Engineering Geothermal Systems in Oil and Gas Reservoirs

Susan Petty
Bill Livesay
Black Mountain Technology

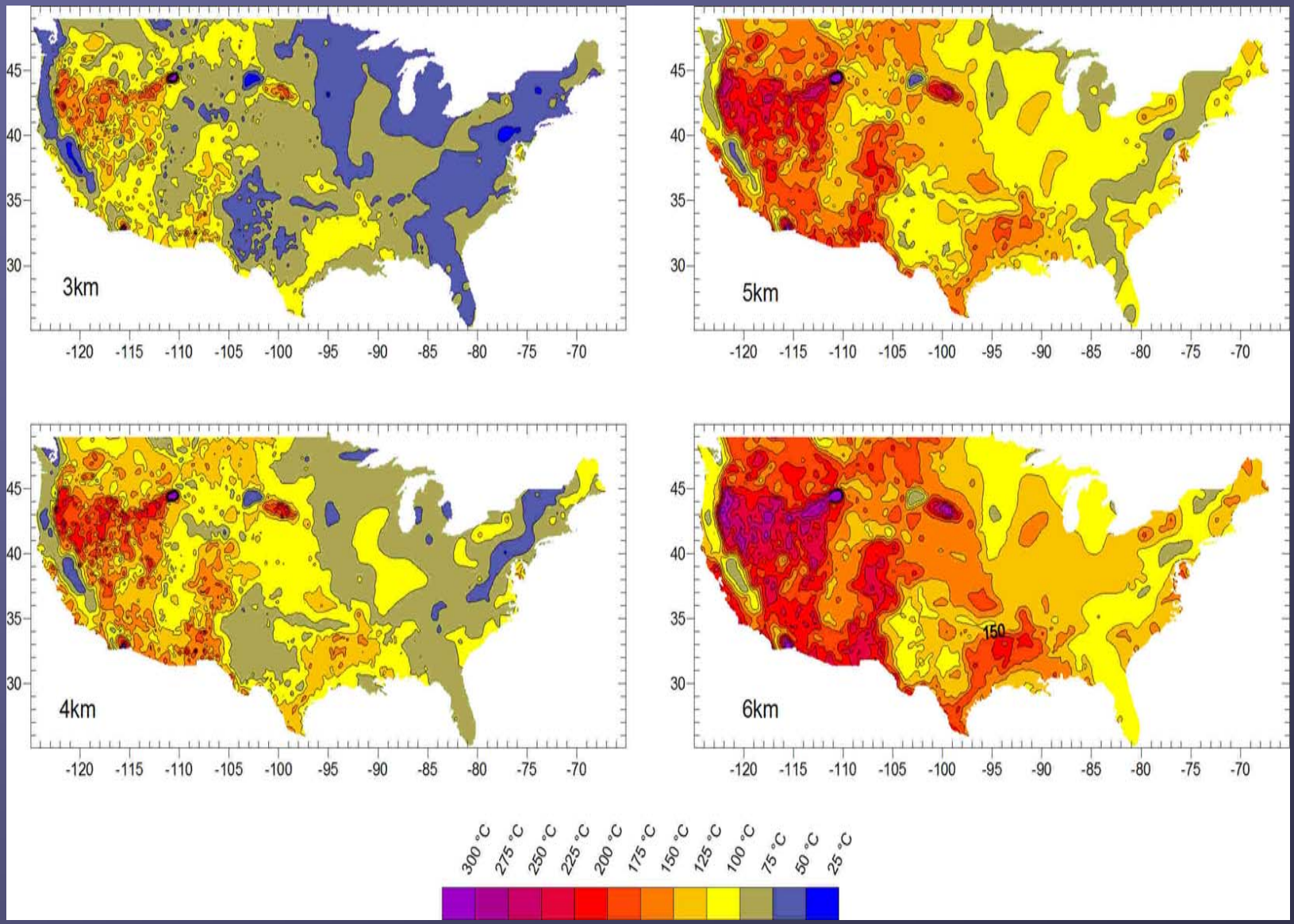
Energy from the Earth's Heat

- Hydrothermal systems
  - Naturally high permeability
  - Can be developed without stimulation
  - Usually at shallow depths <3 km
- Conductive heat energy
  - Greater than 3 km
  - Requires stimulation or other engineering to develop reservoir - EGS
- Hot water in hydrocarbon reservoirs
  - Develop co-produced high temperature fluids
  - Maybe need to be stimulated to produce at high enough flow rates

