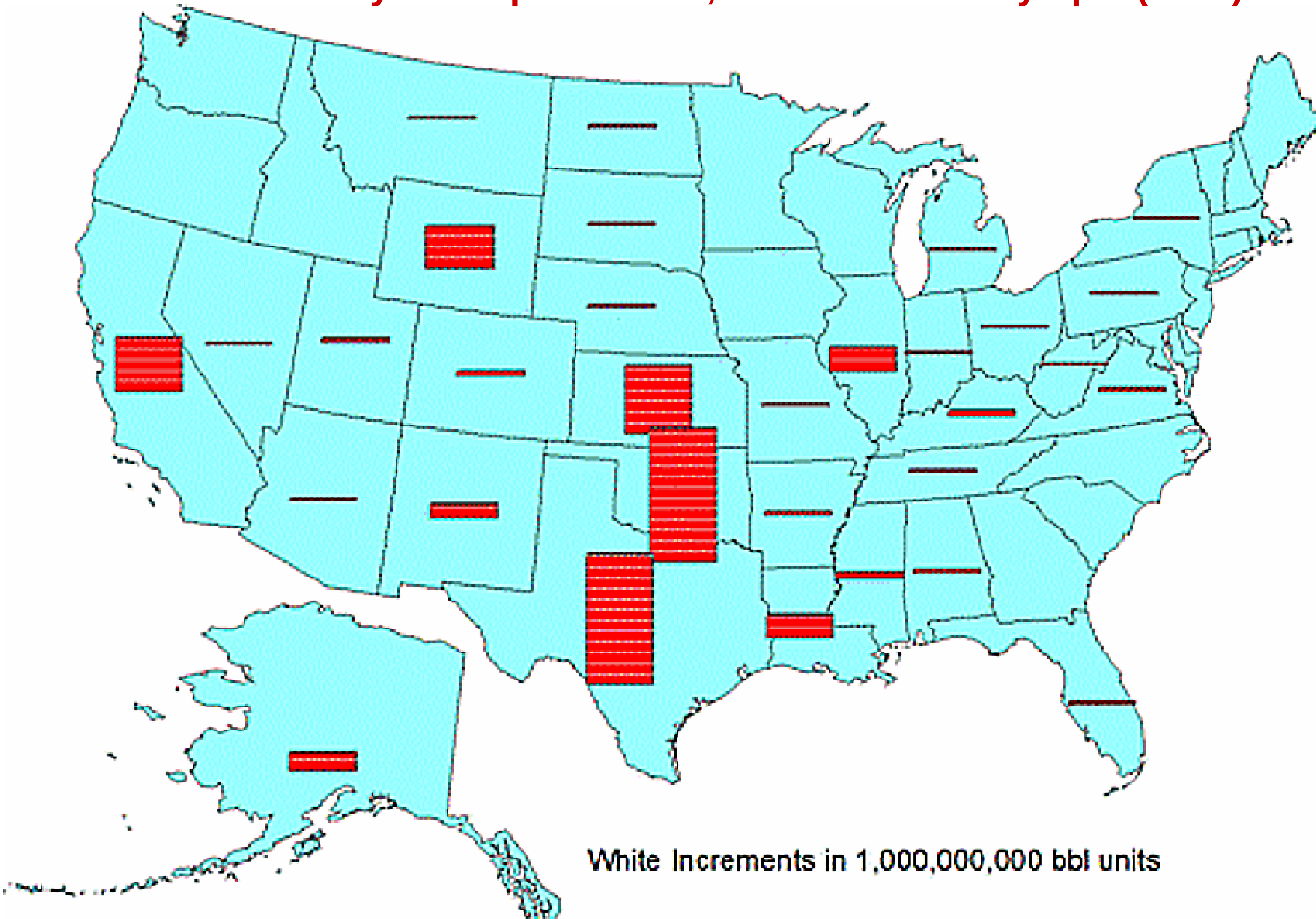
If a recovery factor of 1% is used there is still $4.1x10^6$ MWsec for 20 years available (the present installed electrical power capacity in Texas of $0.1x10^6$ MWe).

