Trip to Wellington Field to observe 3D seismic acquisition and production facilities

Hosted and Led by
Jeff Logan, Paragon Geophysical Services, Inc.
and
Dana Wreath, BEREXCO, LLC.

Co-Leaders Lynn Watney and Saibal Bhattacharya
Kansas Geological Survey

KANSAS STATE UNIVERSITY

HEDKE-SAENGER GEOSCIENCE, LTD

Field Trip Attendees

28 plus 6 students from K-State and 5 additional BEREXCO staff = 39

1	Saibal Bhattacharya	Kanasas Geological Survey
2	Rex Buchanan	Kanasas Geological Survey
3	John Charlton	Kanasas Geological Survey
4	Ed Colson	KU student
5	~~Dustin Damme~~	KU student **George Ndegwa**
6	Saugata Datta	Kansas State University
7	Mike Dealy	Kansas Geological Survey
8	Fatemeh Fazelalavi	KU student
9	Glen Gagnon	Kansas Geological Survey
10	Robert Goldstein	KU Department of Geology
11	Tom Hansen	Bittersweet Energy
12	Ben Haring	KU student
13	Craig Hendix	KU student
14	Breanna Huff	KU student
15	Bruce Karr	Fairfield
16	Bruce Karr's son	
17	David Koger	Remote Sensing
18	Bill Lamb	BEREXCO
19	Jeff Logan	Paragon Geophysical
20	Abdelmoneam Raef	KSU Department of Geology
21	Jennifer Roberts	KU Department of Geology
22	Aimee Scheffer	KU student
23	Marios Sophocleous	Kansas Geological Survey
24	Andrew Sparks	KU student
25	Frank Storms	KU student
26	Lynn Watney	Kansas Geological Survey
27	Dana Wreath	BEREXCO
28	Randy Koudele	BEREXCO

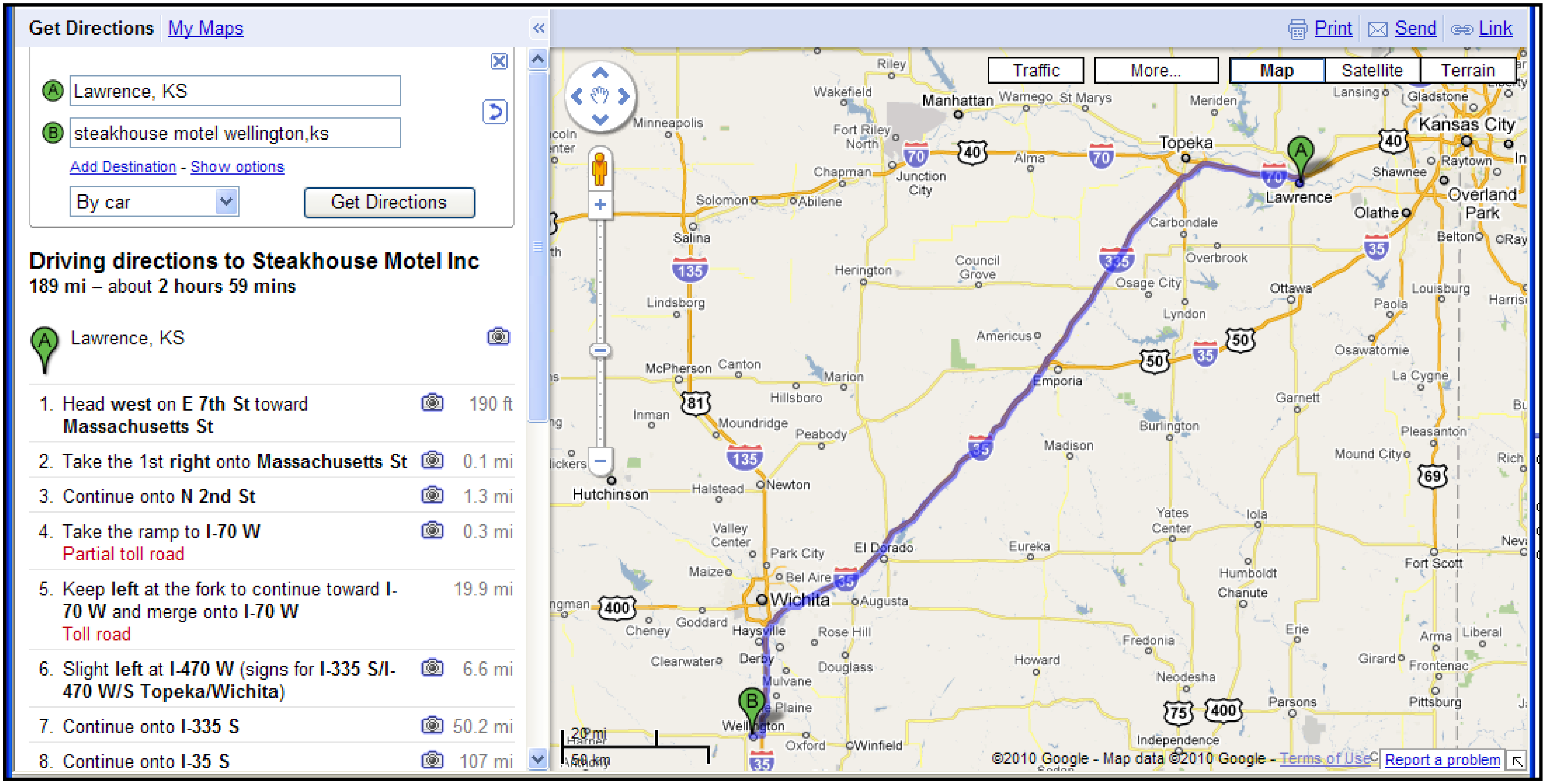
Those traveling from Lawrence:

