

US 2006 Enhanced Geothermal System Resource Evaluation

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Overview

- EGS Feasibility Study
- MIT Coordinating: Dr. Jeff Tester
- Experts in:
 - Hydraulic fracturing
 - Drilling
 - Reservoir management
 - EGS systems
 - Economics
 - Heat flow

EGS Resource Evaluation

- Resource Base vs. Recoverable Resource
- Metrics Influencing Recoverable Resource
 - Fractured volume
 - Fracture spacing
 - Resource temperature
 - Resource Depth
- Determining Developable Resource
 - Inaccessible areas
 - Parks, wilderness, national monuments
 - Other inaccessible or undevelopable areas

EGS Resource Evaluation

- Last Assessment by USGS – 1976-1978
 - USGS Circular 726
 - USGS Circular 790
- What's Changed?
 - Geothermal Map of North America
 - SMU temperature with depth maps
 - State of EGS technology



Resource Base vs. Reserves

- Earth's Heat is Vast
 - Accessible resource
 - Recoverable resource
 - Resource available depends on economics
- Can we talk about reserves?
 - Emerging technology
 - Some testing but no operating projects
 - Economics can be estimated

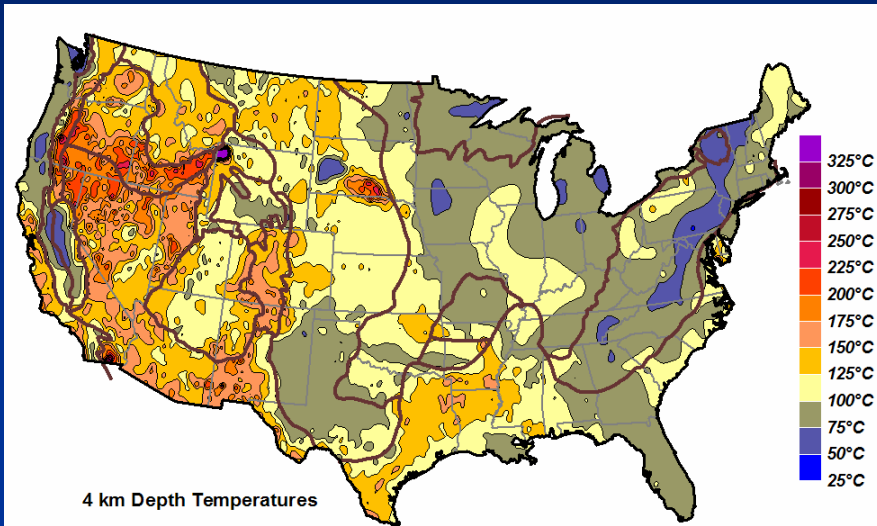


Metrics Influencing Recoverable Reserves

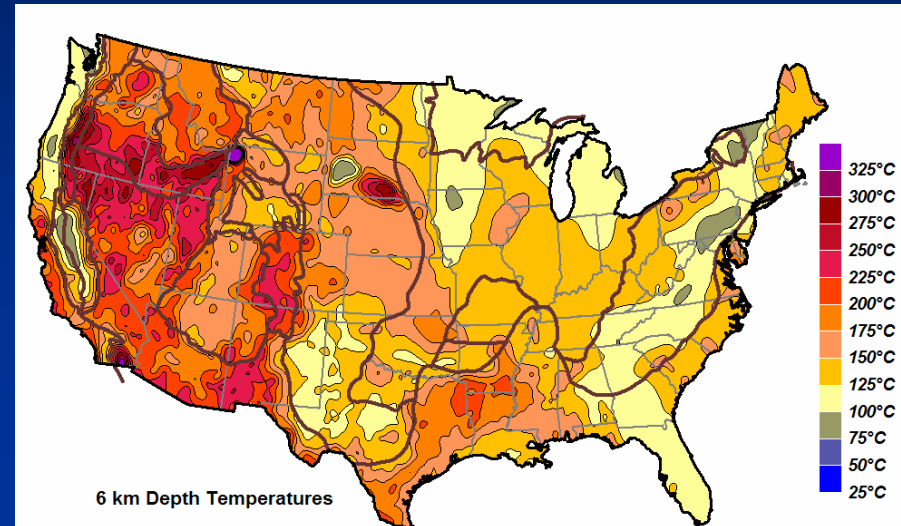
- Temperature
- Fractured Rock Volume
- Fracture Spacing
- Fracture Surface Area