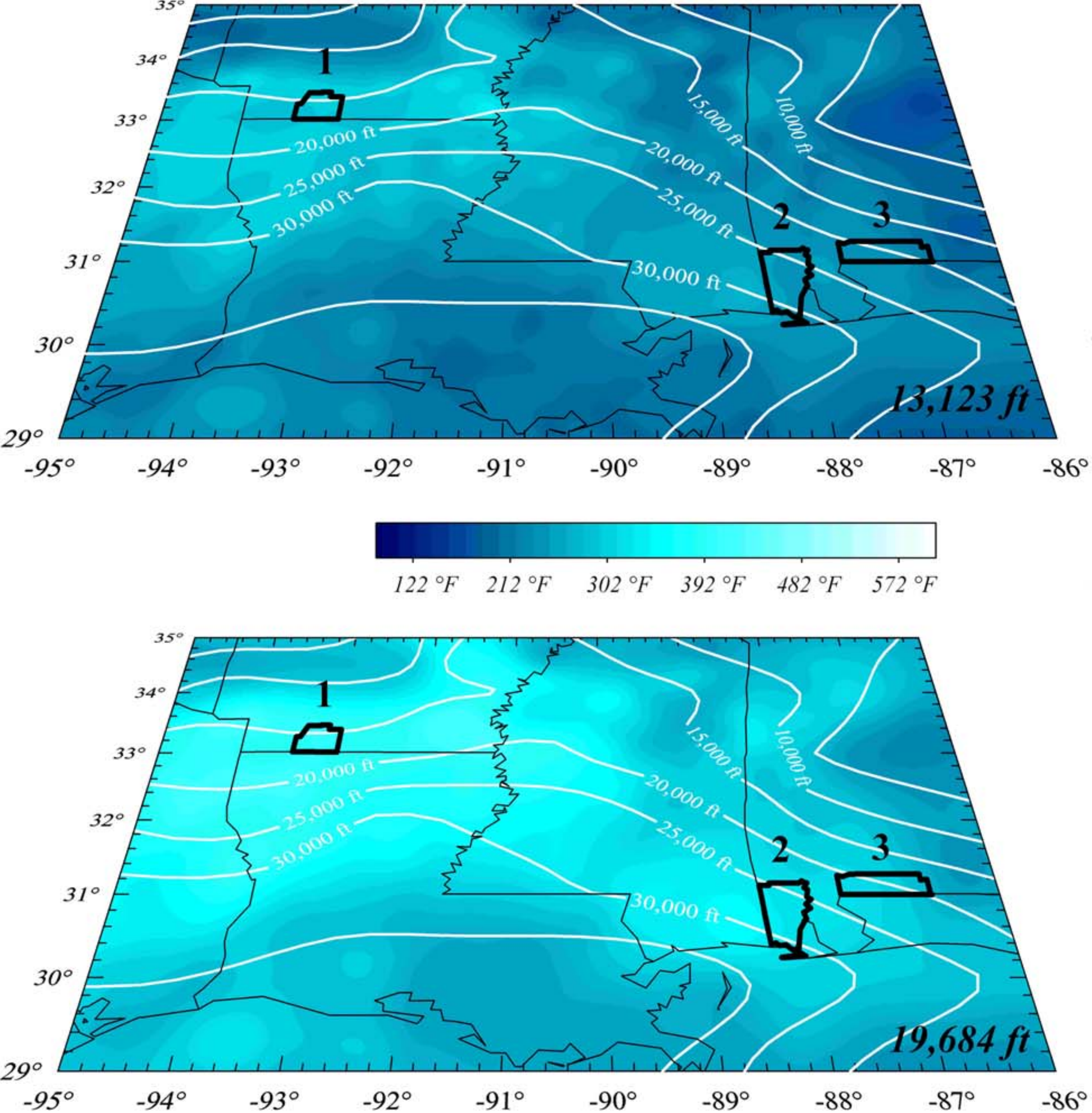
The US Geological Survey has estimated the resource in the geopressured setting in Texas and Louisiana to be $1.74x10^{14}$ MW-20 yrs plus the dissolved gas (10^9 mcf).

The geothermal number is essentially in addition to the EGS component of the resource. In the case of the geopressure there is also the potential for producing huge amounts of gas that would be otherwise uneconomical to produce.

Coproduced Fluids

US Yearly water production, Curtice and Dalrymple (2002).





1

1,077,487 bbl water/month
~7,600 ft @ ~ 210 °F

2

272,836 bbl water/month
21,596-655; 21,762-784 ft @ ~ 325 °F

3

660,479 bbl water/month
15,380-15,470 ft @ ~ 270 °F

Equivalent geothermal power, at a 90% load factor, from water associated with existing hydrocarbon production. WPR is water production rate in thousands of gallons per minute. Conversion efficiency from DiPippo (2006). Alaska, California, Wyoming, and Illinois also have significant water production.

State	Total Water (bbl)	WPR(kgpm)	Power at 210 °F (MW)	Power at 400 °F (MW)
Alabama	203,223,404	15.4	14	38
Arkansas	258,095,372	20.0	18	98
Florida	160,412,148	12.5	11	61
Louisiana	2,136,572,640	162.5	147	796
Mississippi	592,517,602	45.8	42	224
Oklahoma	12,423,264,300	986.6	894	4,832
Texas	12,097,990,120	935.1	847	4,580
	Total:	2,177.8	1,972	10,668

Table 1. Comparison of cost components for conventional hydrothermal development of a water-flood field.

Existing Water-Flood Field Conditions

- **Many wells with BHT's at over 225 °F at 15,000 ft or less**
- **Water produced from wells, stripped of hydrocarbons, and reinjected (paid for by disposer!)**
- **In-place infrastructure of power lines, roads, pipelines**
- **Possible continued stripping of gas and oil in otherwise non-economic wells**

