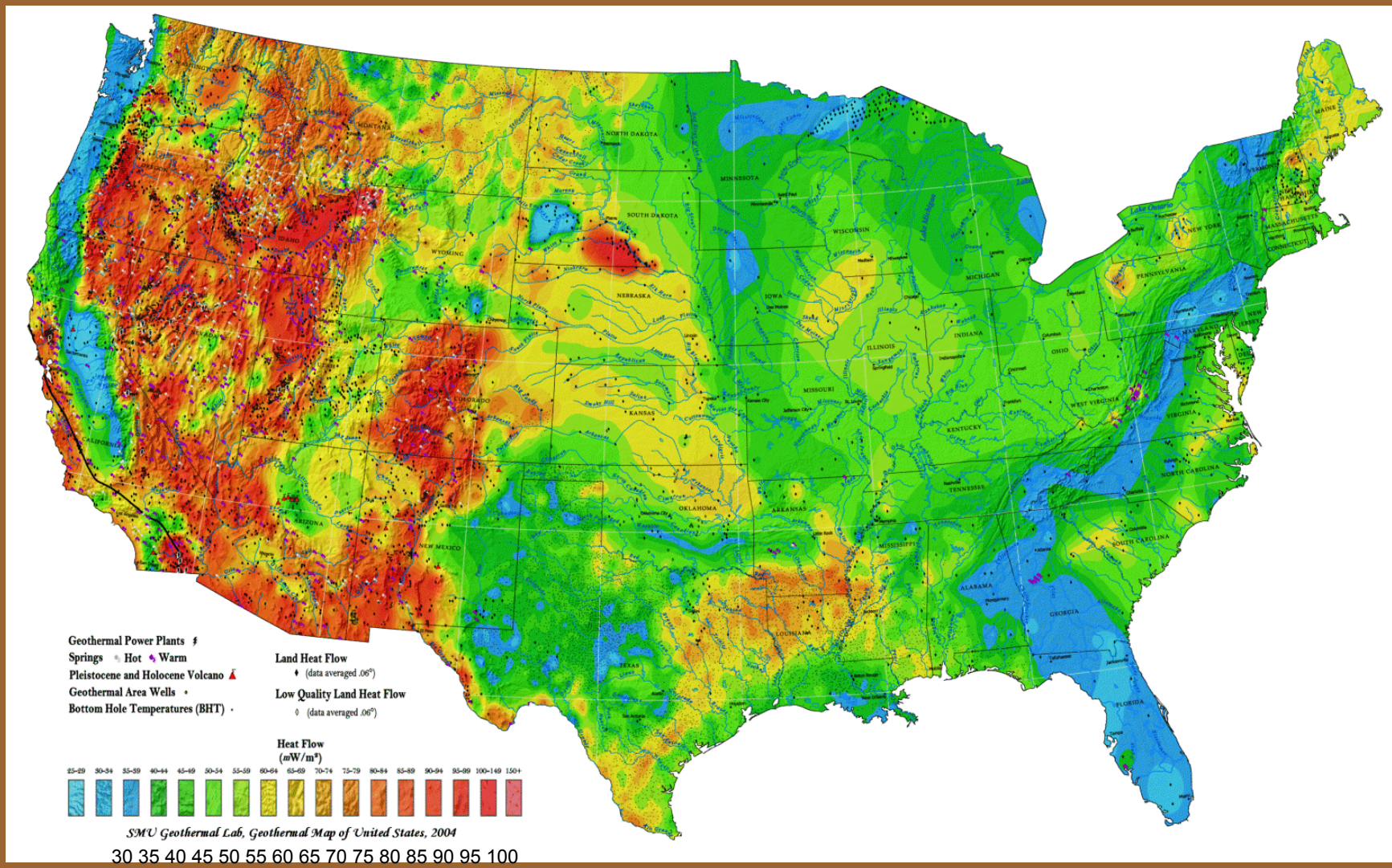
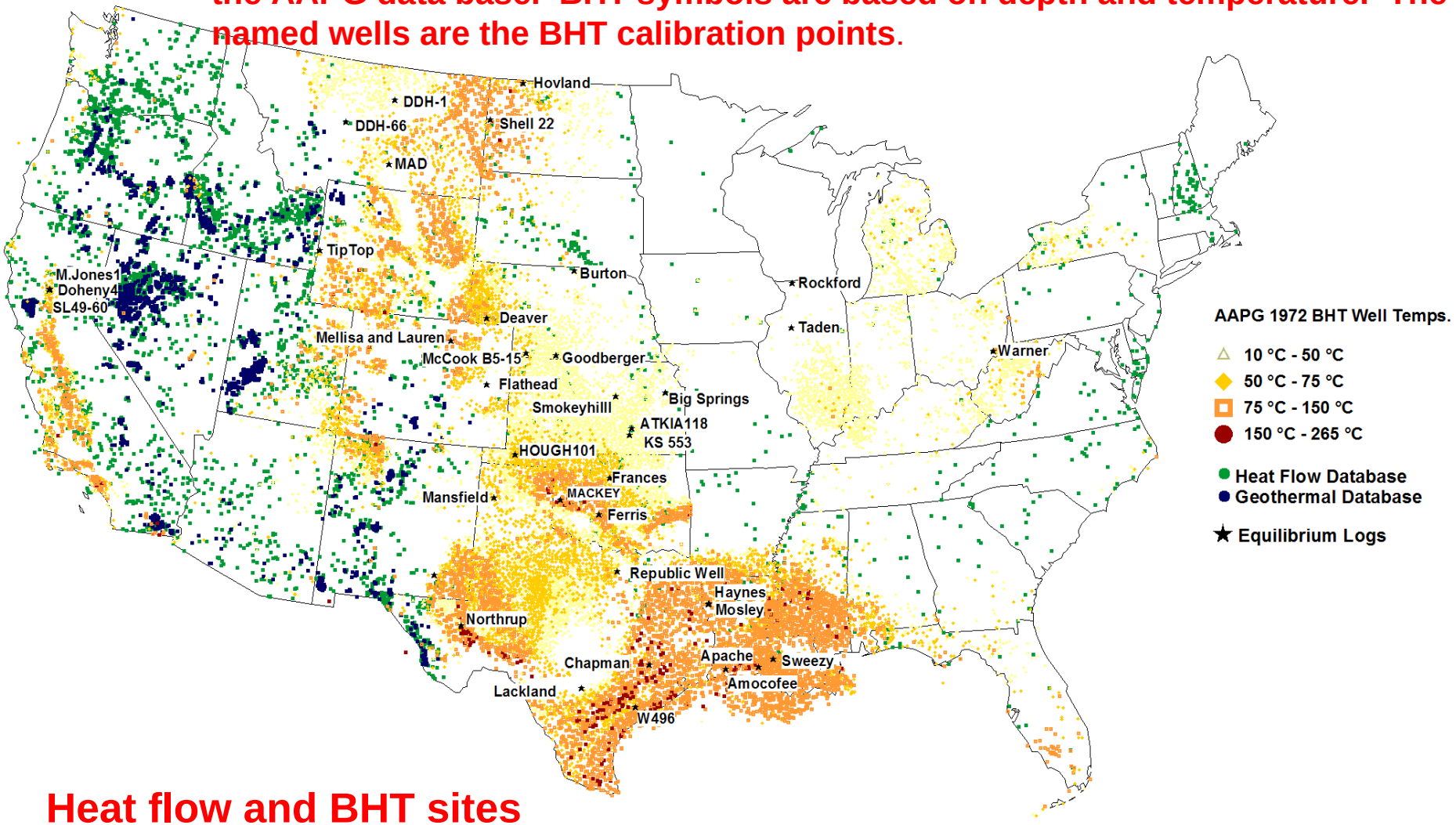



# 2004 Geothermal Map of North America (Blackwell & Richards)

**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**

## CALCULATION OF TEMPERATURE AT DEPTH

**Input values**: Surface heat flow ($Q_0$), Mantle heat flow ($Q_m$), Thermal conductivity for sediments ($K_s$), Sediment thickness ($X_S$), Surface temperature ($T_0$), Surface sediments ($A_s$), Surface basement ($A_b$), Radioactive layer (r).