Geology vans meet Survey SUV #1 in upper (north) parking lot of the Survey at 7 a.m. and proceed to Wellington to rendezvous at Steakhouse Restaurant

Riding in Survey SUV #1: Rex, John C., Marios, and Saibal

Survey SUV#2: Lynn leaving at 6:30 a.m. to pick up Glen Gagnon in Emporia (~8 am.) and Mike Dealy and in Wichita (~9:45), then drive to Wellington.

Lawrence to Wellington via Kansas Turnpike – 189 miles (3 hour drive)



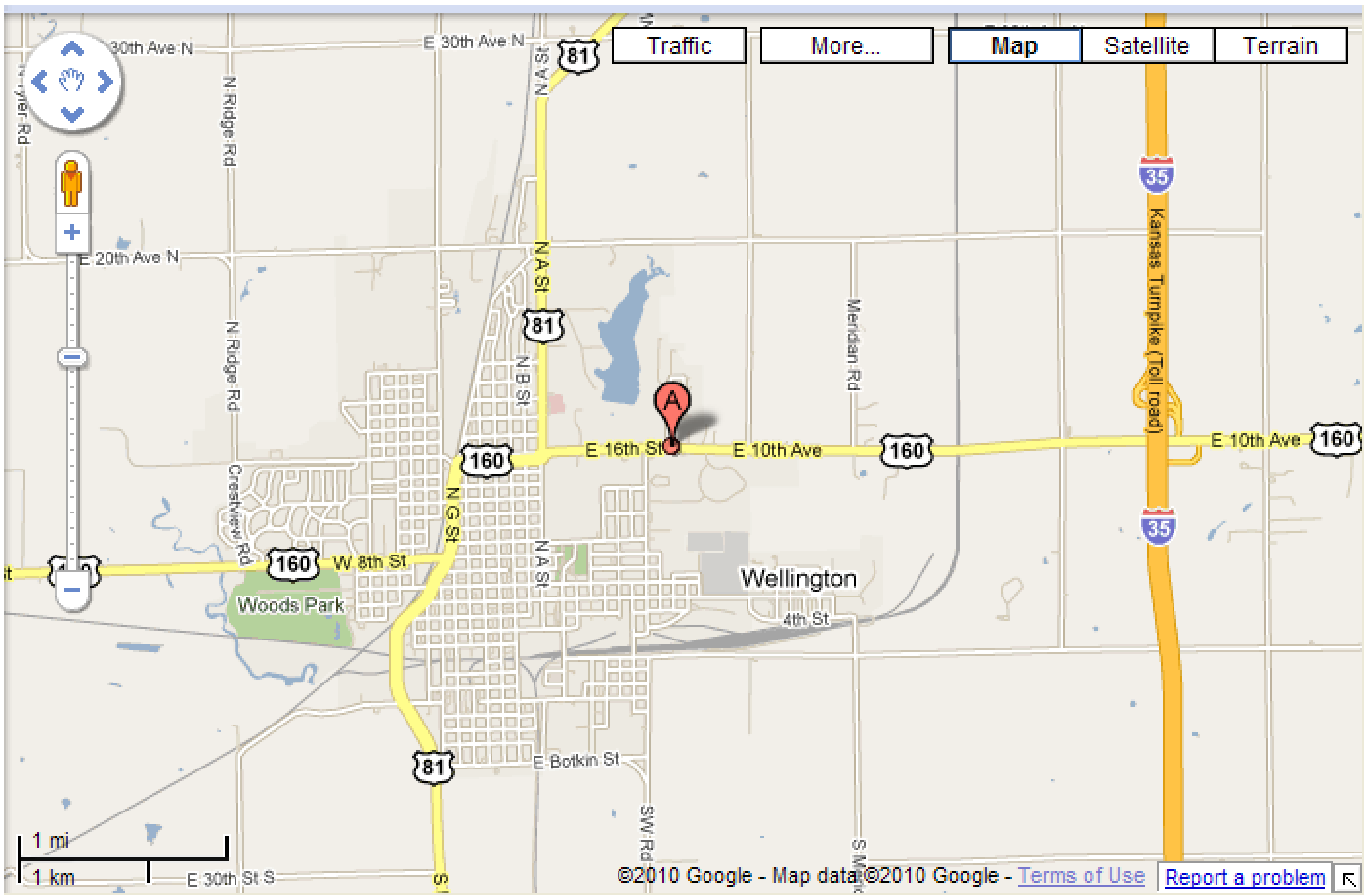
Initial meeting location in Wellington:

