Texas Geothermal Energy:

A Focus On Permian Basin And Trans-Pecos Regions

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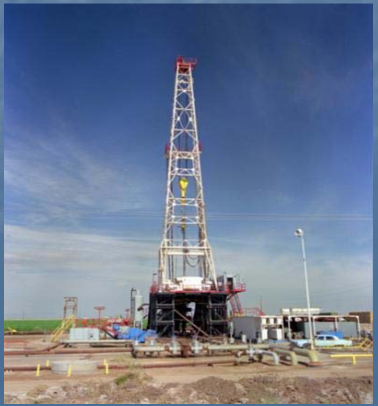
The University of Texas of the Permian Basin
Center for Energy & Economic Diversification

UTPB
THE UNIVERSITY OF TEXAS OF THE PERMIAN BASIN

* Which well is for natural gas? *
* Which well is for geothermal? *



Research Funded By:

* DOE grant of $194,458 to study deep Permian Basin geothermal energy (part of an anticipated 3-year Congressional appropriation) (# DE-FG36-05GO 85023).

* State Energy Conservation Office grant of $40,000 to help study deep Permian Basin geothermal energy and to develop a state-wide geothermal program (# CM540).

Electric Power Production Equivalence

Geothermal energy and geothermal plants are described in MW (megawatt) deliverability.

Size range 10 to 250 MW.

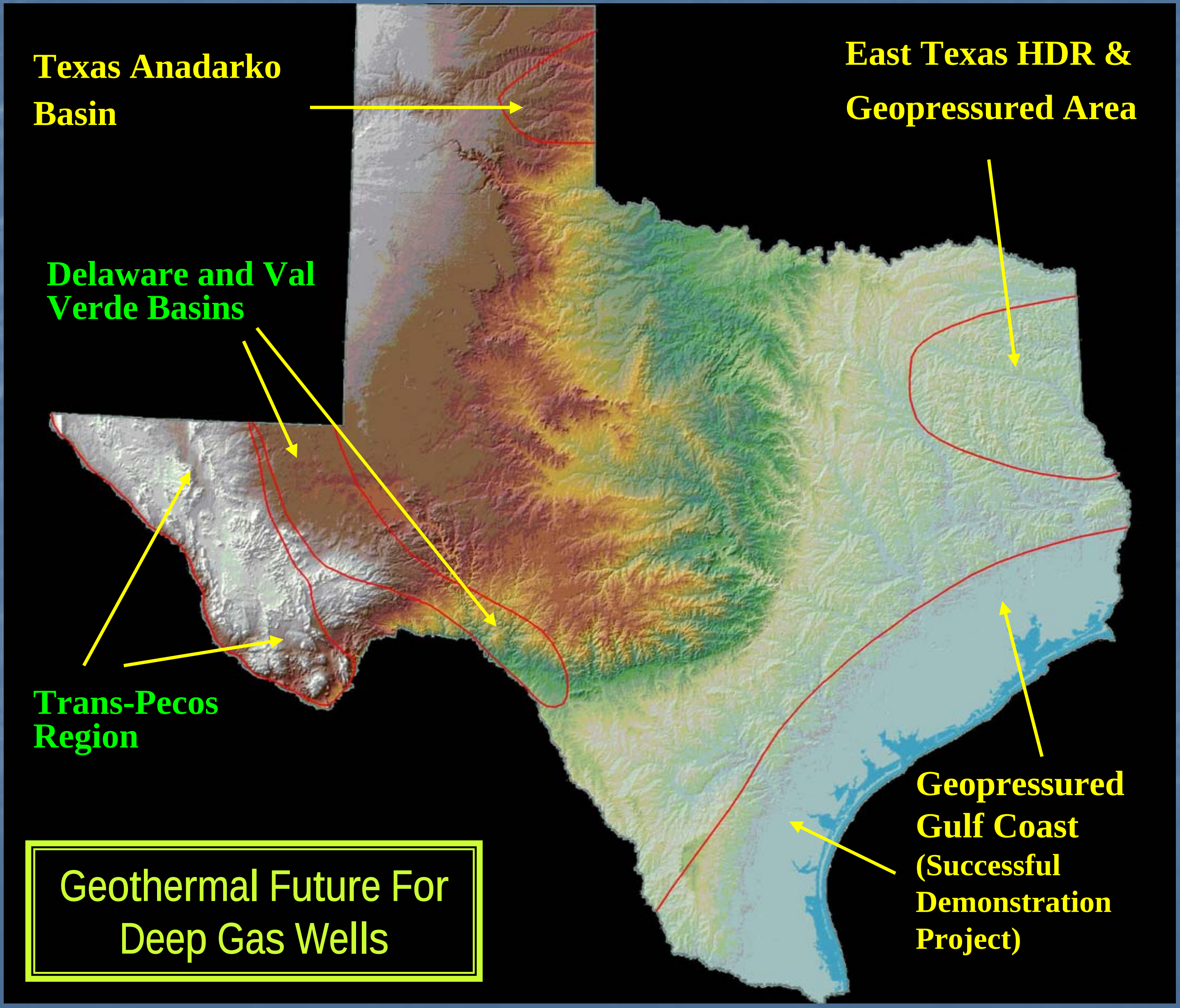
One MW (8,760,000 kWh) of electricity will meet the needs of approx. 1,000 households (approximately 4,000 people).

1 bbl crude oil = 1,699 kWh electricity
1 mcf gas = 303 kWh electricity

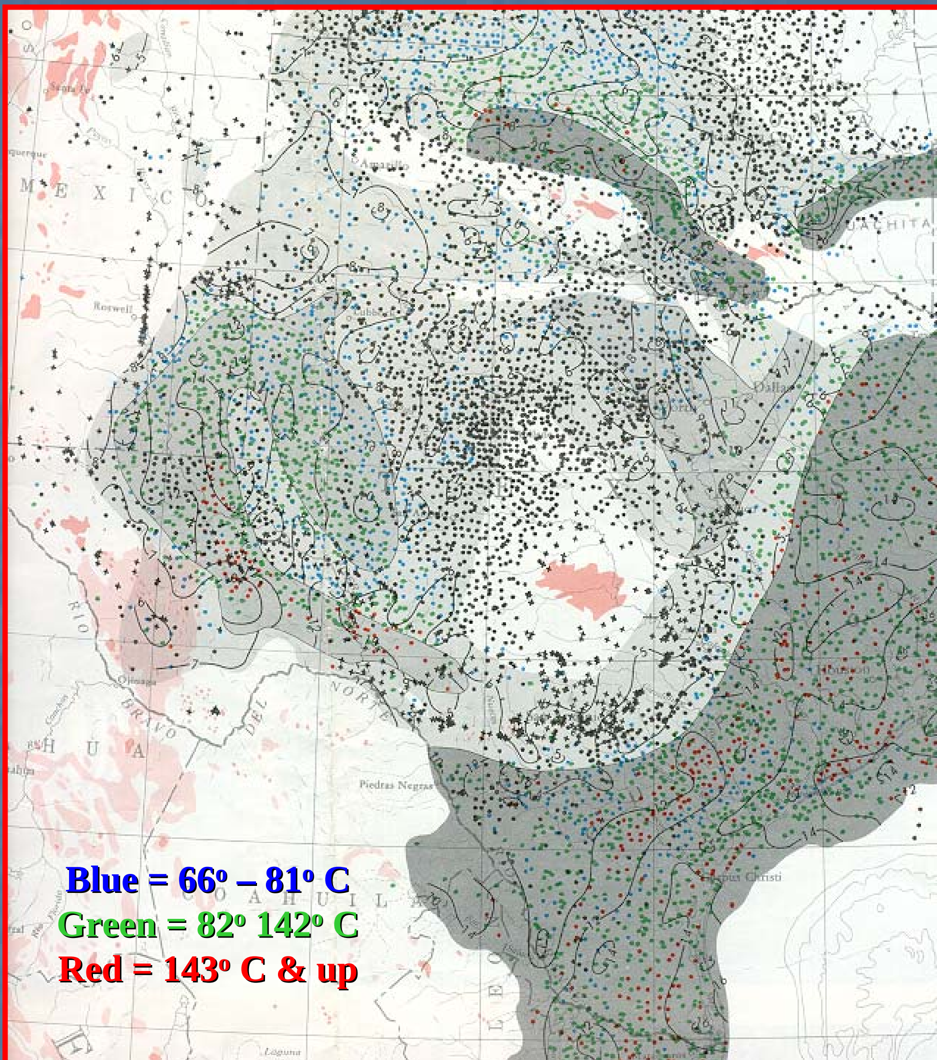
A 250 MW generating plant requires 1,288,994 bbls of oil or 7,227,722 mcf of natural gas in one year.

Target Areas For Electrical Power Generation

If we look at Texas, with the idea of a new energy resource, we have to ask where are the target areas for this resource…. say for electrical power generation? There are five.

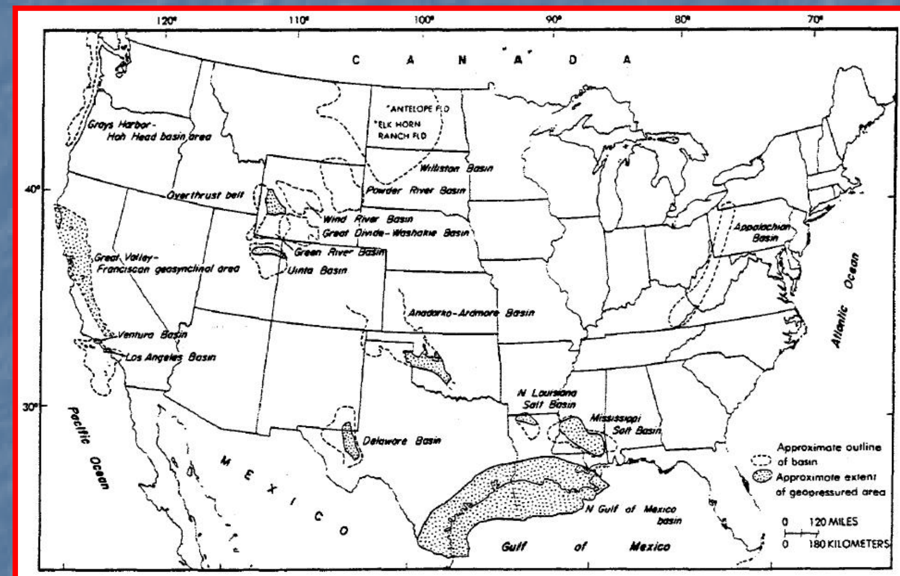


1976 USGS/AAPG North American Geothermal Study



Dark gray region = area where contoured isotherm is 150ºC (302ºF)

Geopressured Areas – Wallace, 1982, GSA Meeting



Geopressured reservoir = sedimentary rock under higher than normal confining pressure

(0.465 lb/in^2/ft).