**Sediment Contribution**

$$T_S = \frac{Q_0 X_S}{K_S} - A_S \frac{X_S^2}{K_S}$$

Where $A_s$=1 μW/m$^3$

**Basement Contribution**

$$T_b = \frac{Q_m}{K_b} - A_b r^2 \frac{1 - e^{-\frac{X_b}{r}}}{K_b}$$

Where $A_b=(Q_{below\_sediments}-Q_m)/r$

Temperature at depth

$T=T_s+T_b$

**Correct for surface temperature**

$T_{final}=T+T_0$

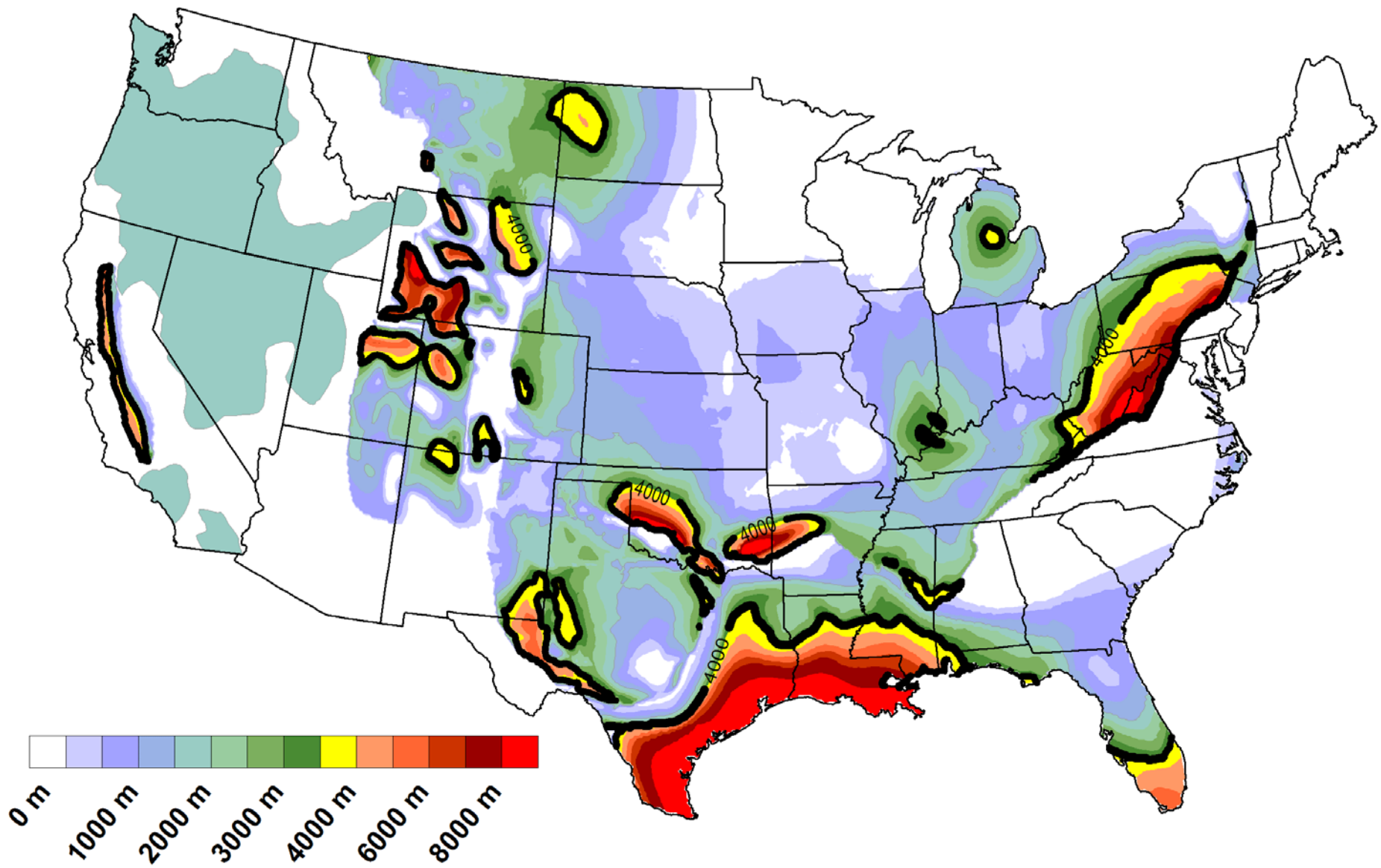
**Flow chart for calculation of temperature and heat content at depth.**

**Note: 1 kW-sec = 1 kJ and angle brackets denote depth-averaging.**

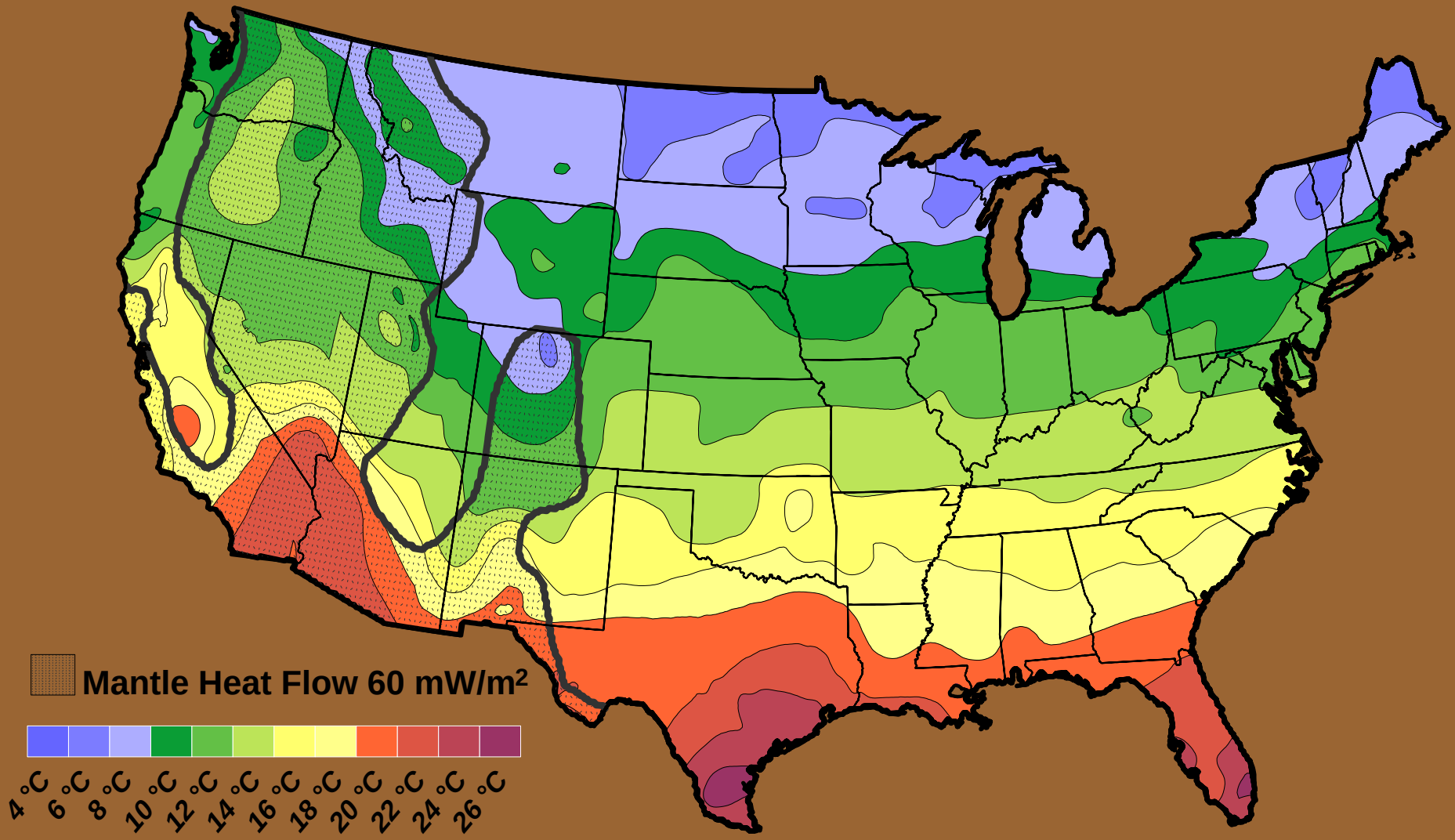
For 3 and 4 km $K_s$ was from BHT data; below 4km $K_S=K_b=2.6$; For most of the U.S. r = 10 km. If sediment thickness exceeds 3 km then r = 13-$X_S$ (Sediment thickness)

| Temp Range °C from 3, 4, 5, 6, 7, 8 & 10 km maps | Average Temp., $T_i$, for each zone (°C) | Rock Density ρ = 2550 kg/km$^3$ | Heat Capacity $C_p$ = 1 kJ/kg°C | Volume of rock slices in zone i from maps, $V_i$ = km$^3$ | Thermal Energy per slice in zone i, $Q_i$ (kJ) |
|---|---|---|---|---|---|

