

# PIONEER

NATURAL RESOURCES

## A Raton Basin Geothermal Prospect

Hal Macartney

SMU Geothermal Conference

Dallas TX June 14-15, 2011

NYSE: PXD  
[www.pxd.com](http://www.pxd.com)



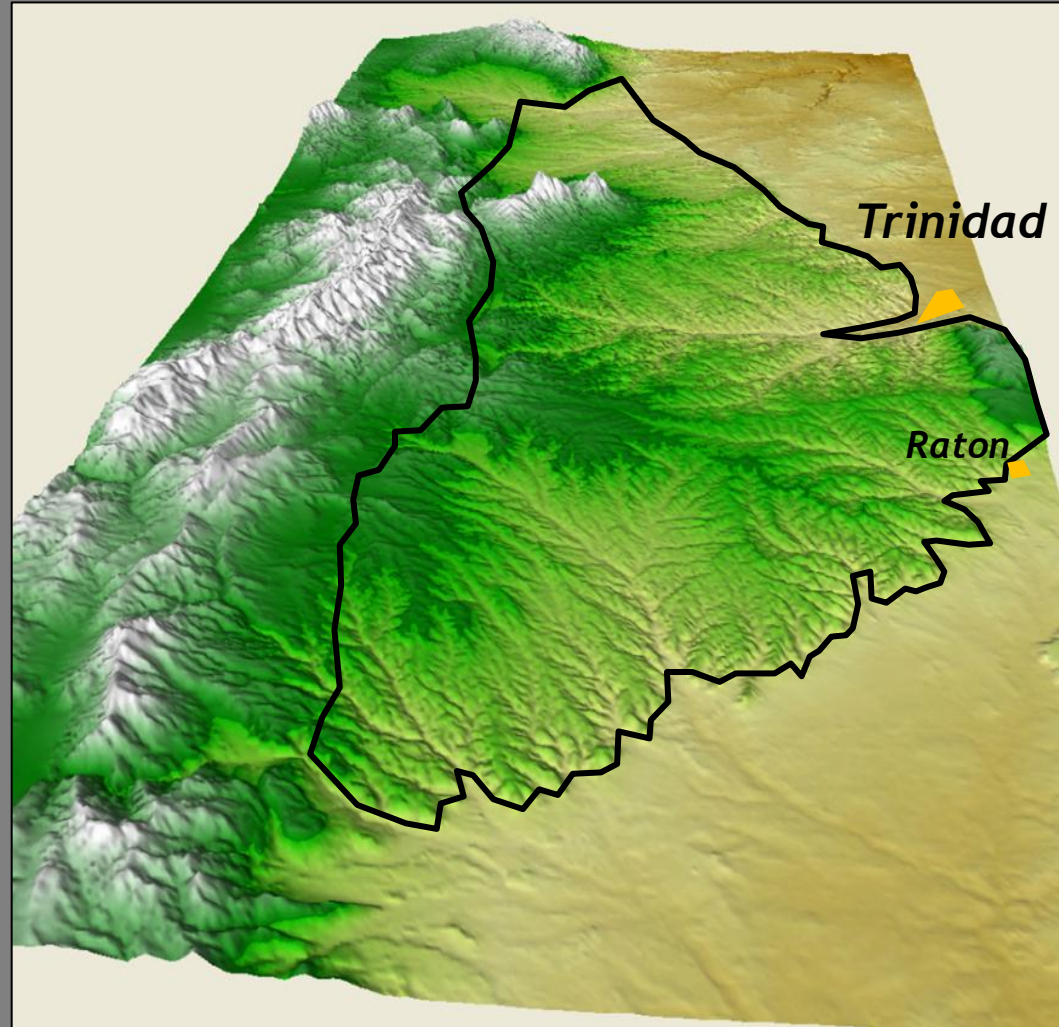
- **Thermal anomaly**
- **Resource assessment**
- **Reservoir assessment**
- **Pilot project**
- **Next steps**



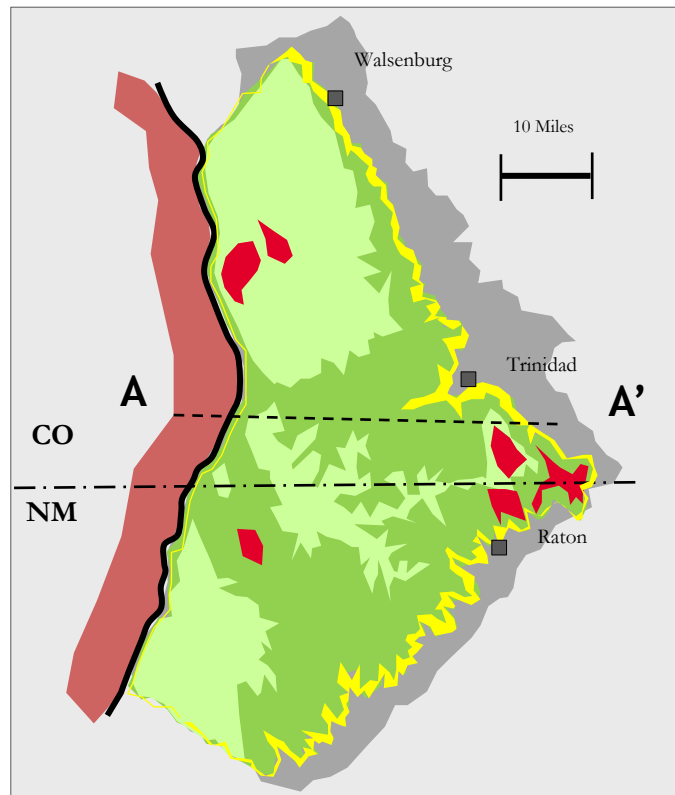
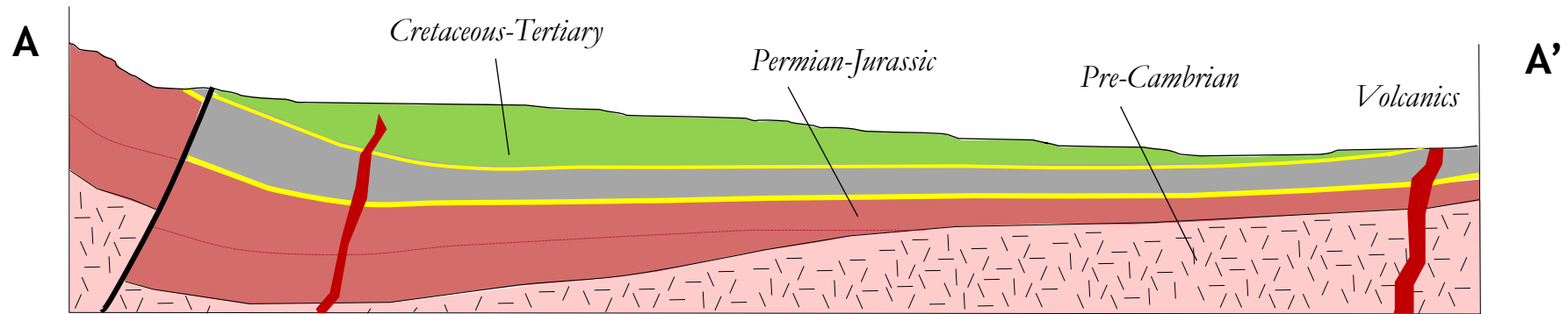