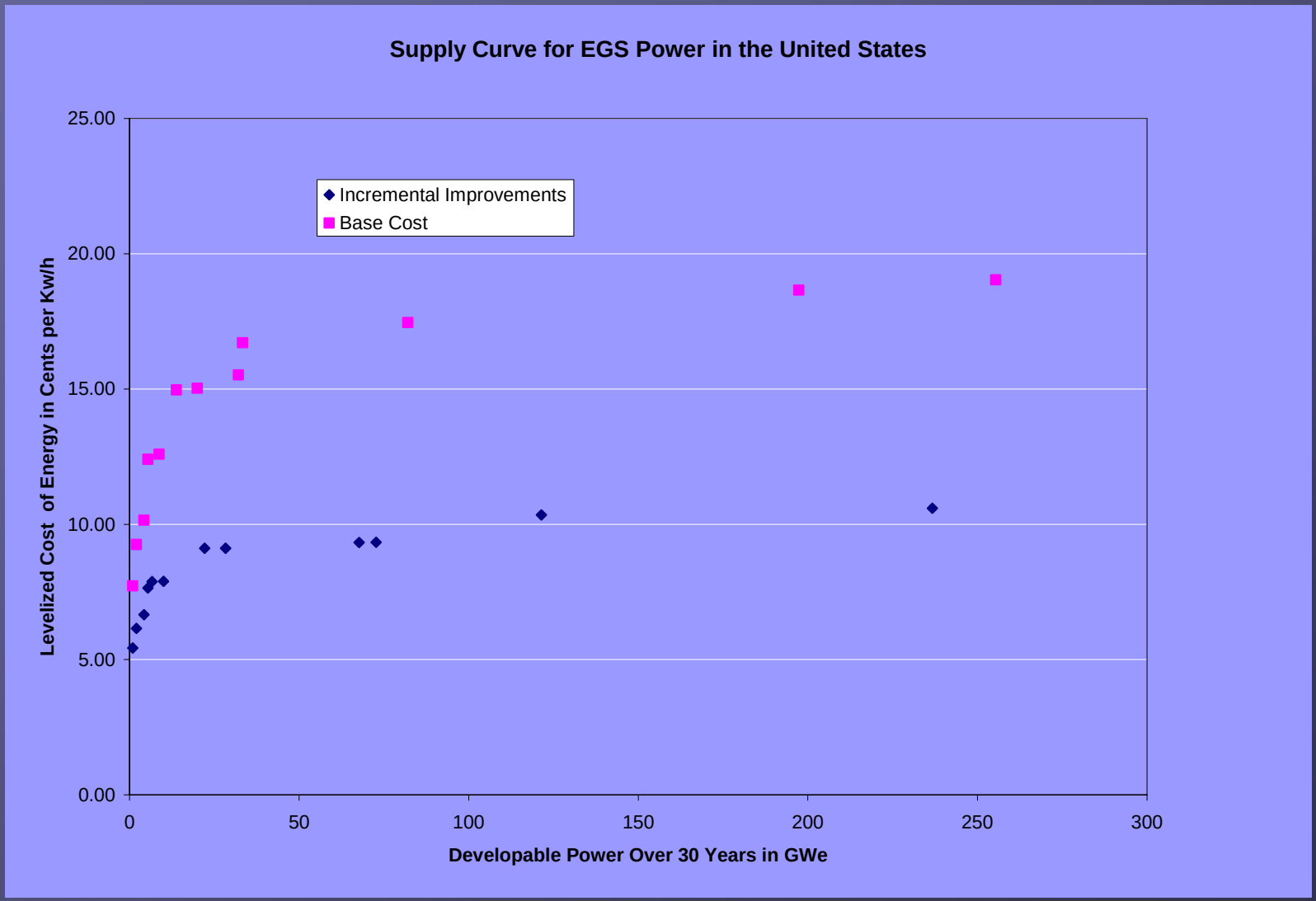
The Geothermal Resource in Oil and Gas Settings