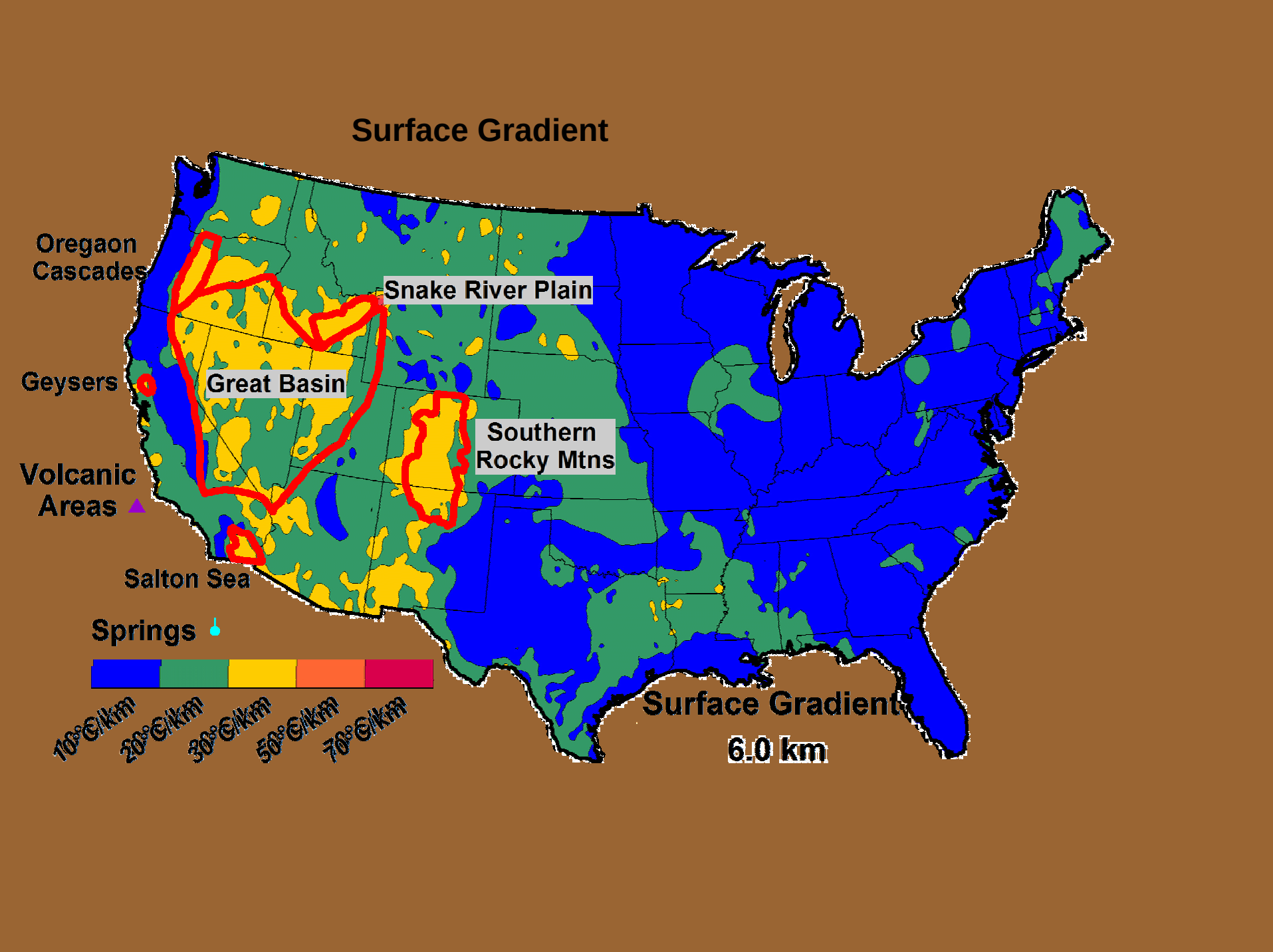
$$Q_i = \rho C_p V_i [\Delta T_i] = \rho C_p V [\langle T_i \rangle - T_{sgw}]$$



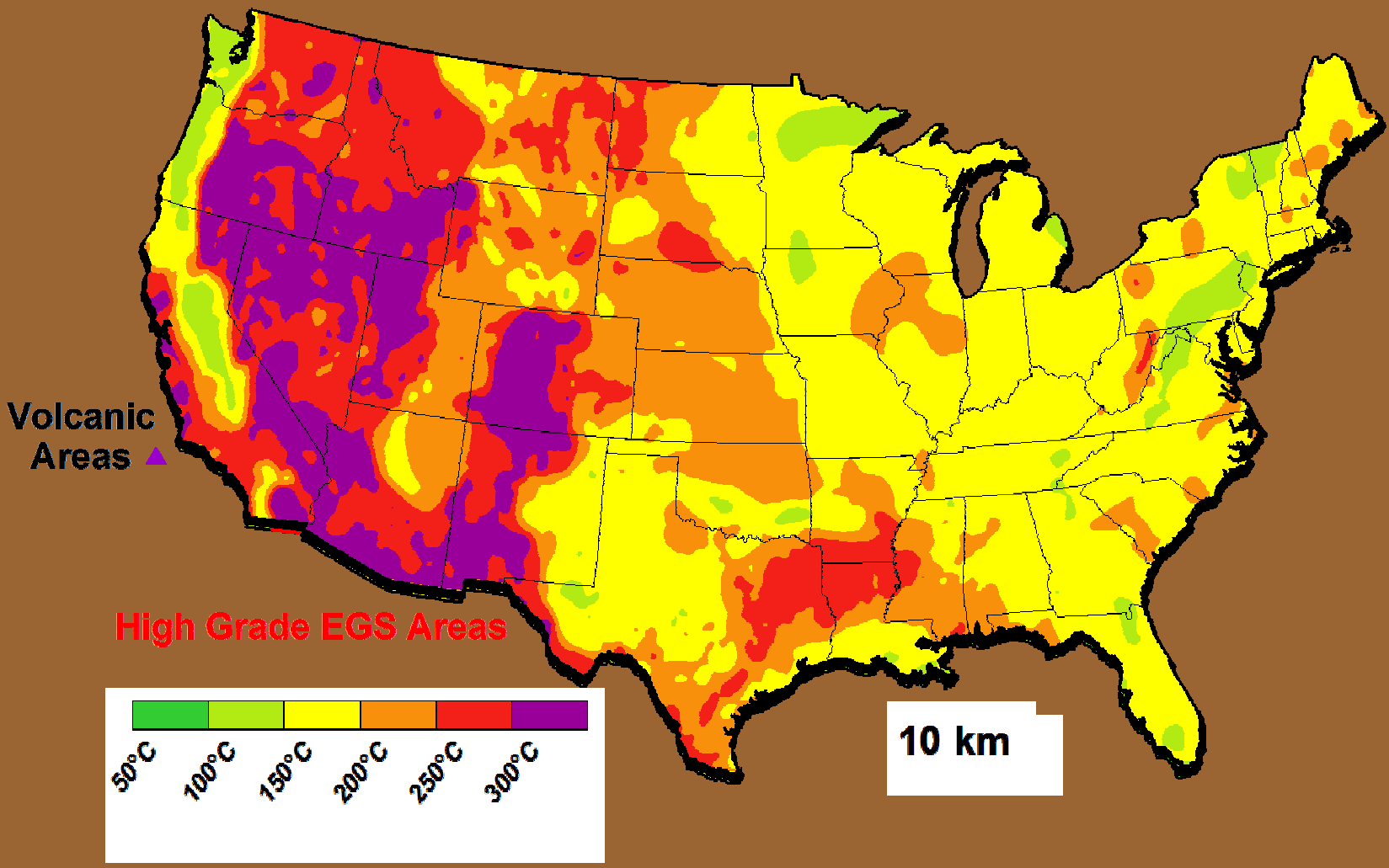

Sediment thickness map (in meters, modified from AAPG Basement Map of North America, 1978). The 4 km depth contour is outlined with a bold black line. Low-conductivity regions in the western United States are in blue/green.



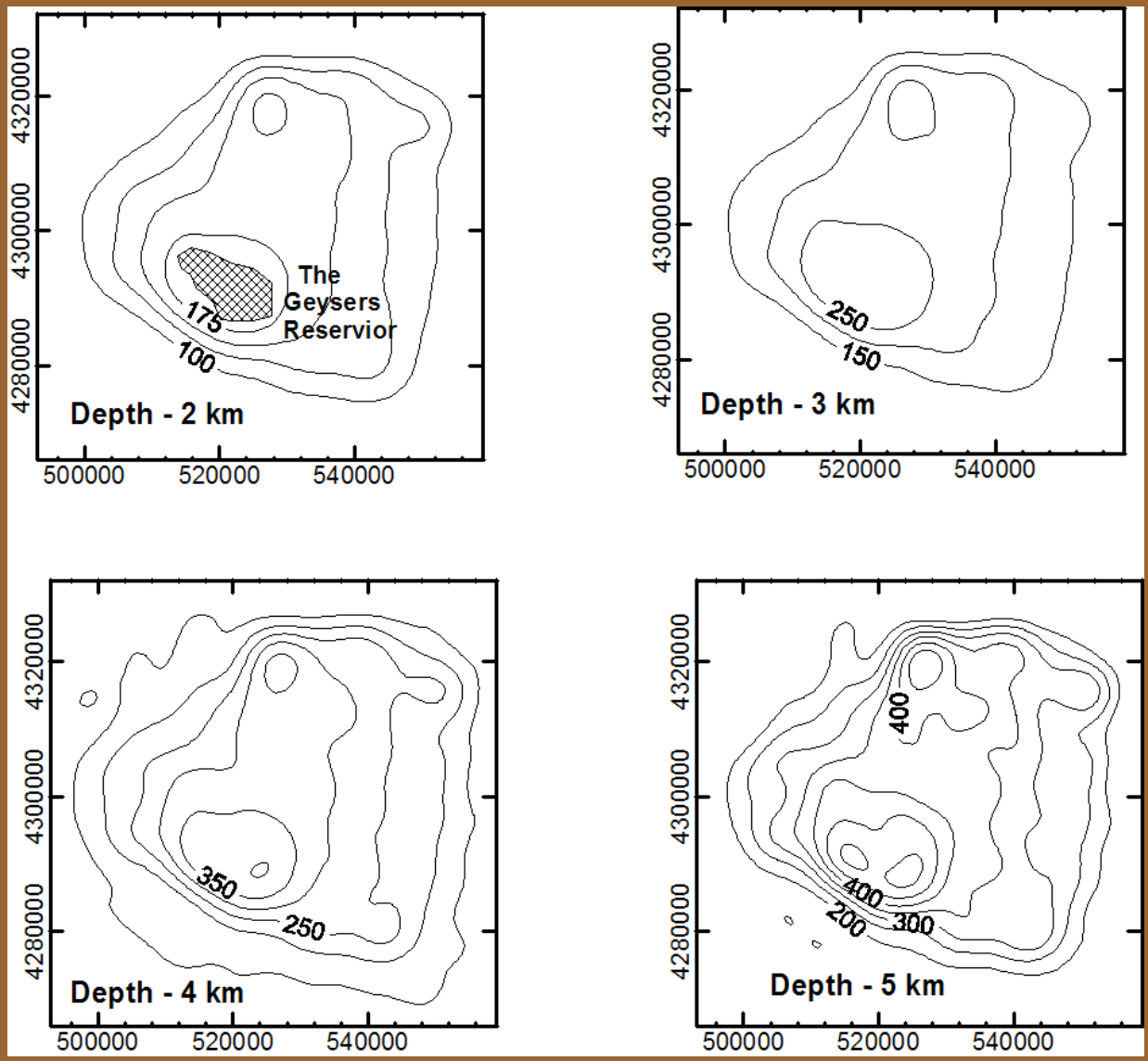

Map of surface temperature (colors, Gass, 1982) and generalized mantle heat flow for the conterminous US (dotted area inside heavy black line is greater than 60 mW/m$^2$, the remainder of the area is 30 mWm$^2$)