Permian Basin - Deep

University Lands Location Map Within Area Of Study

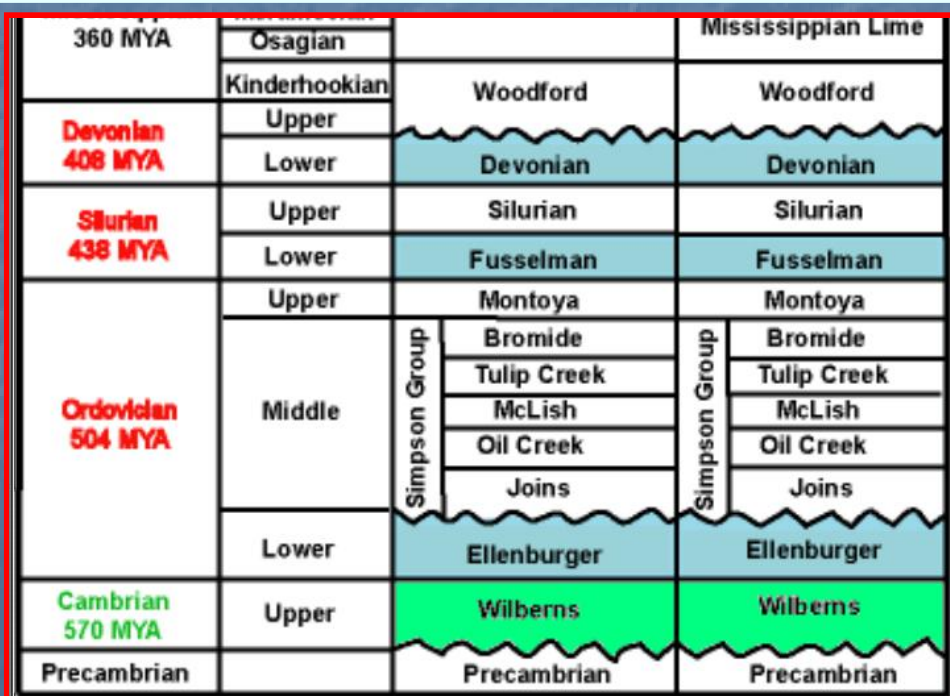
Oil And Gas Lease Sale No. 107

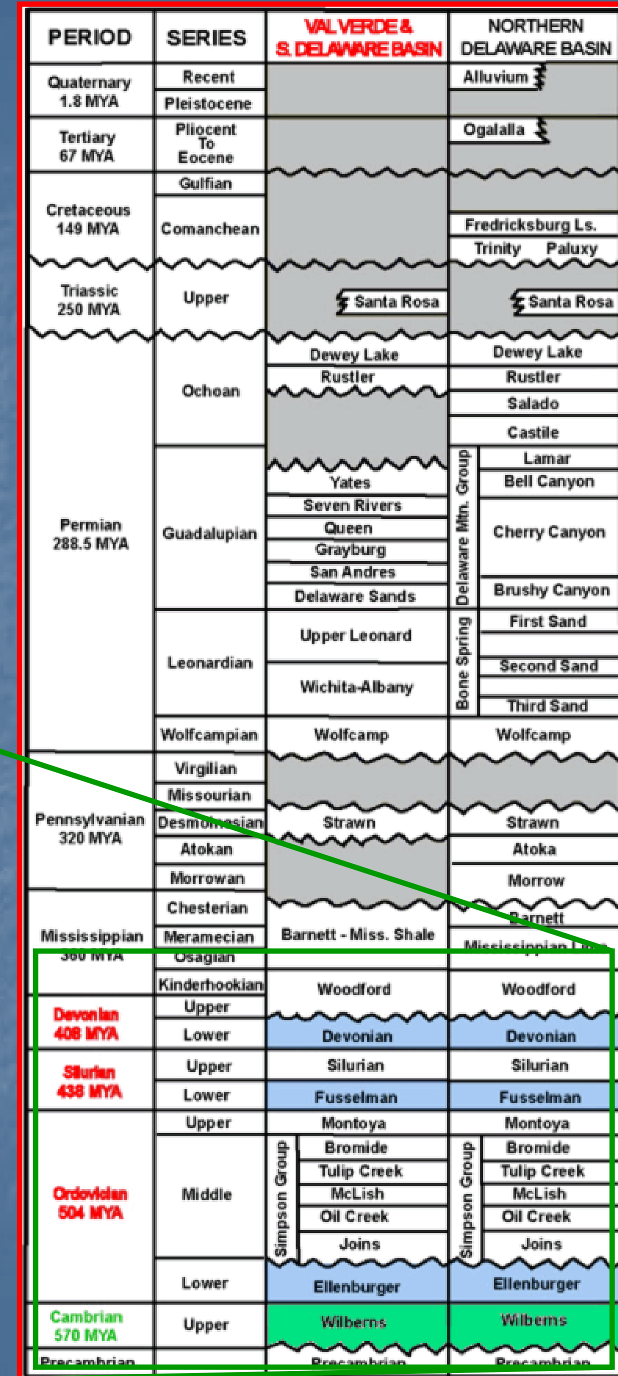
April 20, 2005

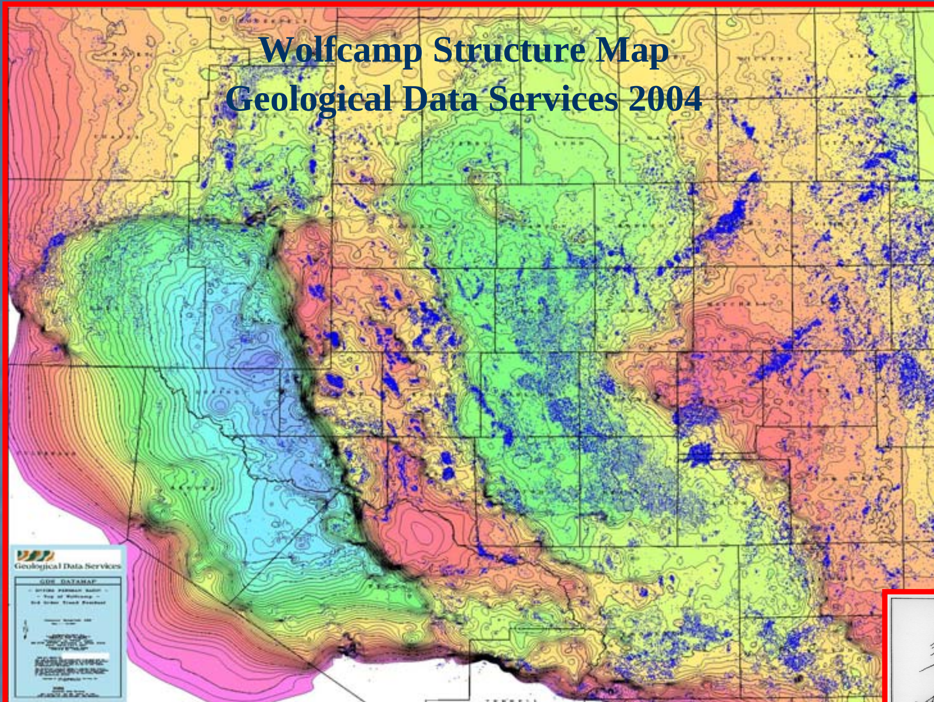
Yellow = Leased Blue = Leased (Horizontally Severed) White = Unleased Green = Nominated Tracts

There are a several possible stratigraphic targets within the Delaware and Val Verde Basins.

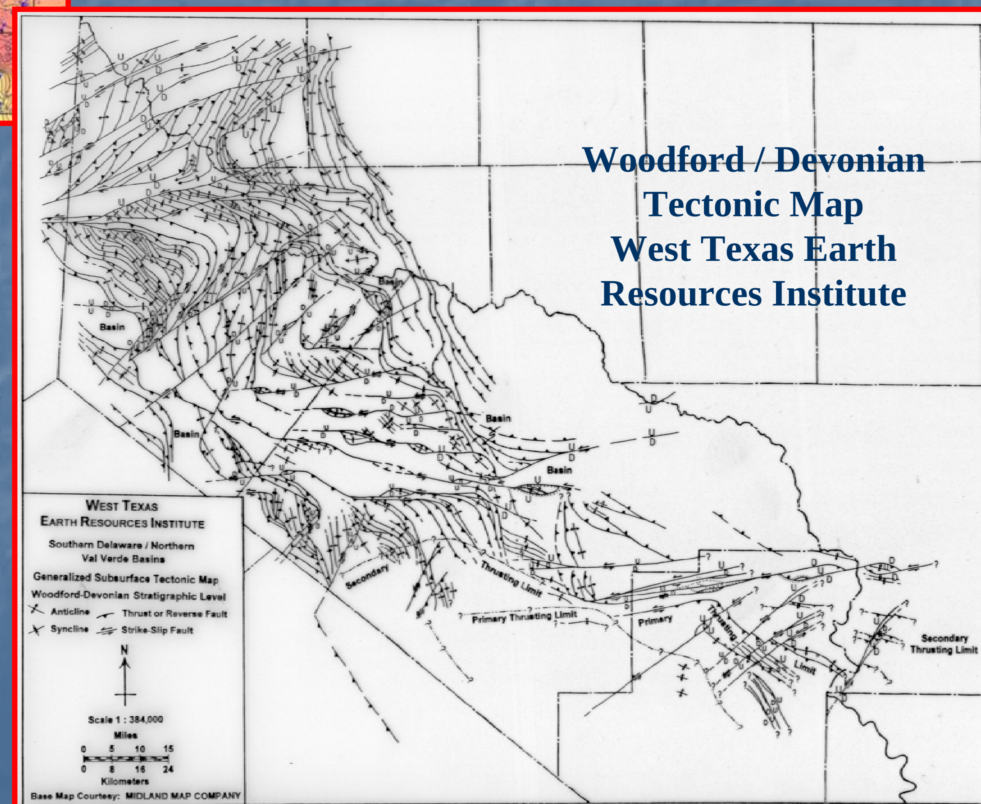
Devonian	Porosity Range	2 to 25%
	Avg. Porosity	6 to 8%
	Fracture Permeability Range	1 to 2,840 md
	Avg. Permeability	10.5 md
Fusselman	Porosity	3 to 11%
	Avg. Porosity	4 to 5%
	Fracture Permeability Range	2 to 26 md
	Avg. Permeability	8.5 md
Ellenburger	Porosity	2 to 14%
	Avg. Porosity	4%
	Fracture Permeability Range	0.1 to 2,250 md
	Avg. Permeability	75 md