Steakhouse Motel and Restaurant

parking lot

1311 E 16th St, Wellington, KS 67152

(620) 326-2266

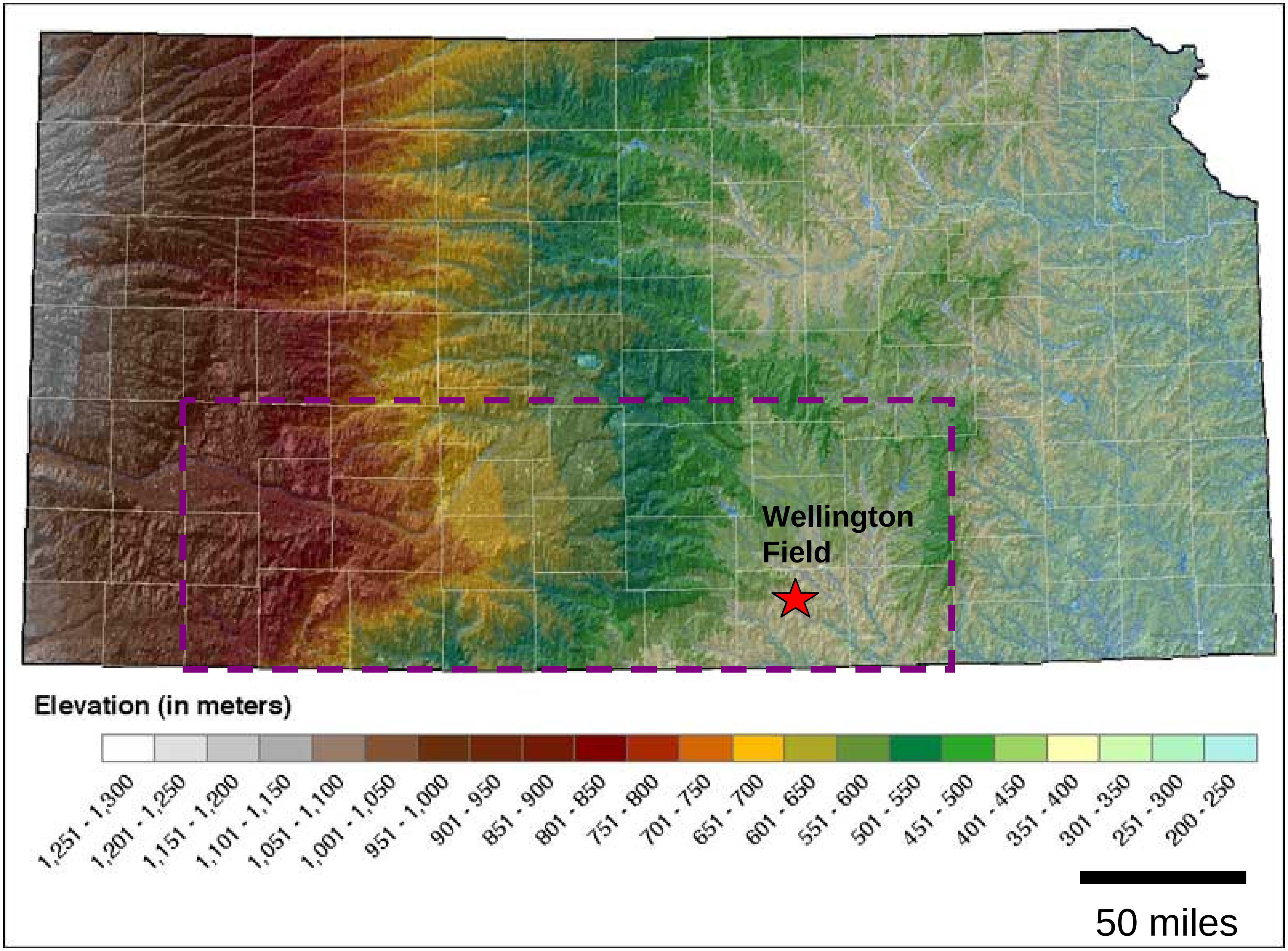


Steakhouse
lat 37.2752   long -97.3823

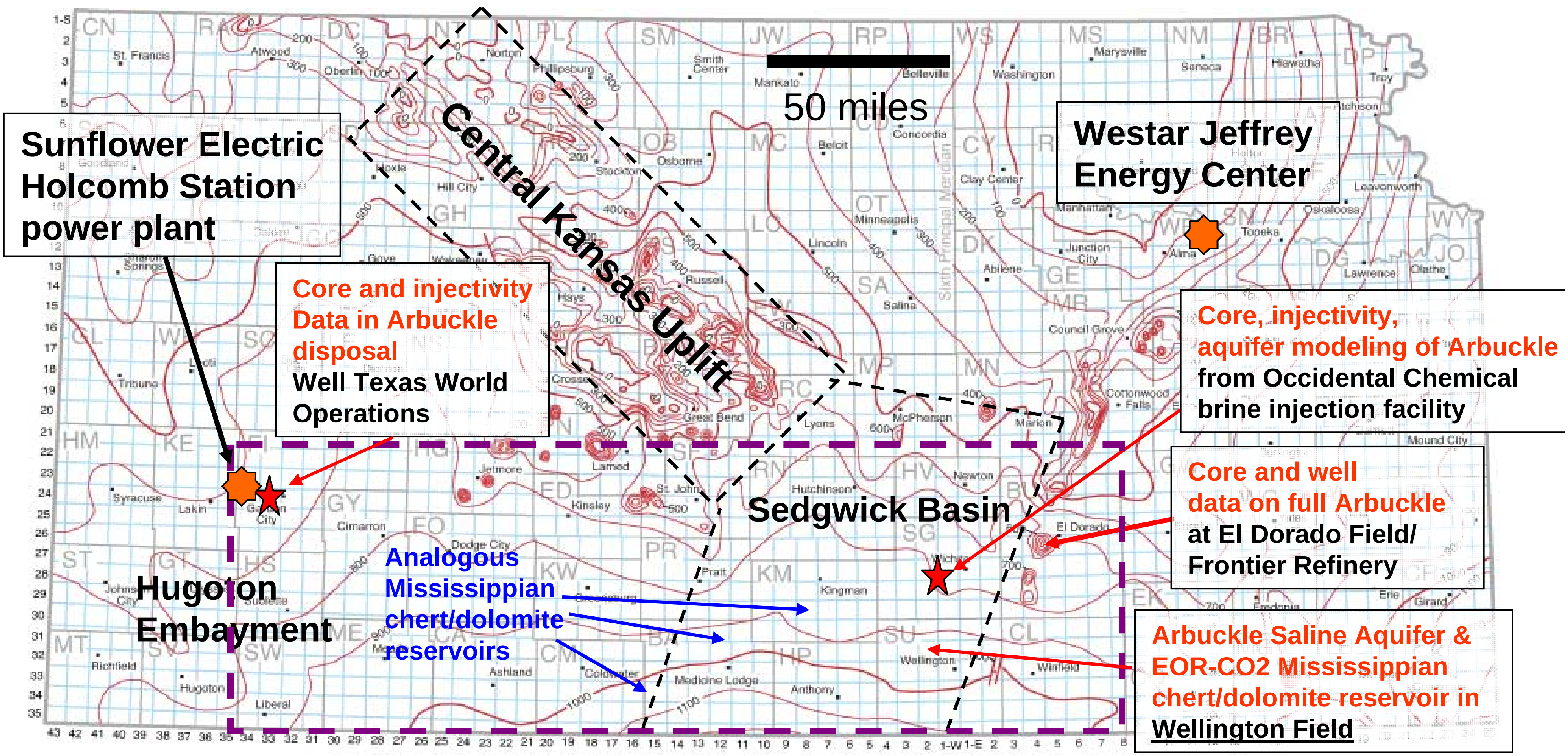
Itinerary

- 1. Drive from Lawrence or Manhattan to meet Paragon Geophysical and BEREXCO, LLC. team at the Steakhouse parking lot in Wellington, KS at 10:30 a.m. (Attendees should have boots and Paragon will provide hard hats and vests).
- 2. Proceed to observe seismic acquisition in Wellington Field located on northwest edge of the town site (led by Jeff Logan, Paragon).
- 3. Return to Steakhouse Restaurant for lunch hosted by Paragon Geophysical Services, Inc.
- 4. Return to Wellington Field to observe production facilities including producing and injection wells and injection plant (led by Dana Wreath, BEREXCO, LLC.).
- 5. Return to Lawrence in mid afternoon.

Kansas Digital Elevation Map showing regional study area (purple outline) and field study (red star in Sumner County)