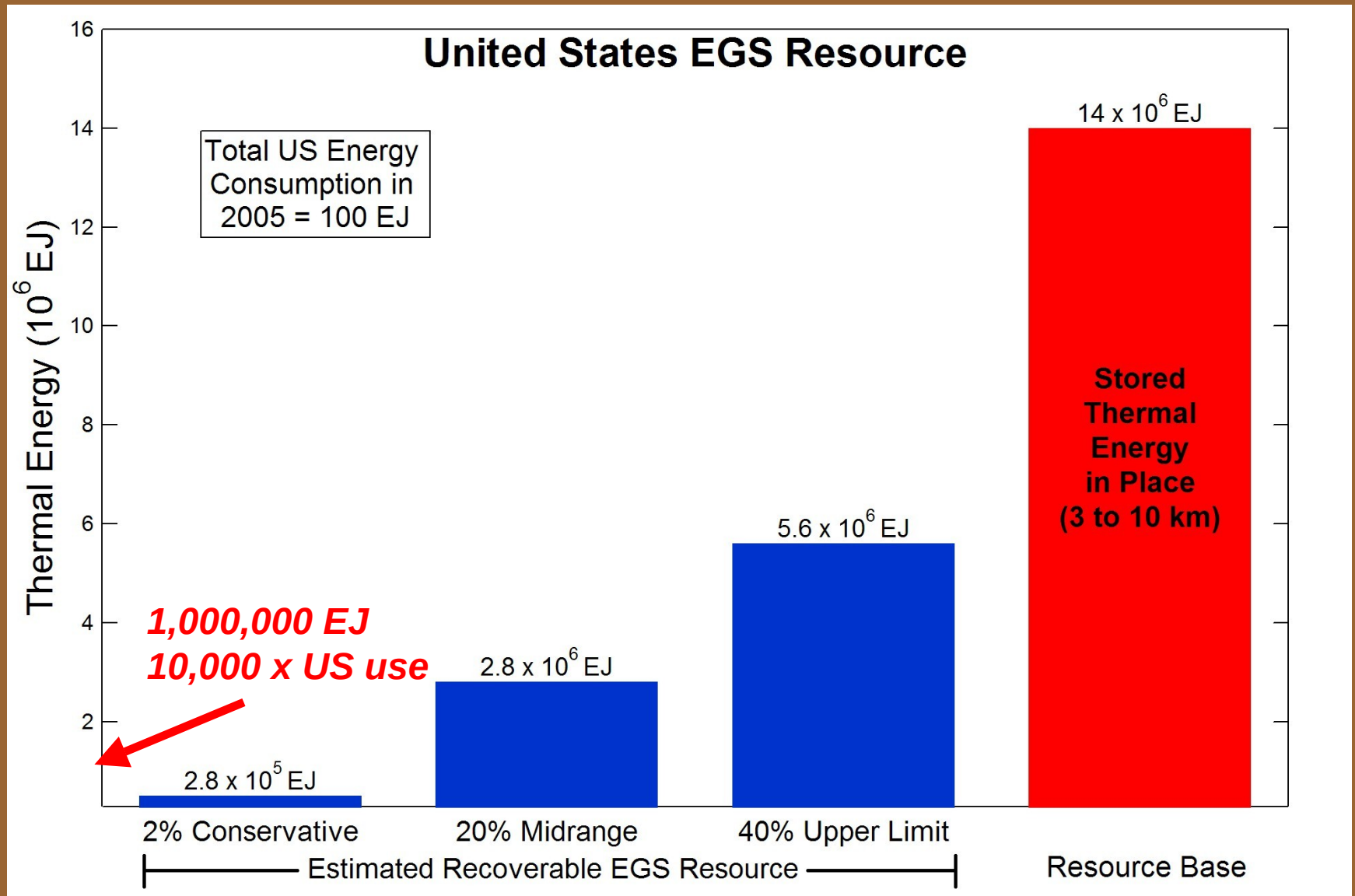

Surface Gradient
Oregaon Cascades
Snake River Plain
Geysers
Great Basin
Southern Rocky Mtns
Volcanic Areas
Salton Sea
Springs
10°C/km
20°C/km
30°C/km
50°C/km
70°C/km
Surface Gradient
6.0 km

# Temperatures at 4.5, 6.5 and 10 km Depths



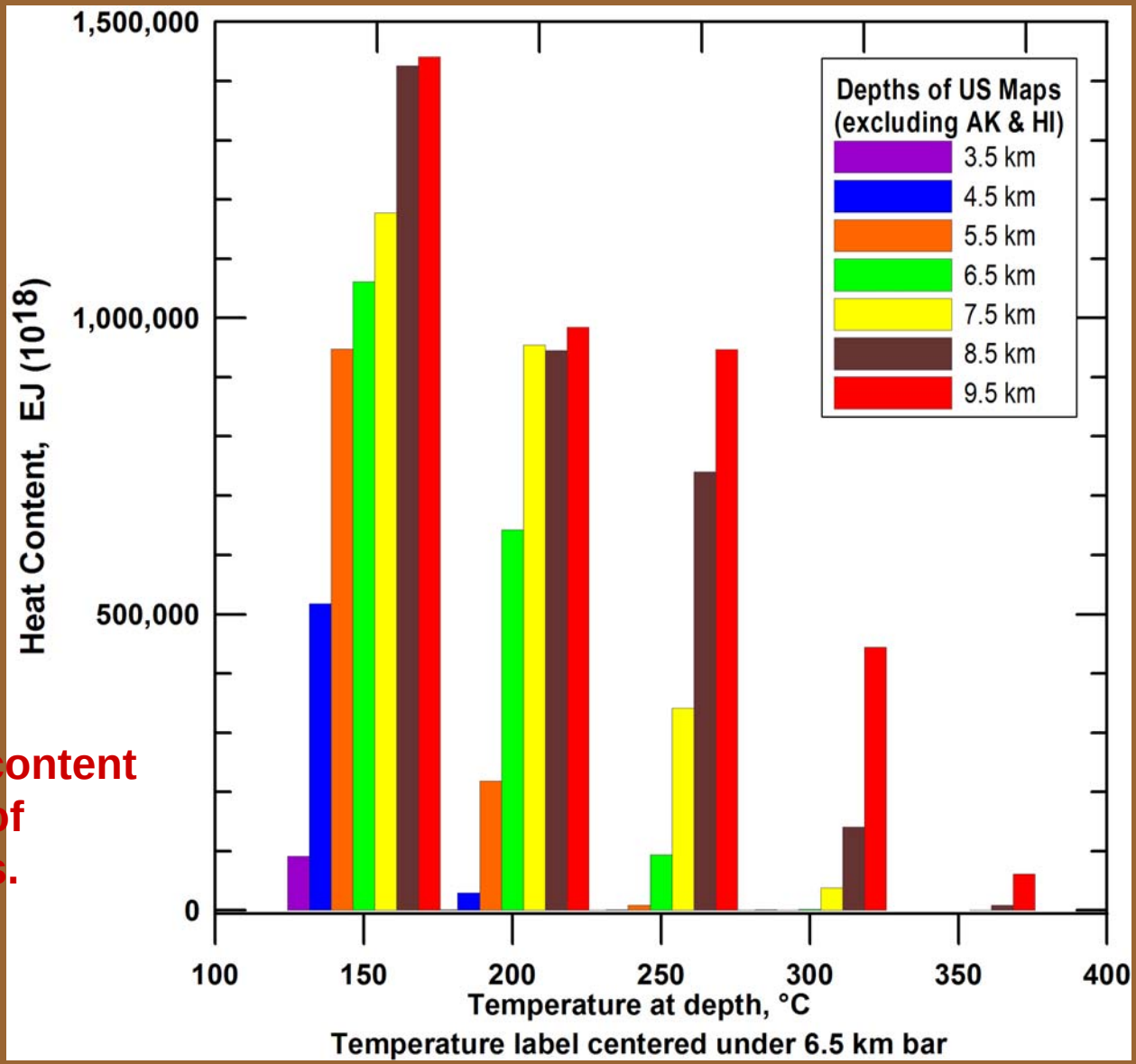
**Temperatures at depths of 2 to 5 km in The Geysers/ Clear Lake thermal area (Erkan et al., 2005)**