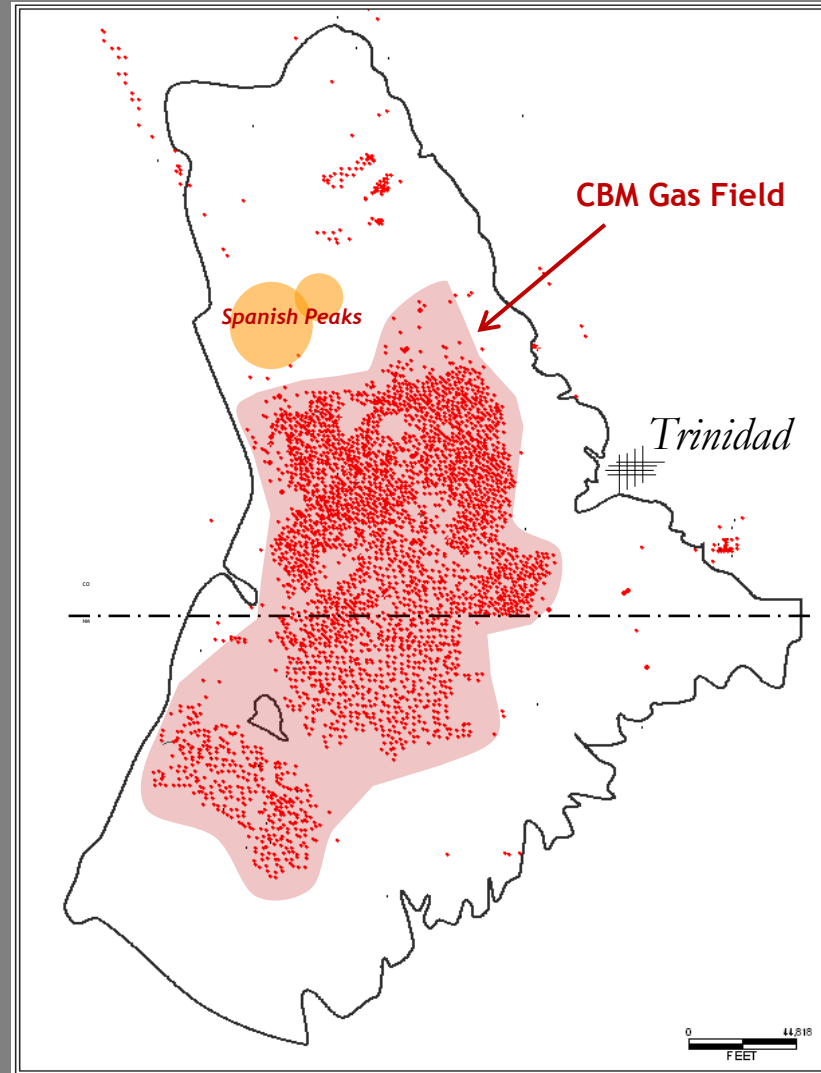
# Raton Basin Geography



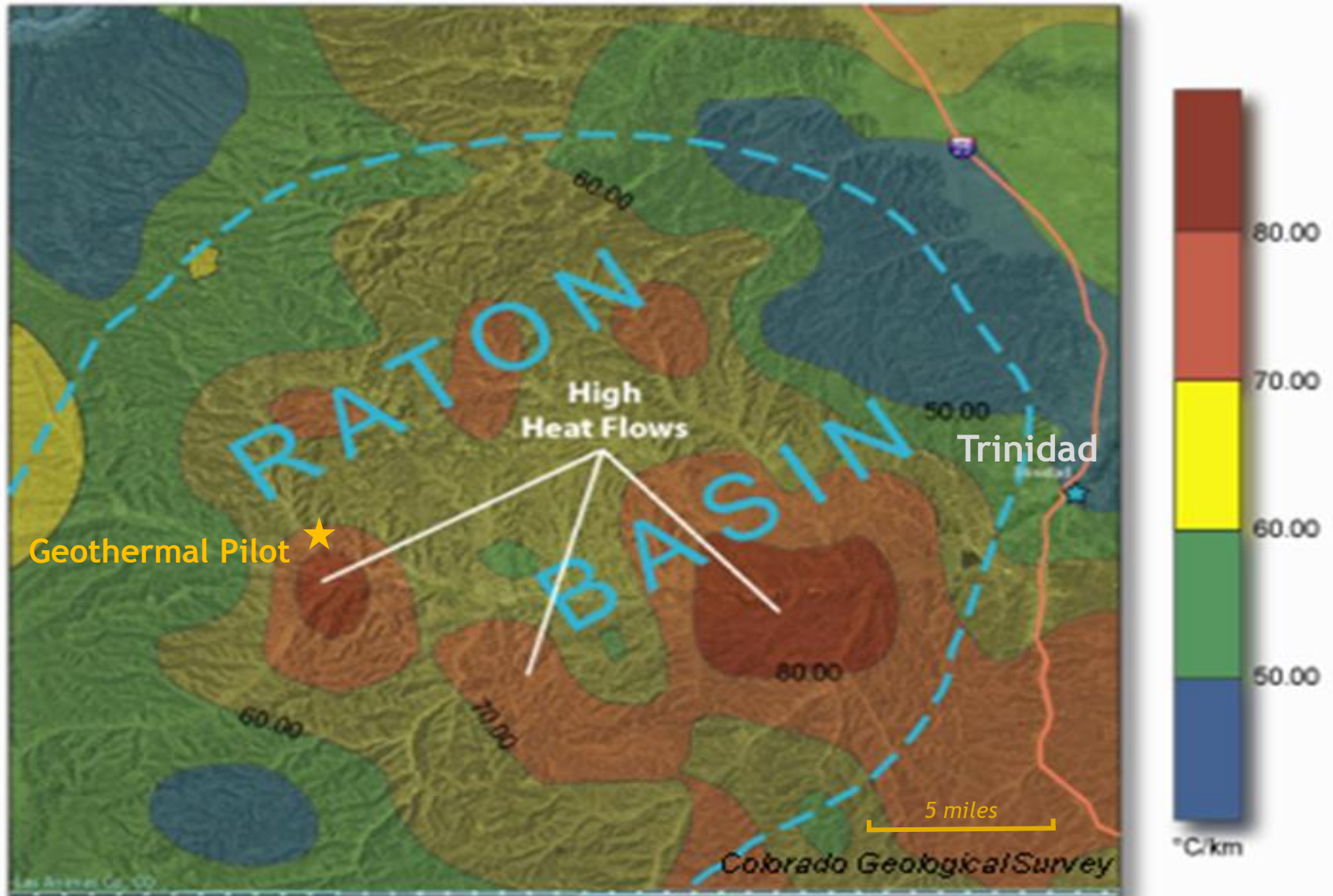
# Raton Basin Geology



# Natural Gas Wells

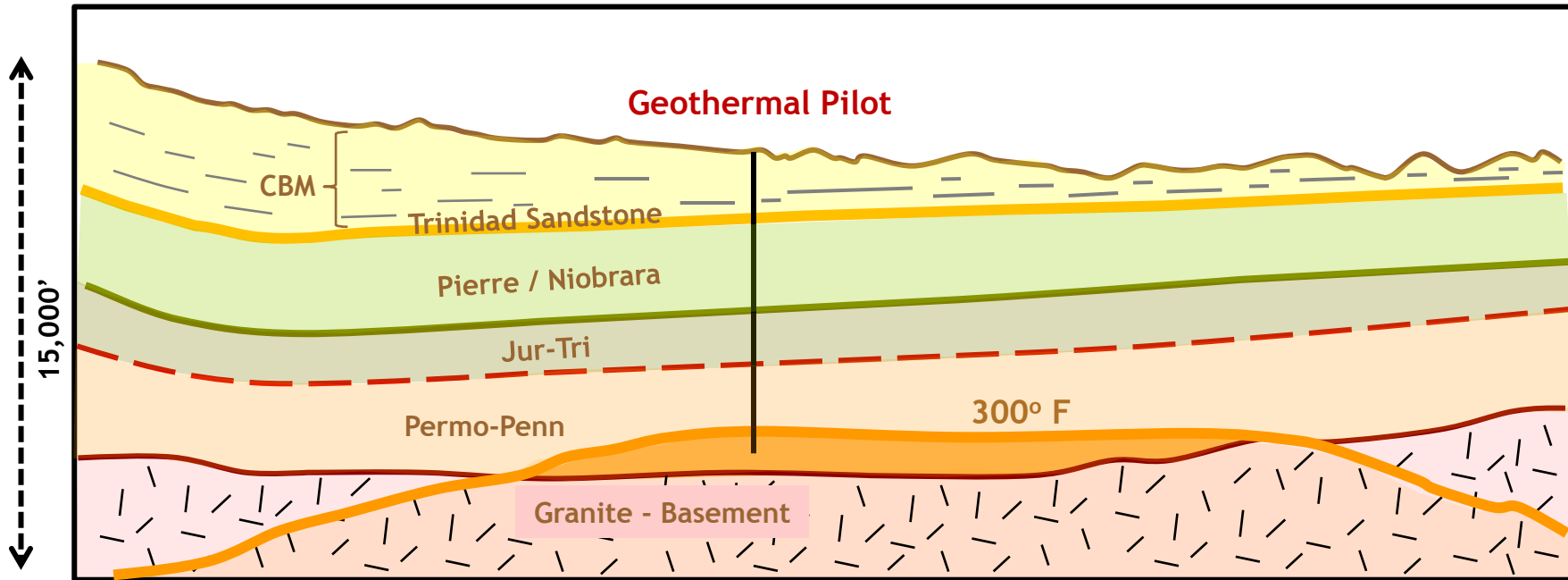


# Raton Thermal Anomaly





# Thermal Resource Assessment

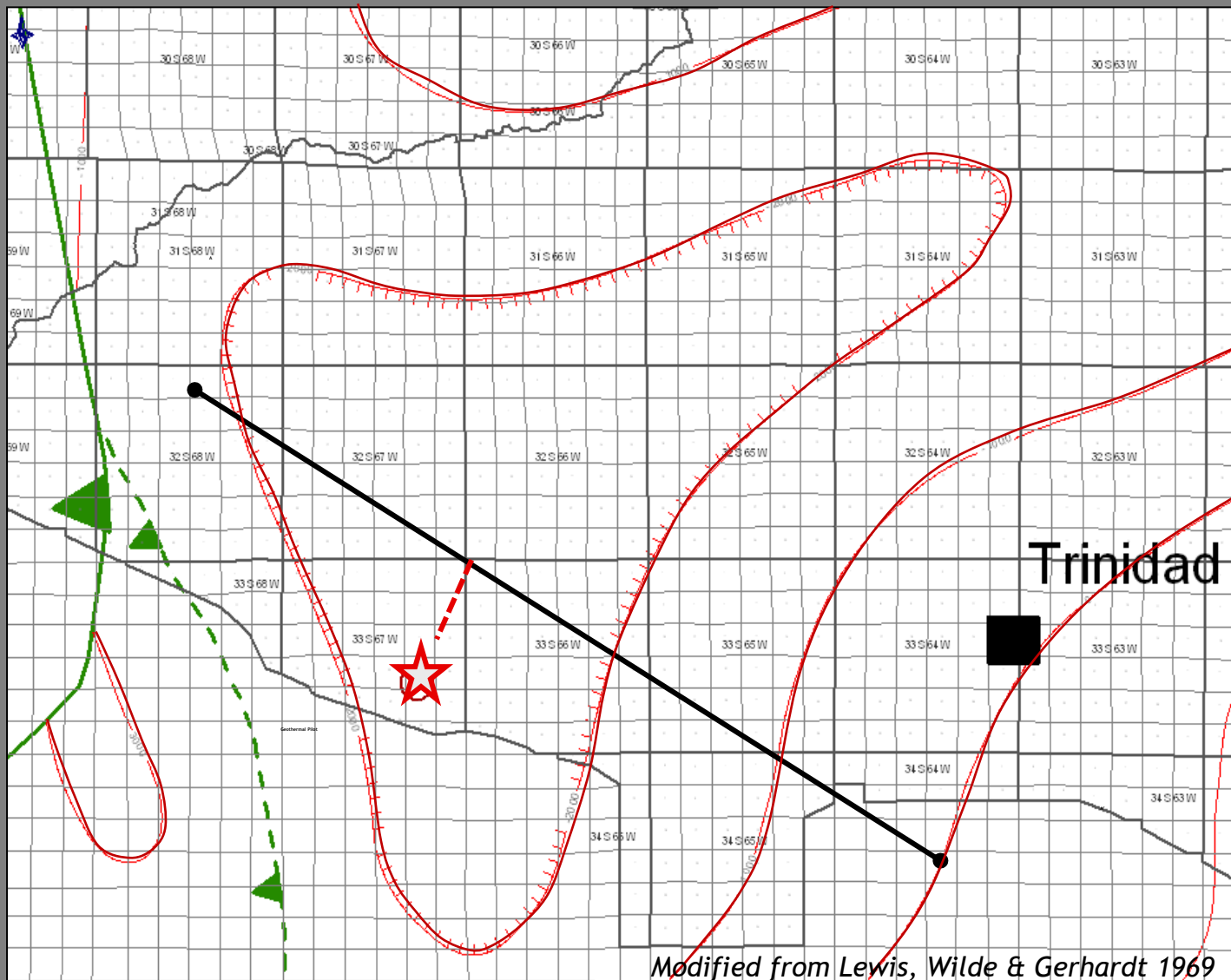


Sketch W-E Cross Section Across the Raton Basin ~10:1 Vertical Exaggeration


- Basement
- 300° F Isotherm Surface
- Sedimentary package > 300° F



# Basement Mapping



# Geothermal Gradient


JLC

01459489

## CEMENT BOND LOG

071-08219

Company Red River Ranch Holdings LLC  
Well Red River 13-4  
Field Purgatorie River  
County Las Animas  
State Colorado

Company Red River Ranch Holdings LLC  
Well Red River 13-4  
Field Purgatorie River  
County Las Animas  
State Colorado

RECEIVED

FEB 11 2005

COGCC

Location API # 05-071-08219-00 Other Services Perf

1946' FTL & 626' FWL

SEC 13 TWP 35S RGE 69W

Permanent Datum Ground Level Elevation 9165  
Log Measured From Ground Level  
Drilling Measured From Ground Level


K.B. \_\_\_\_\_  
D.F. \_\_\_\_\_  
G.L. 9165

Date	12/6/04
Run Number	One
Depth Driller	2305
Depth Logger	2252
Bottom Logged Interval	2250
Top Log Interval	Surface
Open Hole Size	7 7/8"
Type Fluid	Water
Density / Viscosity	///
Max. Recorded Temp.	130 DEG F
Estimated Cement Top	124
Time Well Ready	Portable Mast
Time Logger on Bottom	7:23
Equipment Number	T244
Location	Trinidad
Recorded By	Allen
Witnessed By	Mr Junior Minton

Borehole Record				Tubing Record			
Run Number	Bit	From	To	Size	Weight	From	To
Casing Record				Size	Wgt/Ft	Top	Bottom