Temperature



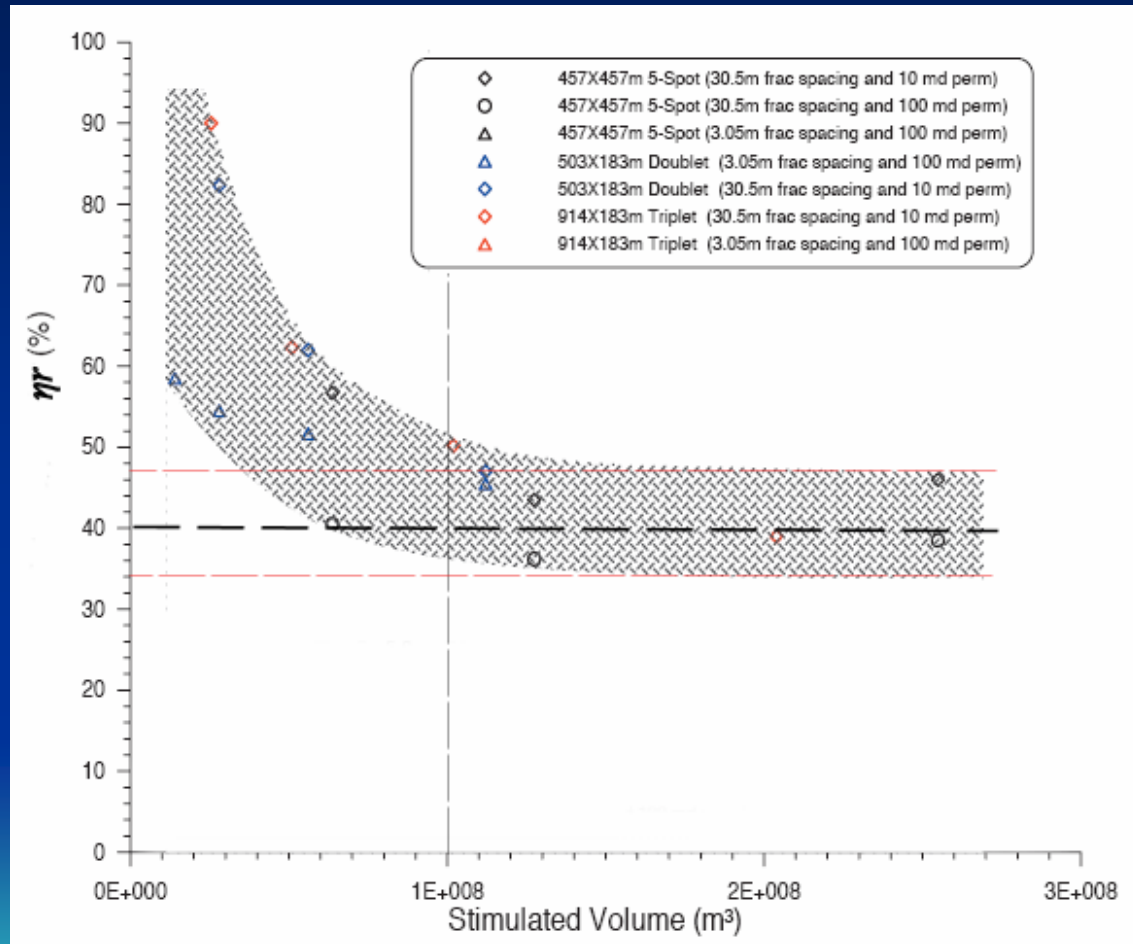
4 km



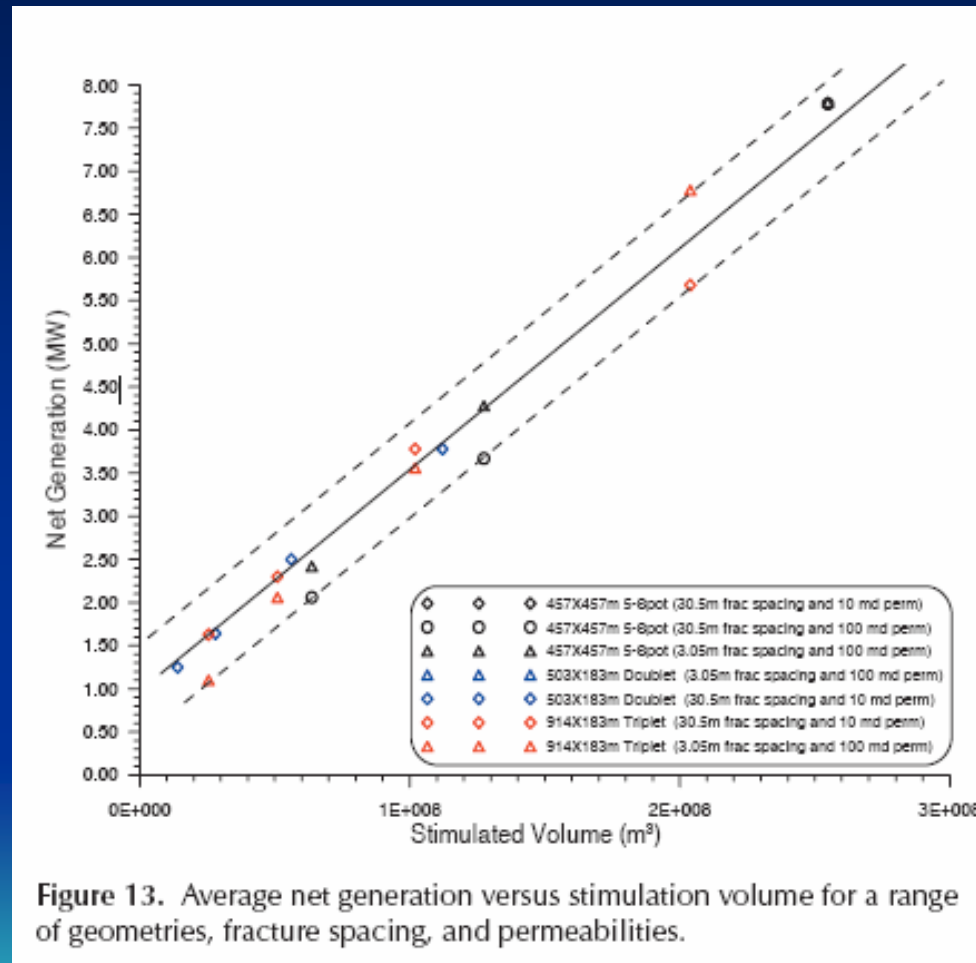
6 km



Fractured Rock Volume

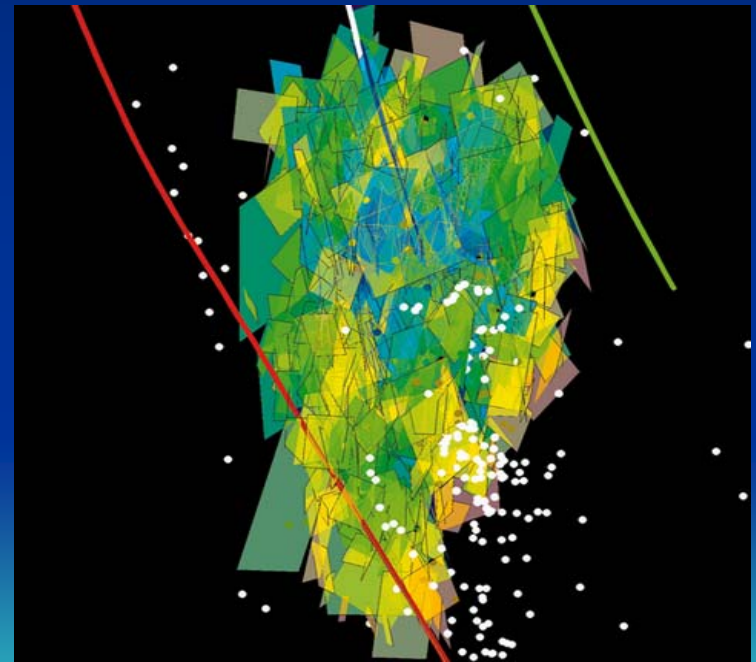


Fracture Spacing



Fracture Surface Area

- Reservoir is a heat exchanger
- Surface contact area directly relates to recoverable heat
 - More fractures per wellbore
 - Larger well spacing
 - Injector/producer geometry