Direct Costs to Develop a Water-Flood Field

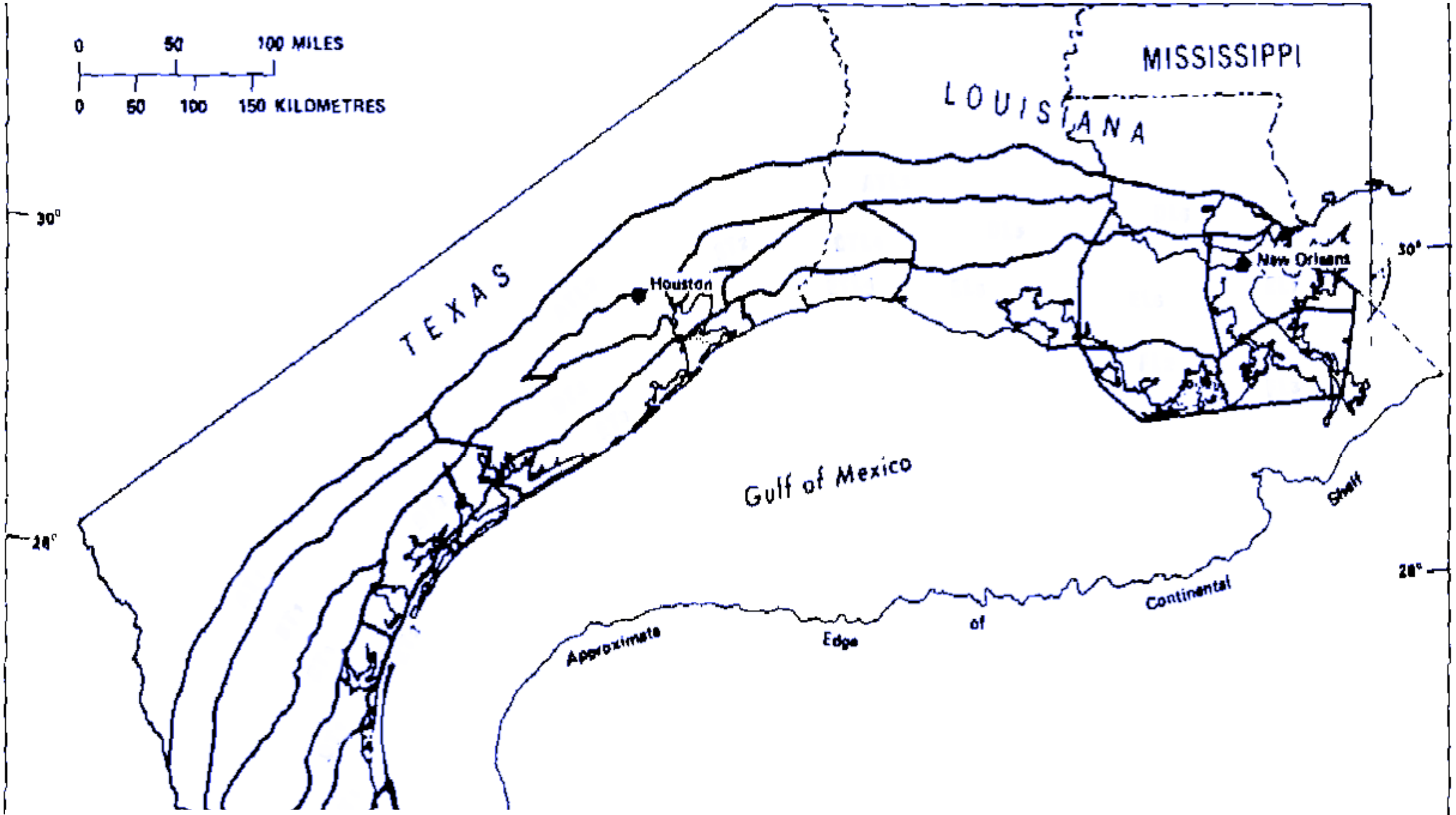
- **Build power station**
- **Minor surface infrastructure upgrades (i.e., insulating collection pipes)**

Tea Pot Dome, Wyoming

Geopressure

- Pleasant Bayou, Brazoria, Texas 1989-1990

Circular 725 - Geopressured Geothermal Resource Assessment
Papadouplous et al. (1975)



Category	Thermal Energy 10^{18} Joules	Methane 10^{12} ft^3	Total Energy 10^{18} Joules
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EGS - Sedimentary and Basement