Surface String				8 5/8"		00	268
Prot. String						00	N/A
Production String				5 1/2"	17#		
Liner							

Comments

All interpretations are opinions based on inferences from electrical or other measurements and we cannot and do not guarantee the accuracy or correctness of any interpretation, and we shall not, except in the case of gross or willful negligence on our part, be liable or responsible for any loss, costs, damages or expenses incurred or sustained by anyone resulting from any interpretation made by any of our office agents or employees. These interpretations are also subject to our general terms and conditions set out in our current Price Schedule.



SUPERIOR

Black Lick, Pa.  
Mercer, Pa.  
Wooster, Oh.  
Cleveland, Ok.  
Trinidad, Co.

## PRODUCTION LOG

Company Pioneer Natural Resources  
Well Weston 23-24 Deep  
Field Purgatorie River  
County Las Animas State CO

Location: API #: 05 071 07566 00 Other Services PRES CONTROL

449' FSL & 1683' FWL

SEC 23 TWP 33S RGE 67W

Permanent Datum Ground Level Elevation 7042'  
Log Measured From Kelly Bushing 18' Above G.L.  
Drilling Measured From Kelly Bushing

K.B. 7060'  
D.F. \_\_\_\_\_  
G.L. 7042'

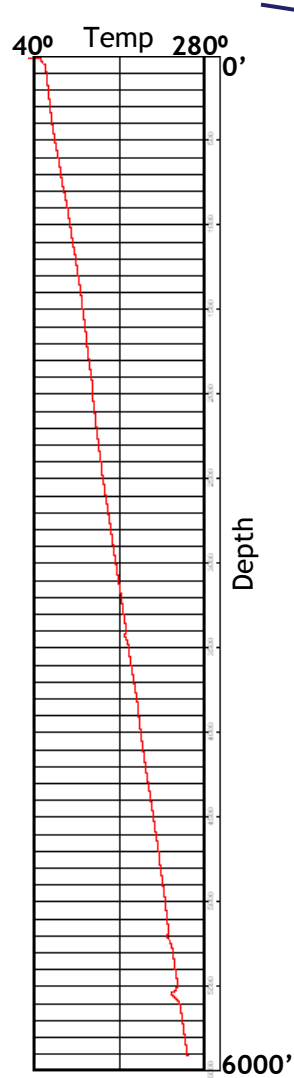
Date	11/16/06
Run Number	one
Depth Driller	4350'
Depth Logger	4300'
Bottom Logged Interval	4300'
Top Log Interval	3800'
Open Hole Size	8 3/4"
Type Fluid	water
Density / Viscosity	///
Max. Recorded Temp.	183F
Estimated Cement Top	NA
Time Well Ready	10:30
Time Logger on Bottom	11:00
Equipment Number	T244
Location	Trinidad
Recorded By	Worley
Witnessed By	

