Geothermal Opportunities in Sedimentary Basins in Colorado

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Colorado Geological Survey

for the

Geothermal in the Oil Field Symposium

Sponsored by RMOTC, GTP, NREL, & DMU

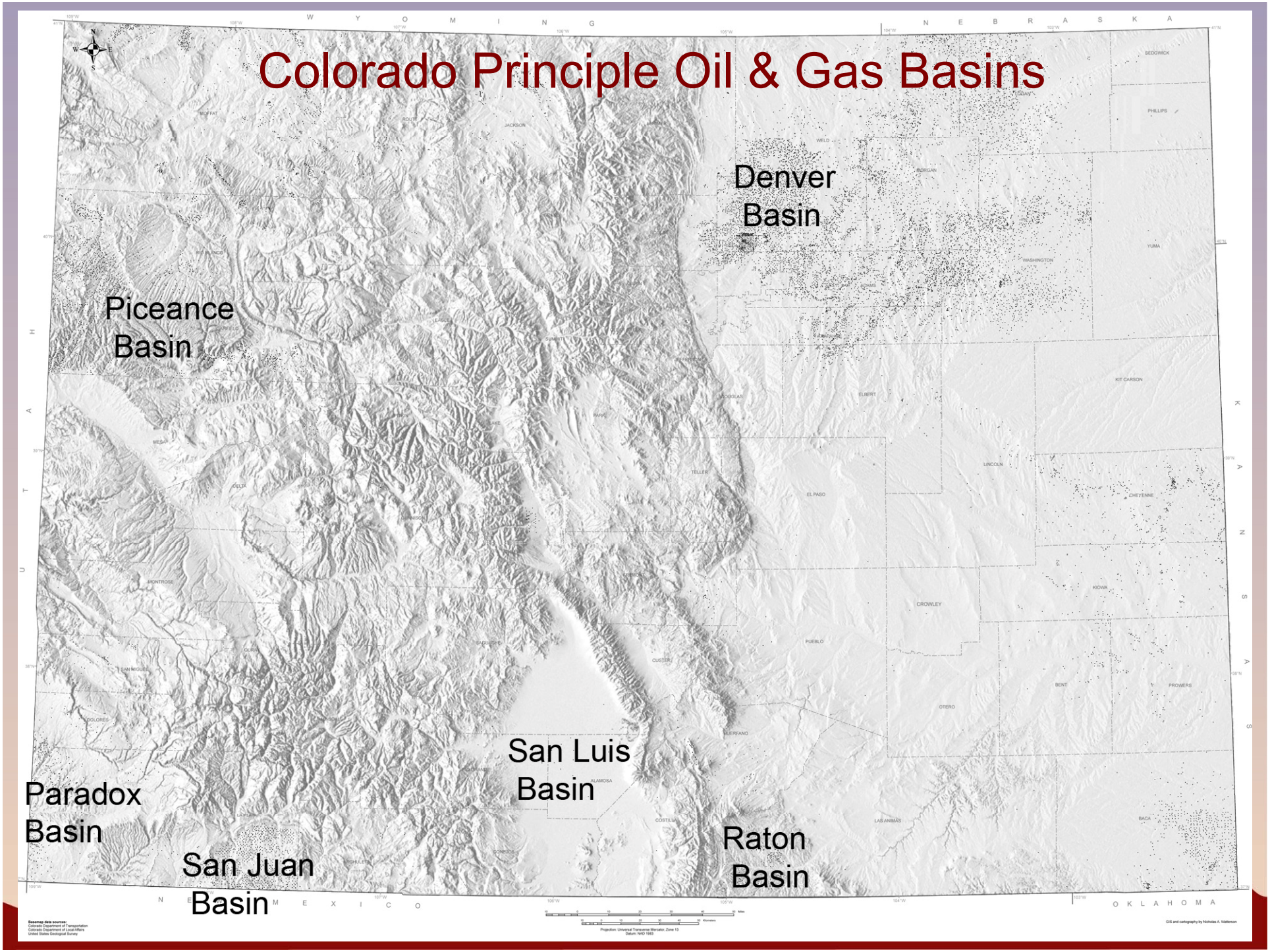
Casper, WY, August 18-19, 2010

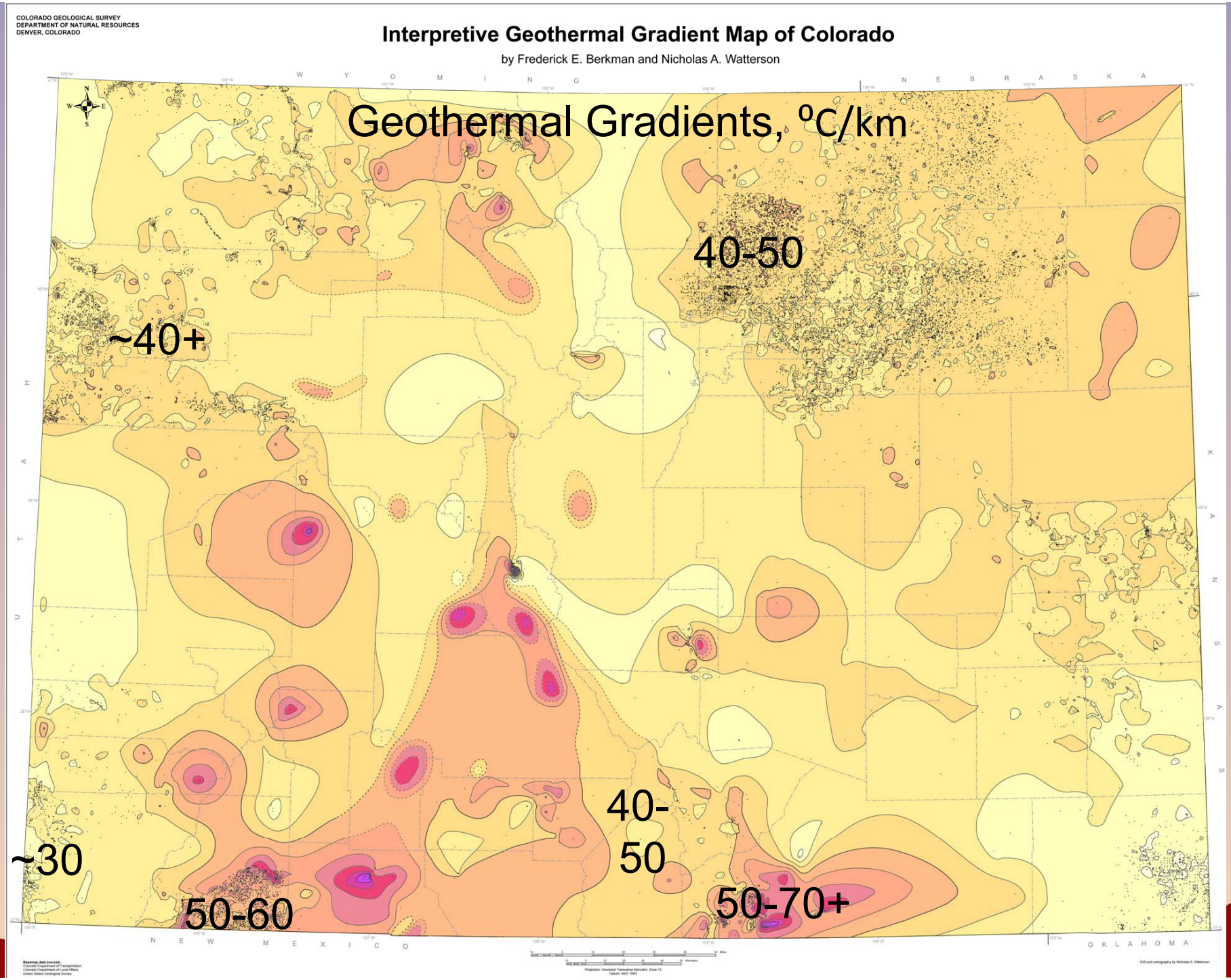
COLORADO GEOLOGICAL SURVEY

Geothermal Opportunities in Colorado Sedimentary Basins

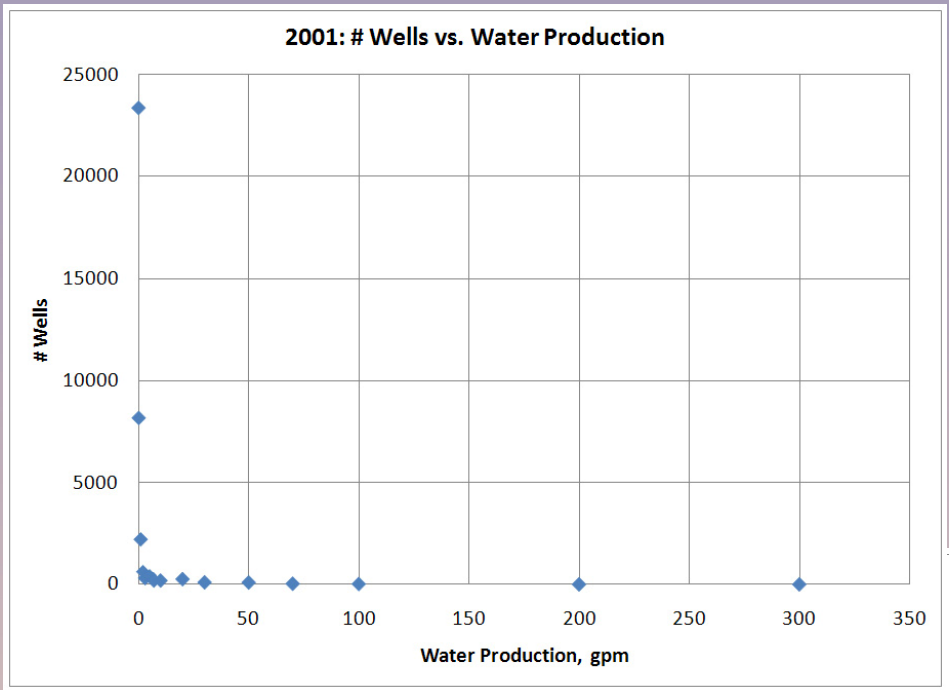
- Colorado principal sedimentary basins
- Co-produced water – what water?
- "Co-production" without co-produced water
  - Germany: Co-produced heat & electricity
- New method for drilling disturbance corrections
  - Cement bond logs revisited
- Applications to Colorado