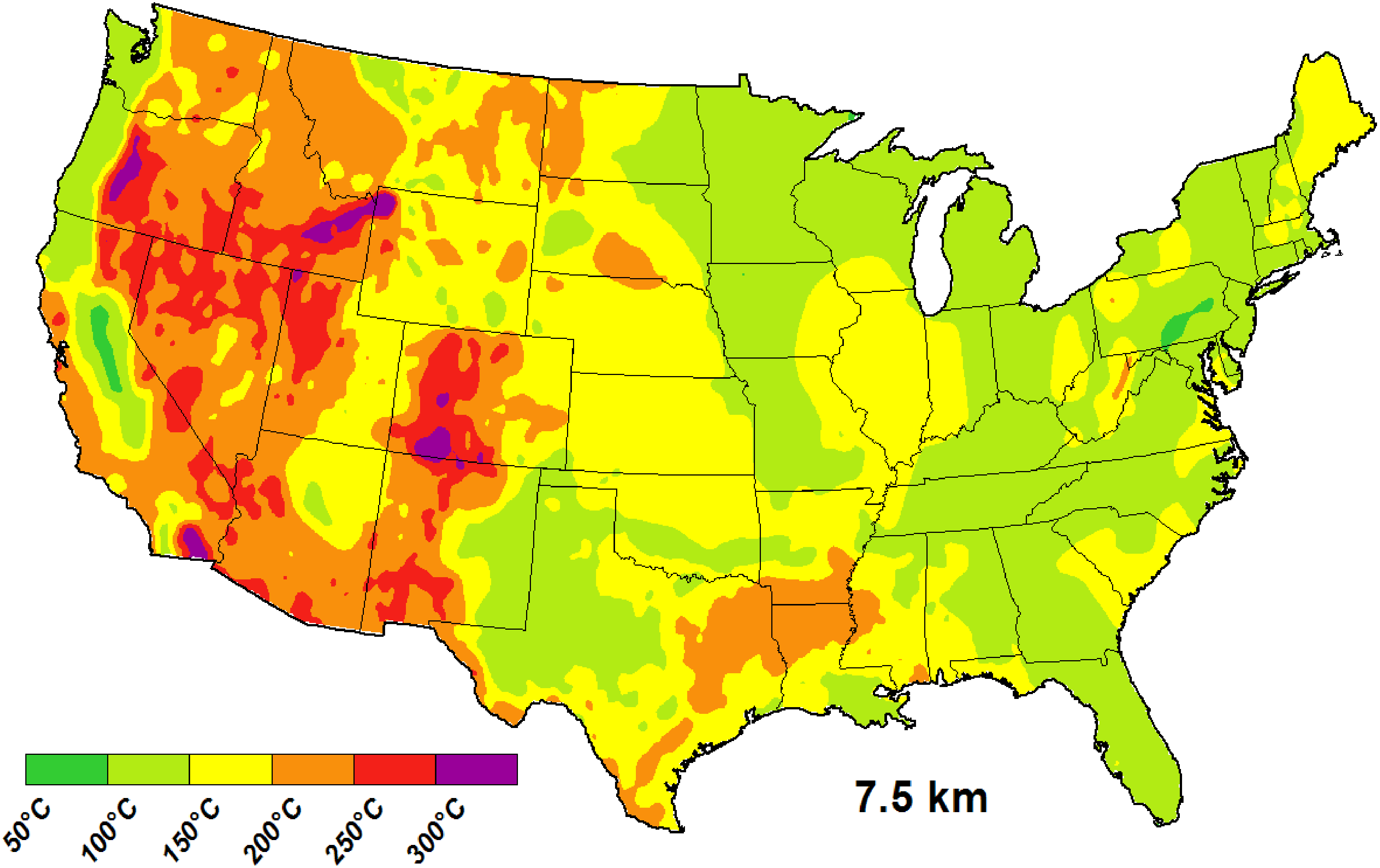
The EGS System

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.

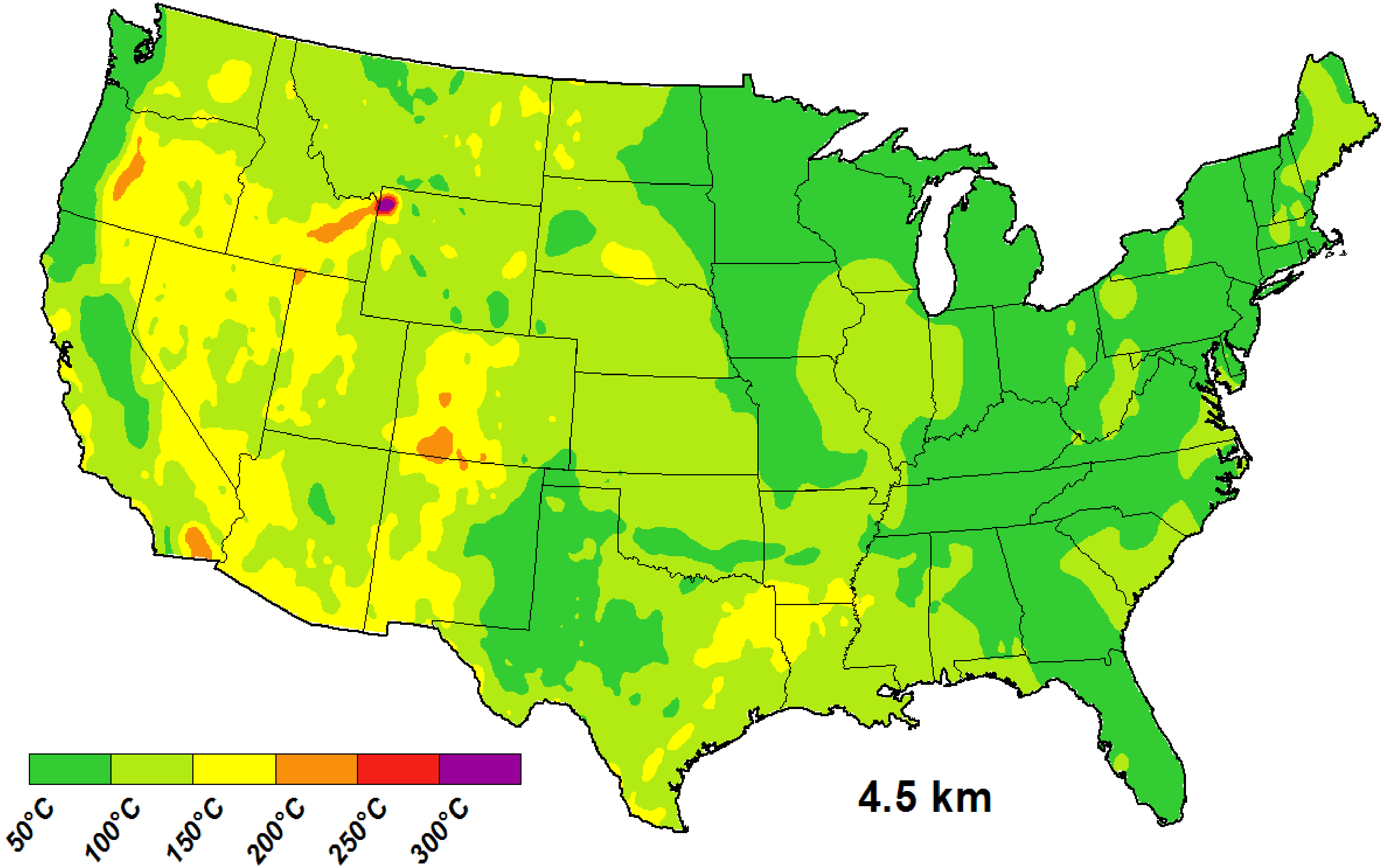
An area that is very favorable is in east Texas and northern Louisiana where the low permeability tight formations of the Jurassic with temperatures over 350 °F are being exploited as tight gas systems.