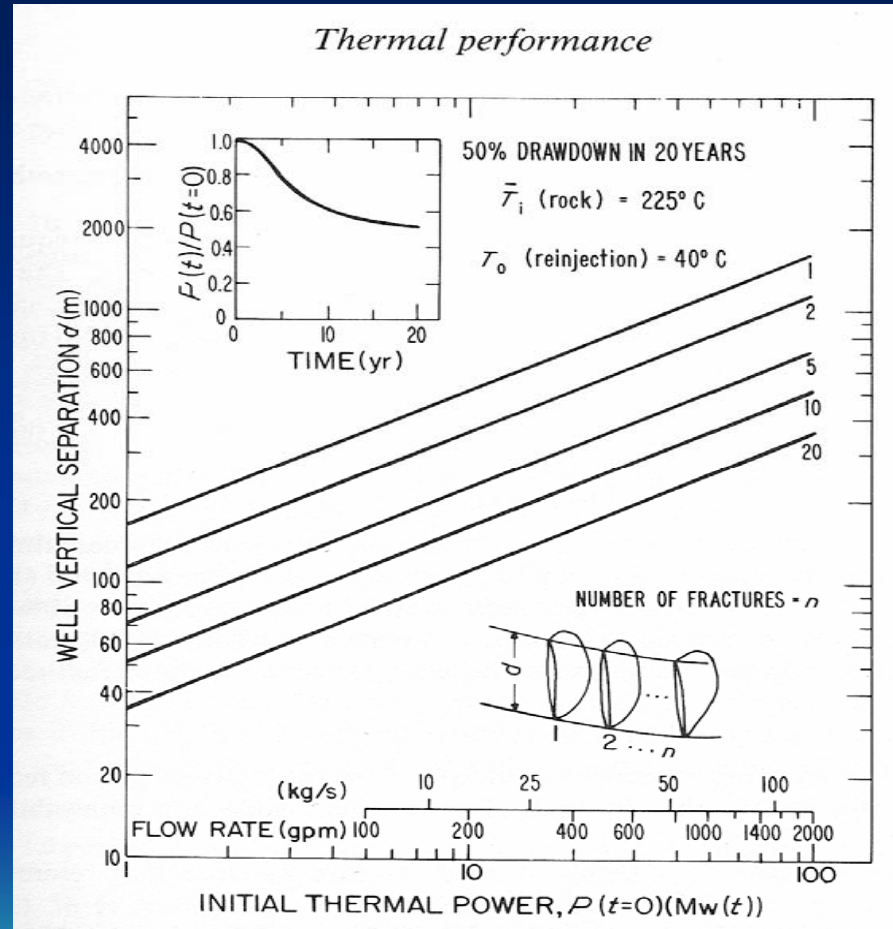


Determining the Recoverable Fraction

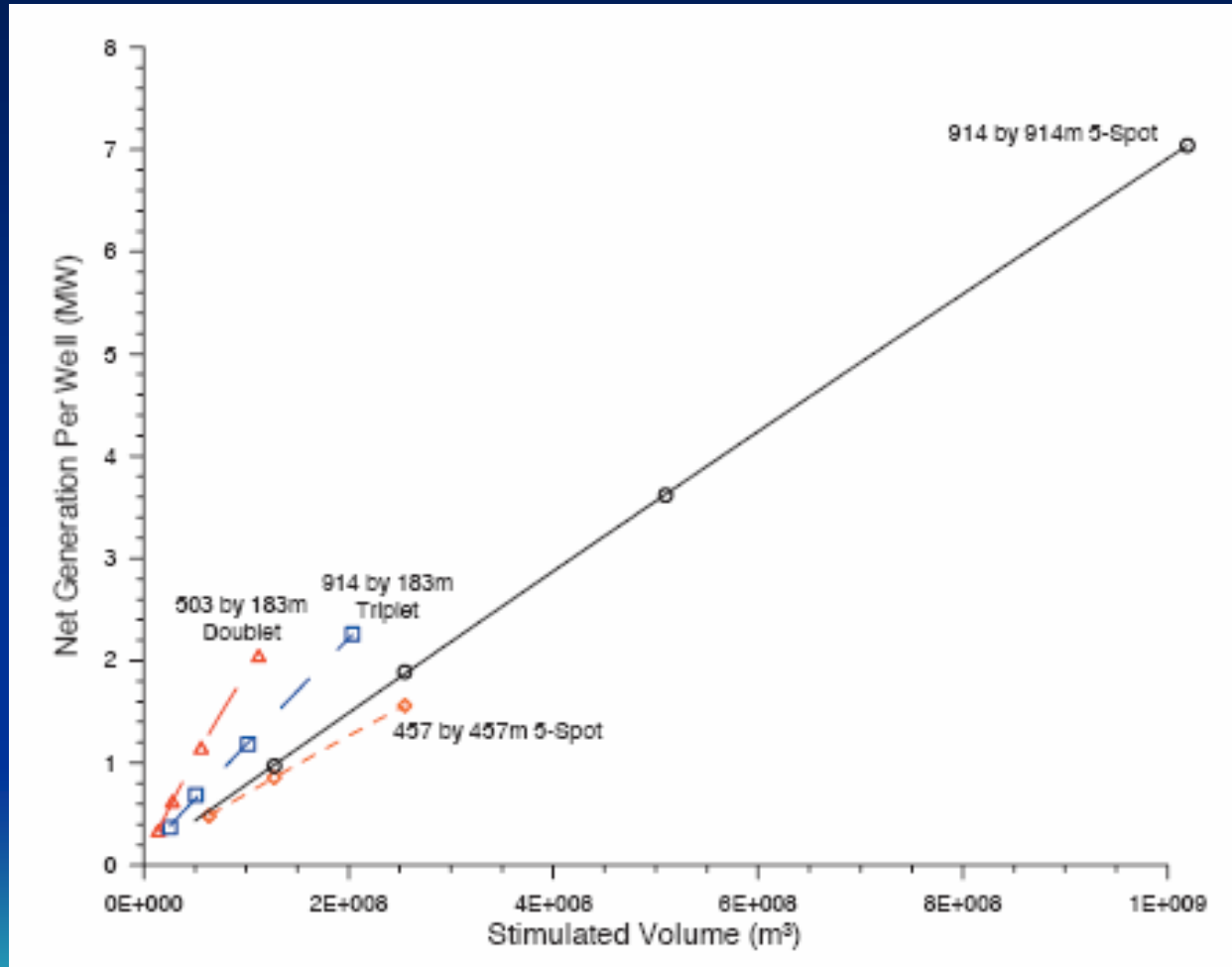
- Abandonment temperature
- Recoverability factor
- Conversion efficiency with temperature
- Inaccessible potential resource areas