**Estimated total geothermal resource base and recoverable resource given in EJ or $10^{+18}$ Joules.**

**Histograms of heat content in EJ, as a function of depth for 1 km slices.**



**Histograms of US area at a given temperature, as a function of depth for 1 km slices.**

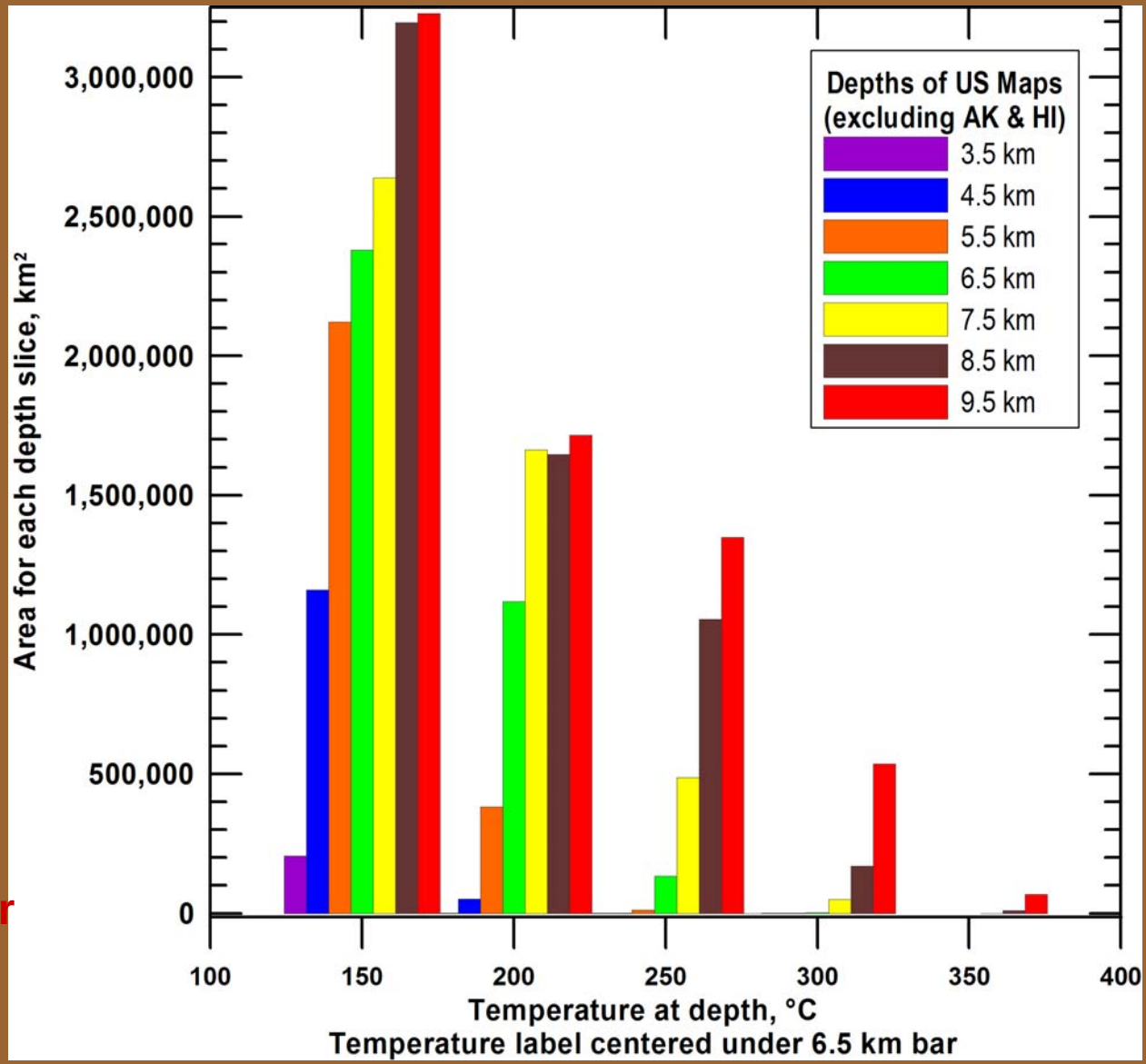


**Table 1.1 Estimated U.S. geothermal resource base to 10 km depth by category**

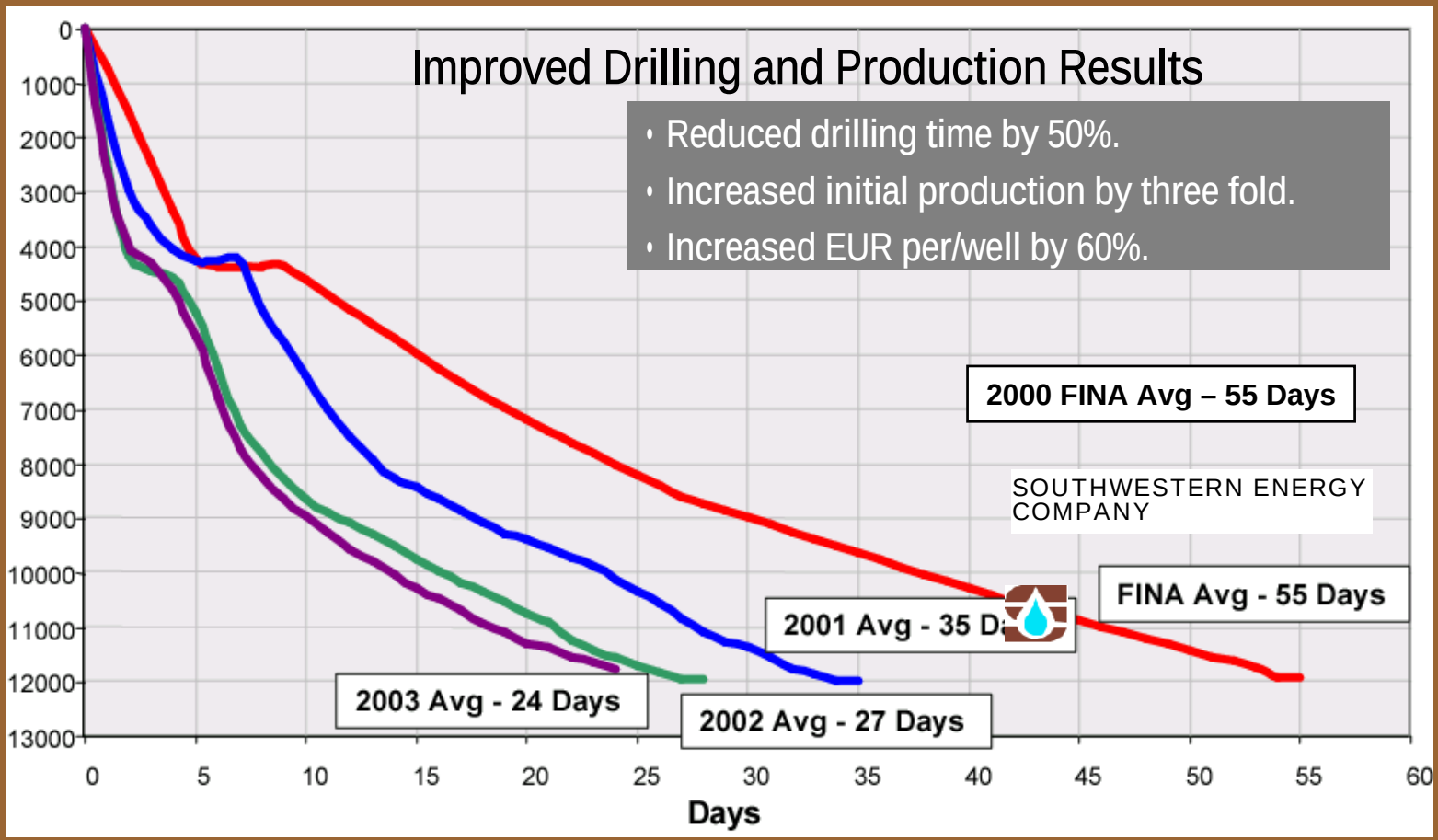
| Category of Resource | Thermal Energy, in Exajoules ($1EJ = 10^{18}$ J) | Reference |
|---|---|---|
| **Conduction-dominated EGS** | | |
| Sedimentary rock formations | >100,000 | This study |
| Crystalline basement rock formations | 13,900,000 | This study |
| Supercritical Volcanic EGS* | 74,100 | USGS Circular 790 |
| **Hydrothermal** | 2,400 – 9,600 | USGS Circulars 726 and 790 |
| **Coproduced fluids** | 0.0944 – 0.4510 | McKenna, et al. (2005) |
| **Geopressured systems** | 71,000 – 170,000** | USGS Circulars 726 and 790 |