Example T-D Curves from east Texas and Louisiana

Example Cases: Cooper Basin,
Australia,
Gross Schossberg Germany

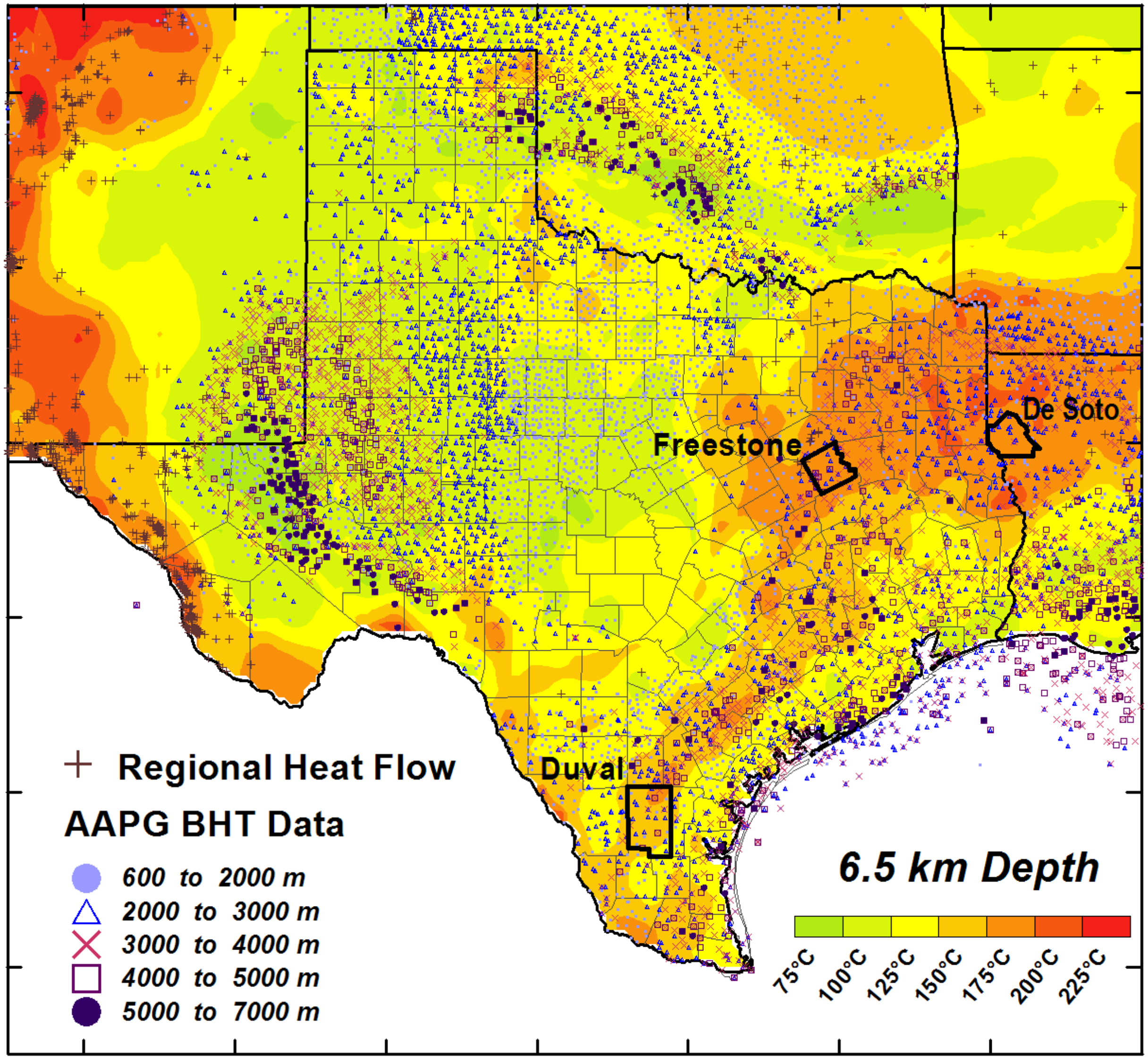


Mean Temperature 7-8 km
21,000 to 24,000 ft



Mean Temperature 4-5 km

12,000 to 15,000 ft



De Soto
Freestone
Duval
Regional Heat Flow
AAPG BHT Data
600 to 2000 m
2000 to 3000 m
3000 to 4000 m
4000 to 5000 m
5000 to 7000 m
6.5 km Depth
75°C
100°C
125°C
150°C
175°C
200°C
225°C