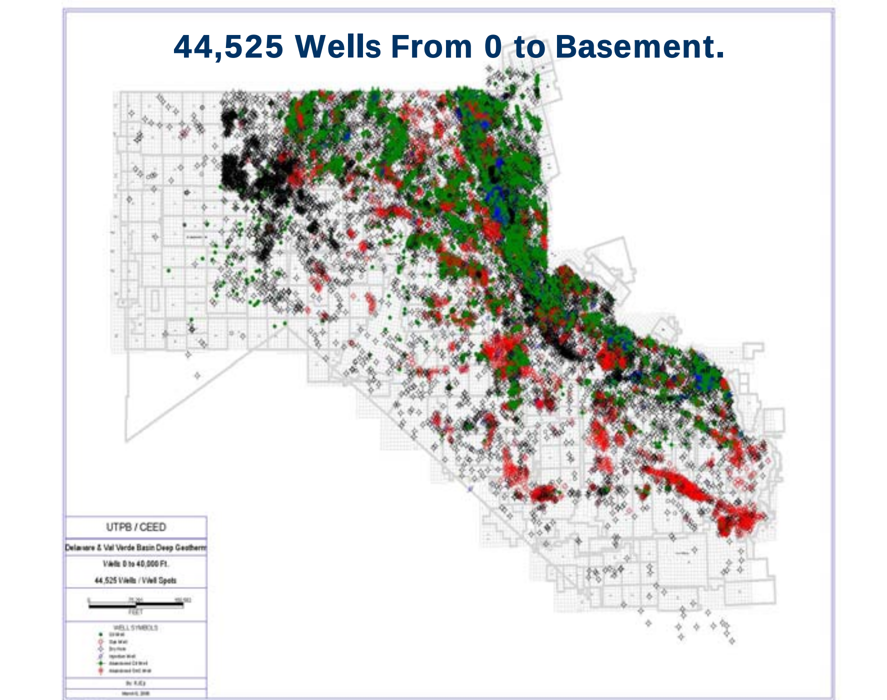


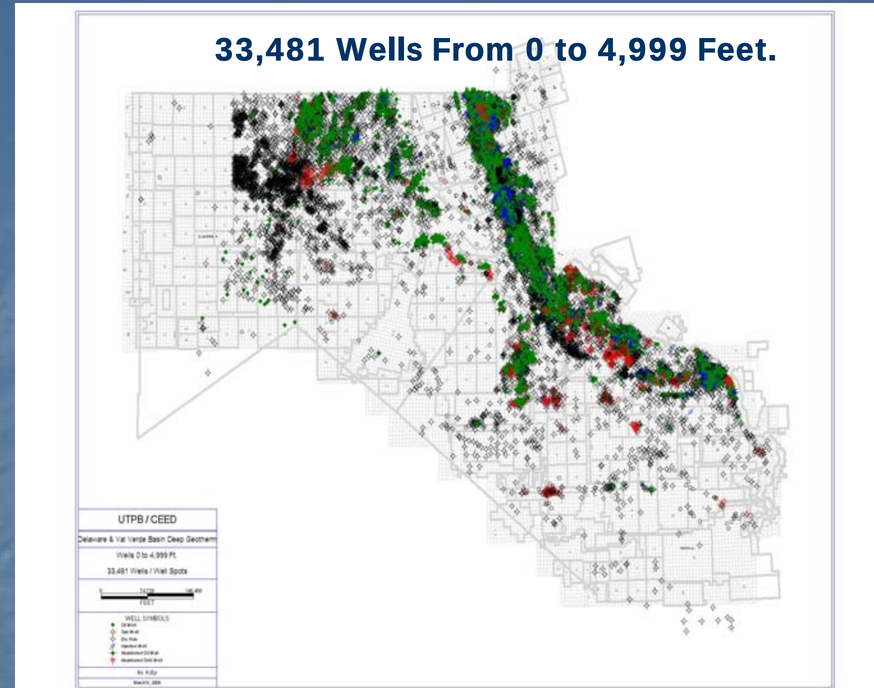
The Delaware and Val Verde Basins represent the deepest and hottest sub-basins of the entire Permian Basin.

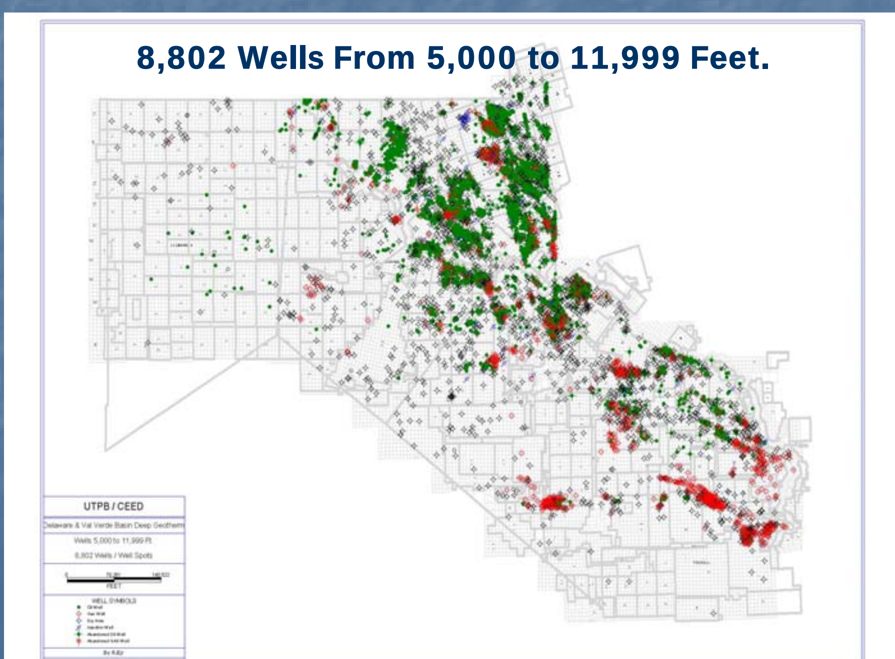


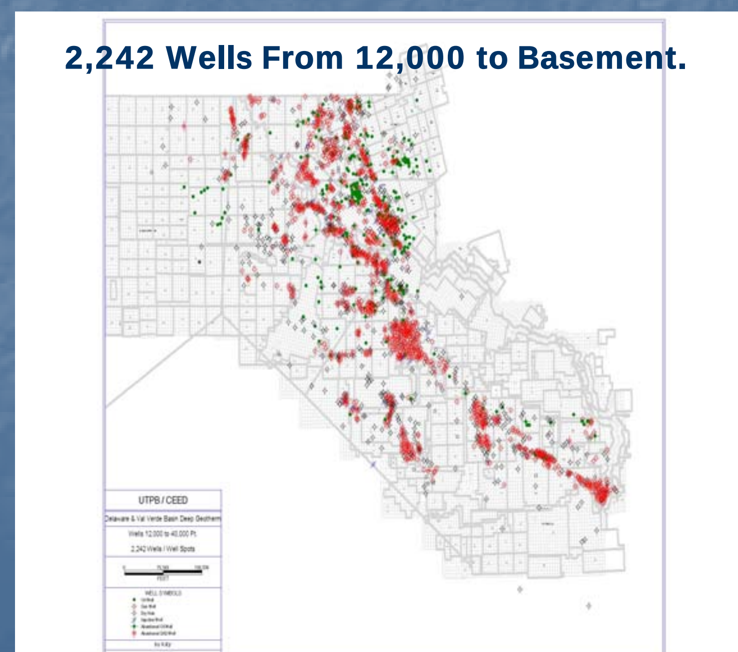
Tectonics and structure must be integrated into subsurface maps to determine relation of structures and temperature data.

There are many wells to use in this analysis.









GDS data with Topographic Mapping Company grid. Petra Software.