Colorado Principle Oil & Gas Basins



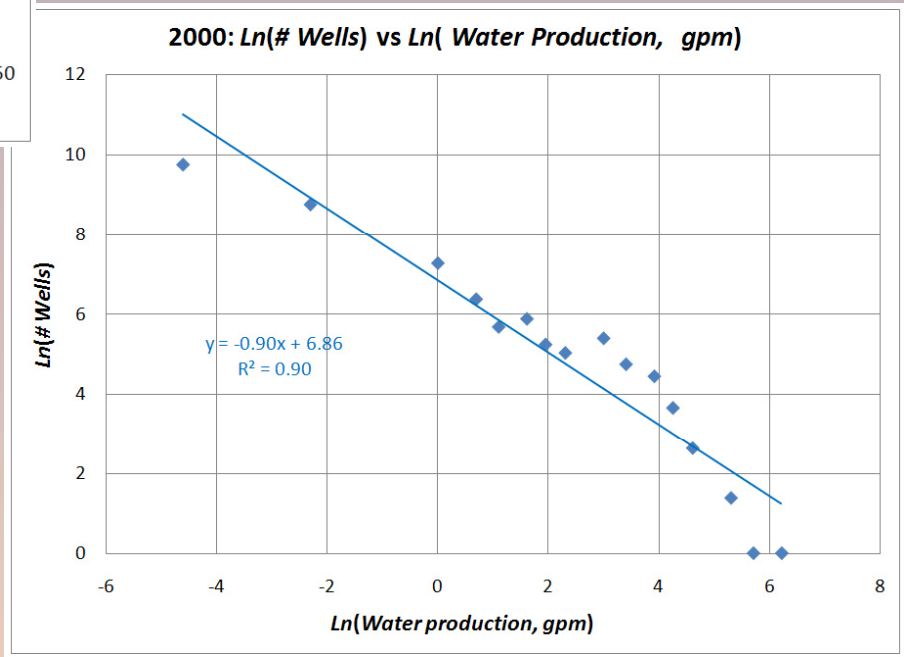

COLORADO GEOLOGICAL SURVEY
DEPARTMENT OF NATURAL RESOURCES
DENVER, COLORADO
Interpretive Geothermal Gradient Map of Colorado
by Frederick E. Berkman and Nicholas A. Watterson
Geothermal Gradients, ºC/km
40-50
~40+
40-
50
~30
50-60
50-70+
W Y O M I N G
N E B R A S K A
U T A H
K A N S A S
N E W M E X I C O
O K L A H O M A

Colorado Water Co-Production 2000



$$ln(\#\ wells) = -0.9\ ln\ (H_20,\ gpm) + 6.86$$

$$[R^2 = 0.90]$$



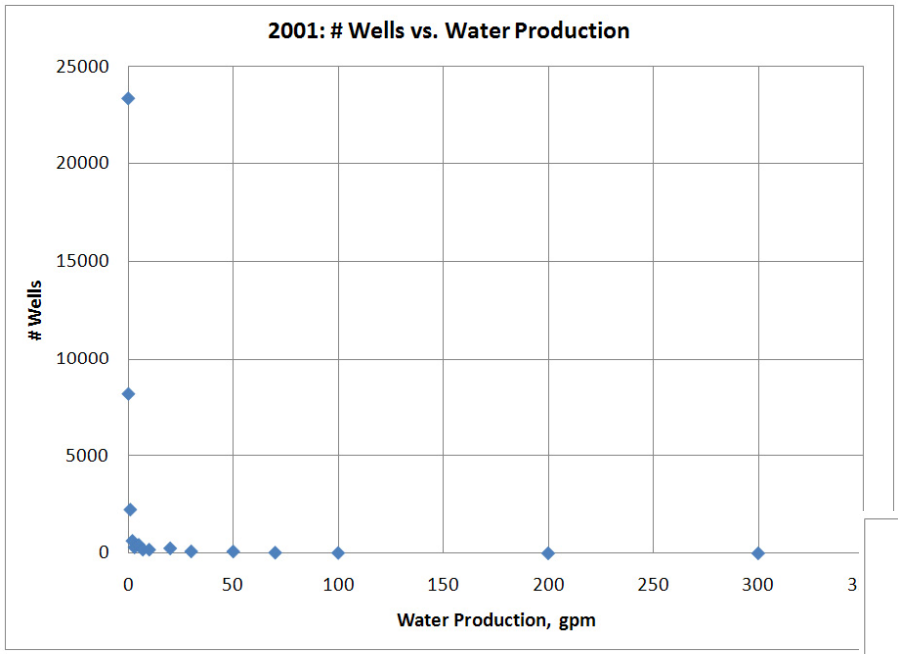
H_2O, gpm	# wells
100	15
300	5.6
500	3.5