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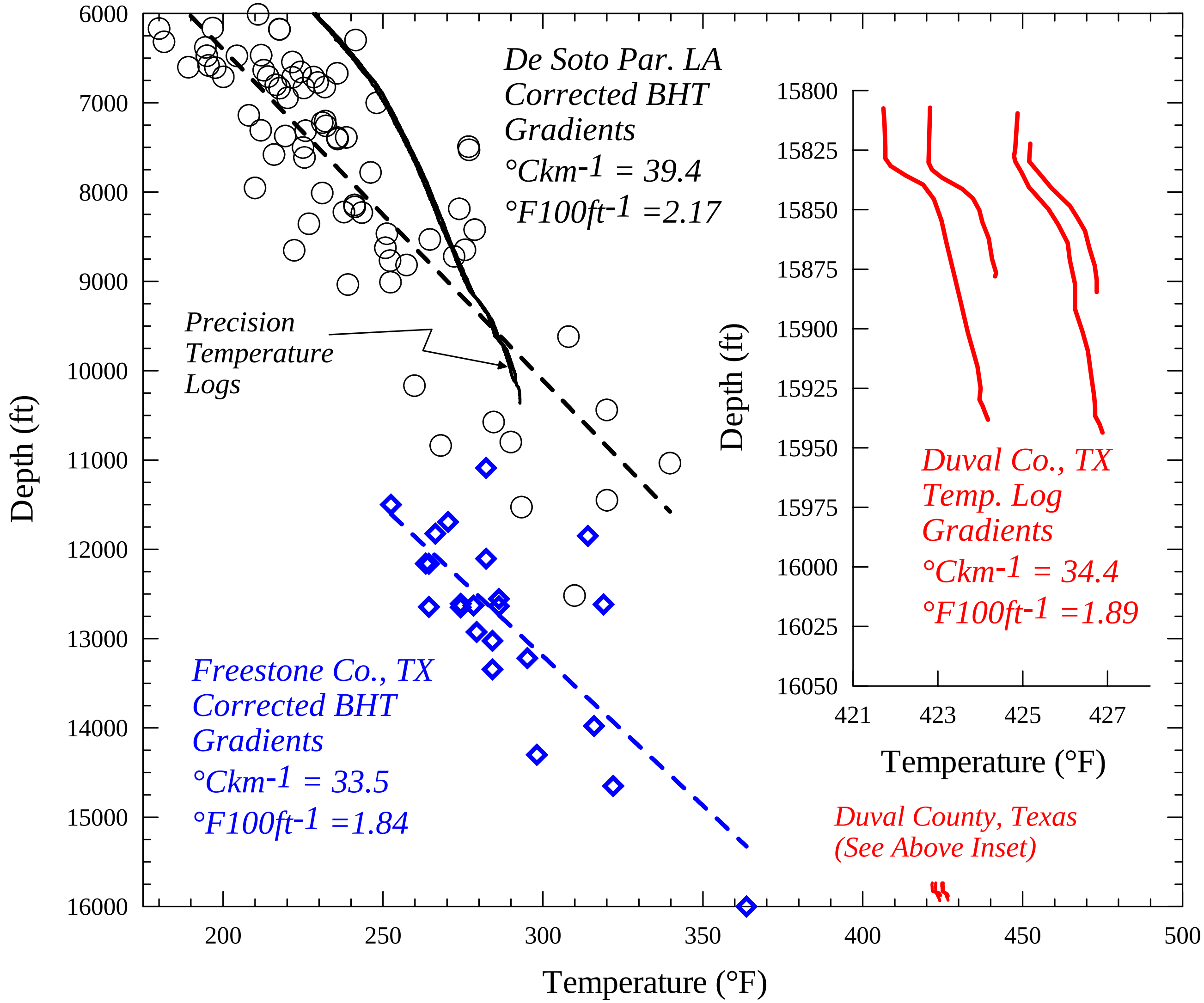
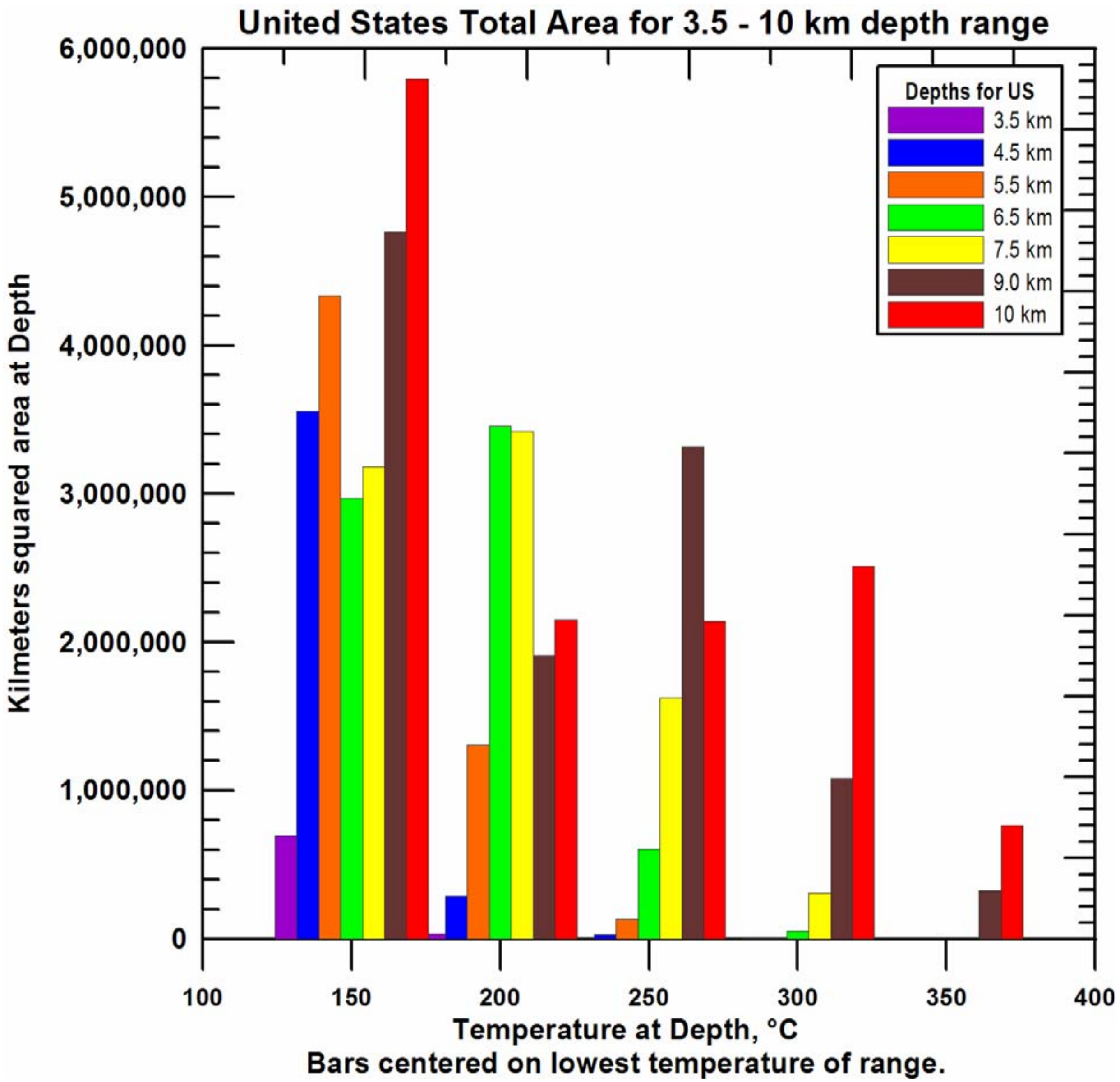
SOUTHERN METHODIST UNIVERSITY