- **Conductive systems >3 km**
  - **Geopressured resource**
  - **Decreasing natural permeability with depth**
  - **Need to enhance or improve permeability for economic geothermal production**
- **Shallow convective systems at <3 km**
  - **High temperature fluids from depth**
  - **Circulate on faults and fractures**
  - **May have high permeability**
  - **Normal pressure**

Size of the Resource



Supply of EGS Power at Cost



EGS in Oil Fields

- Oil and gas wells provide data for geothermal development
  - Temperature with depth
  - Lithology
  - Depth to bedrock
  - Pressure/stress
- Wells of opportunity
  - Maintains revenue from depleted fields
  - Recoups cost of dry holes

EGS in Oil Fields

- Europe
  - Soultz
  - Landau
  - Grosse Schönebeck
  - Unterhaching
- Australia
  - Cooper Basin
  - Paralana GreenEarth Energy
  - Hot Rock Ltd
  - Geogen VictoriaT
  - Torrens Energy Ltd
  - Granite Power

Resource Development

- Scenario 1 – Use wells of opportunity
  - Benefits
    - Saves cost of drilling
    - Existing data on stress may be available
    - May have reservoir data
    - Water already stored in sedimentary rocks
  - Drawbacks
    - Needs to be re-completed for water production
    - High flow rates needed for economic production
    - Small diameter = larger pressure drop
    - High reservoir pressure may make injection into reservoir costly

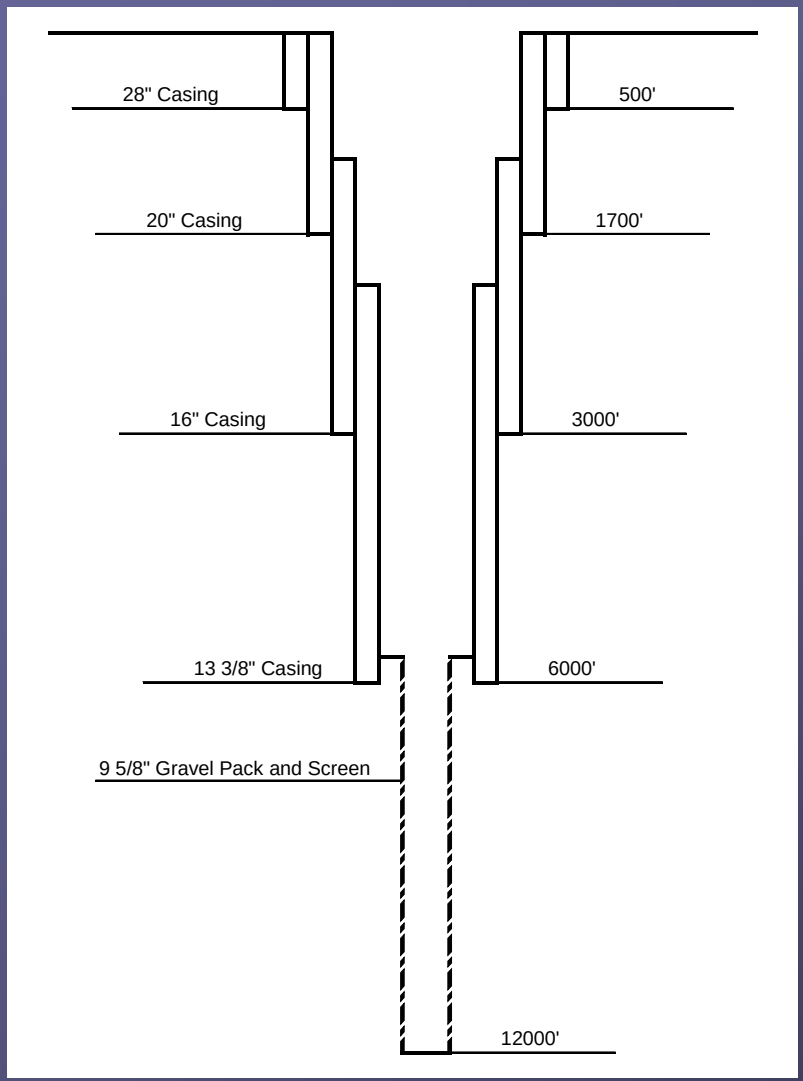
Resource Development

- Scenario 2 – Drill New Wells
  - Benefits
    - Large size borehole can be drilled to maximize flow rates and accommodate a pump
    - Well can be completed in hot water zones
    - Temperature vs. Depth can be optimized
    - Water already stored in sedimentary rocks
    - Can be drilled to reach higher temperatures in underlying crystalline rocks
  - Drawbacks
    - Deep wells can be very expensive
    - Drilling risk must be considered
    - May not have data in target zone