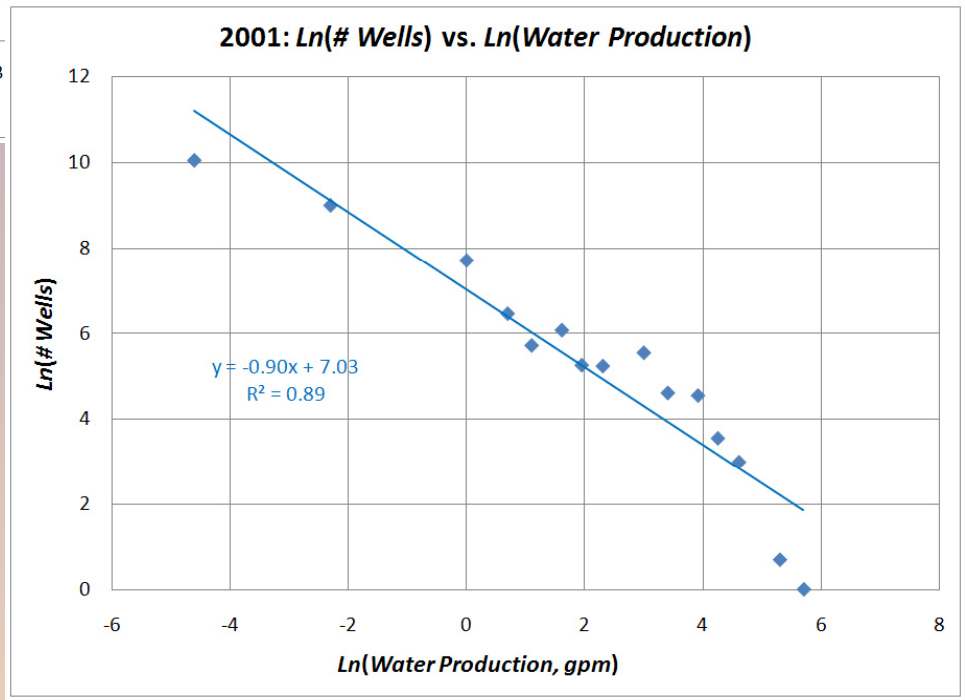
100 gpm ≈ 3,430 bbl/d

Colorado Water Co-Production 2001

$$ln(\#\ wells) = -0.9\ ln\ (H_20,\ gpm) + 7.03$$

$$[R^2 = 0.89]$$



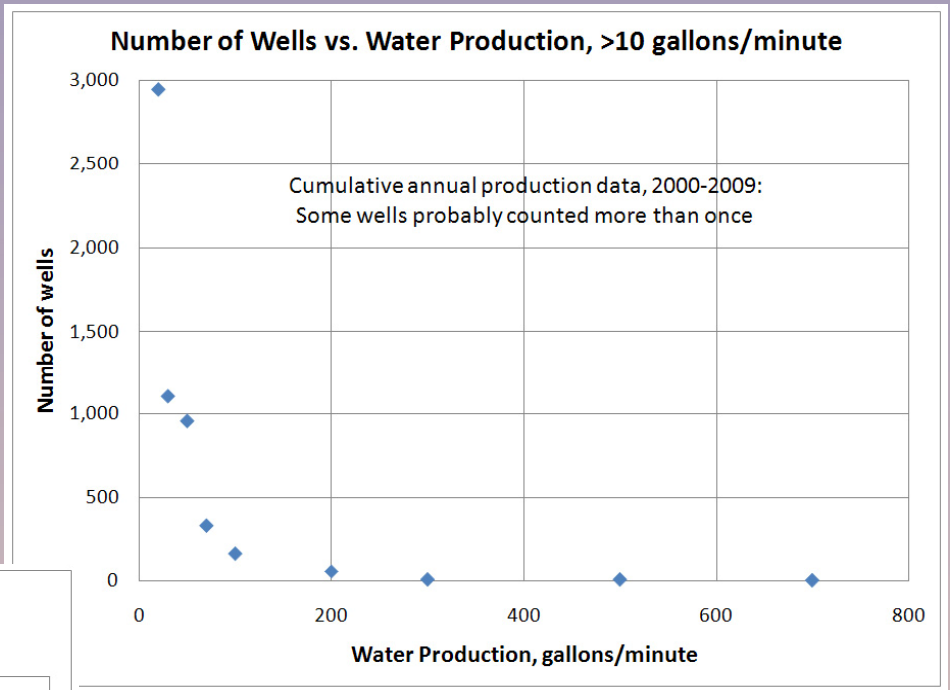


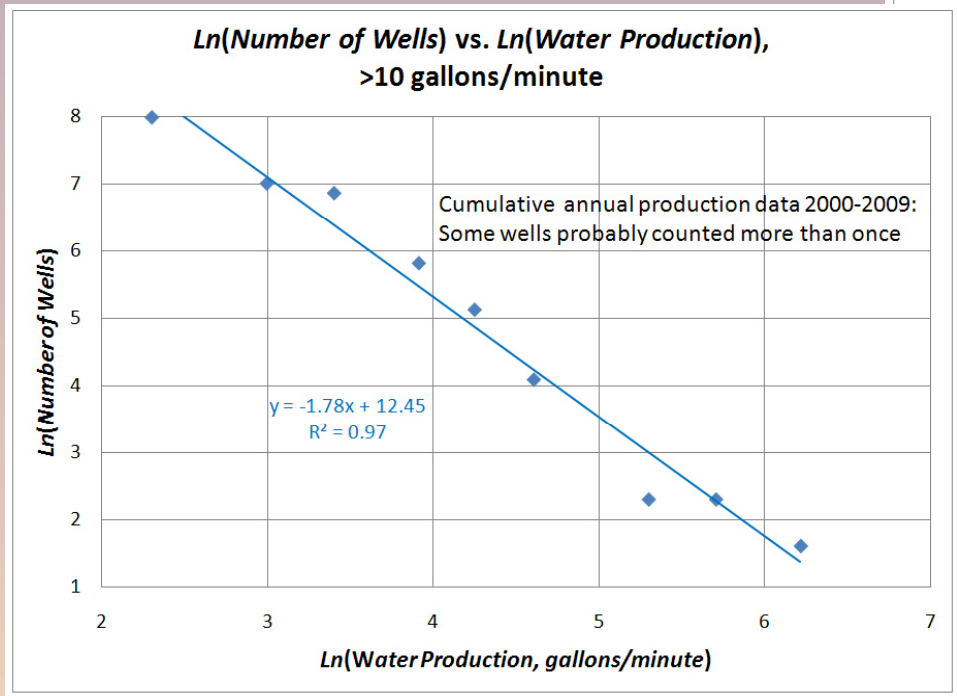
H_2O, gpm	# wells
100	18
300	6.7
500	4.2

Colorado Water Co-Production 2000-2009, >10 gpm

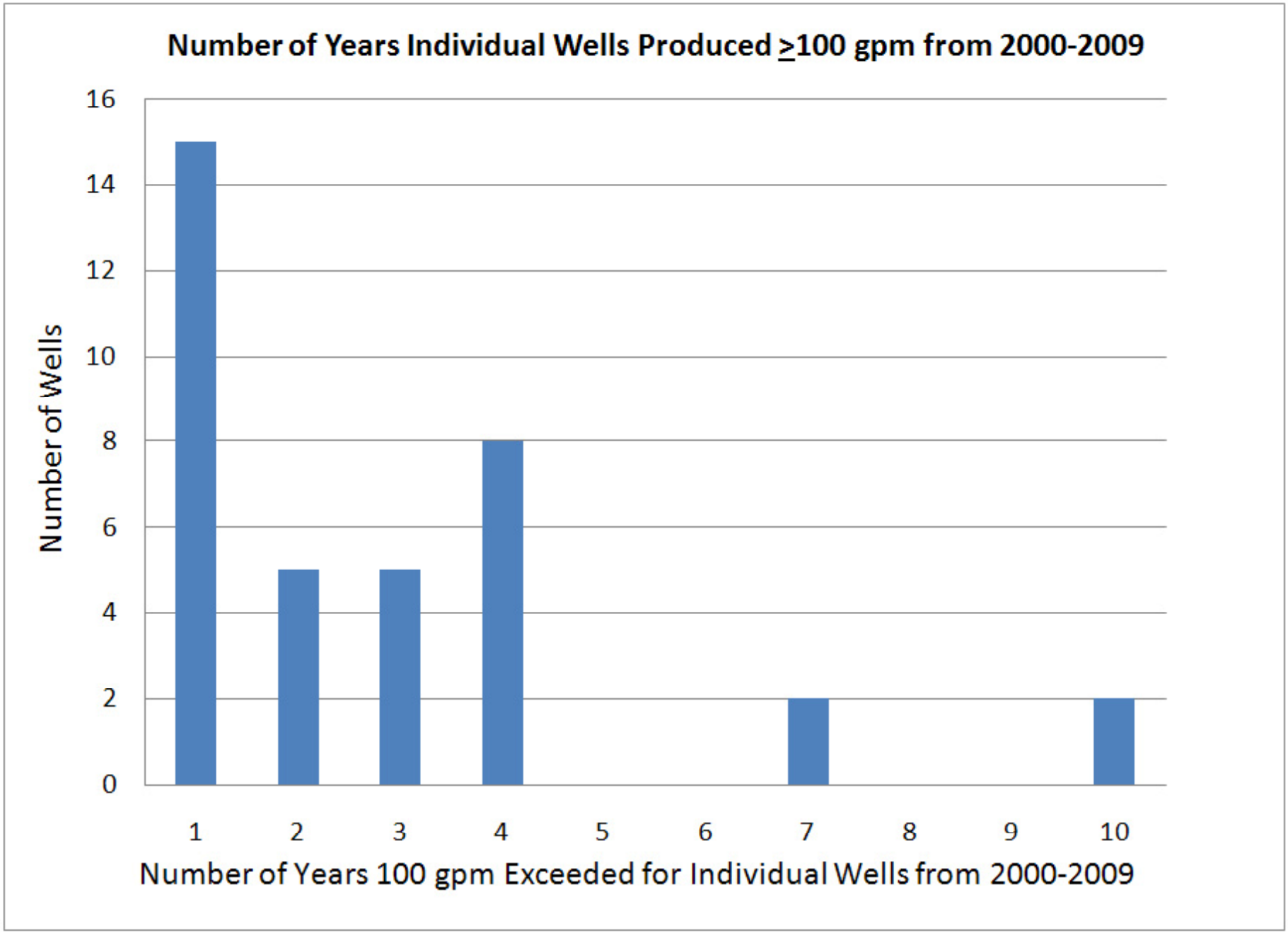
$$\ln(\#\ \text{wells}) = -1.8\ \ln(H_20,\ \text{gpm}) + 12.4$$