Precision temperature log and BHT data for areas in the Texas and Louisiana. All three areas are situated in the high gradients areas paralleling the Gulf Coast. The existence of temperatures in excess of 250 °F by 9,000-12,000 ft suggest favorable conditions for future geothermal development.



The most favorable EGS resources are considered less than 7 km and with temperatures >150°C. There are at least 17 million kilometers with these requirements, totally a thermal energy potential of 8,600,000 x 10^{18} Joules.

Table 2. Comparison of cost components for "EGS" development for Texas geothermal development vs. reality in oil patch situations.

<u>Components of Direct EGS Development Cost</u>

- **Drill wells that reach hot temperatures (>300°F),**
- **Fracture and/or horizontally drill wells to develop high water flow and/or acquire make-up water,**
- **Install infrastructure, roads, piping, and power line routing,**
- **Build power stations.**

Table 2 Continued

Actual Texas Field Conditions

- Many wells with BHT's over 300°F at 15,000 ft or less,
- Wells fractured or horizontally drilled in many cases,
- Water available from well or adjoining wells in fields or as disposal water (paid for by disposer!),
- In-place infrastructure of power lines, roads, pipelines,
- Possible continued stripping of gas and oil in otherwise non-economic wells.

Direct Costs to Develop a Gulf Coast EGS System

- Build Power station,
- Re-complete wells in some cases and test flow system,
- Minor surface infrastructure upgrades (i.e., insulating collection pipes, etc)