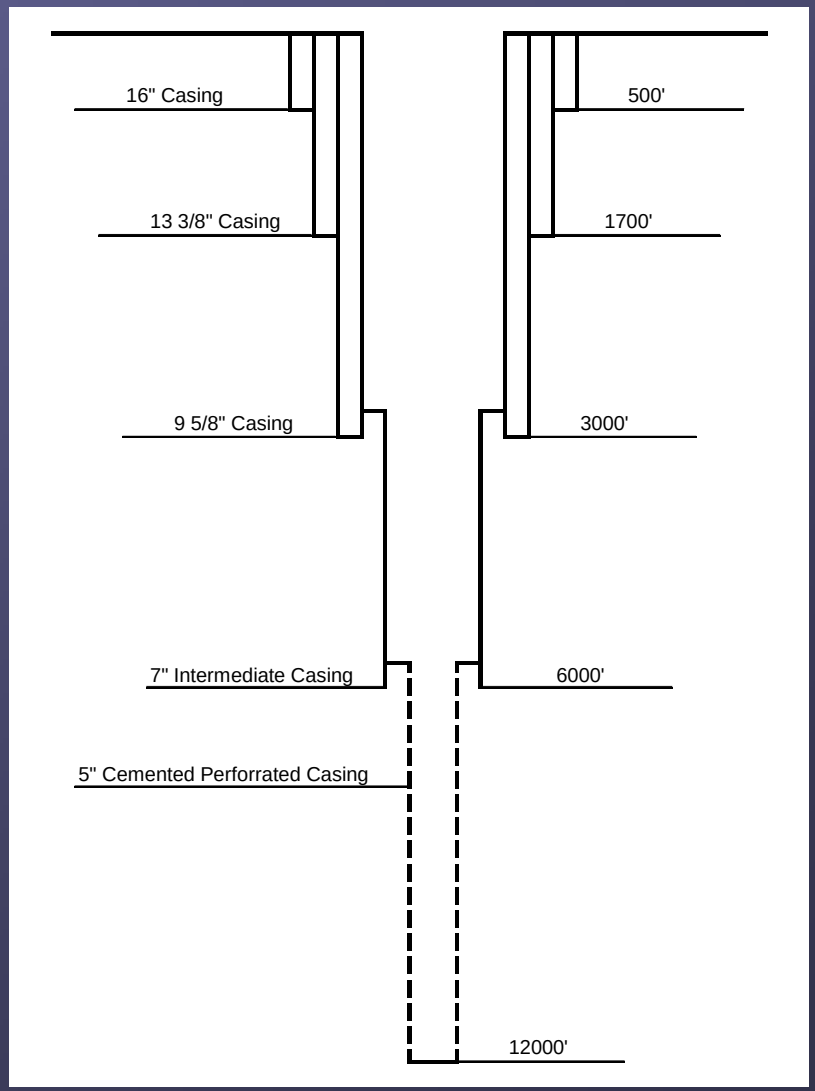
Enhancing Permeability in Oil Fields

- Current practice geothermal stimulation
  - Pump very high volumes of cold water from the surface at just above the critical pressure for shear failure
  - Stimulate pre-existing micro fractures
  - No gels and usually no proppants
- Current practice oil field stimulation
  - Pump at very high pressures
  - Produce an extended fracture with large aperature
  - Jack open with gels and hold open with proppants
  - Creates a potential short circuit for cool water to return