Data Base In Pecos County

	A	B	C	D	E	F	G	H	I	J	L	M	N	O	P
1	Entry #	Box #	API number	Field	Operator	Well Name	Location								
2					(on log)	(including #)	Block	Tp	Sec	Survey	Driller's	Logger's	Date		Temp
3											depth	depth			
4														(F)	(C)
44	40	181		Oates NE	Humble	Eichenhofer #1	3		156	T&PRR	15897				-
45	41	110	42-371-11074	NE Oates	E OIL & REFIN	B.W Vallat #1	3		157	T&PRR	13730	13,723	06/01/68	212.00	100.00
46	42	110	42-371-30440	Oates	en Oil Corpora	choffer-State #1	3		158	T&PRR	15000	15,003	12/27/70	162.00	72.22
47	43	110	42 371 106820	Wildcat	Gregg Oil Co.	Kennedy #1	3		165	T&PRR	5130	5,128	02/28/61	106.00	41.11
48	44	110	42 371 01140	Wildcat	Bond Oil Co.	J.R. Kennedy #	3		168	T&PRR	5026	5,037	03/25/61	100.00	37.78
49	45	110	42 371 33181	Wildcat	Texaco	anzanita Unit #	3		169	T&PRR	17050	5,010	11/01/80	107.00	41.67
50	46	110	42 371 11188	Oates NE	Sinclair	Wofford #1	3		179	T&PRR	15500	15,516	08/21/68	255.00	123.89
51	47	110	42 371 11157	Oates NE	Humble	Mitchell #1	3		180	T&PRR	15106	15,104	08/04/68	225.00	107.22
52	48	110		Wildcat	Saxet	Oates "A" #1	3		180	T&PRR	906				-
53	49	110	42 371 33051	Oates NE	Exxon	Dates G U 4 #2	3		181	T&PRR	13988	13,962	10/04/80	250.00	121.11
54	50	110		Oates NE	Humble	Dates G U 4 #1	3		181	T&PRR	14375	4,628	12/07/67	131.00	55.00
55	51	110	42 371 10671	Oates NE	Humble	Smith #1	3		182	T&PRR	13725	5,887	10/19/65	98.00	36.67
56	52	110	42 371 00583	Wildcat	Comer	Oates #1	3		183	T&PRR	4512	4,506	01/11/61	104.00	40.00
57	53	110		Oates NE	Humble	Davis #1	3		183	T&PRR	13950	13,960	10/02/68	310.00	154.44
58	54	110	42 371 10860	Oates NE	Humble	Belding #1	3		184	T&PRR	15050	6,118	03/31/67	109.00	42.78
59	55	110		Oates NE	Great Western	Oates #1	3		195	T&PRR	2274	2,274	01/16/53	94.00	34.44
60	56	110	42 371 30032	Oates NE	Humble	Shell #1	3		196	T&PRR	13859	13,859	06/23/69	295.00	146.11
61	57	110	42 371 10929	Oates NE	Humble	tes Gas Unit 2	3		197	T&PRR	14700	14,307	11/11/67	229.00	109.44
62	58	110		Oates NE	mbers & Kenn	tic Eichenhofe	3		197	T&PRR	14800	14,795	06/13/68	235.00	112.78
63	59	110	42 371 11077	Oates NE	mbers & Kenn	tic Eichenhofe	3		198	T&PRR	14600	14,792	06/11/68		-
64	60	110		Oates NE	western Natur	Dulaney #1	3		199	T&PRR	15123	15,131	01/14/70	242.00	116.67
65	61	110	42 371 30575	Wildcat	C&K	ownsend Est #	3		208	T&PRR	14,972				-
66	62	TL/95/F2	42-371-01084	VILDCAT)	L PETROLEUM	uth-University	16		1	UT Lands	7,400	1,618	12/17/59	80	26.67
67	63	TL/95/F2	42-371-10955	VILDCAT)	ROWN, H. L., J	University #3-1	16		3	UT Lands	7,250	7,253	12/04/67	114	45.56
68	64	UT Lands	42-371-36805	DS (DEVO	PETROLEUM	niversity "4" #3	16		3	UT Lands					-
69	65	UT Lands	42-371-37276	DS (DEVO	WESTERN DR	iversity "16-3"	16		3	UT Lands					-
70	66	TL/95/F2	42-371-30512	HAYES (C	PETROLEUM	University #1	16		4	UT Lands	6,285	6,271	06/04/71		-
71	67	UT Lands	42-371-30512	HAYES (C	PETROLEUM	University #1	16		4	UT Lands					-
72	68	UT Lands	42-371-36396	DS (DEVO	PETROLEUM	University "4" #1	16		4	UT Lands					-
73	69	UT Lands	42-371-36506	DS (DEVO	PETROLEUM	University "4" #2	16		4	UT Lands					-

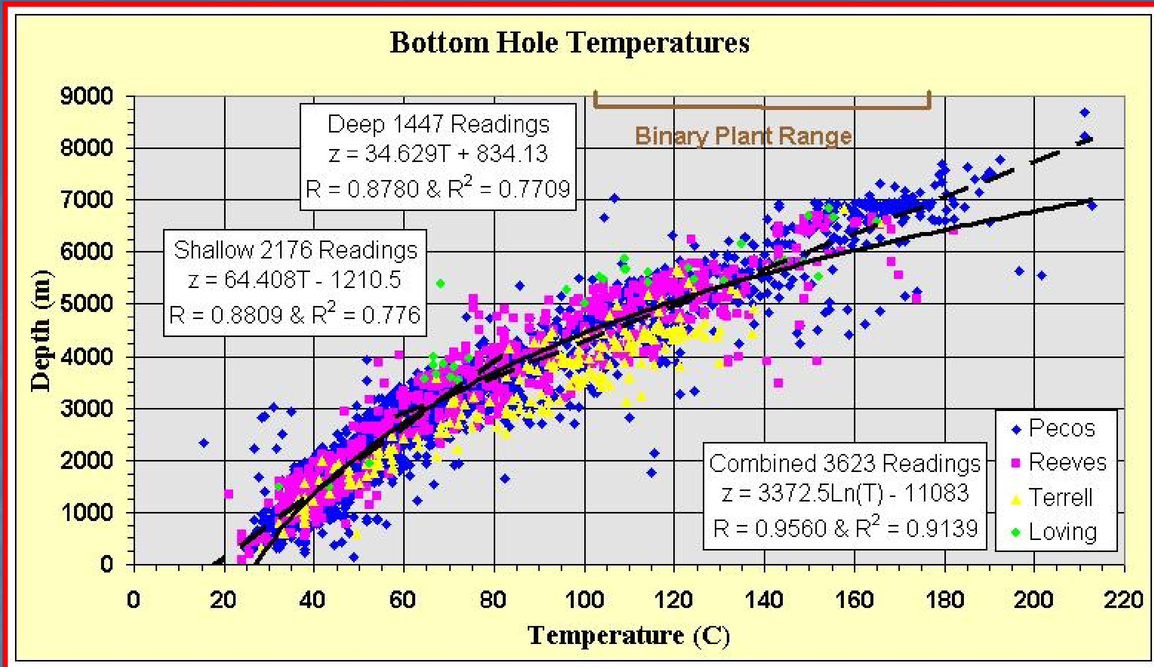
general / Basic / DSTs / temps / engineering / Pecos County / Tops / Sheet1

Ready Sum=24252 NUM

Average BHT within each 1,000 foot depth interval.

	Pecos		Pecos - UT Lands		Terrell		Terrell- Mike's work		Terrell - UT Lands		Crockett		Val Verde		Brewster	
depth	# wells w temps	mean temp	# wells w temps	mean temp	# wells w temps	mean temp	# wells w temps	mean temp	# wells w temps	mean temp	# wells w temps	mean temp	# wells w temps	mean temp	# wells w temps	mean temp
2,000	178	95.99	34	94.26	2	100.00	2	96.50			3	92.66				
3,000	140	103.01	12	97.17	2	113.50	3	92.00			2	163.5?				
4,000	138	107.48	3	101.00	3	111.67	10	109.00			5	116.20			5	107.00
5,000	320	112.29	18	115.33	2	150.50	11	105.45	4	112.50	5	138.20			3	129.00
6,000	124	119.62	7	123.14	9	135.89	16	117.19	1	error	10	166.80			3	111.33
7,000	106	129.19	16	125.56	13	145.69	25	141.16	4	139.00	11	173.27			1	138.00
8,000	83	139.25	5	131.20	7	155.00	27	154.44	15	155.20	3	180.67			1	148.00
9,000	106	145.51	3	146.33	22	190.63	34	179.91	8	165.50	2	211.50			4	172.75
10,000	153	161.75	6	159.83	39	163.21	39	177.74	1	165.00	2	223.50			1	230.00
11,000	121	170.12	3	176.67	21	207.29	39	196.21	12	191.50						
12,000	85	186.95	3	188.33	16	205.38	48	232.88	11	189.00	5	236.60			1	205.00
13,000	76	216.20			10	227.00	18	220.00	0		9	287.22				
14,000	59	229.24	1	193.00	71	252.39	52	238.33	5	208.20	28	279.61				
15,000	76	230.33	2	265.50	18	247.83	18	241.83	2	248.50	8	288.50				
16,000	38	256.08	1	230.00	8	250.13	5	221.00	1	243.00			1	281	1	275.00
17,000	22	256.68			6	268.67	8	252.38	1	254.00	1	334.00	1	295		
18,000	22	275.68	4	268.25	8	301.75	10	287.40								
19,000	9	280.11	2	287.00	1	251.00	1	251.00					1	310		
20,000	24	296.33	2	300.67	3	329.67	2	322.50							2	315.00
20,500	(12)	297.75														
21,000	38	314.05	1	296.00	1	268.00										
21,500	(30)	316.37														
22,000	99	323.05	2, 1 error	320.00	2	355.00	1	332.00								
22,500	(66)	232.14														
23,000	13	347.69														
23,500	3	335.33														
24,000	5	360.60					1	330.00								
24,500	4	363.75	2	364.5	1	330.00										
3440 wells							537 data points									
2039 wells with data							441 with temps									