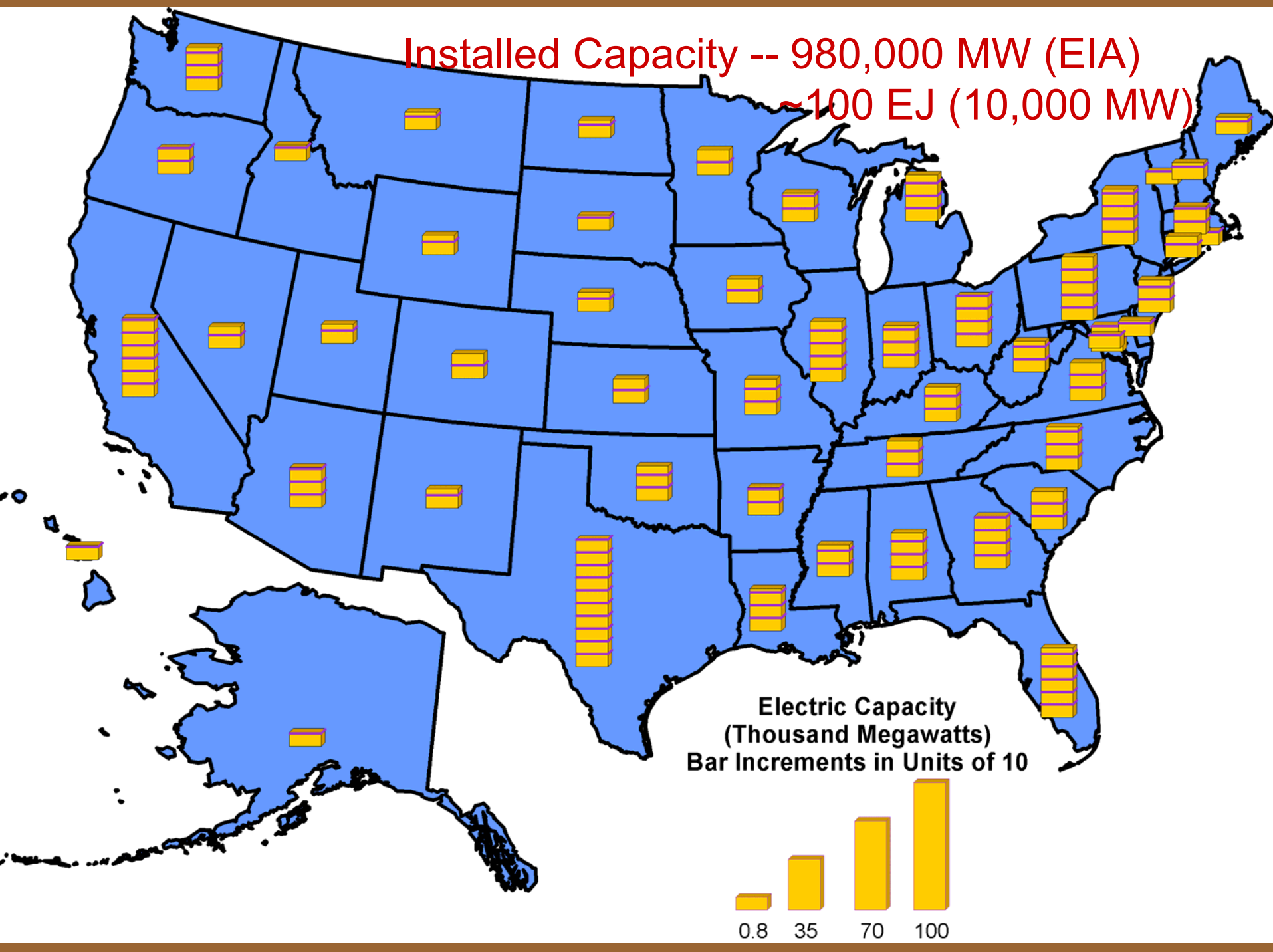
* **Excludes Yellowstone National Park and Hawaii**

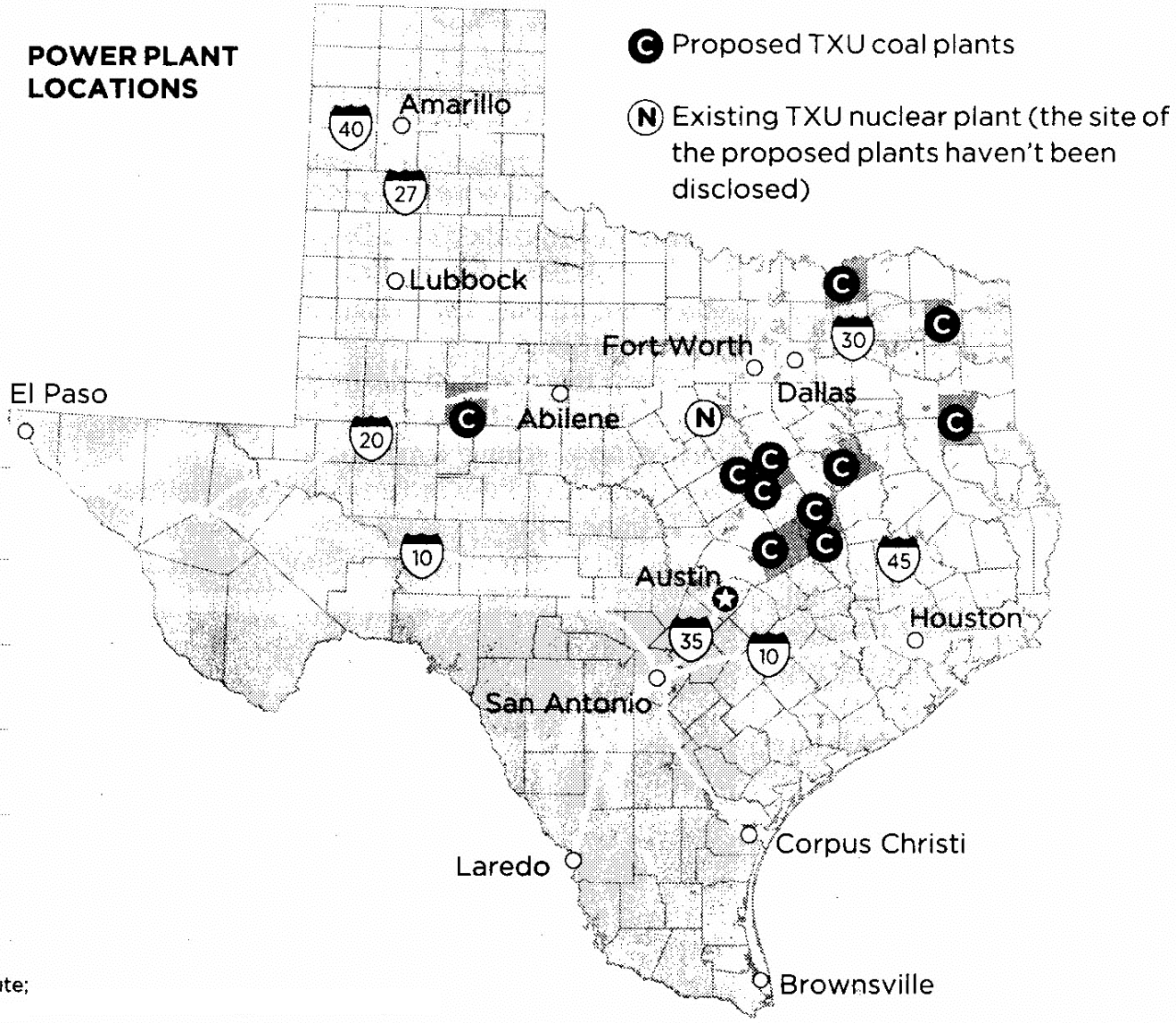
** **Includes methane content**

Remember 100 EJ =US 1 year use

# OVERTON FIELD, EAST TEXAS (COTTON VALLEY TIGHT GAS SANDS) Learning Curve Example




Installed Capacity -- 980,000 MW (EIA)
~100 EJ (10,000 MW)
Electric Capacity
(Thousand Megawatts)
Bar Increments in Units of 10
0.8
35
70
100

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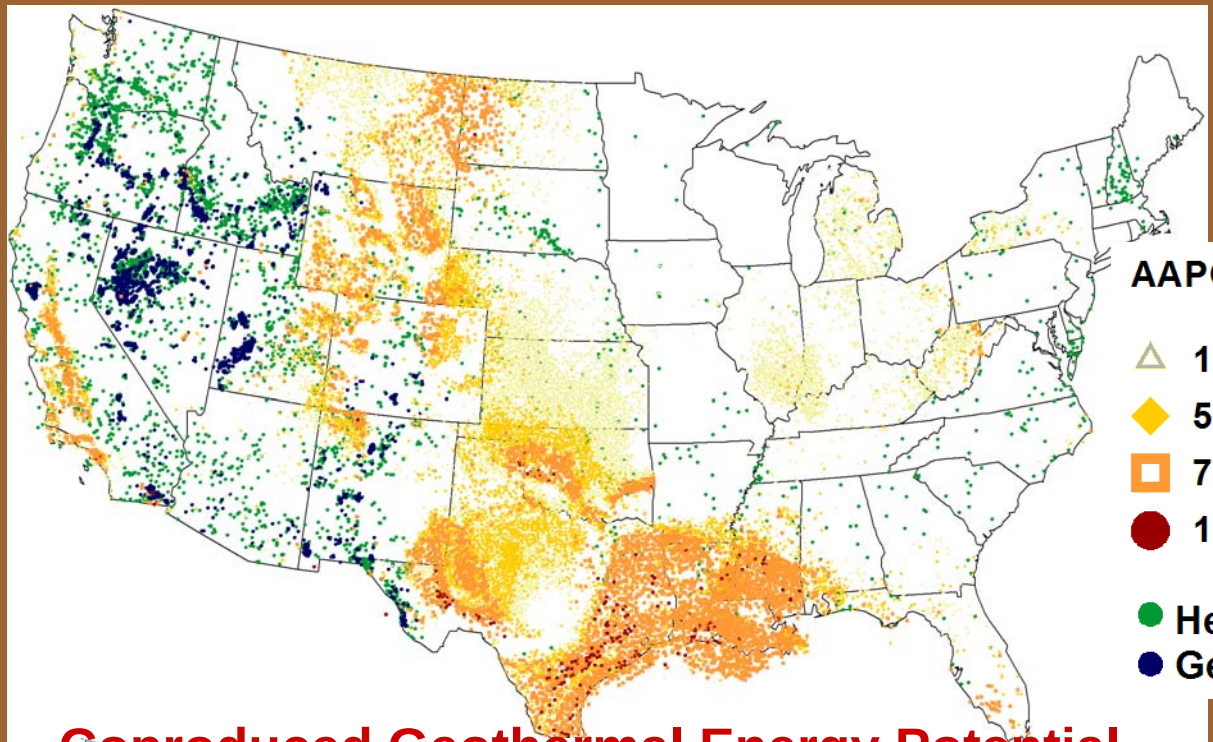
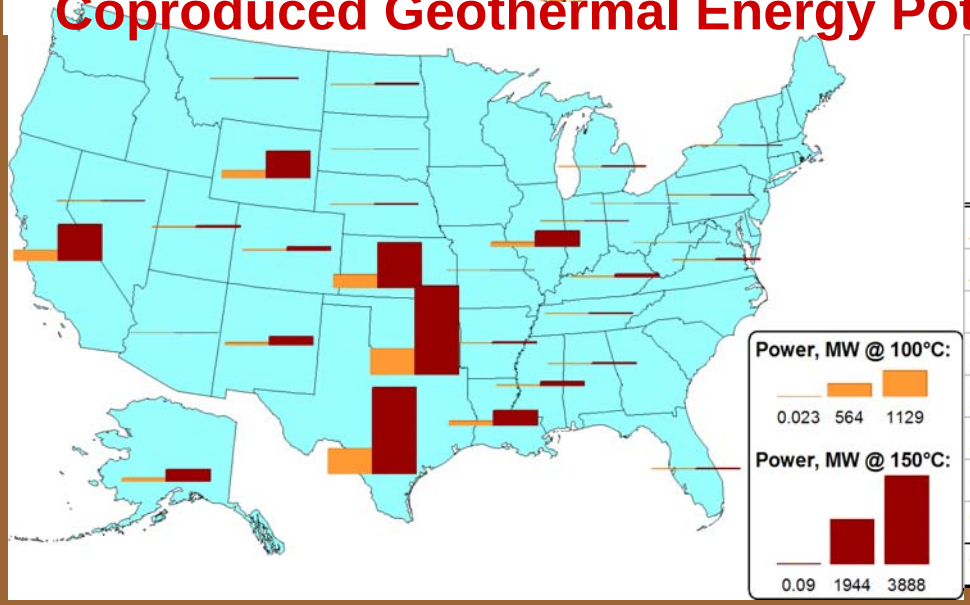