Abandonment Temperature



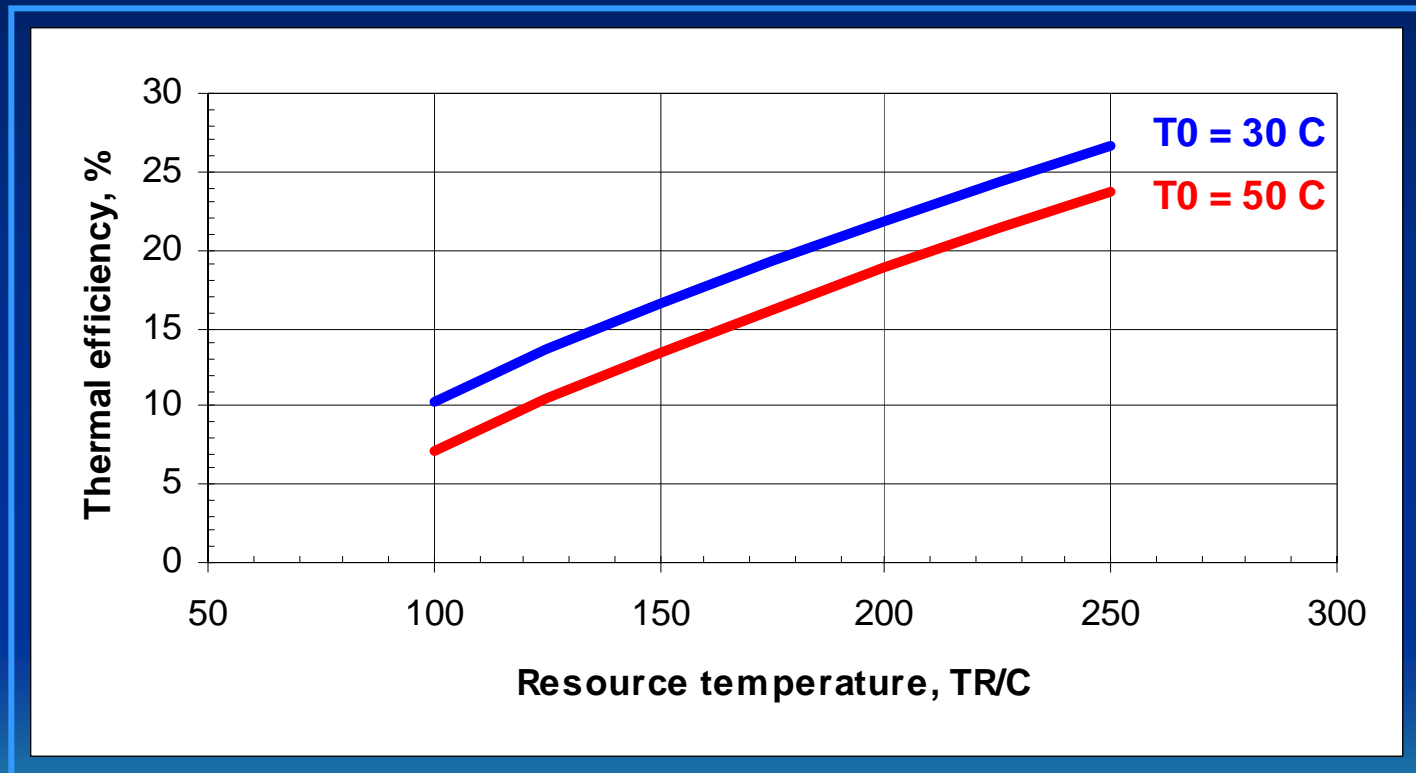
Recoverability Factor



Inaccessible Potential Resource Areas



Usable Energy – Converting Heat to Power



Accessing the Resource

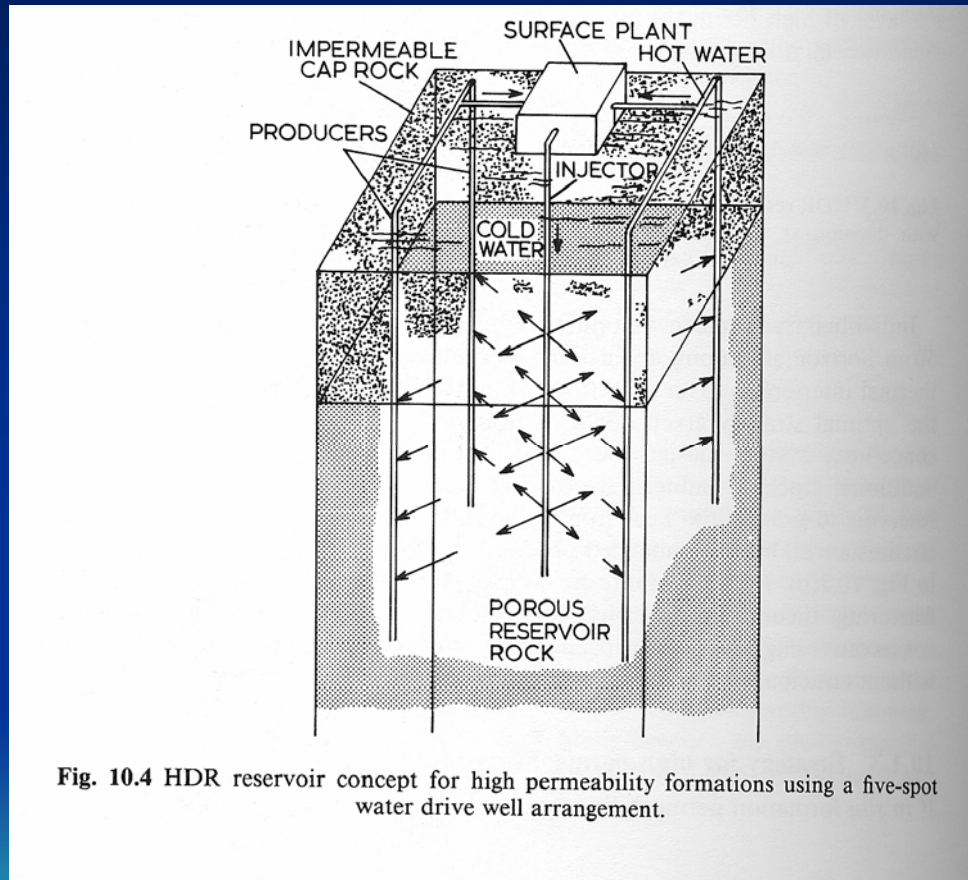


Fig. 10.4 HDR reservoir concept for high permeability formations using a five-spot water drive well arrangement.

Convective vs. Conductive Resource

- Above 3 km
 - High temperature fluids
 - Permeability often controlled by faults and fractures
 - Rock heated by convection of hot water
- Hydrothermal resource – very high permeability
- Shallow EGS resource
 - On margins of hydrothermal systems
 - Volcanic heating