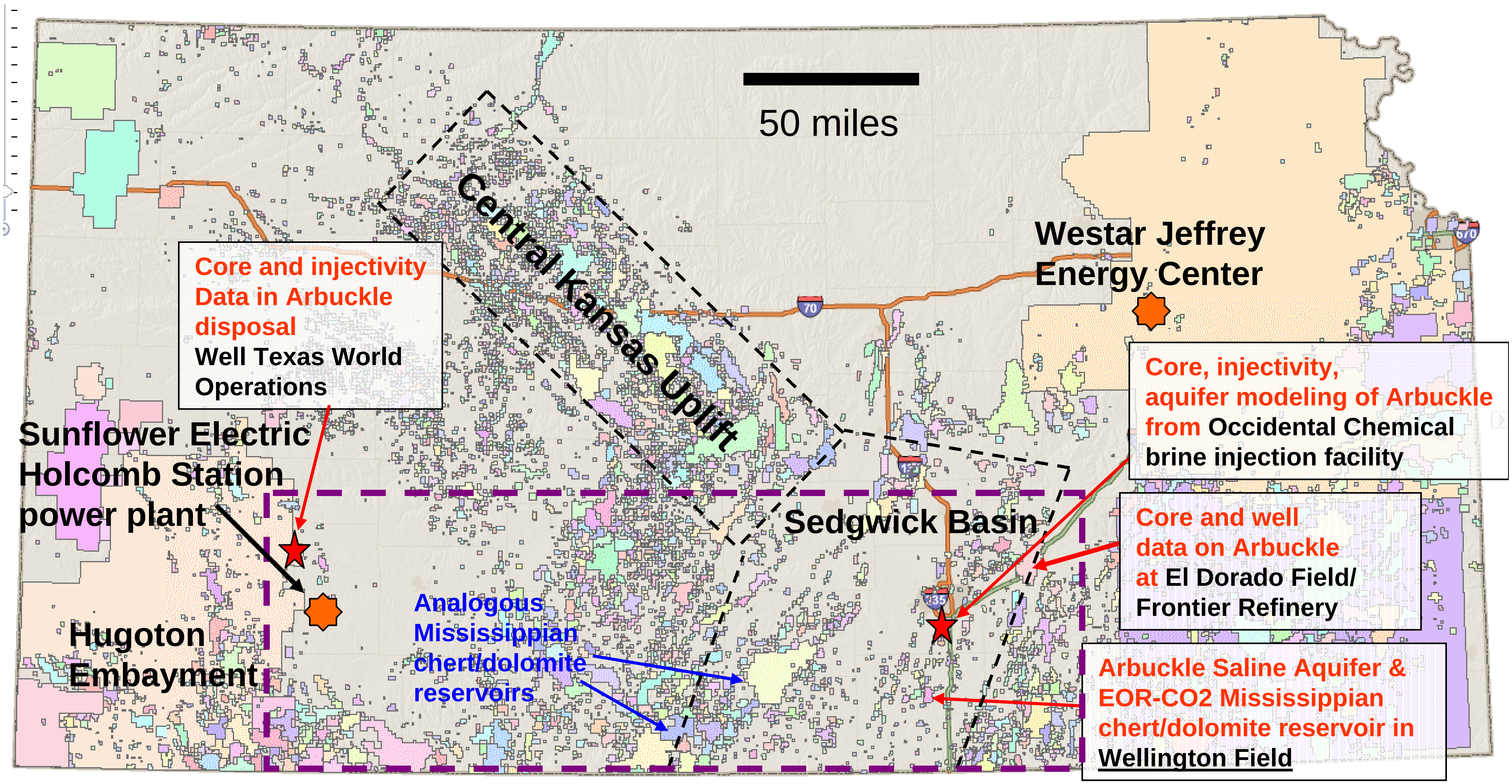


Study area for DOE-CO2 project



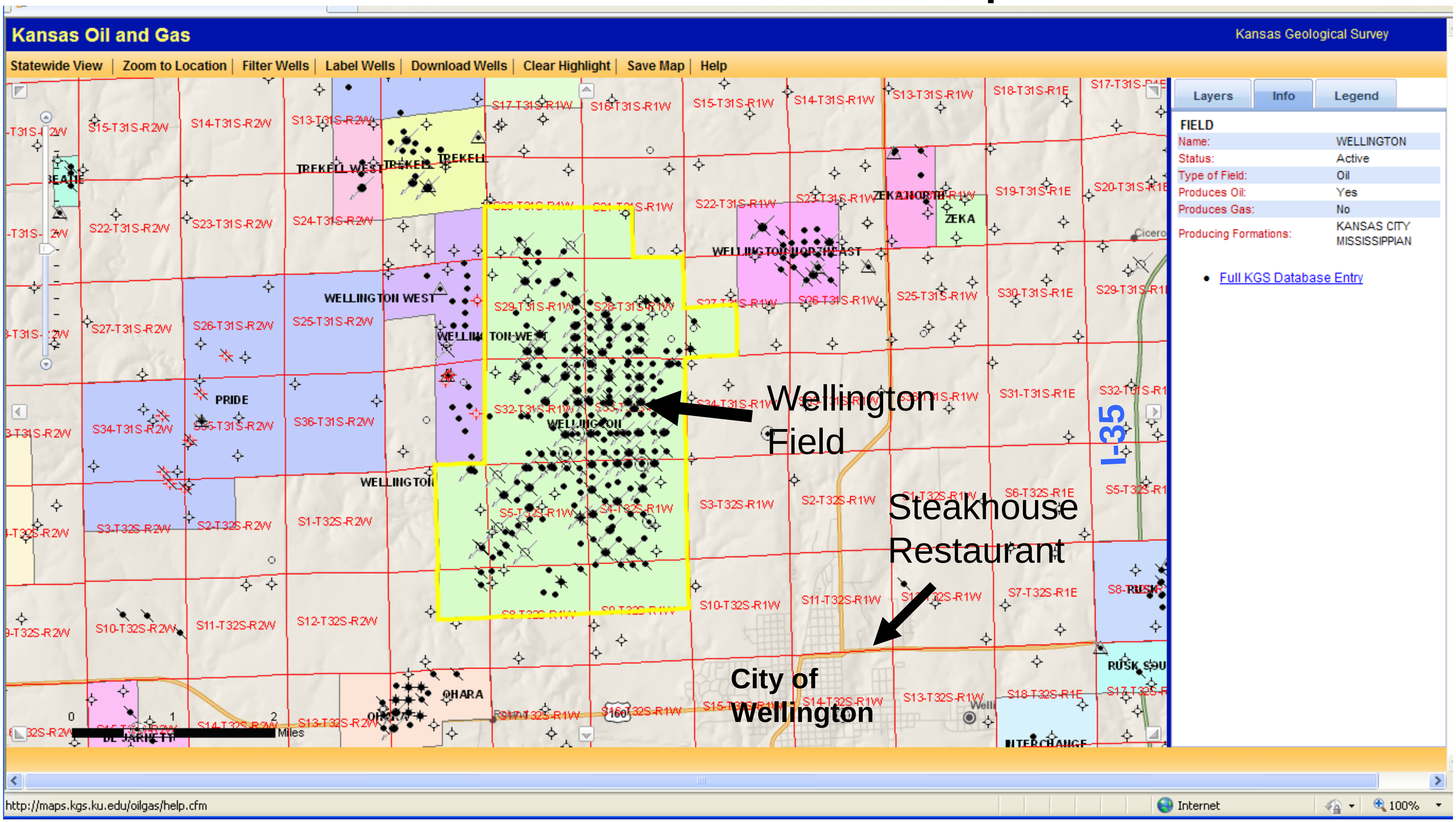
Isopach map of Arbuckle Group strata (base Simpson to Precambrian) from well data up to 1965. Contour interval 100 ft. From Cole (1975) in Franseen et al. (2004). Selected structural features include Hugoton Embayment, Sedgwick Basin and Central Kansas Uplift. Location of Wellington Field and large analogous Mississippian Chat fields are noted. Kansas' two largest coal-fired power plants, Jeffrey Energy Center and Sunflower Electric Holcomb Station are identified.