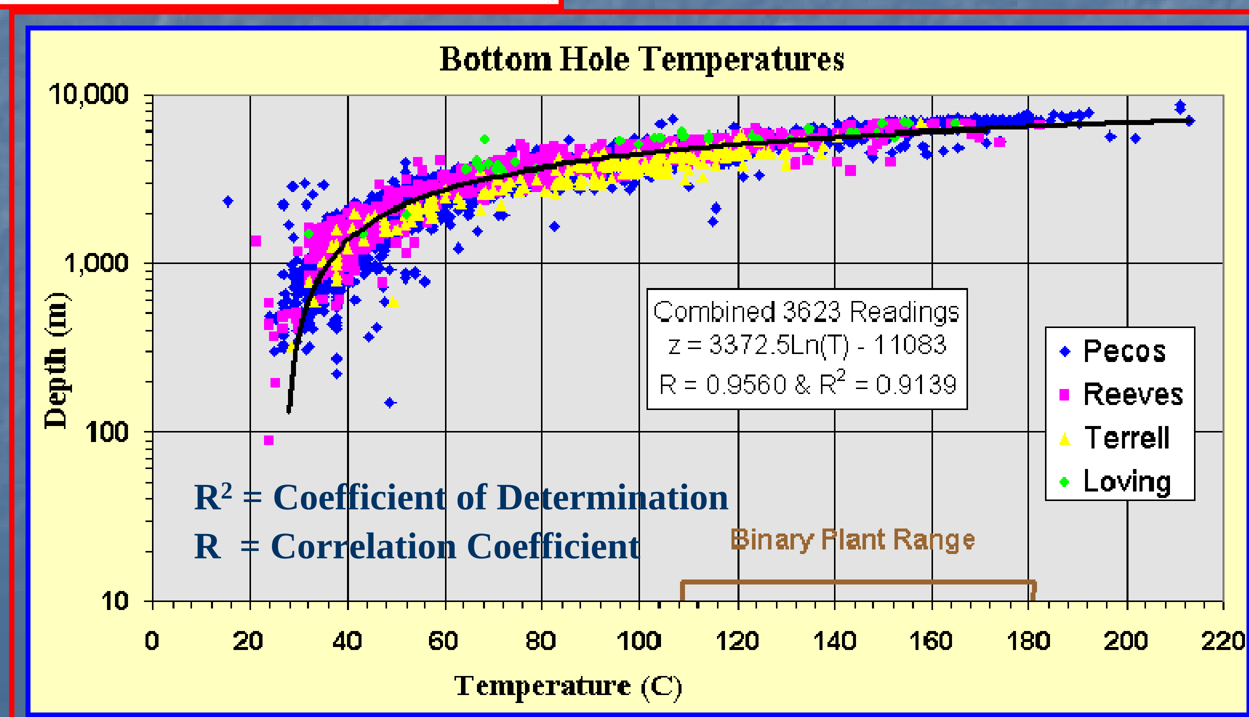
Presidio		Hudspeth		Culberson		Reeves		Loving		Winkler		Ward				County
# wells w temps	mean temp	# wells w temps	mean temp	# wells w temps	mean temp	# wells w temps	mean temp	# wells w temps	mean temp	# wells w temps	mean temp	# wells w temps	mean temp	# wells w temps	mean temp	Name
						30	93.87			2	86	3	87			
						48	99.4			13	104.92	3	94.33			
2	143.50	4	127.50			74	102.32	2	102	4	110.25	5	96.00			
		6	120.83			81	105.85	42	102.24	9	111	10	99.90			
5	149.00	1	108.00	3	116.67	23	120.91	3	106.67	0		37*	114.62			
2	160.50	3	136.67	4	144.25	3	119.33			4	123.75	8	124.00			
5		3	143.00	3	150.00	5	140.2			3	121	5	122.60		168	El Paso
2	211.00			3	159.33	7	166.57	1	182	2	128.5	4	141.50			
2	213.00			3	186.00	14	159.5			1	141	14	138.50			
2	241.00			1	212.00	20	183.3	5	164.6	8	152.25	70	145.89			
3	225.67			2	202.50	21	222.14	4	170.5	2	185	27	167.63		262	El Paso
				1	238.00	29	215.24			4	153	25	147.72			
						13	226.46			0		18	193.33			
1	285.00					29	240.55	1	188	0		19	214.74			
						24	238.46			2	192	17	213.76			
						29	248.28	3	232.66	2	268	22	223.68		278	El Paso
>6000', several		accurate?				14	269.86	4	259.2	1	268	21	233.67			
anomalies - both						12	282.83	1	300	0		8	254.25			
						8	287.75	1	268	4	264.25	13	275.92			
						14	310.79			0		4	281.00			
										1	296	2	307.50			
										just what I've gotten		*33>6500				

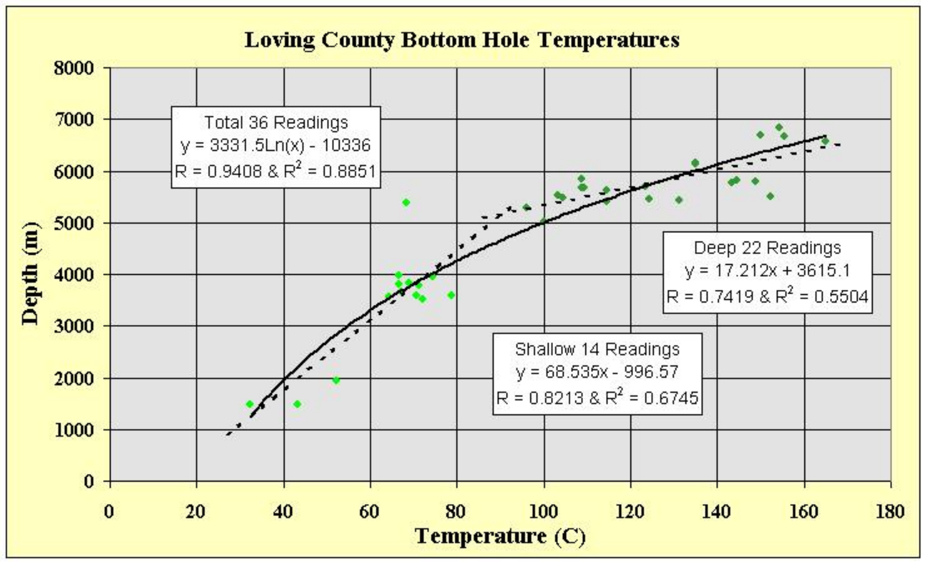


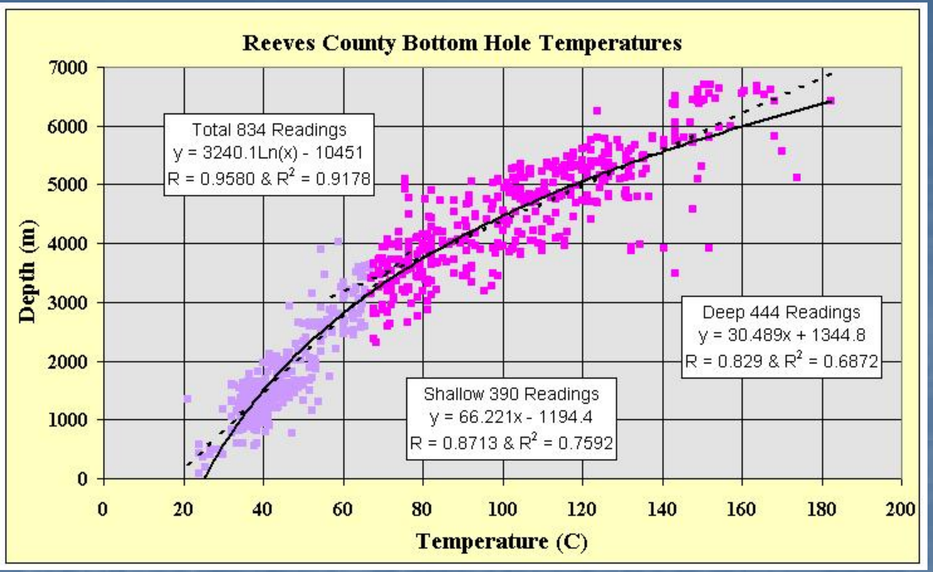
BHT Data Points:
Pecos = 2,559; Reeves = 834;
Terrell = 196; Loving = 36

Data originally compiled by West Texas Earth Resources Institute.

Temperature gradient appears to be lognormal.