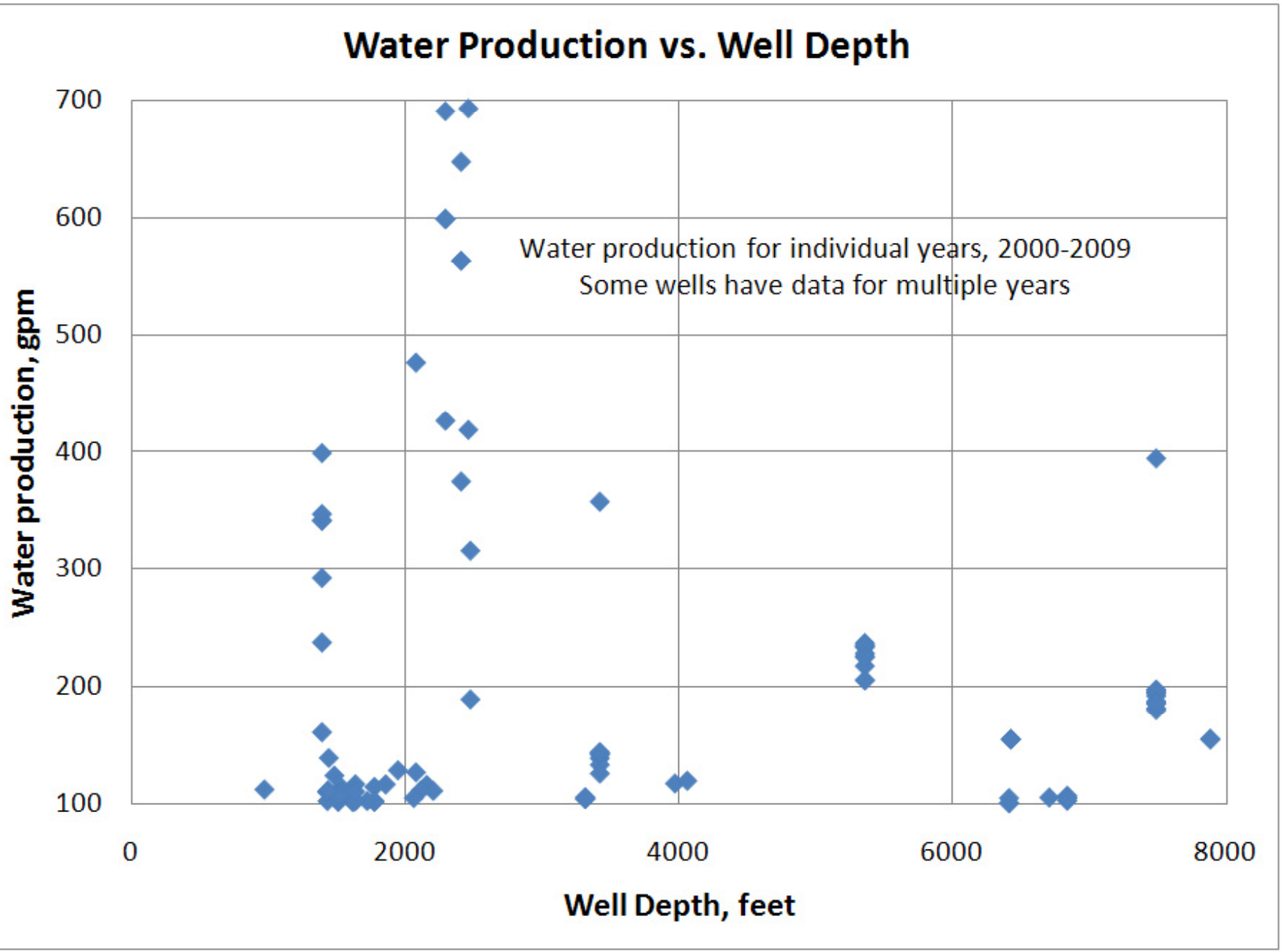
$$[R^2 = 0.97]$$



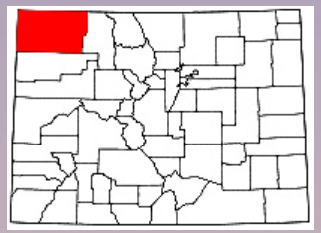


H_2O, gpm	# wells	# wells/yr
100	70	7
300	10	1
500	4	0.4

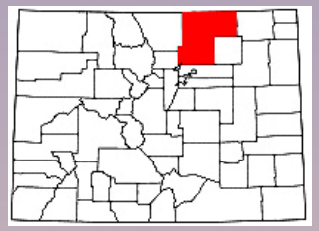

Number of Years Individual Wells Produced ≥100 gpm from 2000-2009
Number of Wells
16
14
12
10
8
6
4
2
0
1
2
3
4
5
6
7
8
9
10
Number of Years 100 gpm Exceeded for Individual Wells from 2000-2009


Water Production vs. Well Depth
Water production for individual years, 2000-2009
Some wells have data for multiple years
Water production, gpm
700
600
500
400
300
200
100
0
2000
4000
6000
8000
Well Depth, feet

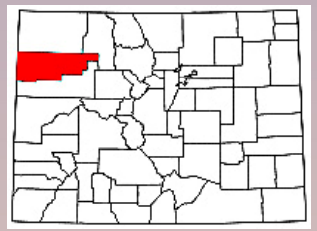
Colorado Counties with Wells Producing >100 gpm Average Over 12 months During at Least 1 Year in 2000-2009



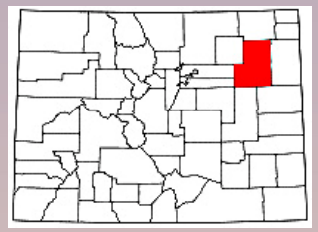
Moffat County
6 wells; Max 394 gpm
Mean 191 ± 101 gpm



Weld County
2 wells; Max 155 gpm
Mean 155 ± 0 gpm

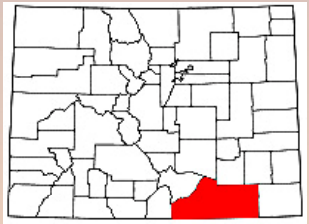


Rio Blanco County
3 wells; Max 106 gpm
Mean 104 ± 2 gpm



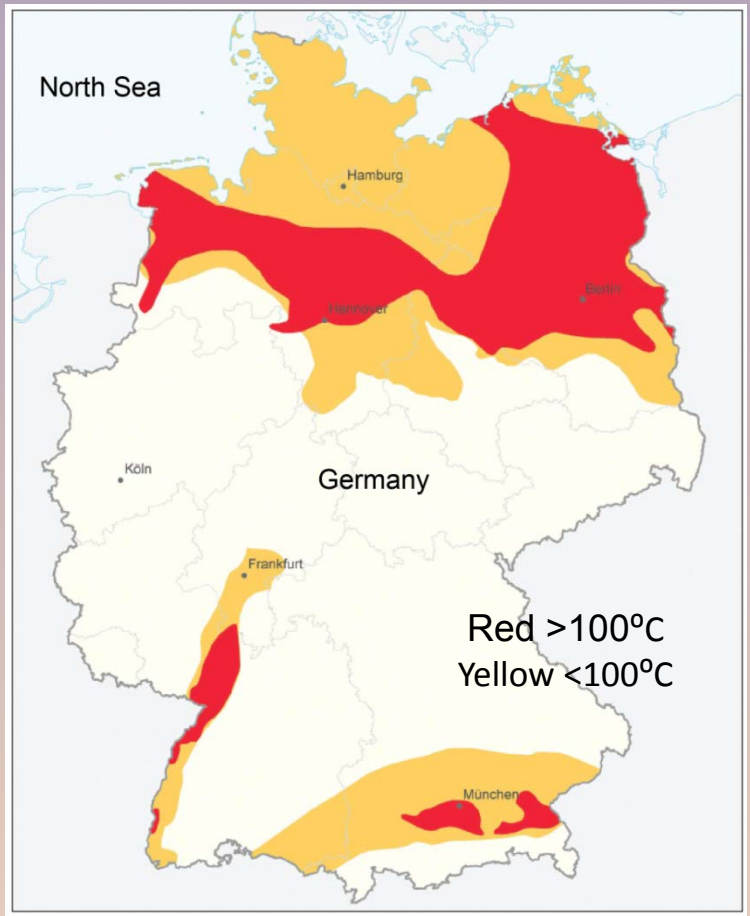
Washington County
1 well; 119 gpm

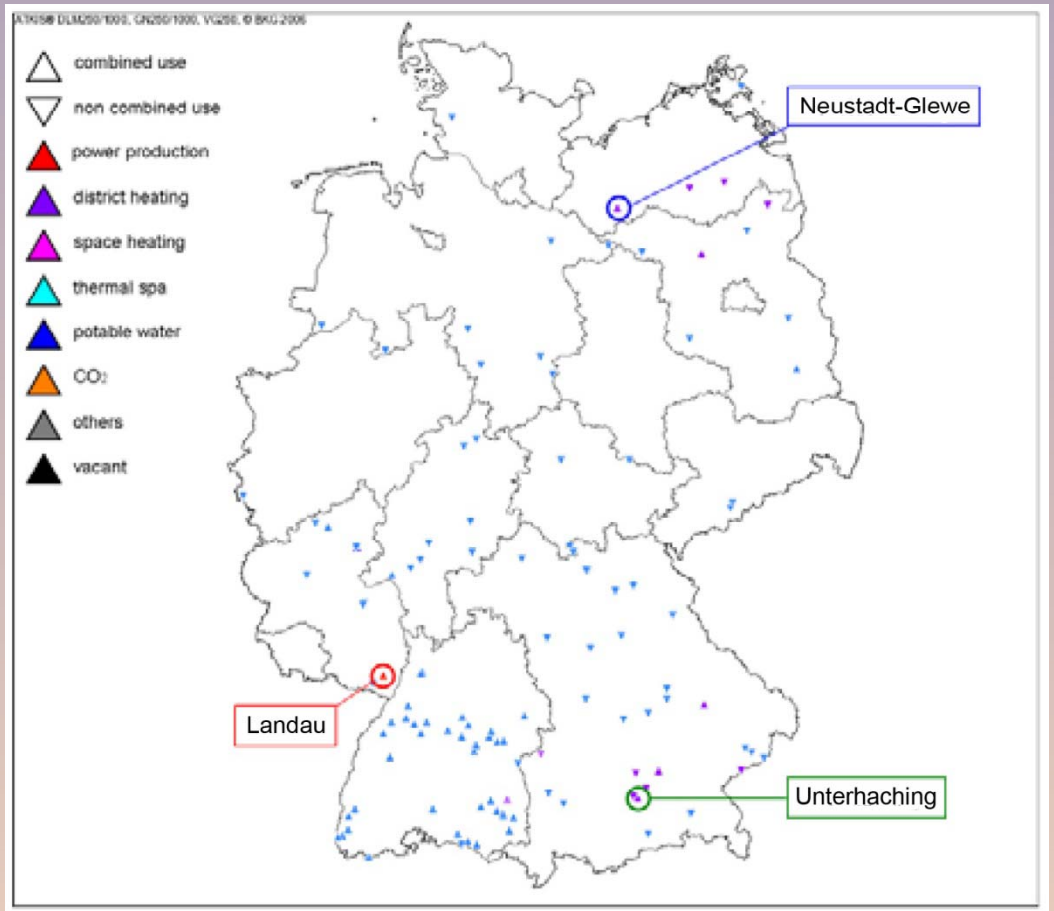
Huerfano County
24 wells; Max 690 gpm
Mean 189 ±154 gpm