Borehole Record				Tubing Record			
Run Number	Bit	From	To	Size	Weight	From	To
Casing Record				Size	Wgt/Ft	Top	Bottom
Surface String				9 5/8"		00	1820'
Prot. String							
Production String				7"		00	4891'
Liner							

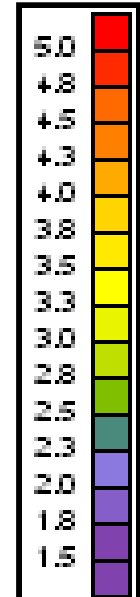
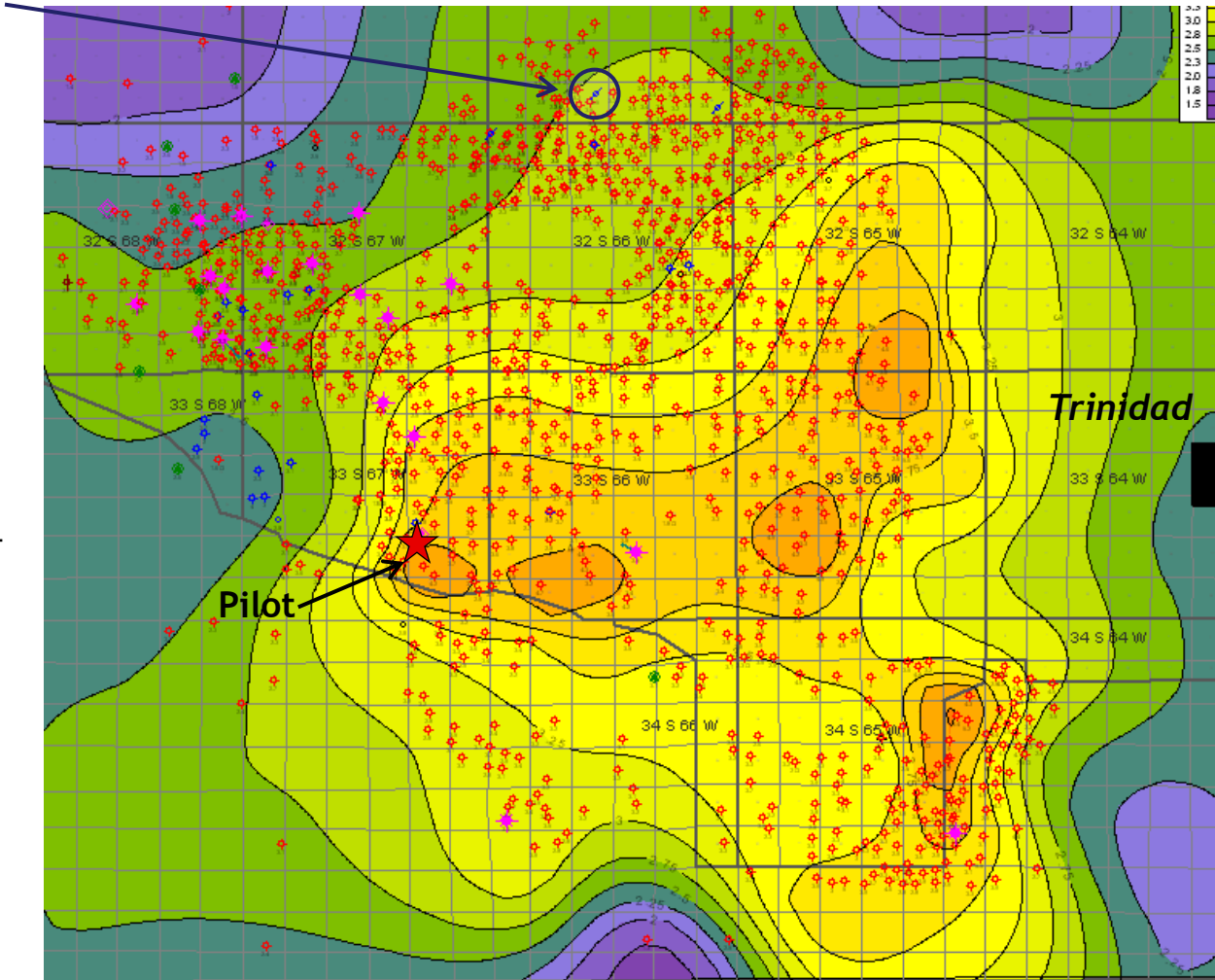
Comments

# Geothermal Gradient

Jarosa 32-33 WDW



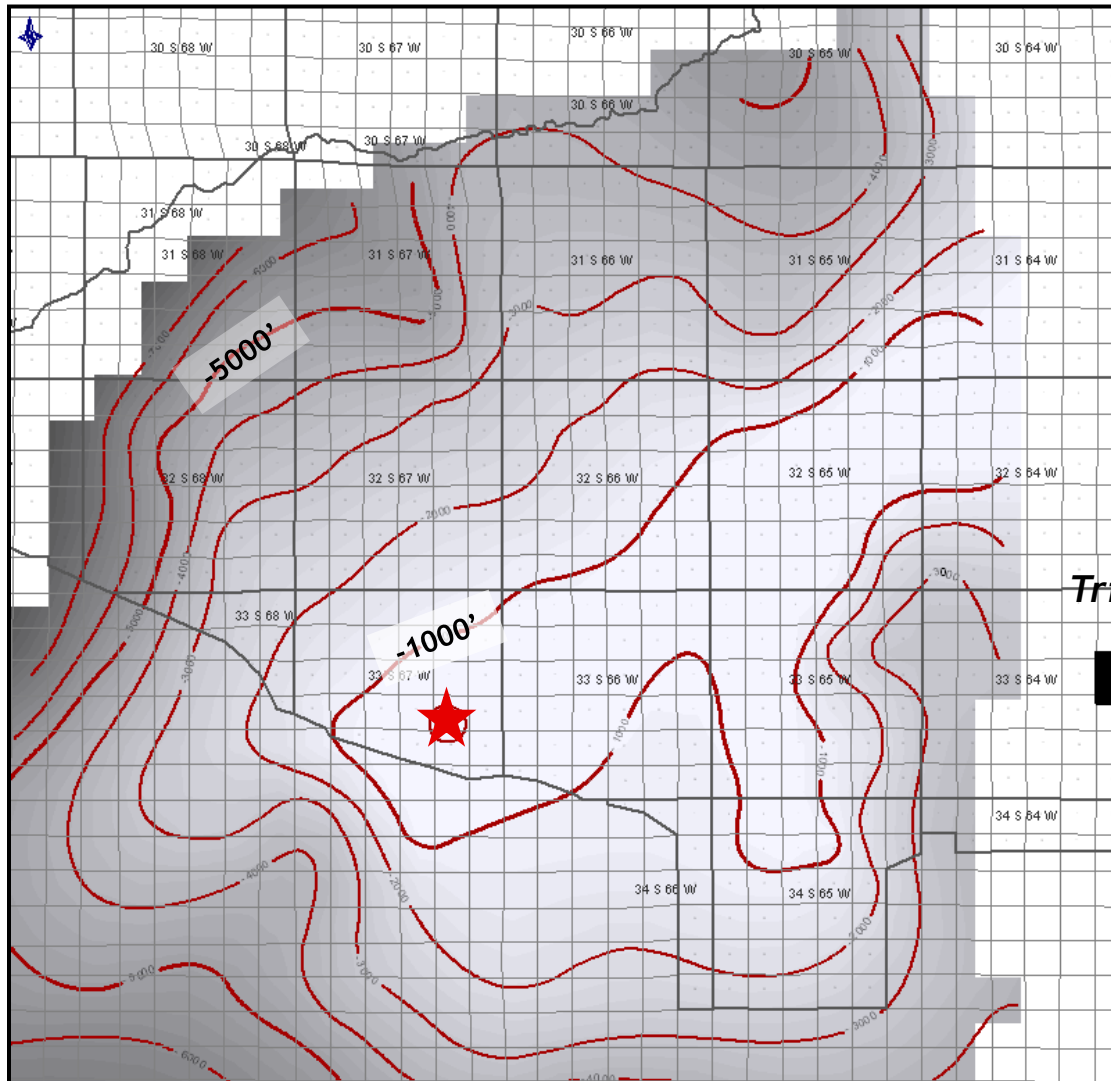
Temperature Log



°F / 100'