Loving = 36

Reeves = 834

Pecos = 2,559

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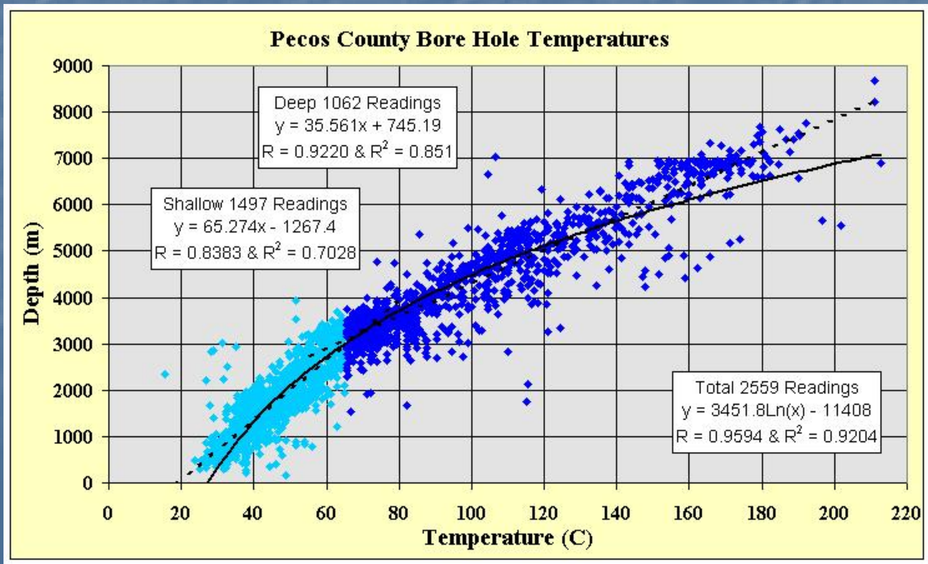
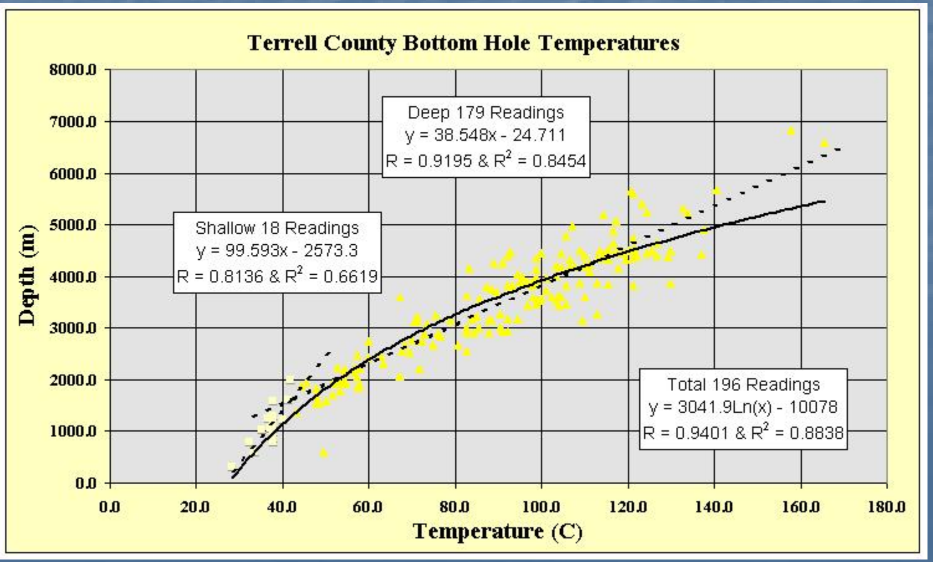
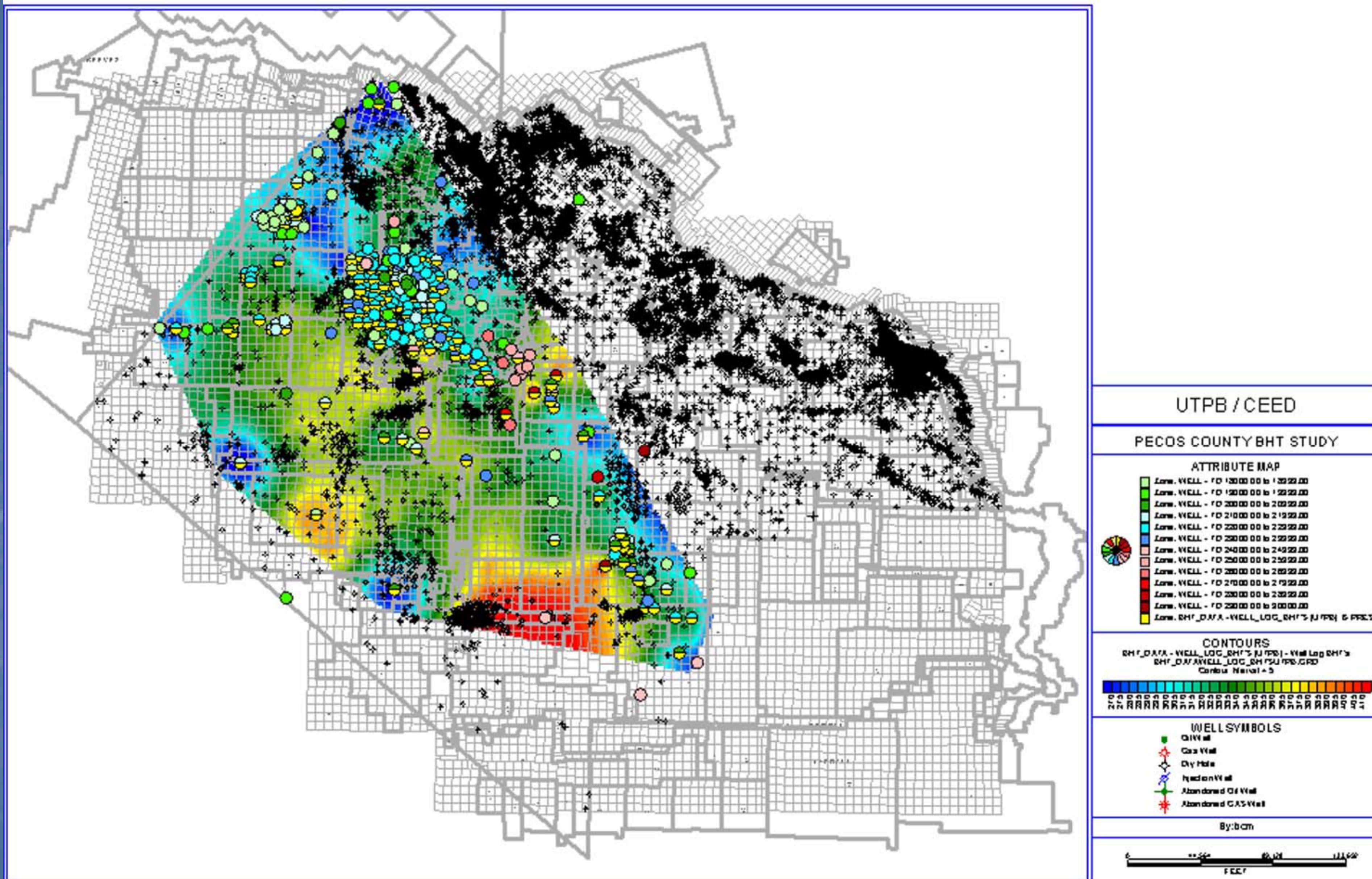
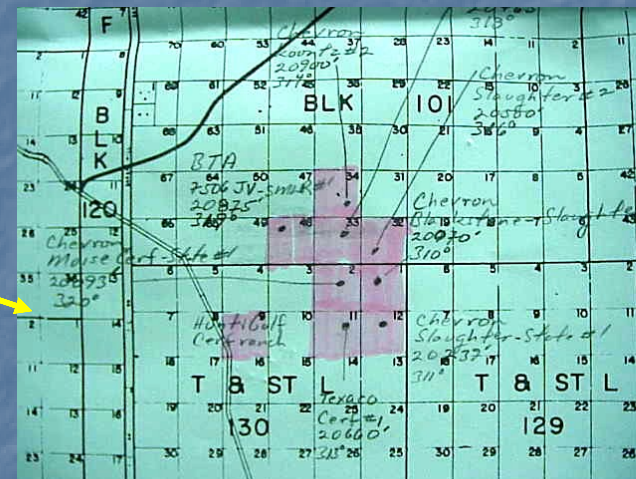




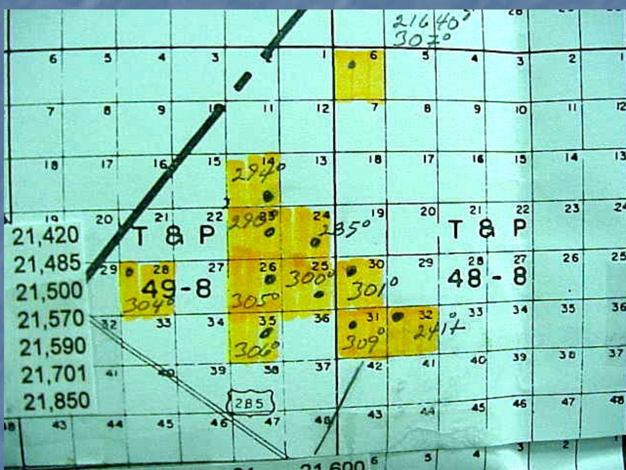


UTPB / CEED
PECOS COUNTY BHT STUDY
ATTRIBUTE MAP
CONTOURS
WELL SYMBOLS
Oil Well
Gas Well
Dry Hole
Injection Well
Abandoned Oil Well
Abandoned GAS Well
By:bcm
FEET