**AAPG 1972 BHT Well Temps.**

- 10 °C - 50 °C
- 50 °C - 75 °C
- 75 °C - 150 °C
- 150 °C - 265 °C

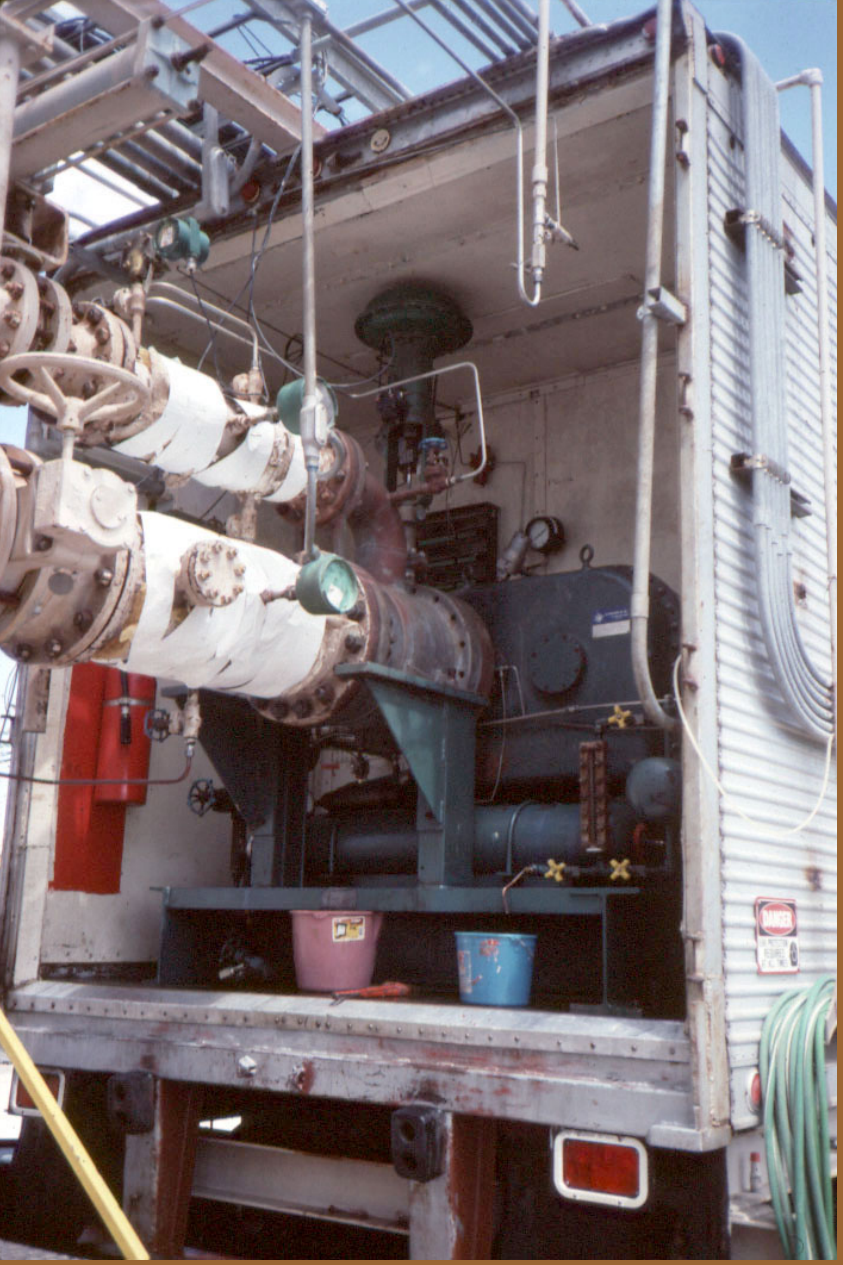
- Heat Flow Database
- Geothermal Database

## Coproduced Geothermal Energy Potential




| State | Total Processed Water, 2004 (bbl) | Power, MW @ 100°C | Power, MW @ 140°C | Power, MW @ 180°C |
|---|---|---|---|---|
| Alabama | 203,223,404 | 18 | 47 | 88 |
| Arkansas | 258,095,372 | 23 | 59 | 112 |
| California | 5,080,065,058 | 462 | 1169 | 2205 |
| Florida | 160,412,148 | 15 | 37 | 70 |
| Louisiana | 2,136,572,640 | 194 | 492 | 928 |
| Mississippi | 592,517,602 | 54 | 136 | 257 |
| Oklahoma | 12,423,264,300 | 1129 | 2860 | 5393 |
| Texas | 12,097,990,120 | 1099 | 2785 | 5252 |
| **Totals** | **32,952,140,644** | **2,994** | **7,585** | **14,305** |

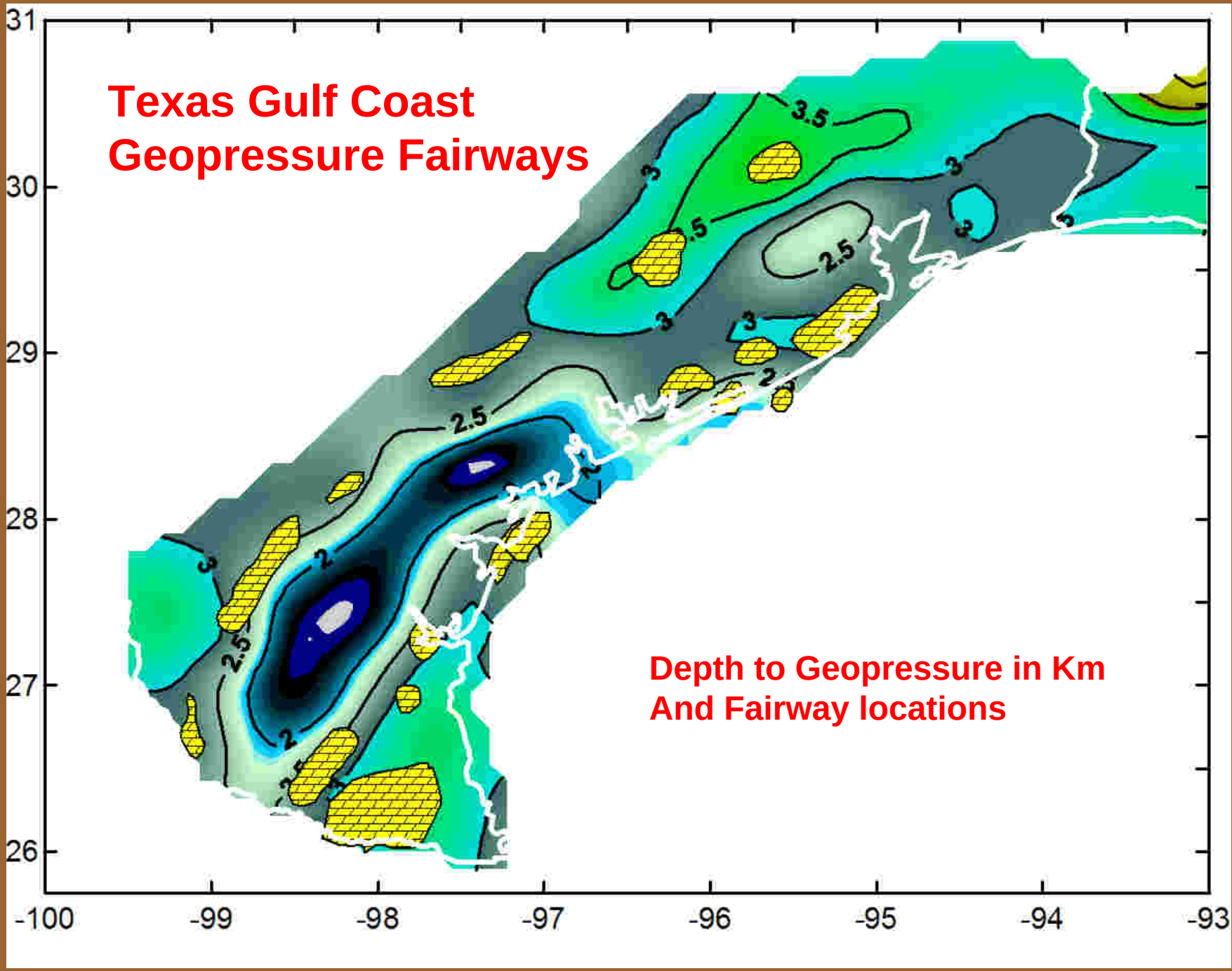

Carrier
UTC Power
Chiller...