Convective vs. Conductive Resource

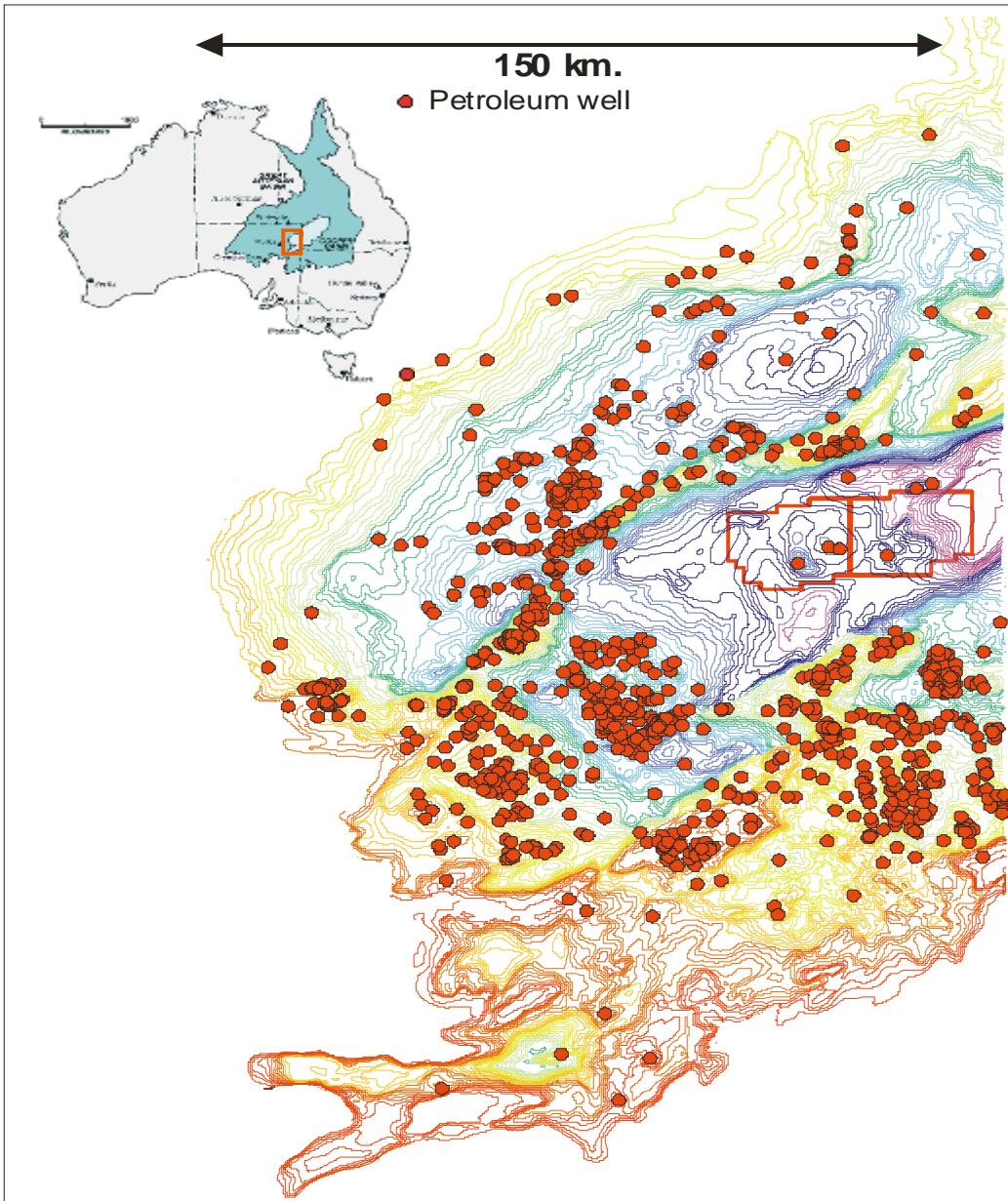
- Shallow EGS resource
 - On margins of hydrothermal systems
 - Volcanic areas
 - Sedimentary basins – oil and gas production
 - Lower natural permeability