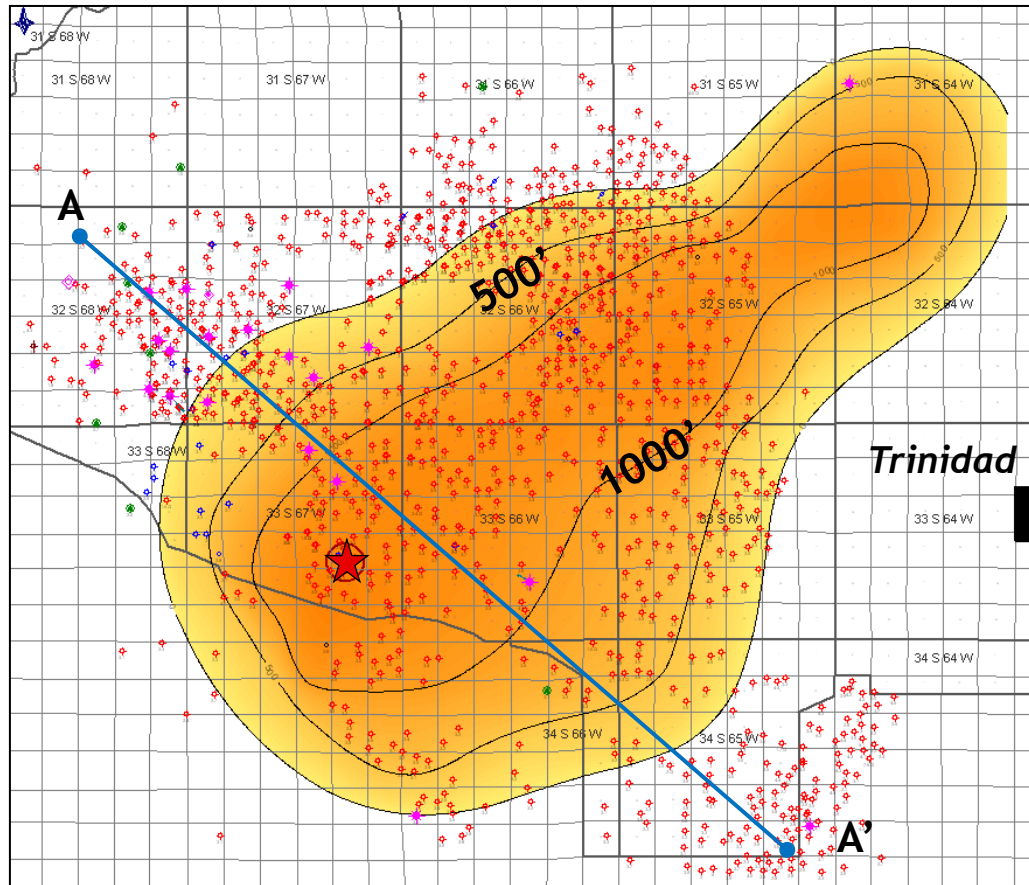


# 300° F Isotherm Surface

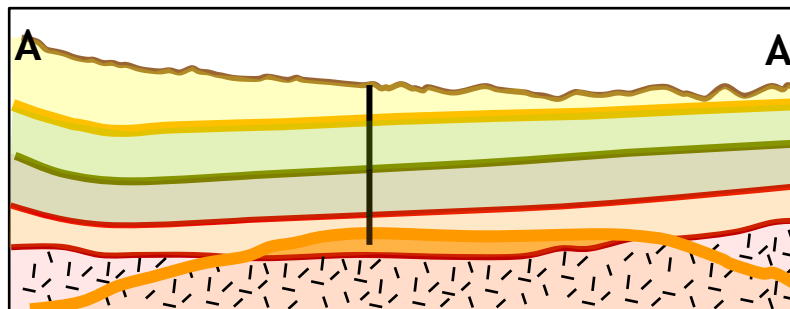


Surface of T=300°F  
CI = 1000'

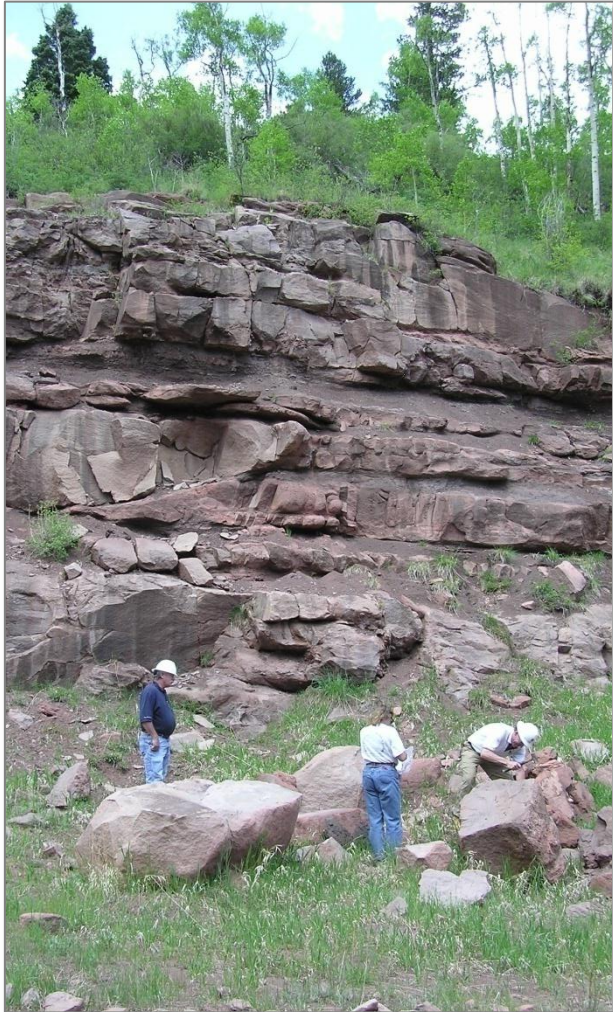
# Sedimentary Rock >300° F



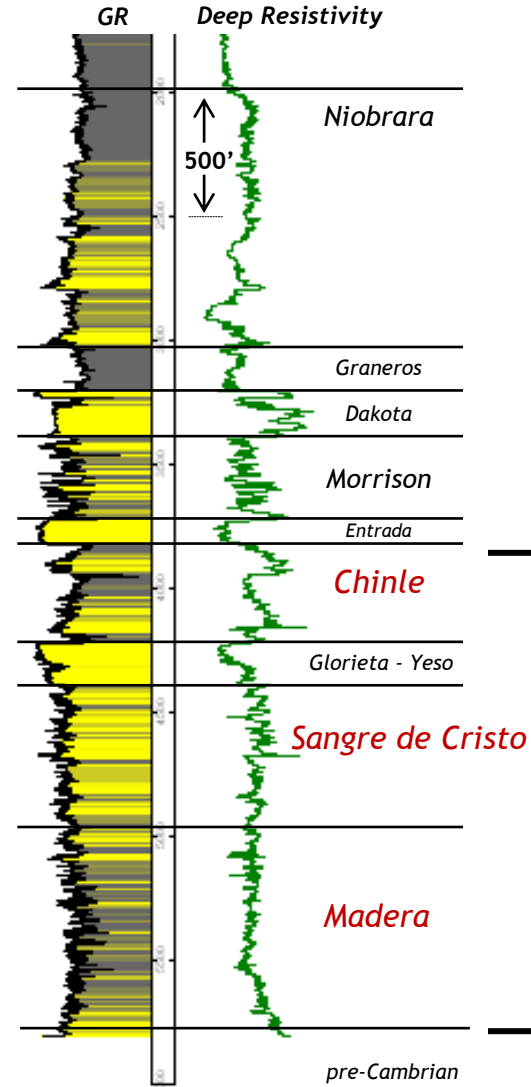
Thickness (ft.)