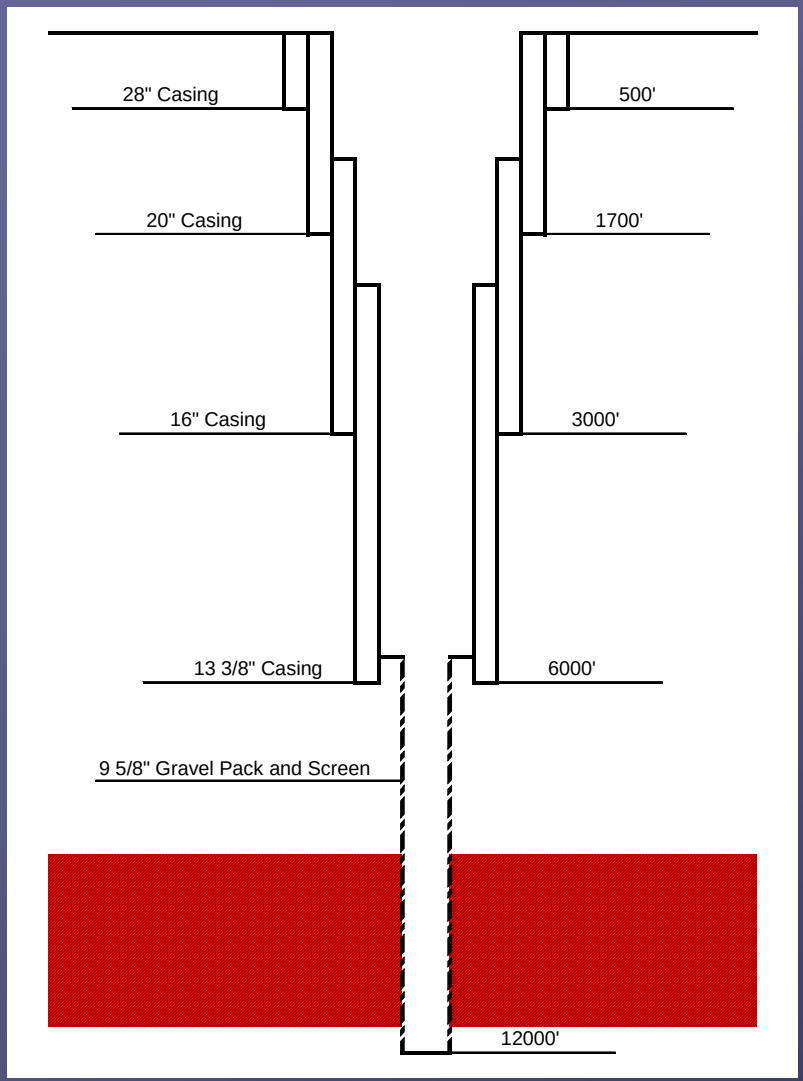
Geothermal Well



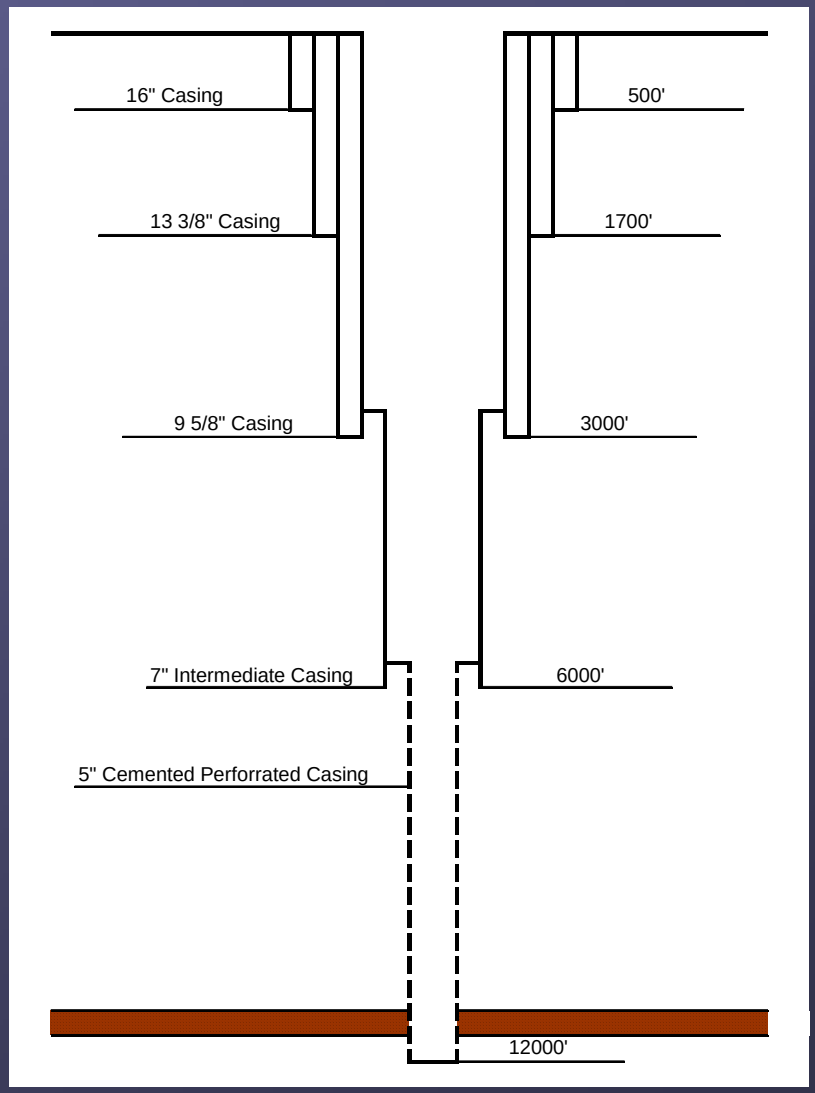
Oil Well

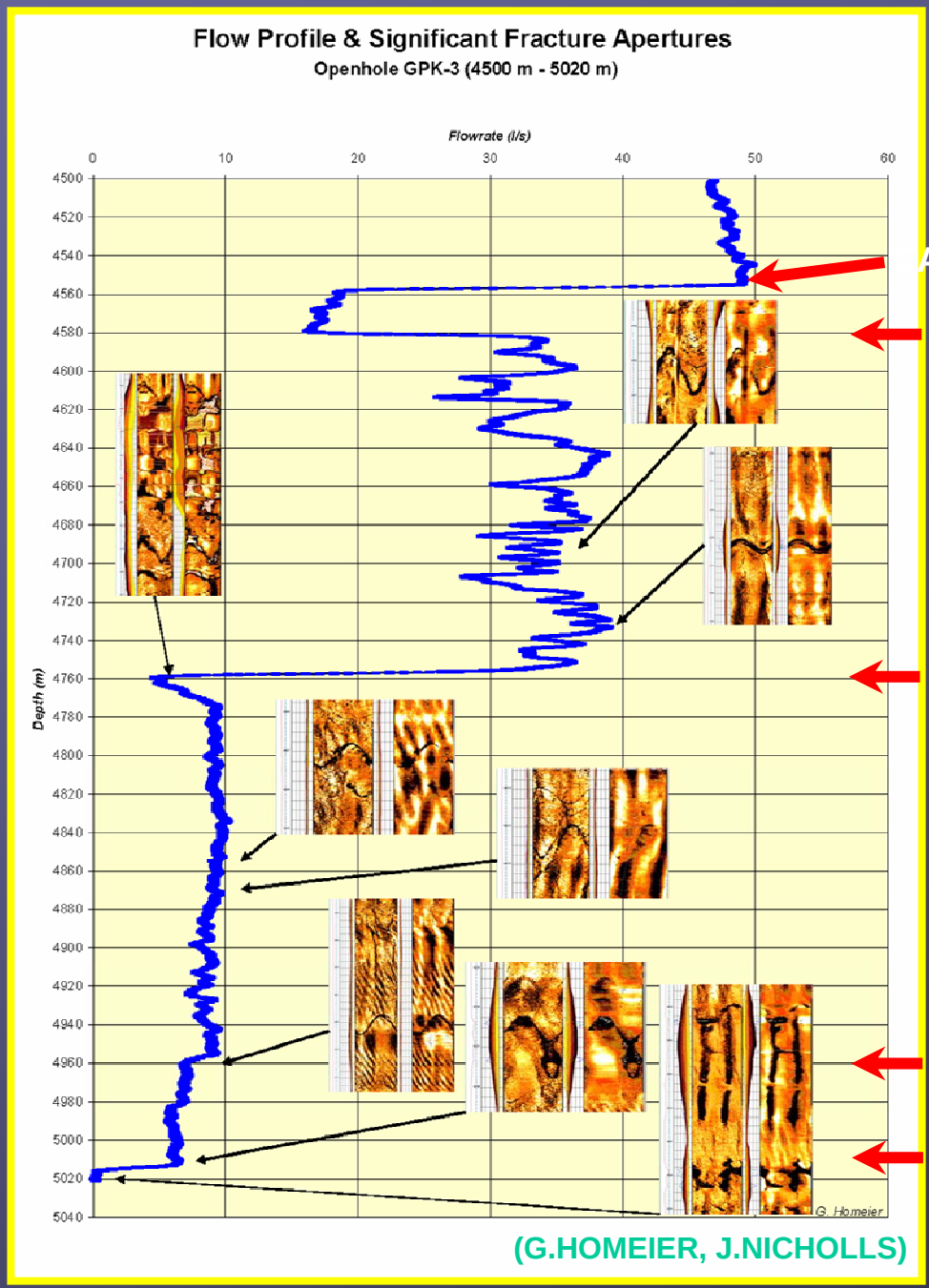


Geothermal Well



Oil Well




Flow Profile & Significant Fracture Apertures
Openhole GPK-3 (4500 m - 5020 m)
Flowrate (l/s)
0
10
20
30
40
50
60
Depth (m)
4500
4520
4540
4560
4580
4600
4620
4640
4660
4680
4700
4720
4740
4760
4780
4800
4820
4840
4860
4880
4900
4920
4940
4960
4980
5000
5020
5040
G. Homeier
ASING SHOE
~ 10% (5 l/s)
~ 70% (35 l/s)
~ 12% (6 l/s)
~ 8% (4 l/s)
(G.HOMEIER, J.NICHOLLS)

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