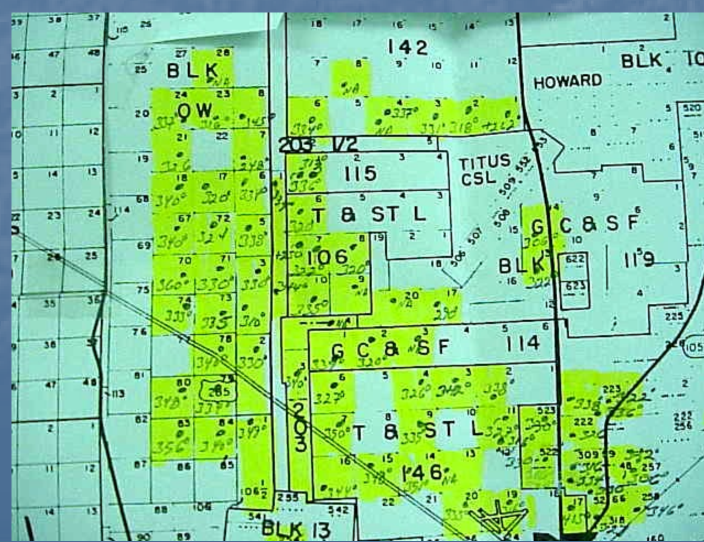
Pecos County @ 18,000 – 19,000 ft



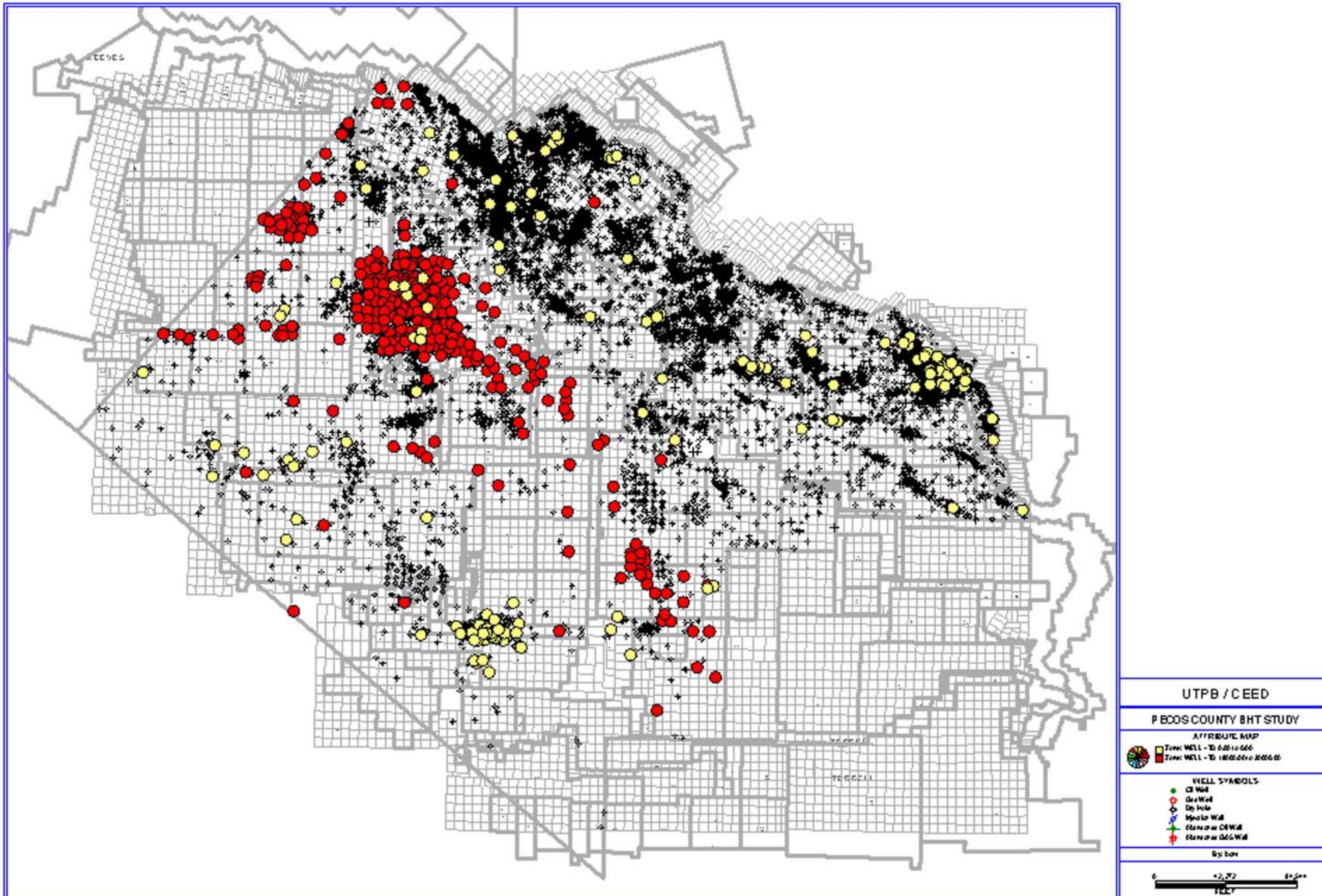
Pecos County @ 20,000 – 21,000 ft



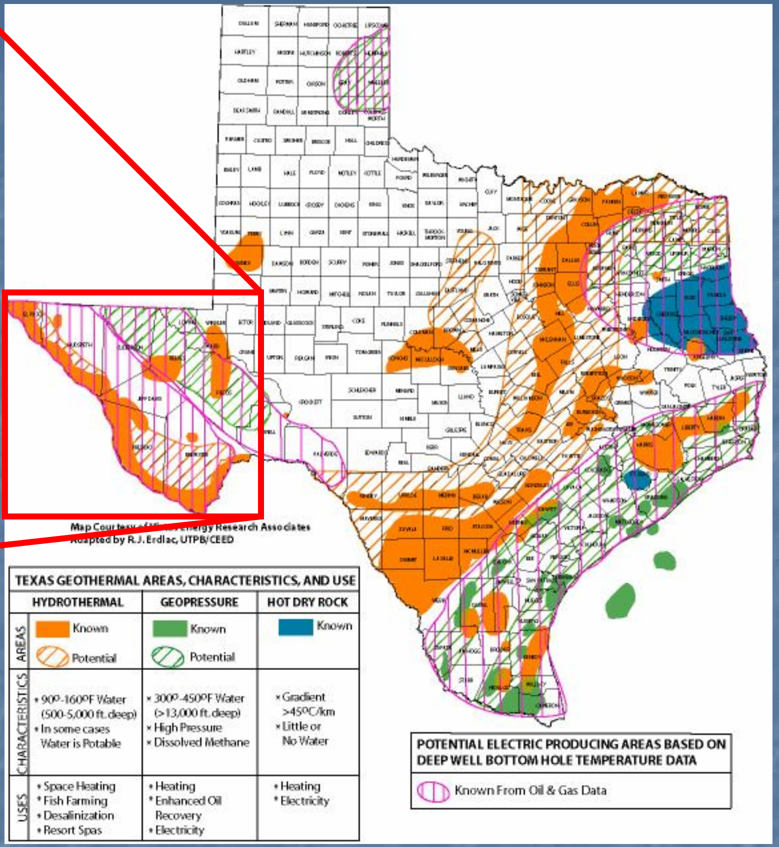
Pecos County @ 21,000 – 22,000 ft



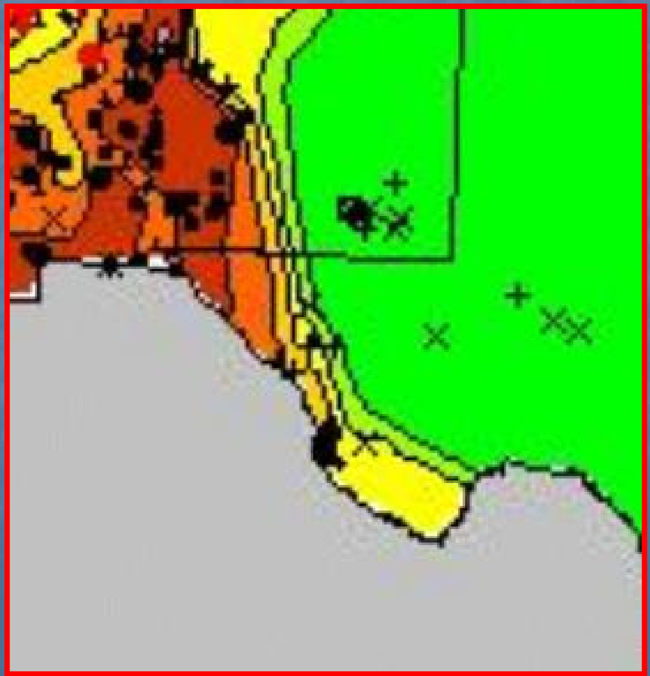
Pecos County @ 22,000 – 23,000 ft

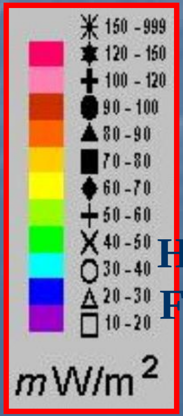

UTPB / CEED
PECOS COUNTY BHT STUDY
Oil Well
Gas Well

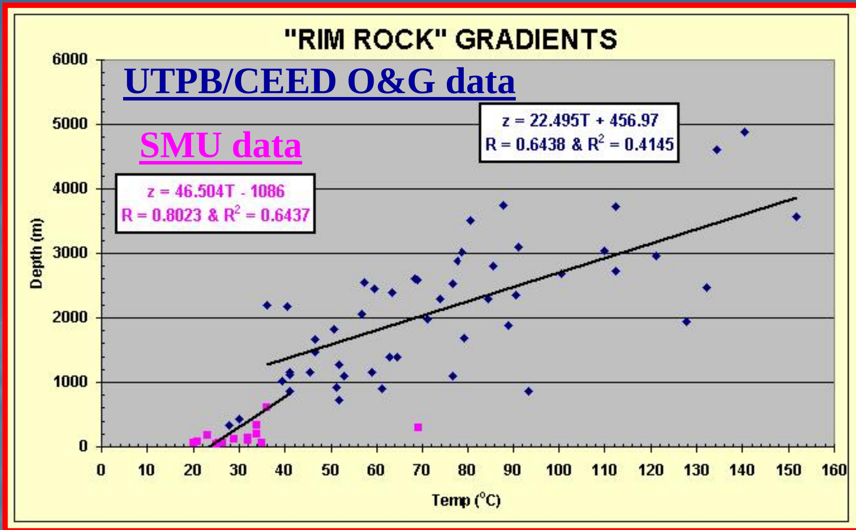
Trans-Pecos Region

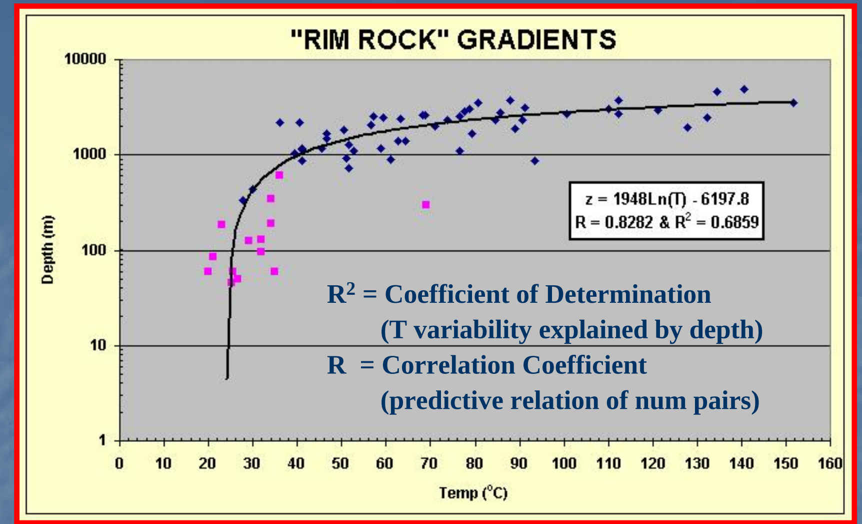


The "Texas Renewable Energy Resource Assessment" map by Virtus saw a hydrothermal potential for the Trans-Pecos, but did not include these temperatures within the realm of electricity generation. Maps developed for the DOE show a thermal gradient similar to the Gulf Coast, but with a heat flux in the north part of the region at 80 *m*W/m² and up, much higher than the 60-70 *m*W/m² found in the Gulf Coast. The temperatures and heat flux do appear to support electric generation. Texas Map adapted by R.J. Erdlac, Jr.