# Reservoir Assessment - Targets



Phelps Dodge #1  
Sec 21, T26N R22W  
Colfax Co. NM

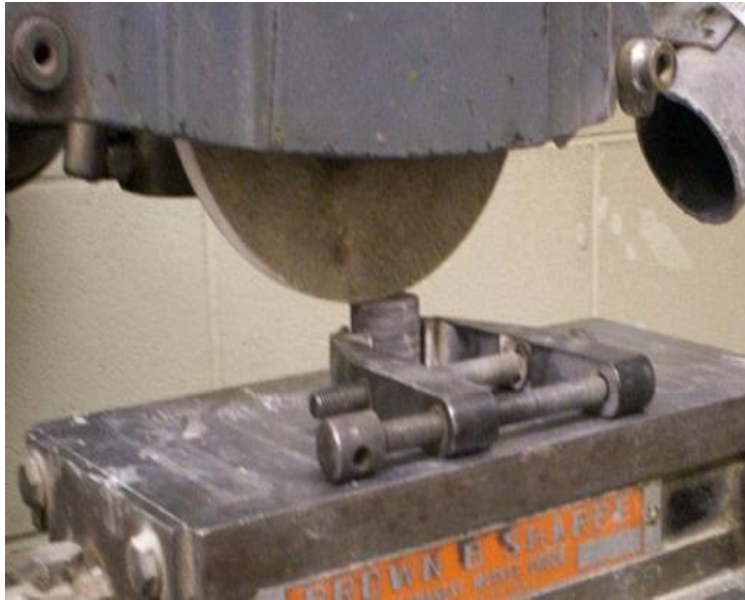




# Outcrop Sampling

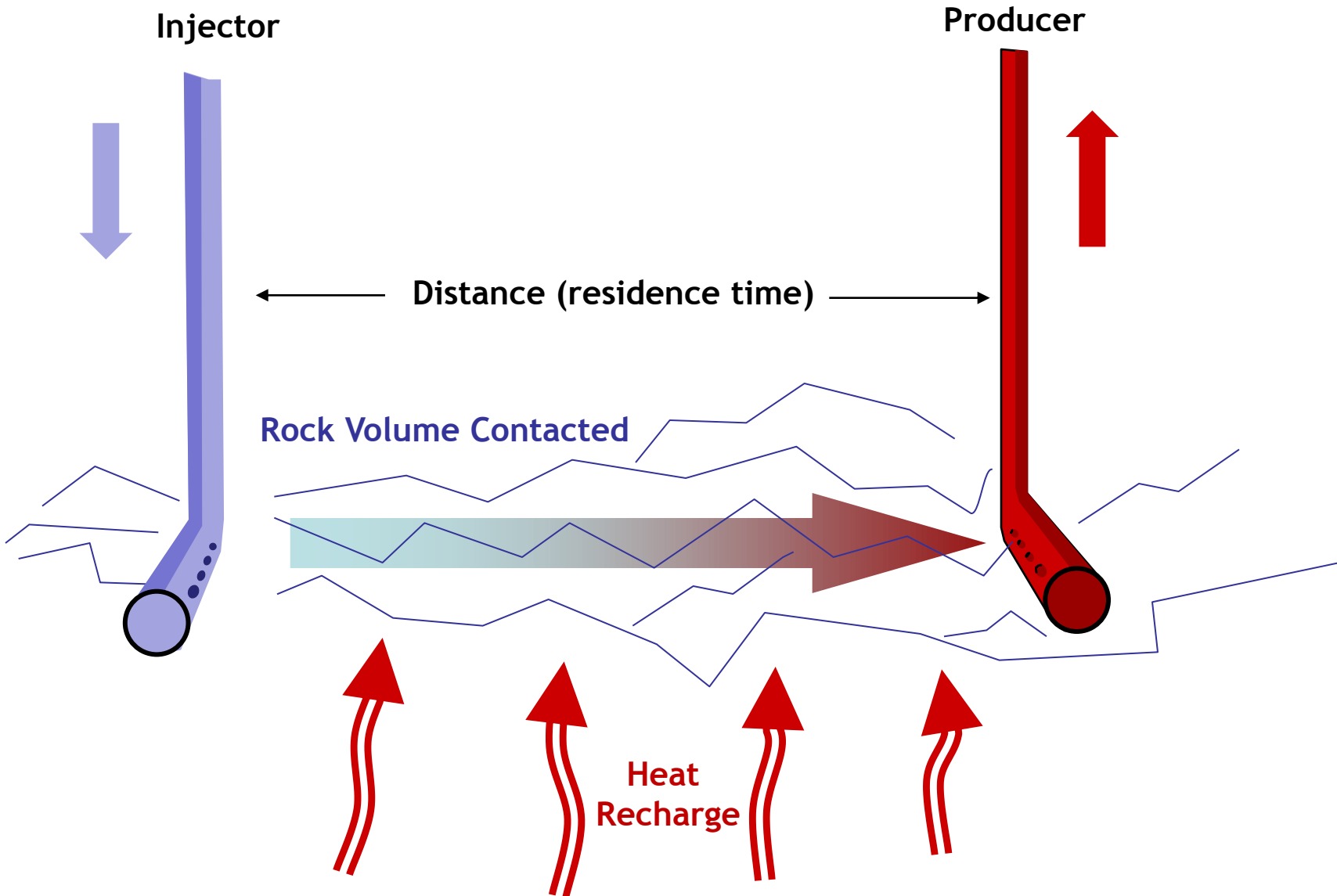


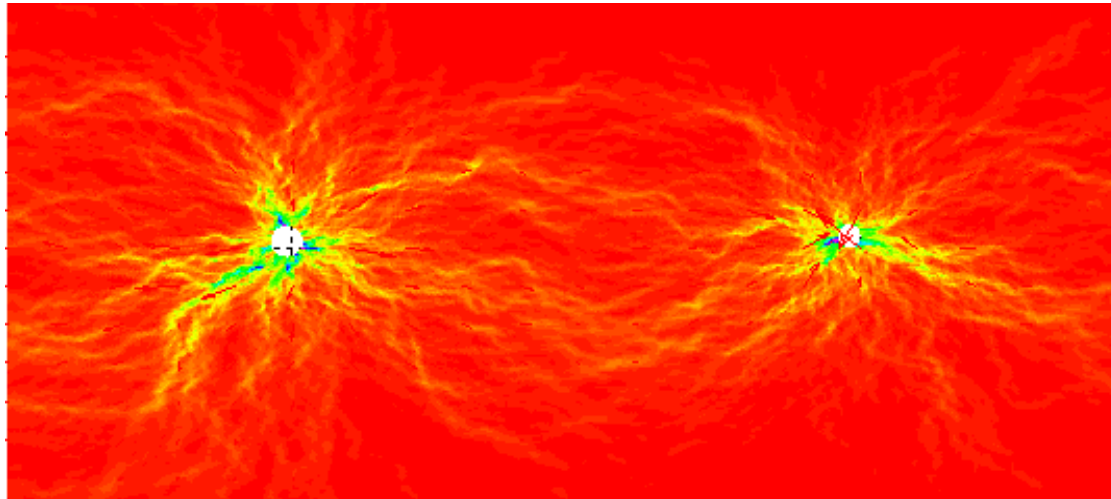






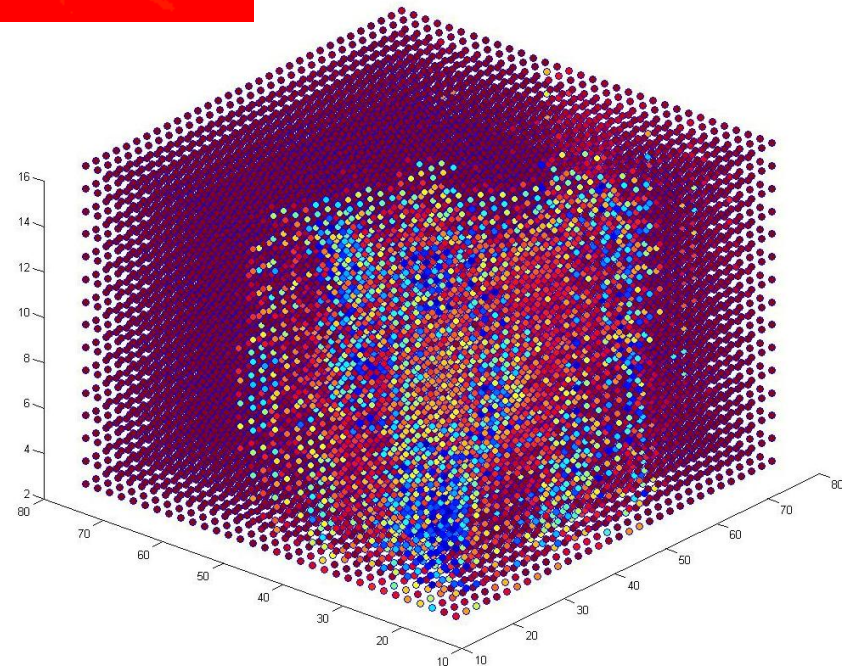




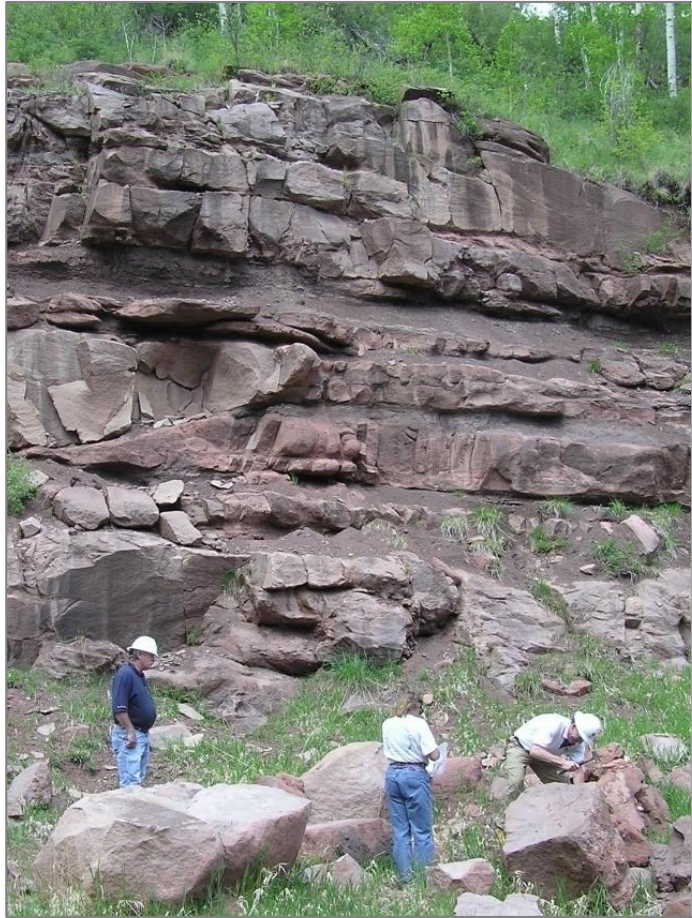


*2D well-to-well  
flow velocity  
fields*

*Pressure/flow for  
spatially correlated  
permeability*

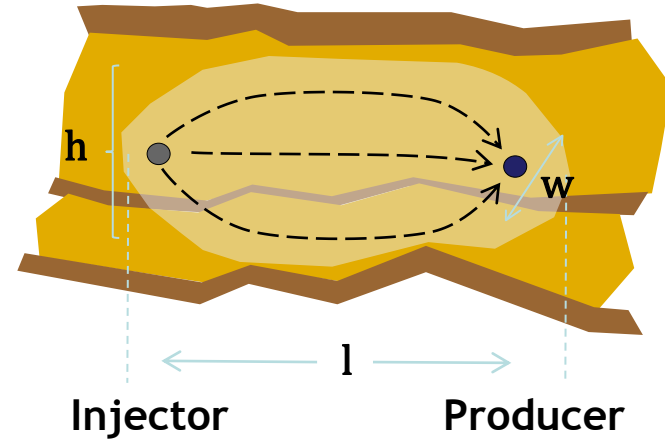


Images from Peter Leary, IESE, Univ. of Auckland



Outcrop of target reservoir,  
Sangre De Cristo fm.  
(Permian), Huerfano Co., CO

## Hydraulic fracture profile



Stimulated rock volume

- $h = 50'$  (15m)
- $l = 250'$  (75m)
- $w = 20'$  (6 m)
- $\rho_{\text{matrix}} = 1.65 \text{ gm/cm}^3$
- $\phi = 6\%$
- $T_{\text{res}} = 300^\circ\text{F}$  (150°C)