Las Animas County
1 well; 112 gpm

Germany: Co-Produced District Heat and Electricity in Sedimentary Basins





Germany: Sedimentary Basin Geo-Hydrothermal Power Production

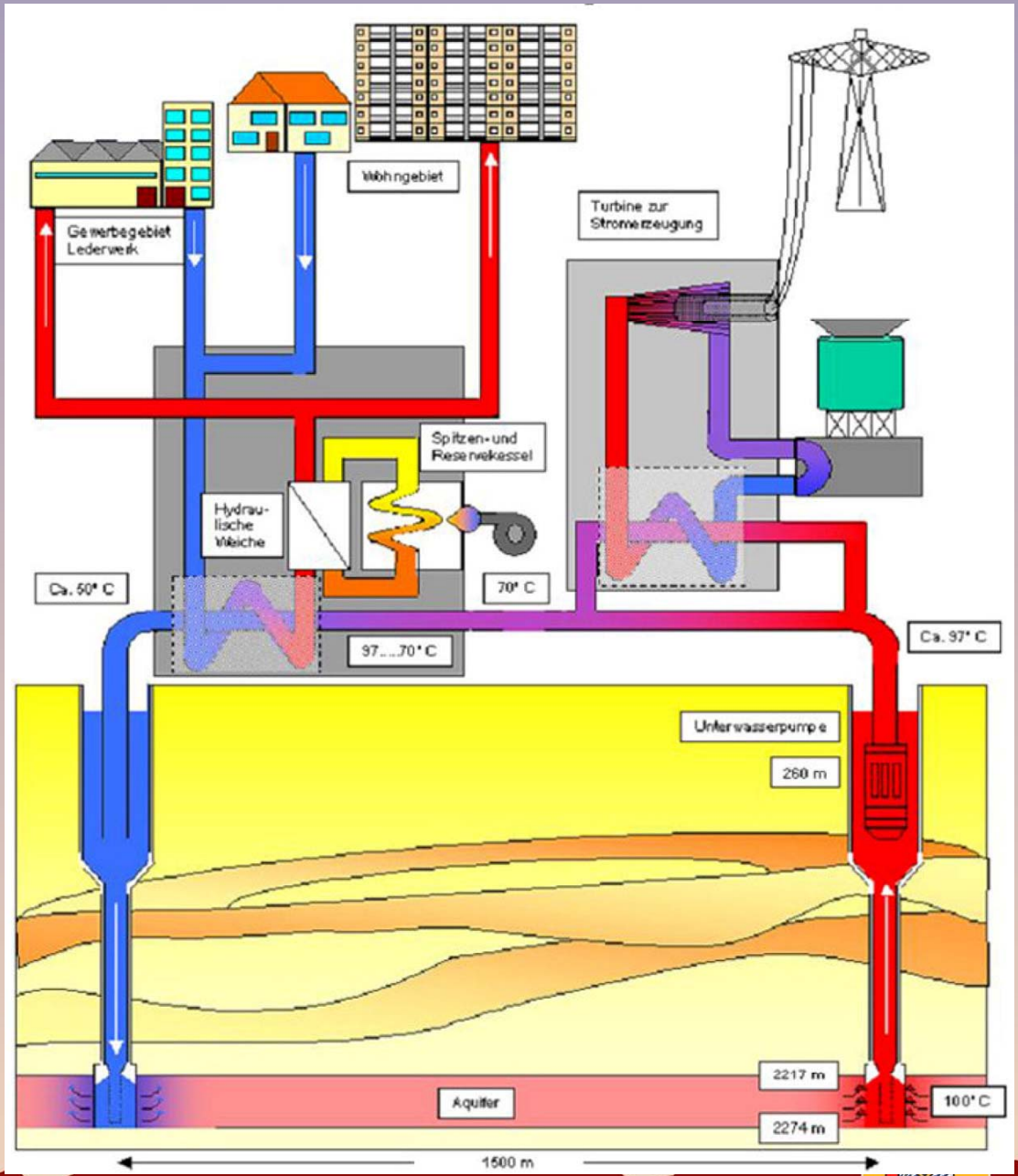
- All systems use well doublets, one production well, one injection well
- Neustadt-Glewe: 98^{0}C; 35 l/s (555 gpm); 2217-2274 m; 250 kW; ORC
- Landau: 150^{0}C; 70 l/s (1,110 gpm; 3000-3400; 3,000 kW; ORC
- Unterhaching; 127^{0}C; 150 l/s (2,378 gpm; 3350-3590 m; 3,360 kW; Kalina