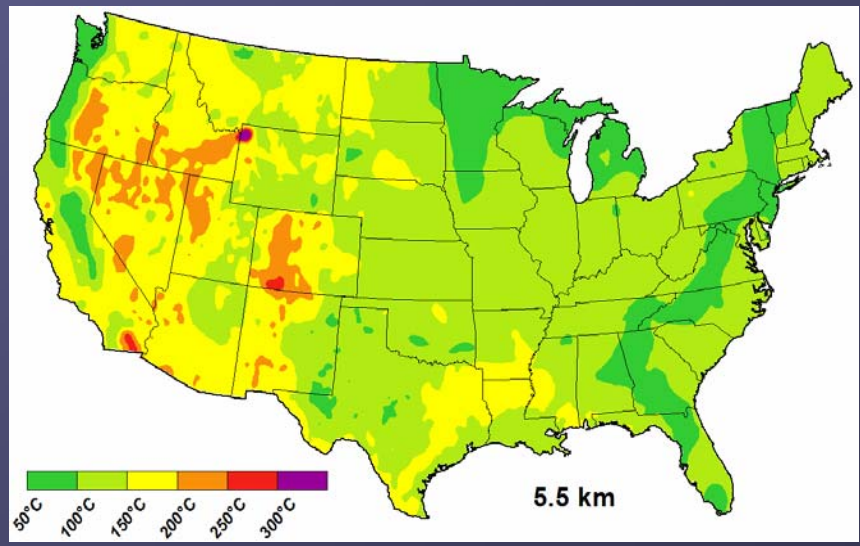
Reality Check EGS

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



Technology gaps and barriers

- Need reliable methods to increase the fractured heat exchange area without inducing felt seismic events or making short circuits
- Need to divert stimulation to zones that have been less affected
- So far, can’t reliably connect into an existing hydrothermal reservoir
- Short circuits may develop during treatment or during long term operation
- Injecting at high pressures to increase flow results in induced seismicity, reservoir growth and fluid loss
- Need to be able to pump production wells with electric submersible pumps at high temperatures to increase flow per well

Future Work to Overcome Gaps and Barriers

- Develop high temperature instrumentation to better evaluate fractures prior to stimulation (discriminate between open and sealed fractures)
- Develop methods to isolate zones for stimulation or divert treatment to unstimulated zones
- Develop methods for repairing short circuits
- Better understand link between stimulation, geology, tectonics and inducing felt earthquakes
- Develop high temperature electric submersible pumps