$\phi = \text{matrix} + \text{fracture porosity}$

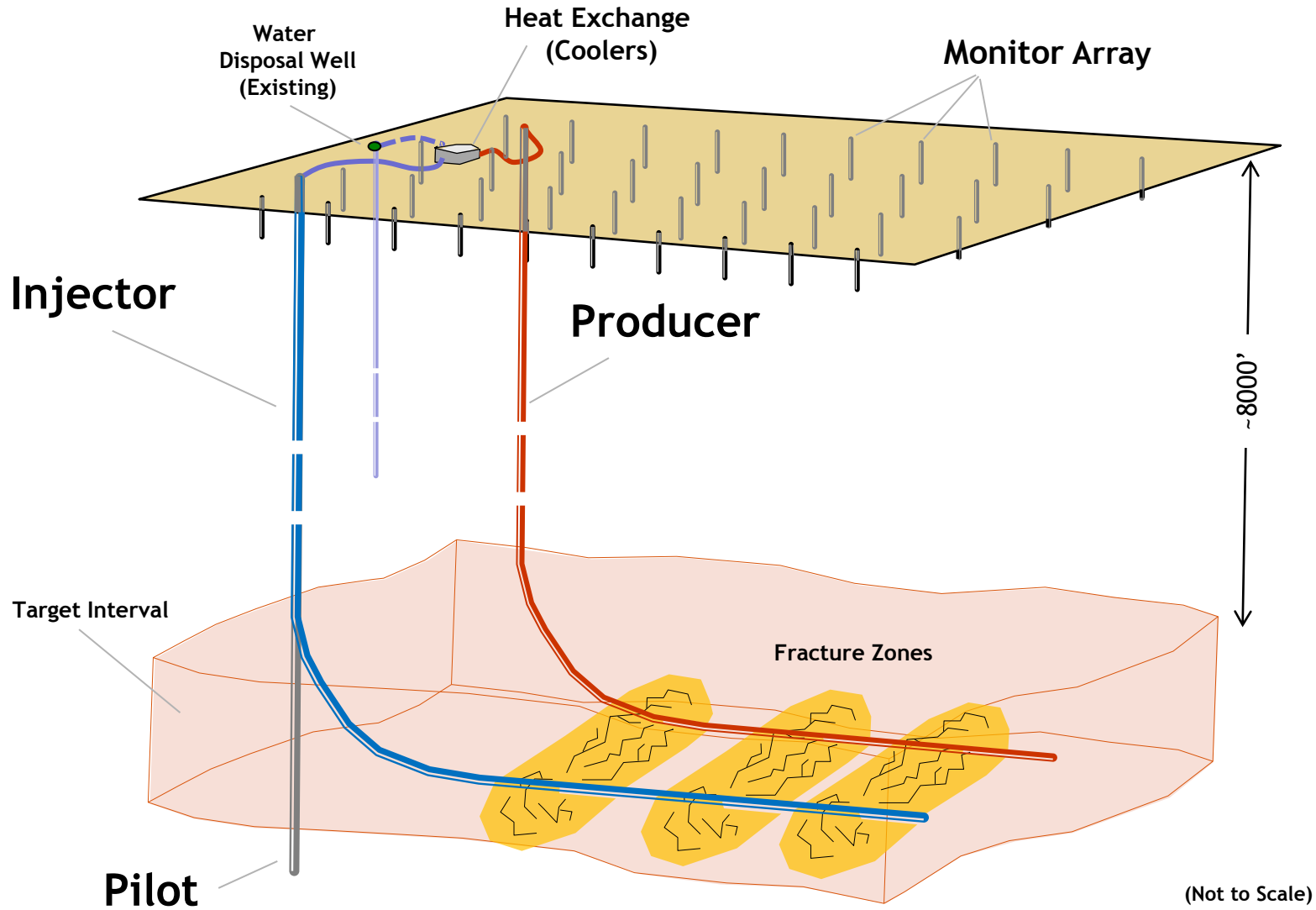


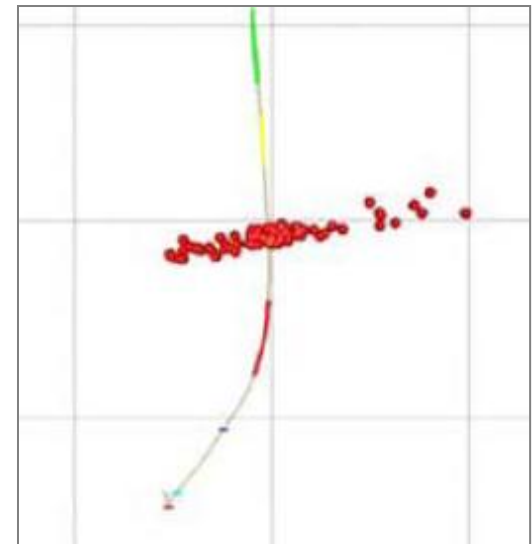
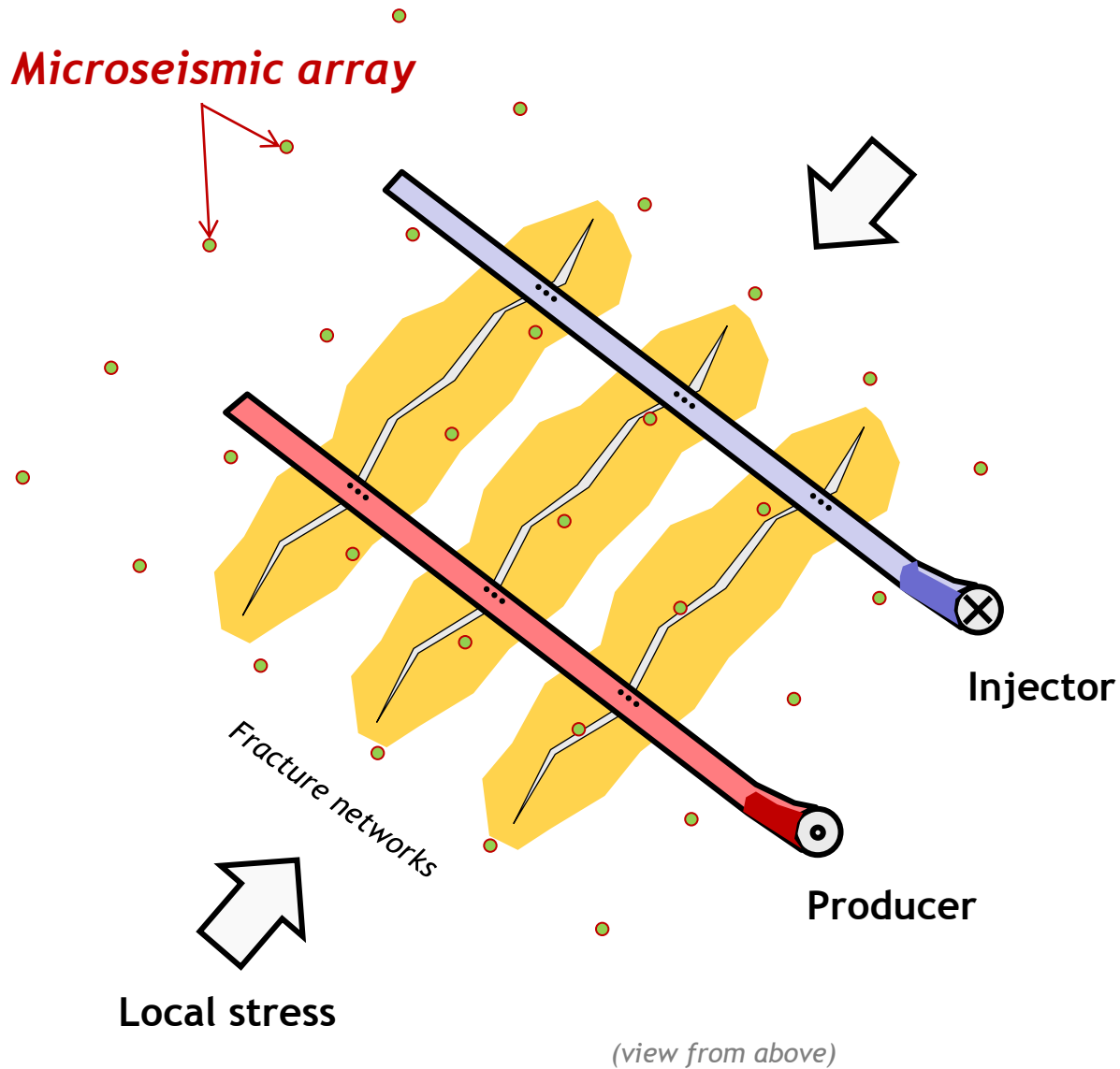
- Heat, at target depth  $P_h$
- Reservoir present  $P_r$
- Drilling & stimulation success  $P_{ds}$
- Flow & containment  $P_f$
- Thermal life (slow depletion)  $P_t$