Neustadt-Glewe

Co-produced heat & electricity plant schematic

Water production from sandstone

Source: European Geothermal Energy Council, 2005

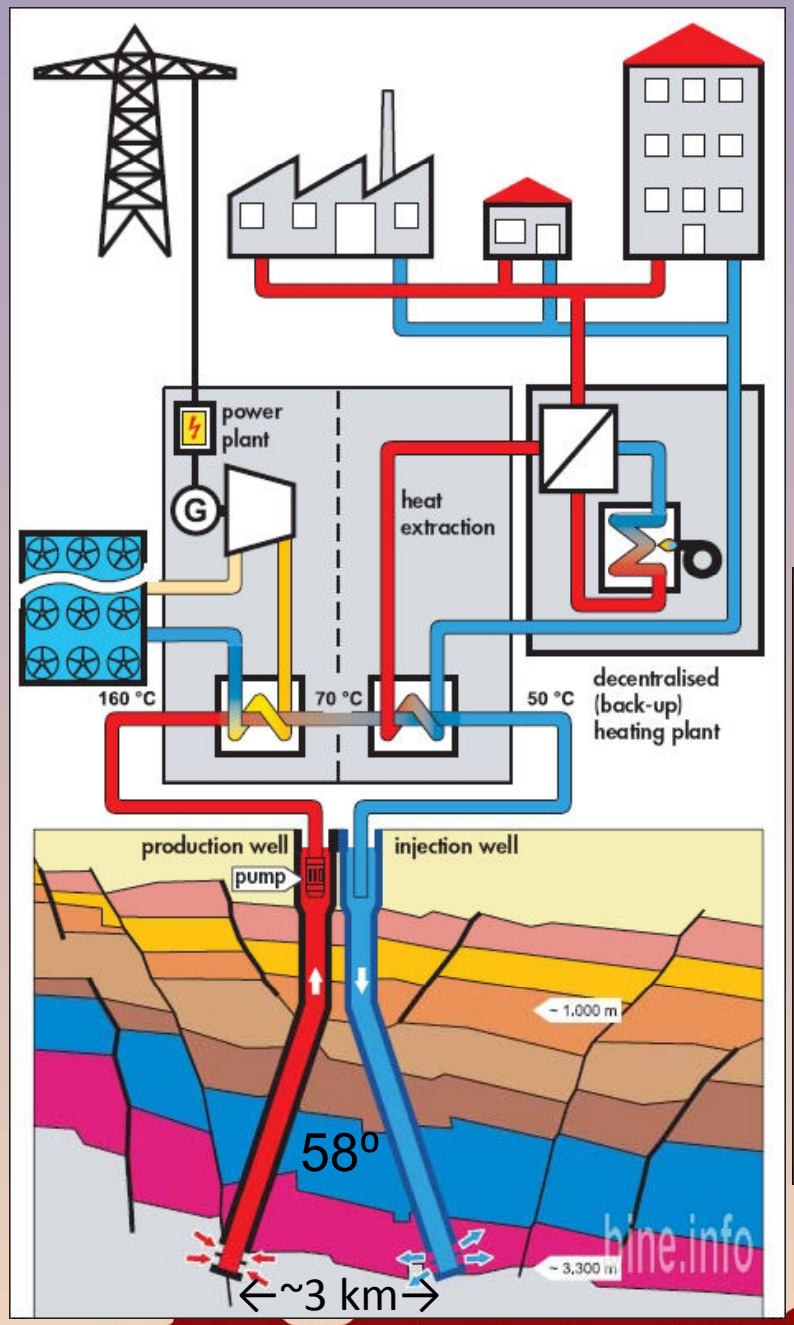


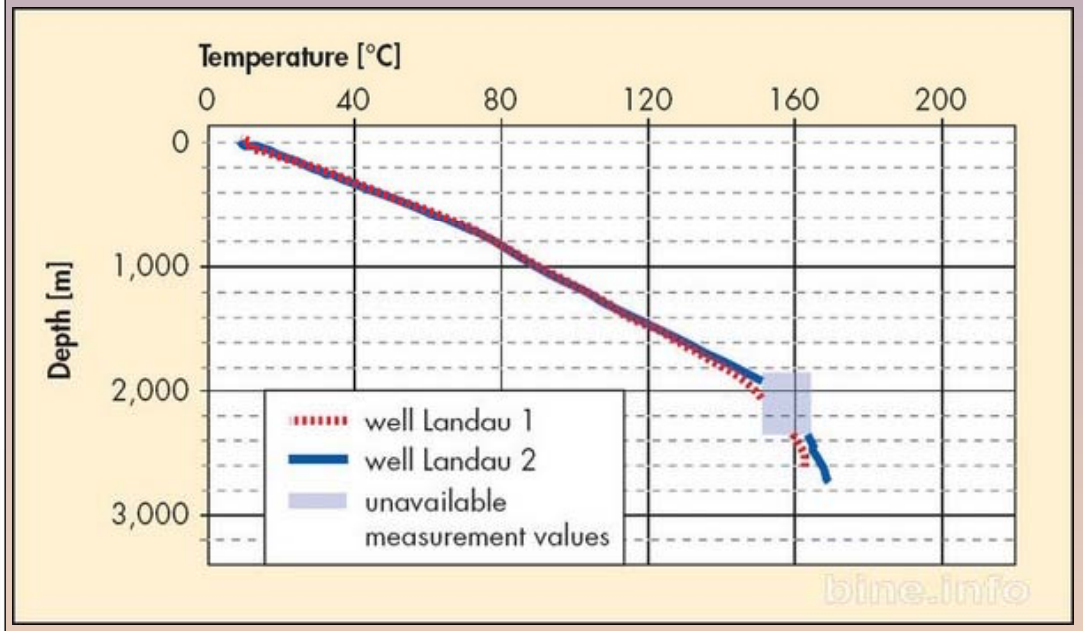
Landau

Primarily power production

Water production from limestone

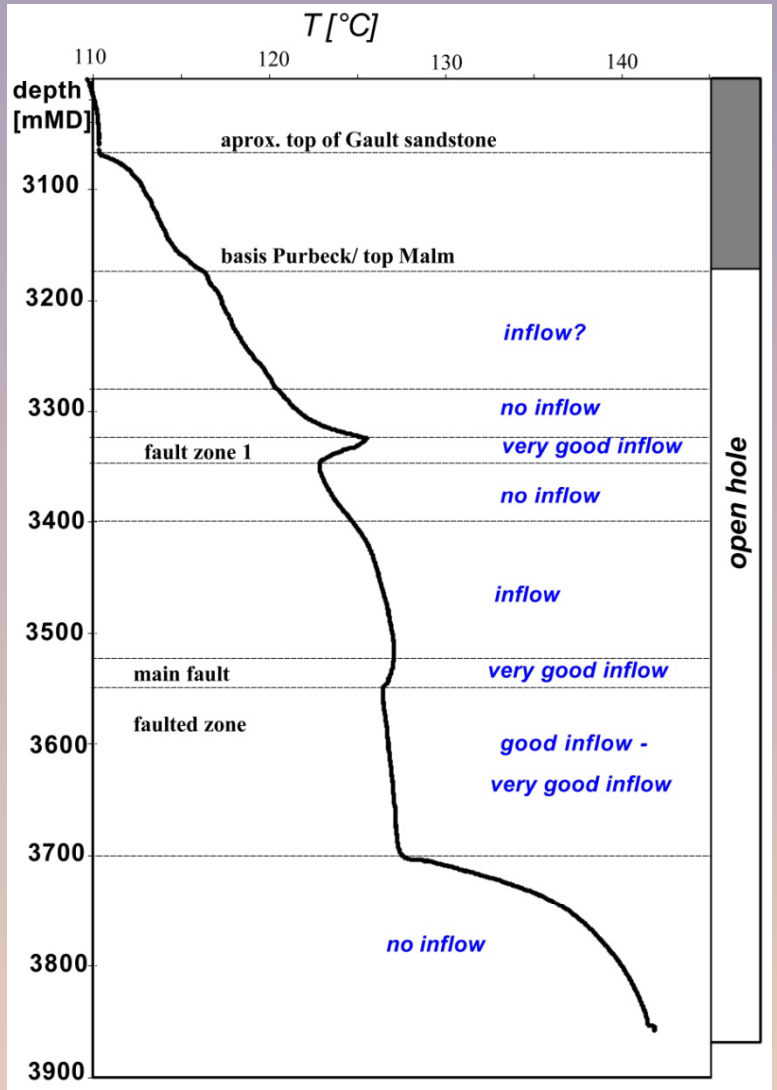
Source: BINE Informationsdienst





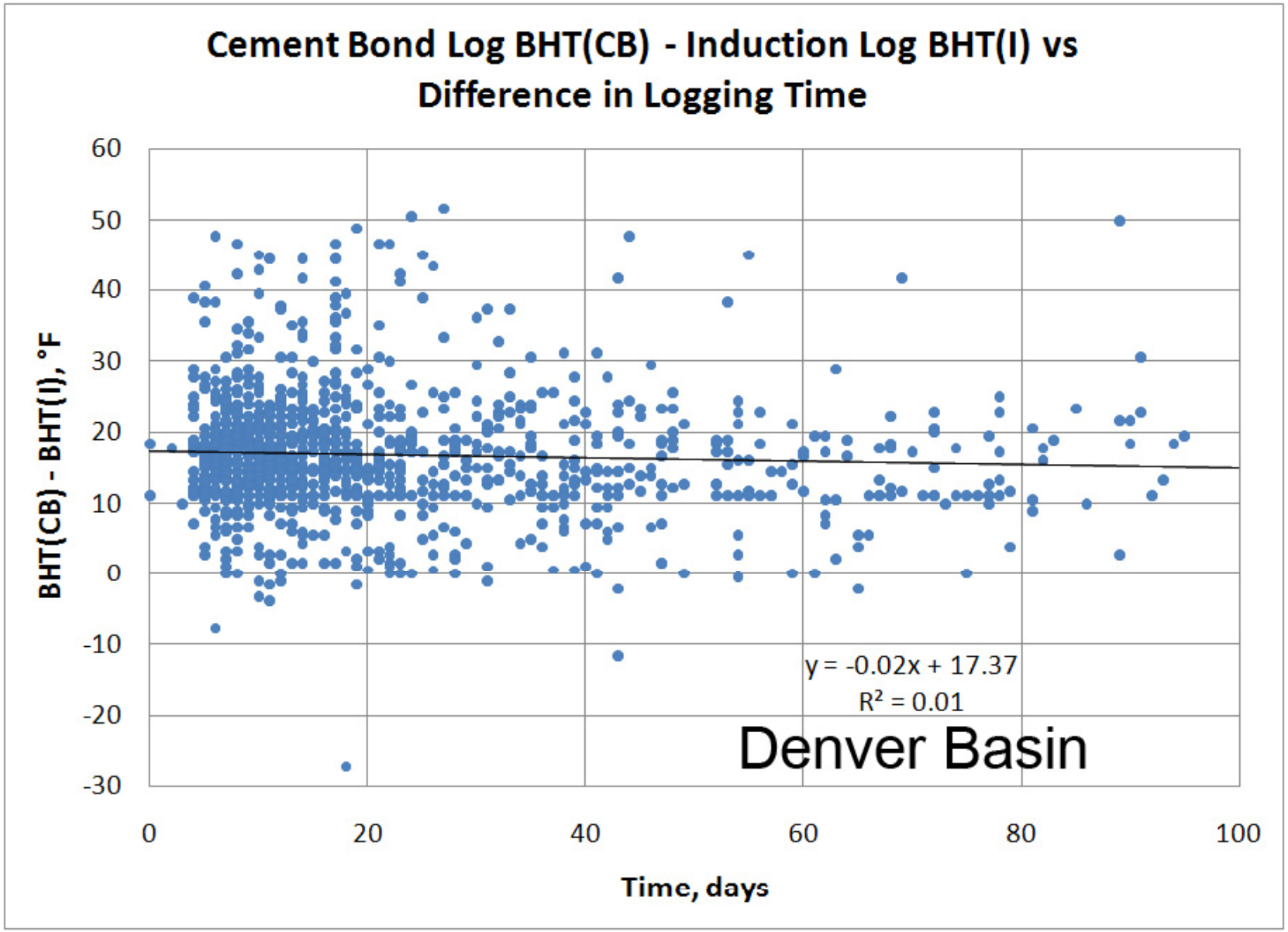
Unterhaching
S. Germany
Fissure Karst Aquifer