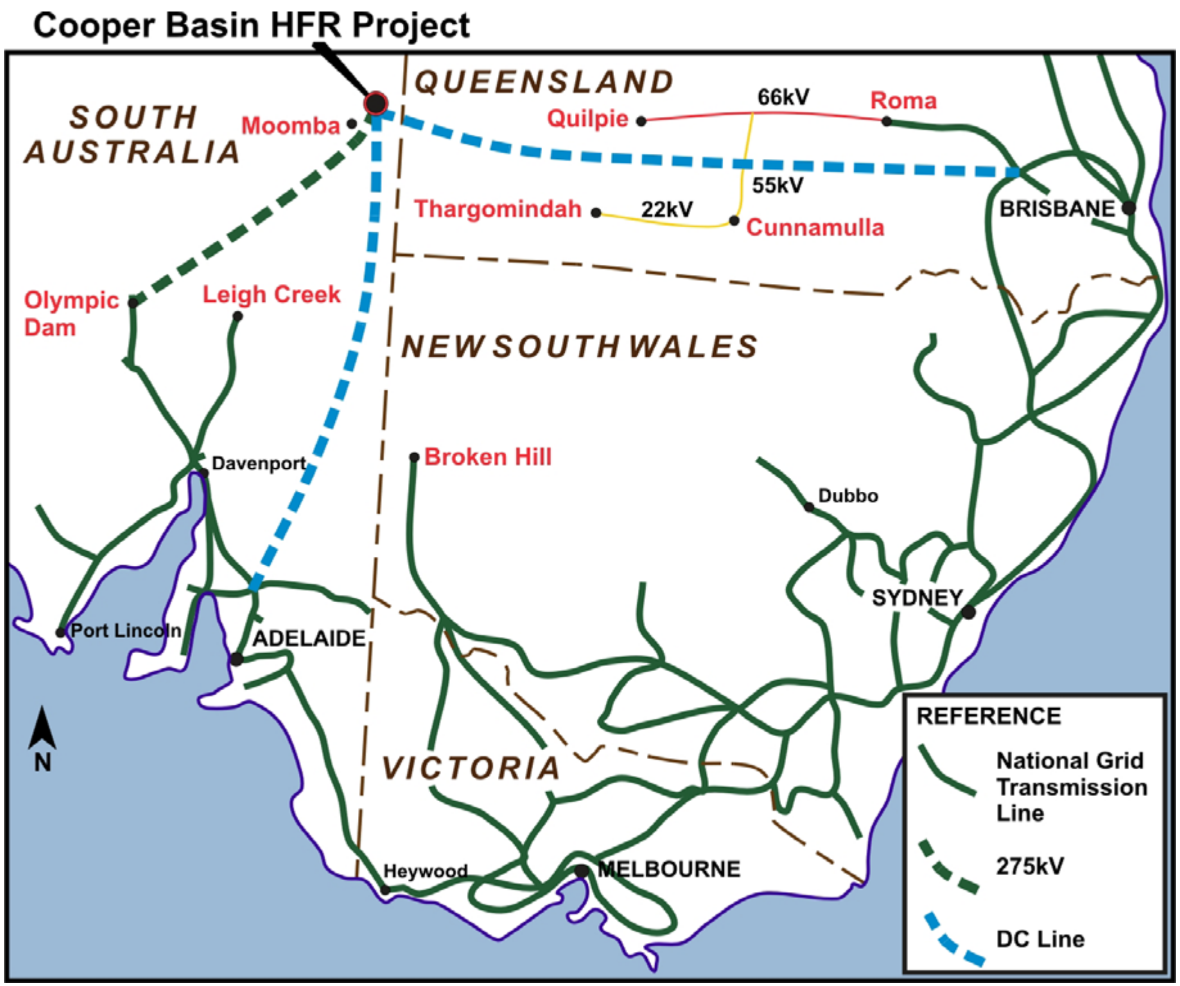
Example-EGS Activity in Australia

Geodynamics Limited

- Company registered November 2000
- Listed Sept. 2002, with 800 shareholders
- Raised more than A$55 million from market since 2002
- Australian Government funding for "Proof of Concept" A$6.5 million
- Now more than 6000 shareholders
- Market capitalisation A$160 million

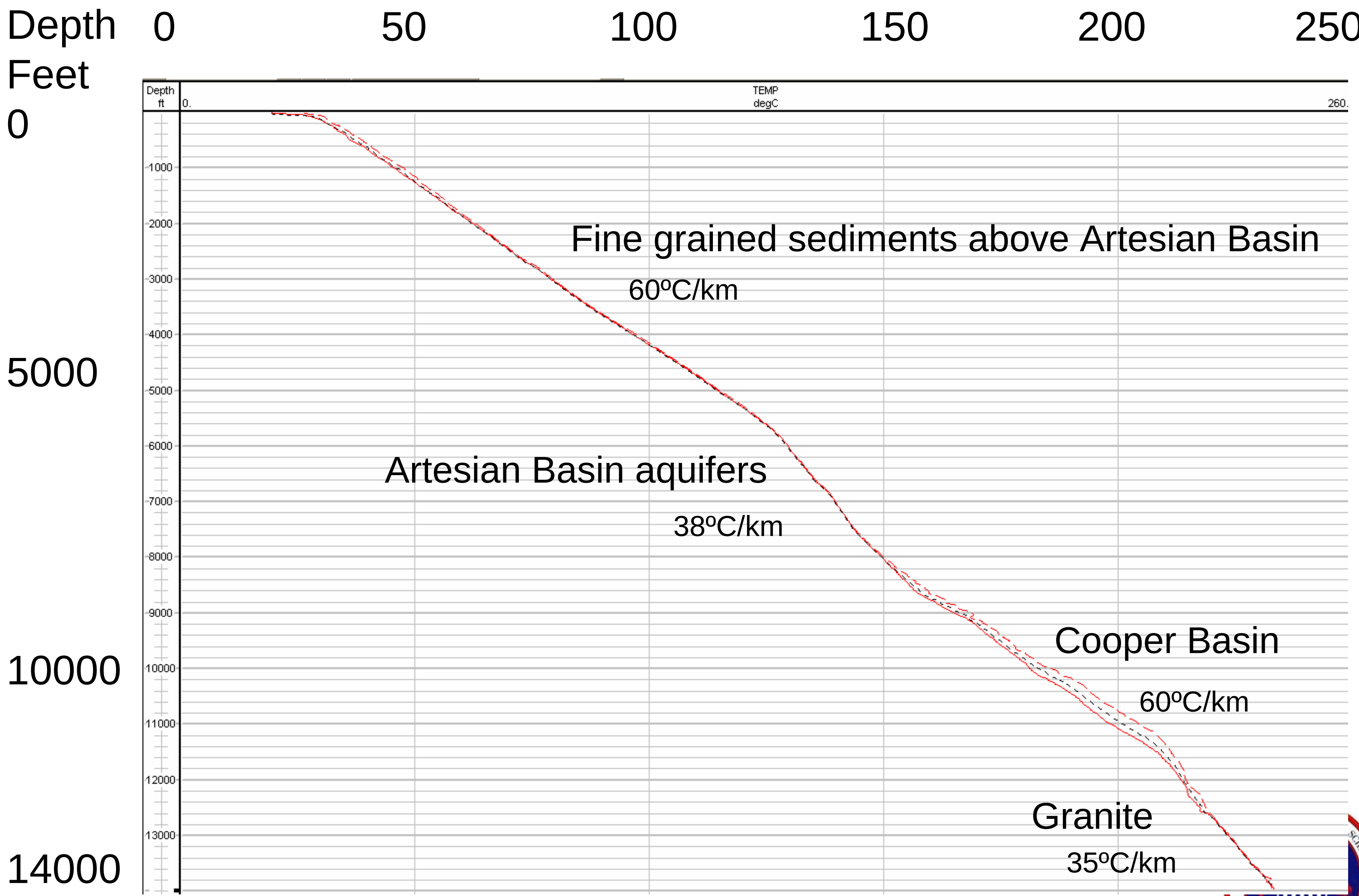
Closing the NEMMCO Grid into a loop Provides benefits on national scale

Innamincka to:
Leigh Creek
= 380km,
Broken Hill
= 470km,
Olympic Dam
= 480km,



Transmission costs = 0.5 – 1.0¢ per kWh transmitted – including transmission losses.

Temperature (°C) in Habanero-1 Cooper Basin

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