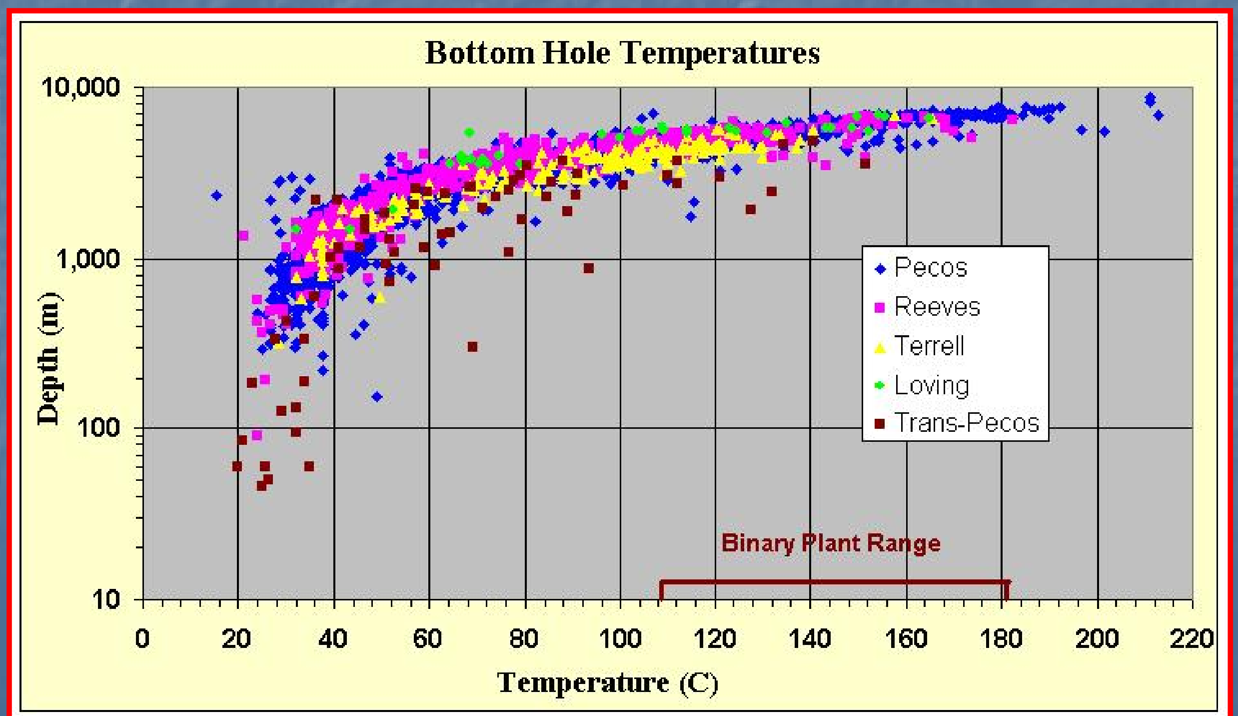






Two straight lines are defined in the normal-normal plot and one logarithmic curve for the log-normal plot. In the first plot, the shallow line gives dT/dz = 21.5°C/km with the deep line having dT/dz = 44.5°C/km, over twice the shallow value. The log-normal curve gives a better statistical fit.

Note proximity of Trans-Pecos wells and those in Delaware Basin, especially in Pecos County.



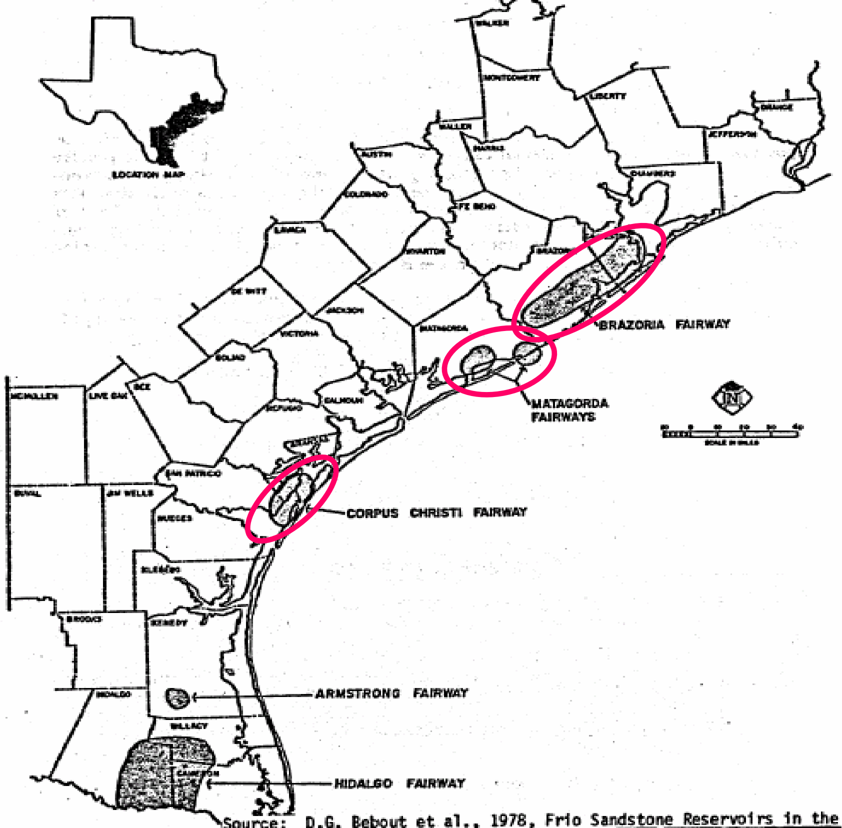
Resource Amount – *Harder To Gage At Present Time*

Gulf Coast

(General Land Office of Texas 1979)

Map 1

POTENTIAL GEOPRESSURED-GEOTHERMAL FAIRWAYS,
FRIO FORMATION, GULF COAST OF TEXAS



Source: D.G. Bebout et al., 1978, Frio Sandstone Reservoirs in the Deep Subsurface Along the Texas Gulf Coast, Report of Investigations No. 91, Bureau of Economic Geology, The University of Texas at Austin.

3

Table 2

ASSUMED VALUES OF FAIRWAY PARAMETERS:
OPTIMISTIC WITH DEEP REINJECTION SCENARIOS

Parameter	Fairway: Brazoria	Fairway: Matagorda	Fairway: Corpus Christi
Reservoir Characteristics			
Temperature	350°F	350°F	350°F
Porosity	22%	20%	20%
Permeability (millidarcies)	50	5	5
Percent fluid recovery (with deep reinjection)	45%	15%	15%
Gas content (SCF/bbl)	50	50	50
Fairway extent (square miles)	908	353	632
Fraction of fairway producible	100%	100%	100%
Wells			
Success ratio in drilling producible wells	50%	50%	50%
Use of unsuccessful production wells for disposal wells	100%	100%	100%
Flow rate per well (bbls/day)	128,838	10,931	10,931
Support area per well (square miles)	11.45	4.01	4.01
Fuel and Electric Generating Plants			
Life of facilities (years)	60	60	60
No. production wells per plant	3	9	9
No. disposal wells per plant	6	18	18
Electrical generating capacity per plant (megawatts)	48.3	12.3	12.3
Gas flow capacity per plant (SCF/yr)	7.05×10^9	1.80×10^9	1.80×10^9
Fairway Development			
No. plants:			
Per fairway	16	6	8
Per fairway fed by wells on PFSL	6	4	8
Production wells:			
Per fairway	48	54	72
In PFSL	8	16*	39
Adjacent to PFSL	10	6**	17
No. disposal wells per fairway	96	108	144
Electrical generating capacity per fairway (megawatts)	773.03	73.78	98.38
Gas flow capacity per fairway (SCF/yr)	1.13×10^{11}	1.08×10^{10}	1.44×10^{10}

* Of 16 wells, 9 are assumed to be in eastern portion, and 7 in western portion.
**Of 6 wells, 2 are assumed to be in eastern portion, and 4 in western portion.

Source: C.D. Zinn. 1977. Operations Research and Systems Analysis of Geothermal-Geopressured Resources in Texas - Final Report. Research Report No. 10, Center for Energy Studies, The University of Texas at Austin.

Gulf Coast *– calculations based upon defined fairways and Pleasant Bayou #2*

Parameter	Fairway			Total
	Brazoria	Matagorda	Corpus Christi	
Fairway extent (sq mi.)	908	353	632	1893
Fraction of fairway producible (%)	100	100	100	xxx
Production wells per fairway	48	54	72	174
Estimated rating on heat alone (1.1 MW/well)	52.8	59.4	79.2	191.4
Estimated rating on heat alone (1 MW/well)	48	54	72	174
Estimated rating on heat alone (0.9 MW/well)	43.2	48.6	64.8	156.6

These calculations do not include the rest of the Gulf Coast!

Based upon single pay zone.

***Delaware Basin** – calculations based upon defined fairways in Gulf Coast that are for sandstone reservoirs and not limestone or dolostone reservoirs.*

Estimated Area	Estimated Well Rating From Heat Only	Fairway Model		
		Brazoria - 48 wells / 908 mi^2	Matagorda - 54 wells / 353 mi^2	Corpus Christi - 72 wells / 632 mi^2
5,544 mi^2	1.1 MW	322 MW	933 MW	695 MW
	1.0 MW	293 MW	848 MW	632 MW
	0.9 MW	264 MW	763 MW	568 MW

Low

High

Values will increase if well rating is higher

Does not include multiple pay zones.

CONCLUSIONS

"The future of the Texas oil and gas industry is tied to The future of a Texas geothermal industry."

- **Companies have the opportunity to use existing and develop new infrastructures towards geothermal development.**
- **This will require the same entrepreneurial spirit that created the oil and gas industry to rise and inaugurate a new energy evolution in the Permian Basin.**
- **This means creating an energy triad …. oil …. gas …. and geothermal combined.**

* Which well is for natural gas? *
* Which well is for geothermal? *

To Be Continued