Stratigraphy	Uha 1a m b.s. TVD	Uha 2 m b.s. TVD	Lithology
Quarternary	-28	-20	gravel, sand
Miocene	-1690	-1685	sand, marl, schluff, limy
Oligocene	-2845	-2785	clay marl, lime marl, claystone
Eocene	-2910	-2875	Limestone, lime marl, sandstone
Upper Cretaceous	-2930	-2905	lime marl
Lower Cretaceous	-3002 ←3.5	-2977 km→	Limestone, lime marl, claymarl, sandstone, breccia, limestone
Jurassic (Malm)	-3350 (f.d.)	-3590 (f.d.)	limestone, dolomite



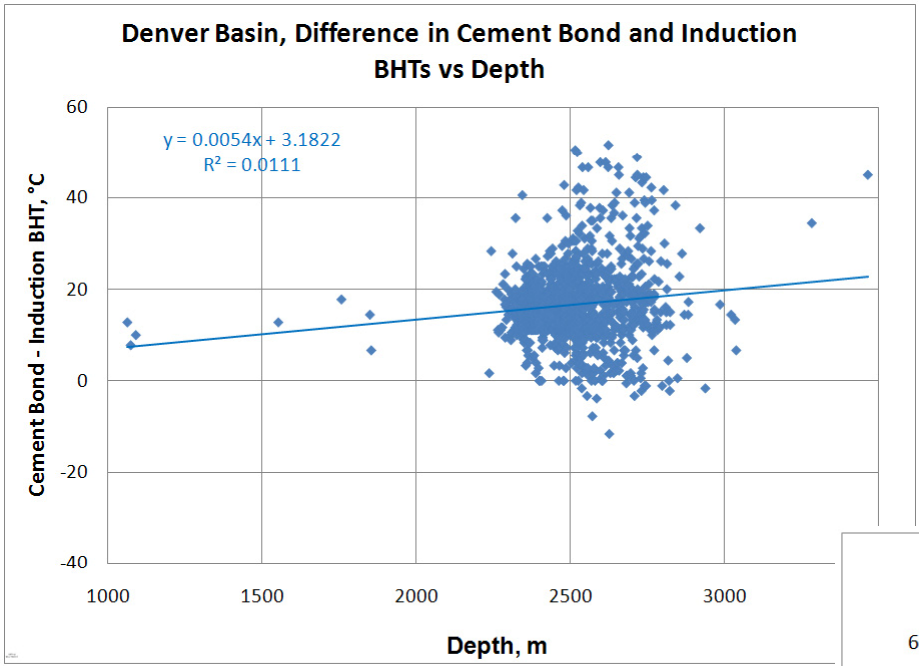
Colorado BHT Data Drilling Disturbance Corrections

- A primary source of exploration data for temperatures in sedimentary basins is BHT data –disturbed by circulation of drilling fluid
- Interpretive Geothermal Gradient Maps in Colorado based primarily on BHT data with drilling disturbance corrections derived from data from other states
- No “traditional” data from which to make Colorado-specific corrections: BHT vs t, DSTs, etc.
- New source of “equilibrium” temperatures: “second” cement bond log BHTs


Cement Bond Log BHT(CB) - Induction Log BHT(I) vs
Difference in Logging Time
BHT(CB) - BHT(I), °F
60
50
40
30
20
10
0
-10
-20
-30
0
20
40
60
80
100
Time, days
y = -0.02x + 17.37
R² = 0.01
Denver Basin