Probability of success  $P_s = P_h * P_r * P_{ds} * P_f * P_t$

*Above ground risk: access & permits, water, energy market*

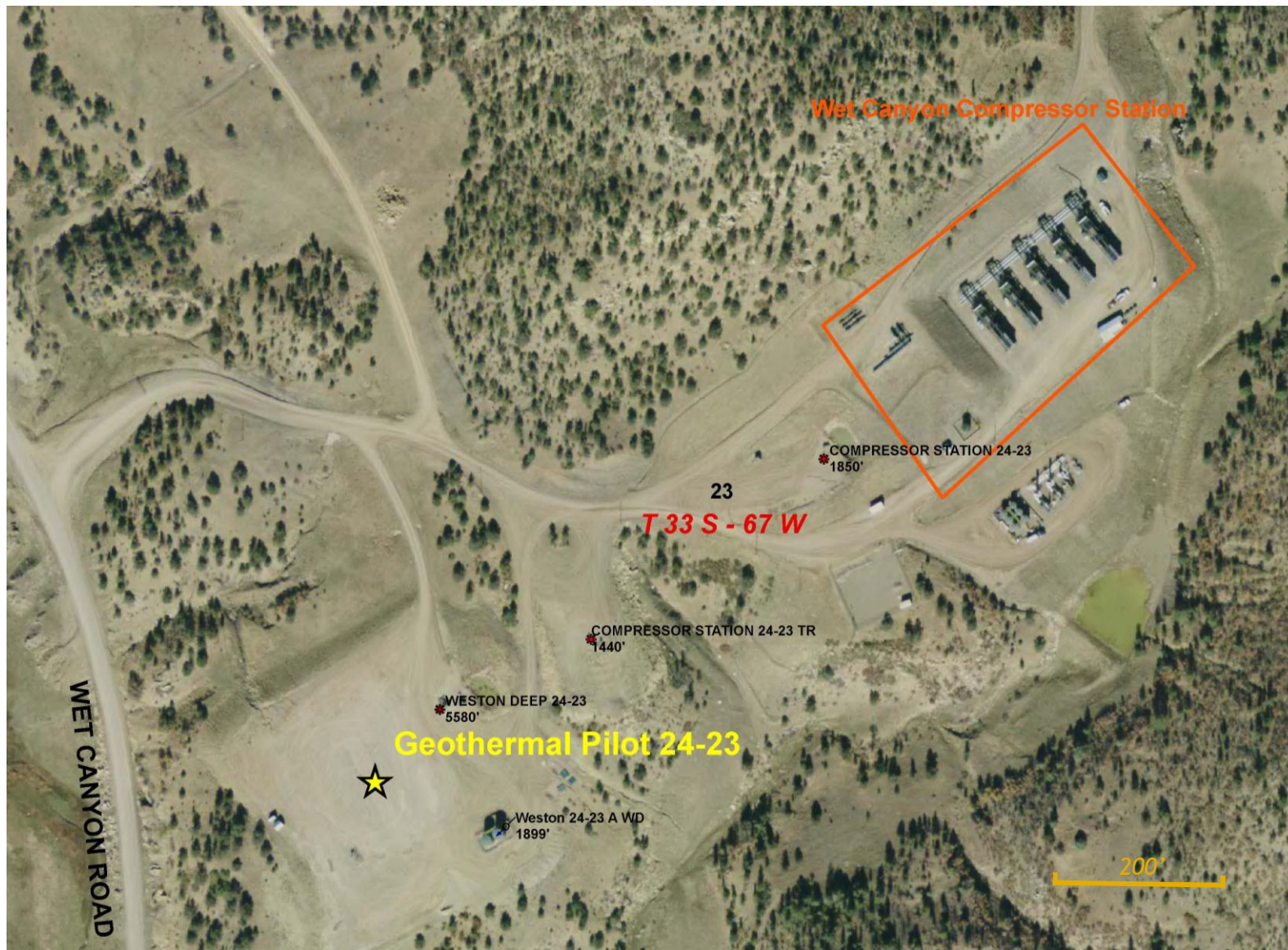
# Pilot Project Schematic





*Example from Hulse et al, SPE 2009*

# Proposed Wet Canyon Site





- Thermal modeling
- Energy balance analysis
- Economic analysis