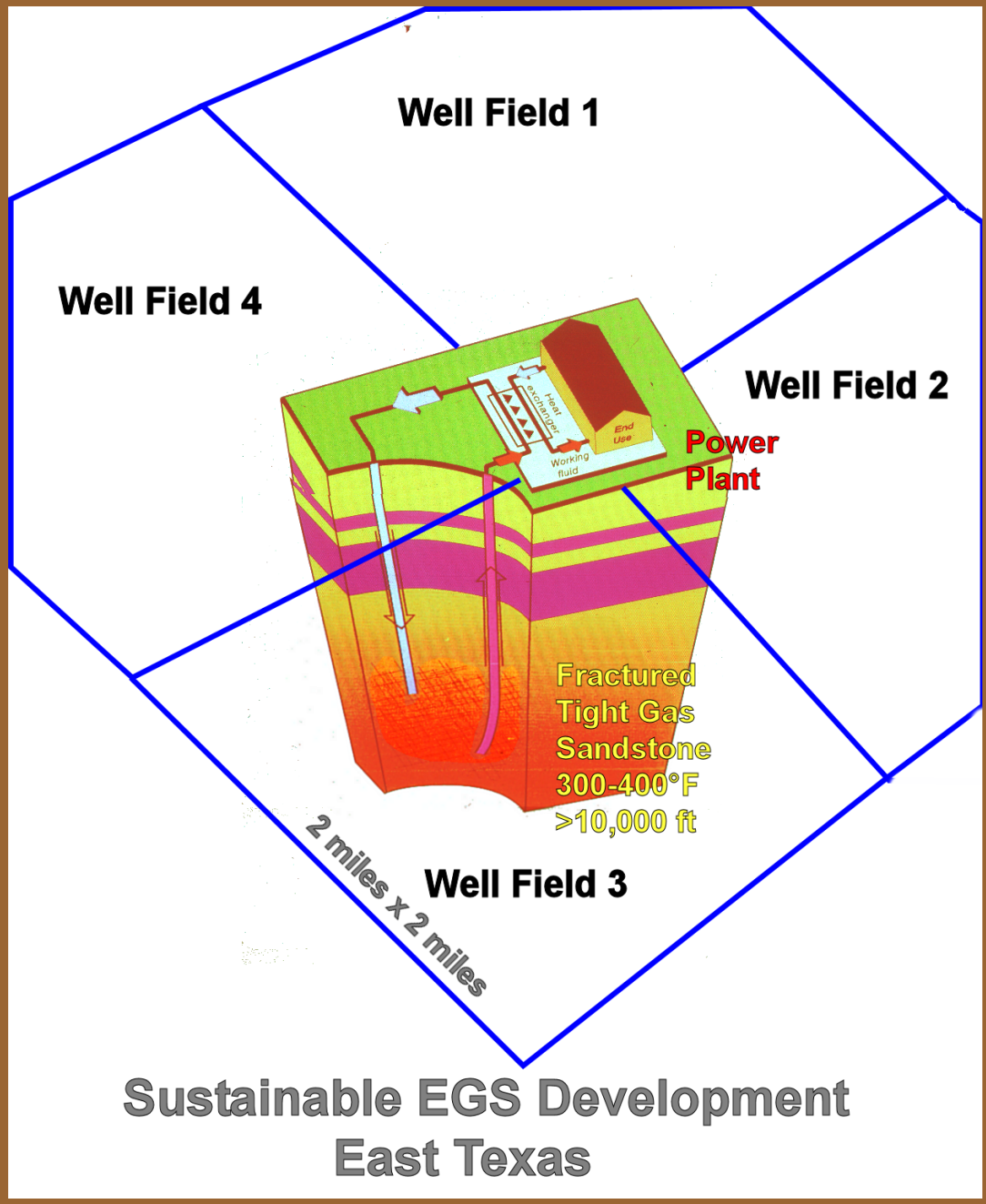


# Pleasant Bayou, Texas


Gas Engine(500 kW, above);

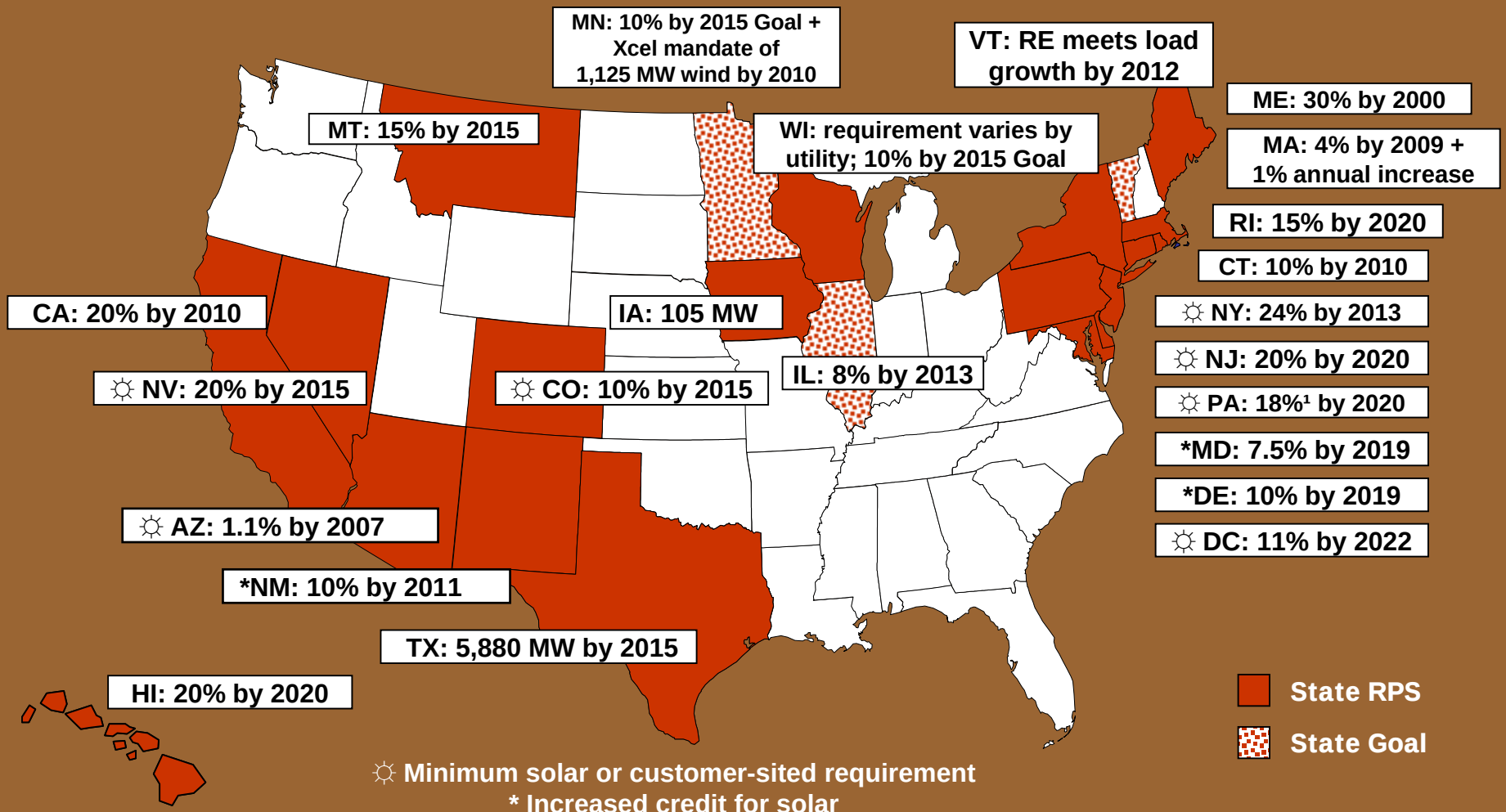
Binary Turbine (500 kW, left)


Texas Gulf Coast
Geopressure Fairways
Depth to Geopressure in Km
And Fairway locations
31
30
29
28
27
26
-100
-99
-98
-97
-96
-95
-94
-93
2
2.5
3
3.5




# 100 MW Sustainable EGS Development in Tight Gas Sands in East Texas and Northern Louisiana

# Renewable Portfolio Standards




☼ Minimum solar or customer-sited requirement
* Increased credit for solar
[1]PA: 8% Tier I, 10% Tier II (includes non-renewable sources)

DSIRE: www.dsireusa.org

April 2006