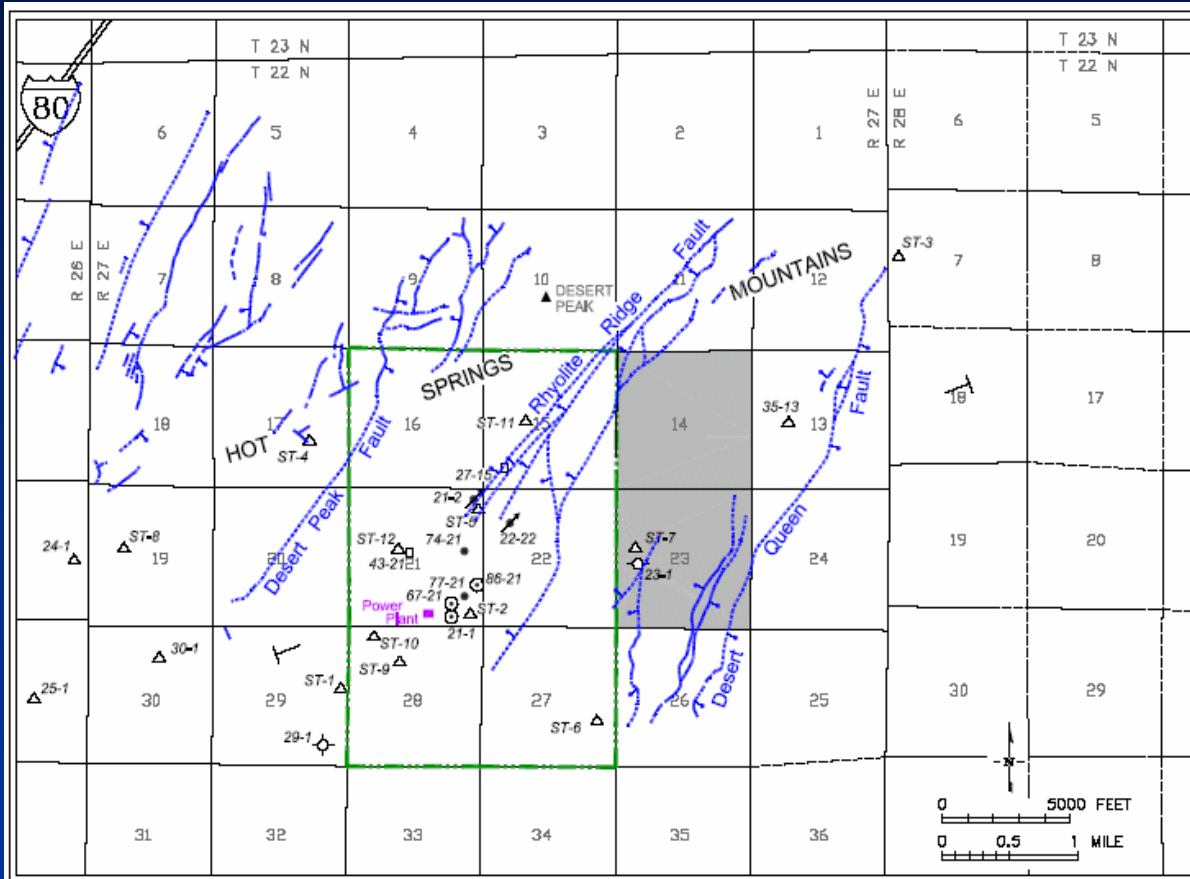
Geothermal from Oilfields

- Soultz, France
 - Pechelbronn oil field
 - Data on depth to bedrock
 - Temperature
 - Oil wells used for seismic monitoring
- Cooper Basin –
 - Depth to bedrock
 - Temperature mapping





Cooper Basin



Supply of EGS Power on the Edges of Existing Hydrothermal Systems

Estimates of Recoverable Resource

Total Recoverable Energy in Net MWe With 20% Recovery Factor						
Depth of Slice in km	Power available for slice	Amount at 150C	Amount at 200C	Amount at 250C	Amount at 300C	Amount at 350C
3 to 4	427,294	370,737	50,969	3,067	2,520	
4 to 5	2,393,924	1,893,486	422,635	71,746	6,057	
5 to 6	4,518,482	2,309,052	1,891,777	308,085	9,567	
6 to 7	8,144,499	1,582,042	5,019,961	1,399,908	142,588	
7 to 8	11,357,673	1,694,606	4,965,429	3,768,381	806,408	122,848
8 to 10	16,776,106	2,536,930	2,536,930	7,701,302	2,820,501	940,120
	43,617,976					