Denver Basin

Drilling Disturbance Correction

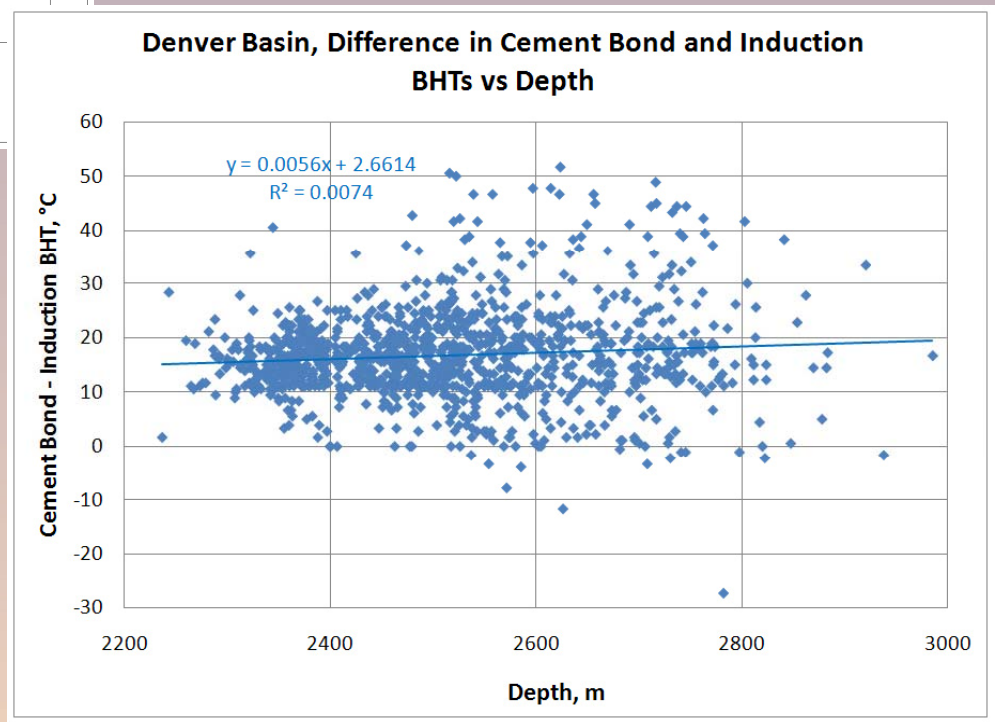


↑

$\Delta T = 0.0054\ z\ (\text{meters}) + 3.2^{o}C$

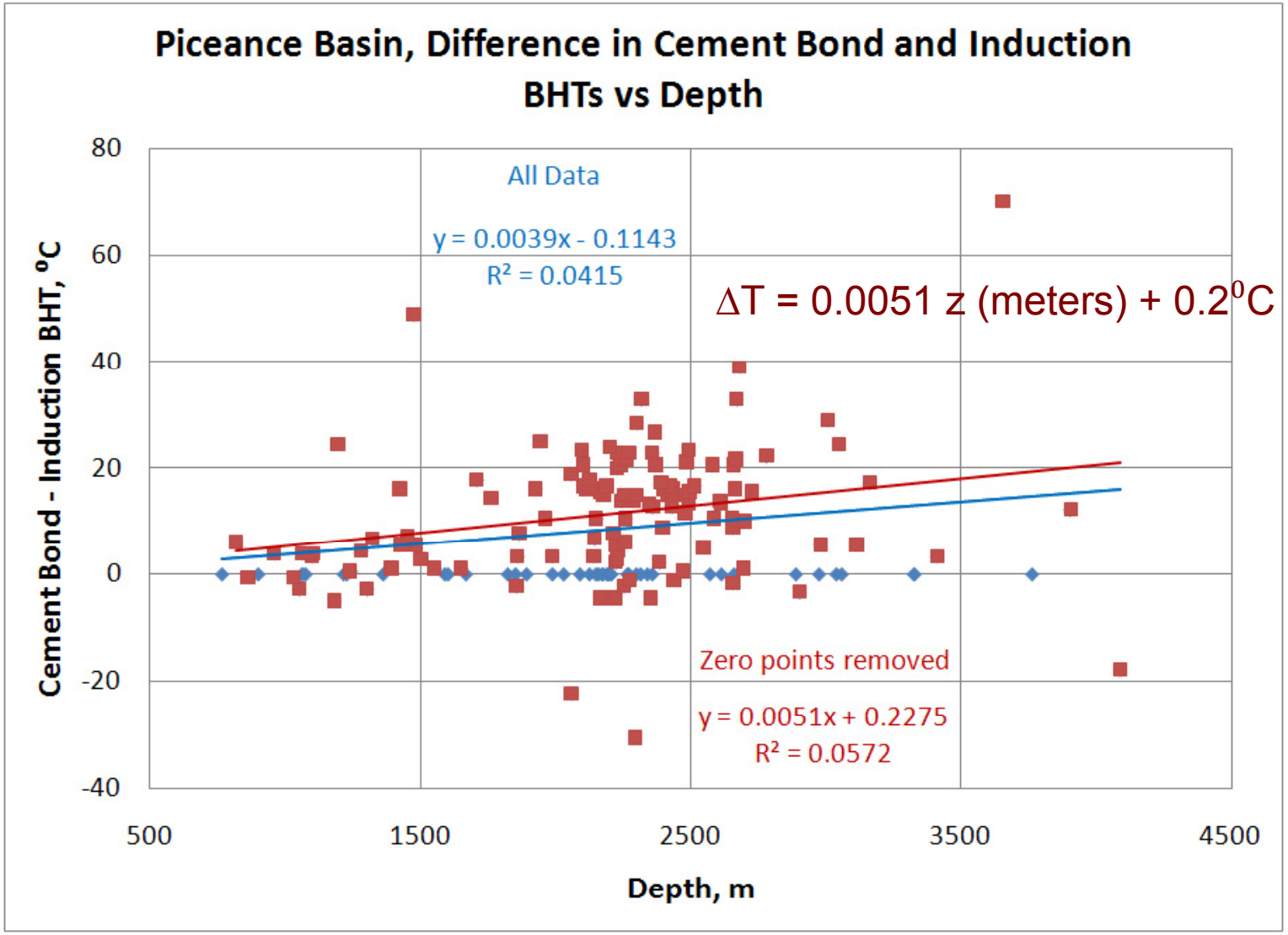
→

$\Delta T = 0.0056\ z\ (\text{meters}) + 2.7^{o}C$



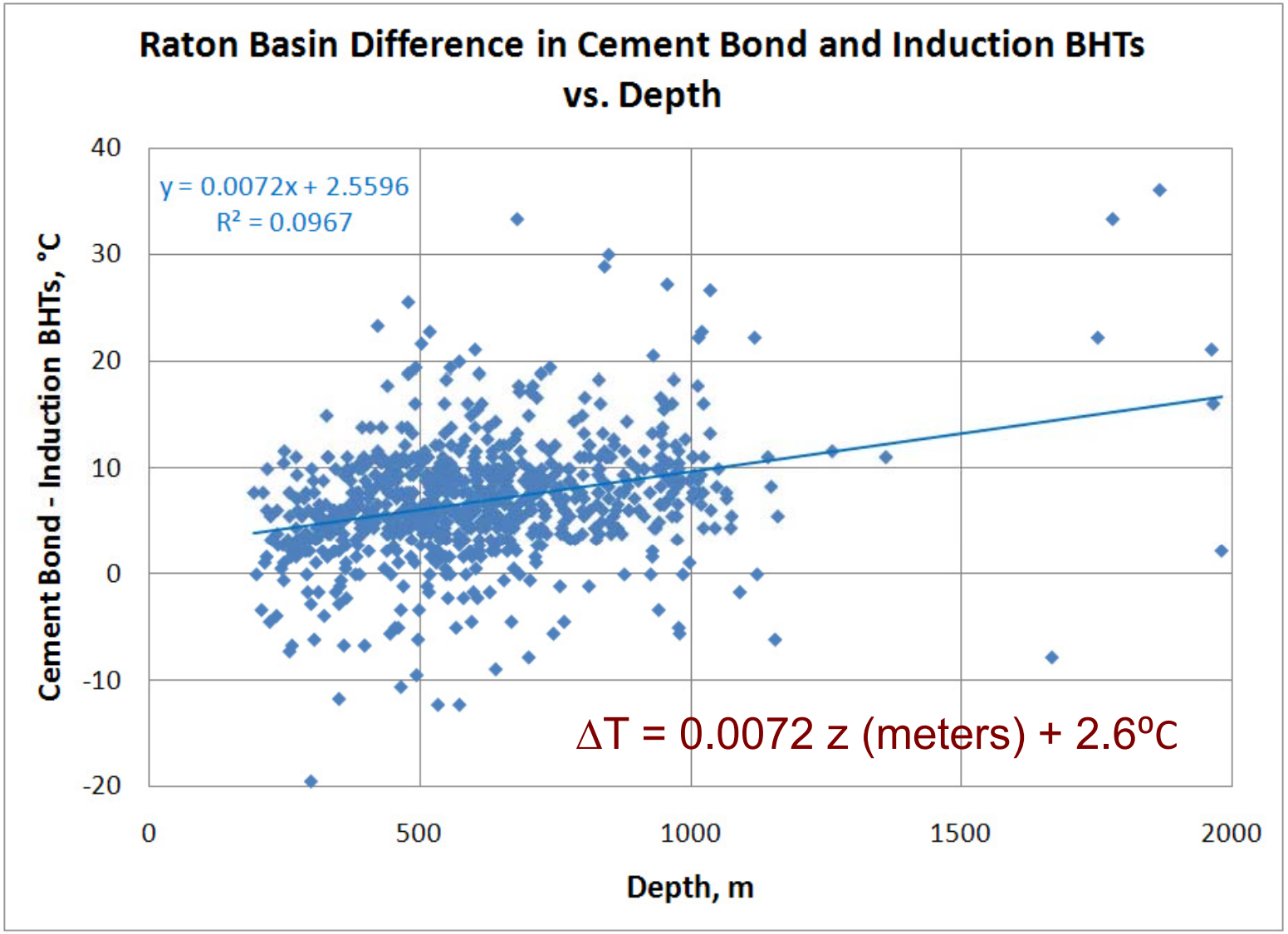
Piceance Basin

Drilling Disturbance Correction



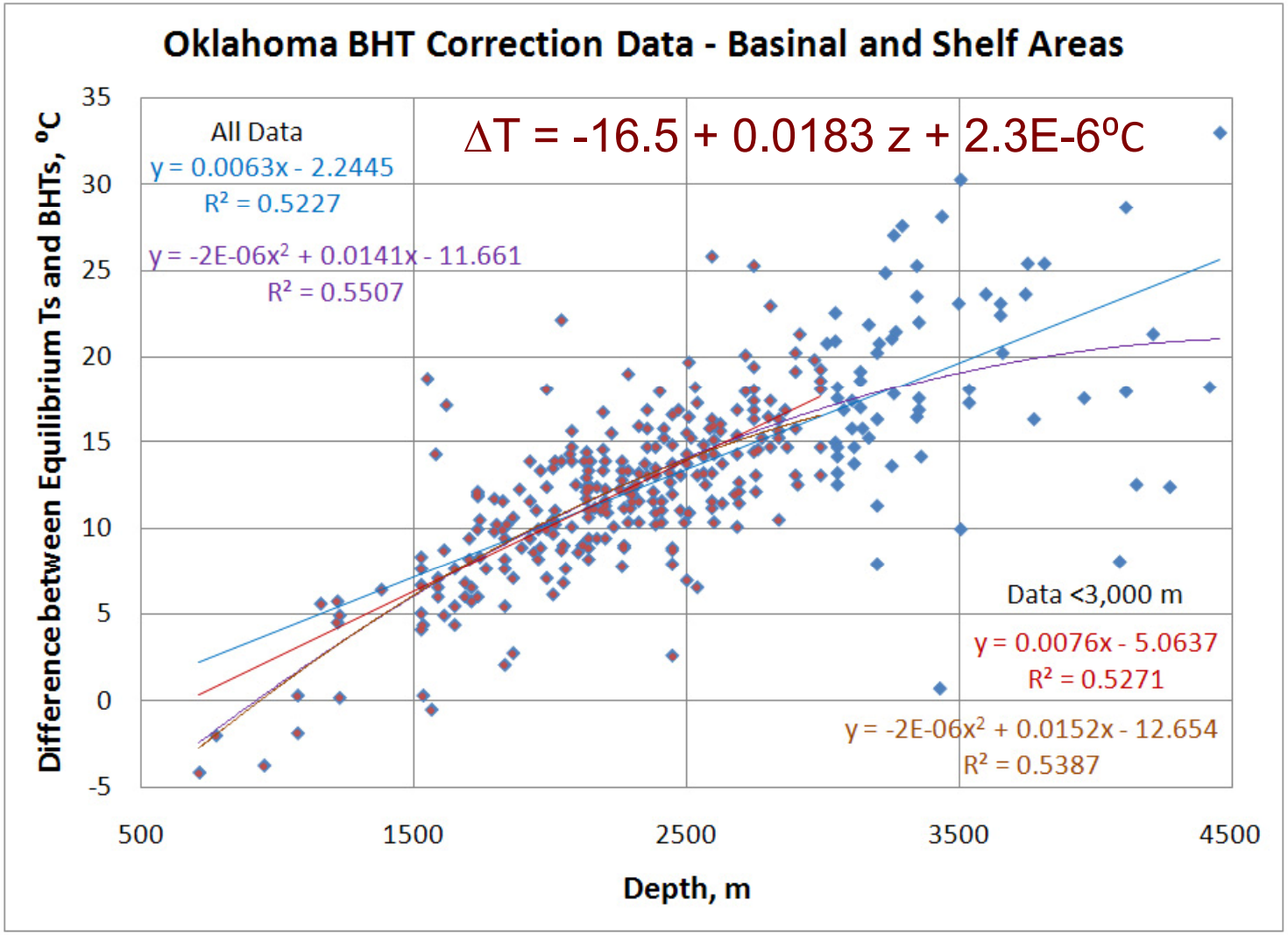
Raton Basin

Drilling Disturbance Correction



Oklahoma

Drilling Disturbance Correction



Applications to Colorado

- High geothermal gradients
  - Raton, San Juan, San Luis, Denver (Piceance) Basins
- No significant hot co-produced waters
- Alternatives:
  - Sedimentary Basin EGS – see next talk
  - Sedimentary Basin Hydrothermal well doublets
- Best sites: new corrections for BHT data
  - (Mississippian) fractured karst carbonates
  - Clastic aquifers
- Next Steps: find sites, find wells, find money

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