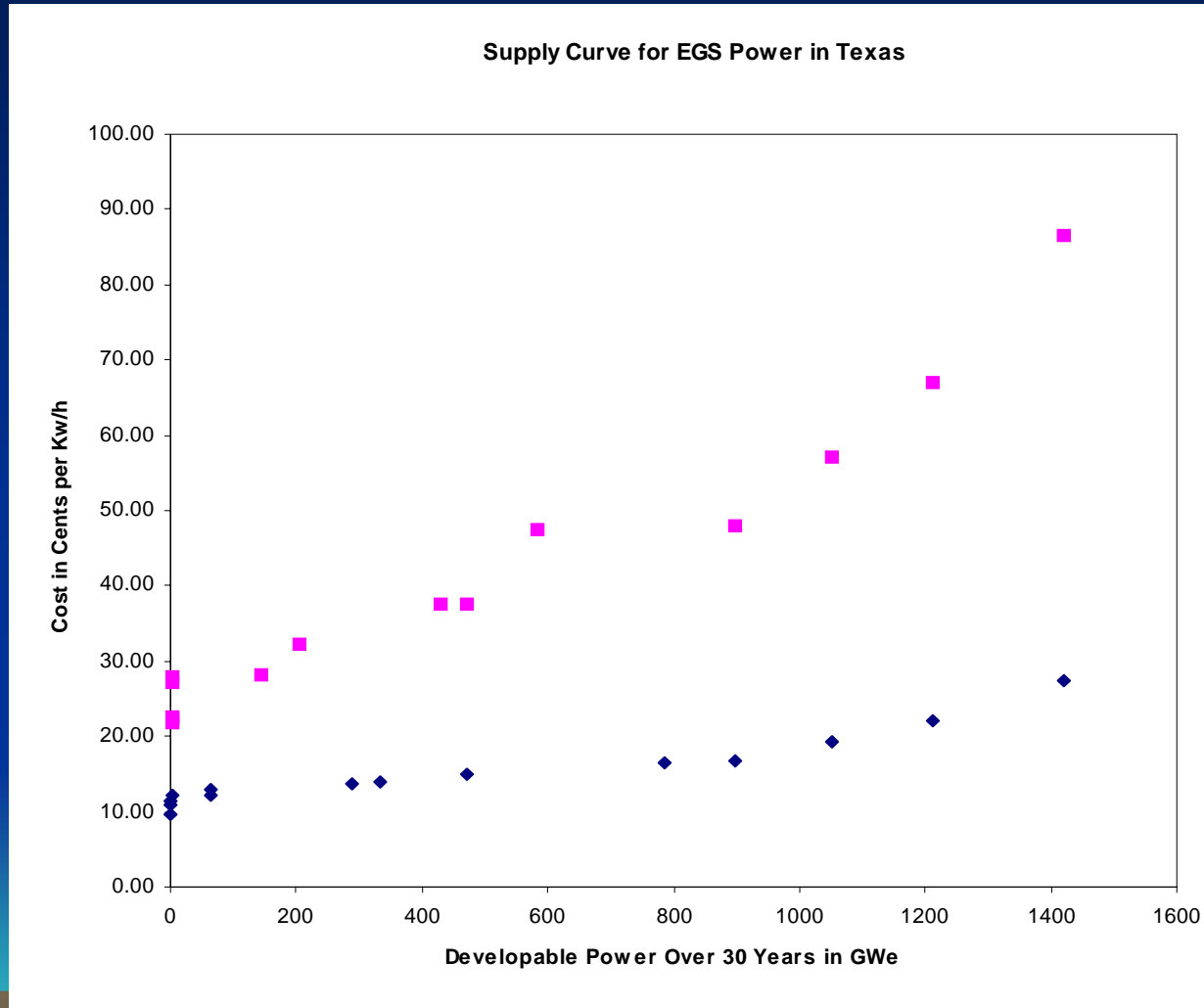


Estimates of Recoverable Resource

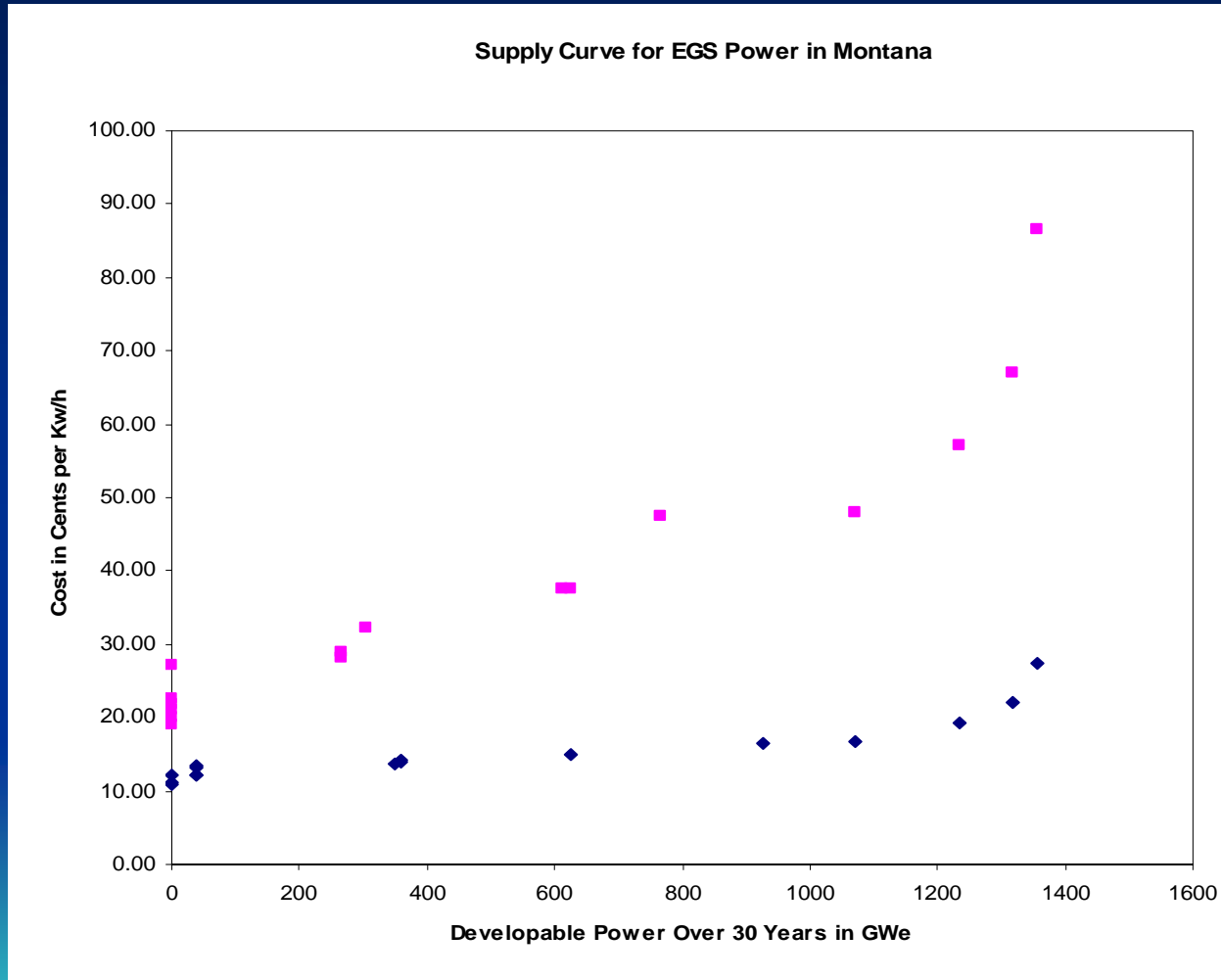
Total Recoverable Energy in Net MWe with 2% Recovery Factor						
Depth of Slice in km	Power available for slice	Amount at 150C	Amount at 200C	Amount at 250C	Amount at 300C	Amount at 350C
3 to 4	42729.35295	37,074	5,097	307	252	
4 to 5	239,392	189,349	42,264	7,175	606	
5 to 6	451,848	230,905	189,178	30,809	957	
6 to 7	814,450	158,204	501,996	139,991	14,259	
7 to 8	1,135,767	169,461	496,543	376,838	80,641	12,285
8 to 10	1,677,611	253,693	253,693	770,130	282,050	94,012
	4,361,798					



Resource and Economics



Resource and Economics



Project Status

- Interim resource evaluation completed
- Economics completed
- Report in review