Oil and Gas Fields and data locations

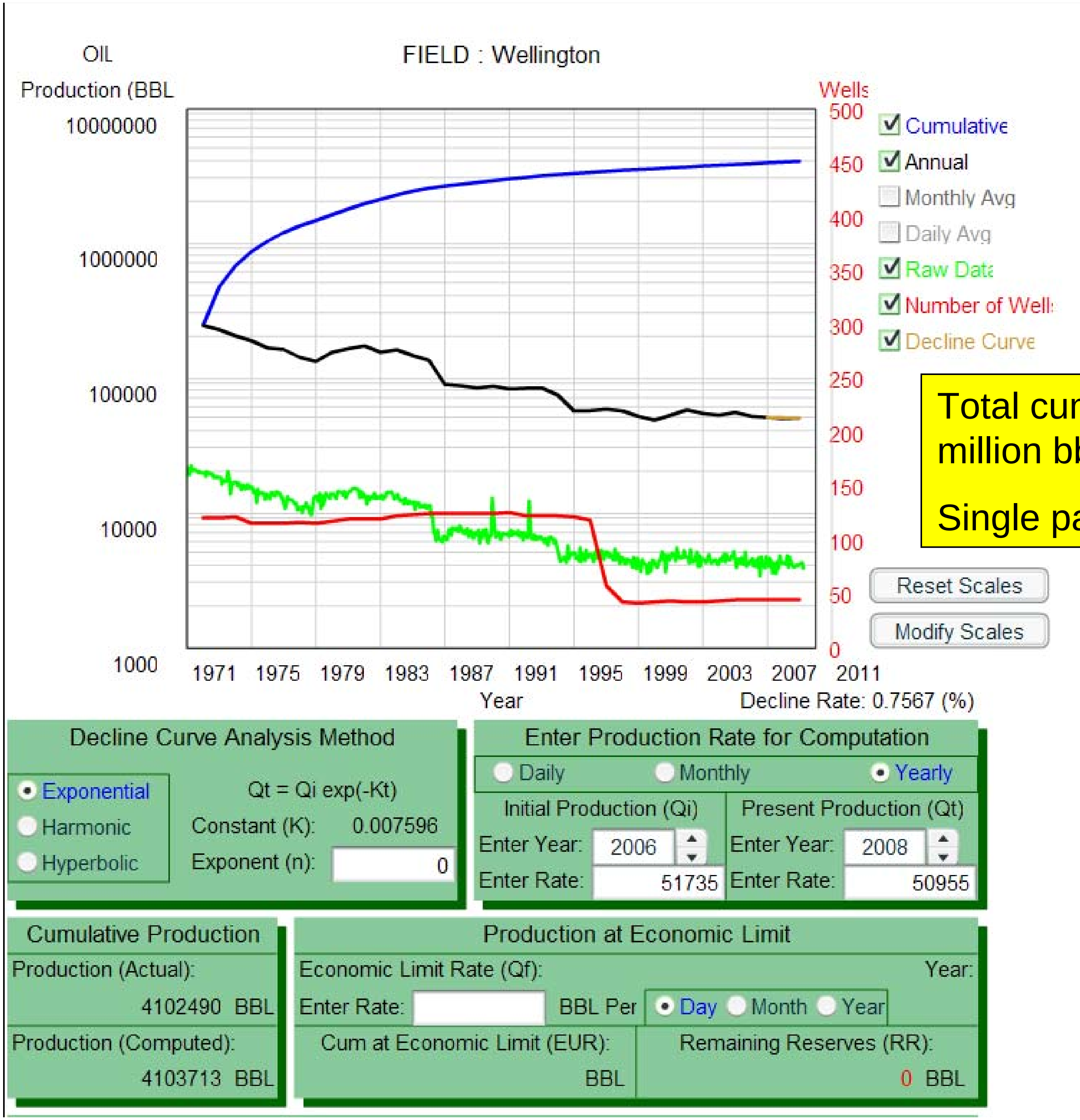


Map of Kansas showing oil and gas fields and outline of study area. Selected structural features include Hugoton Embayment, Sedgwick Basin and Central Kansas Uplift. Location of Wellington Field and large analogous Mississippian Chat fields are noted. Kansas' two largest coal-fired power plants, Jeffrey Energy Center and Sunflower Electric Holcomb Station are identified.

Wellington Field on the Interactive Oil and Gas Map Viewer

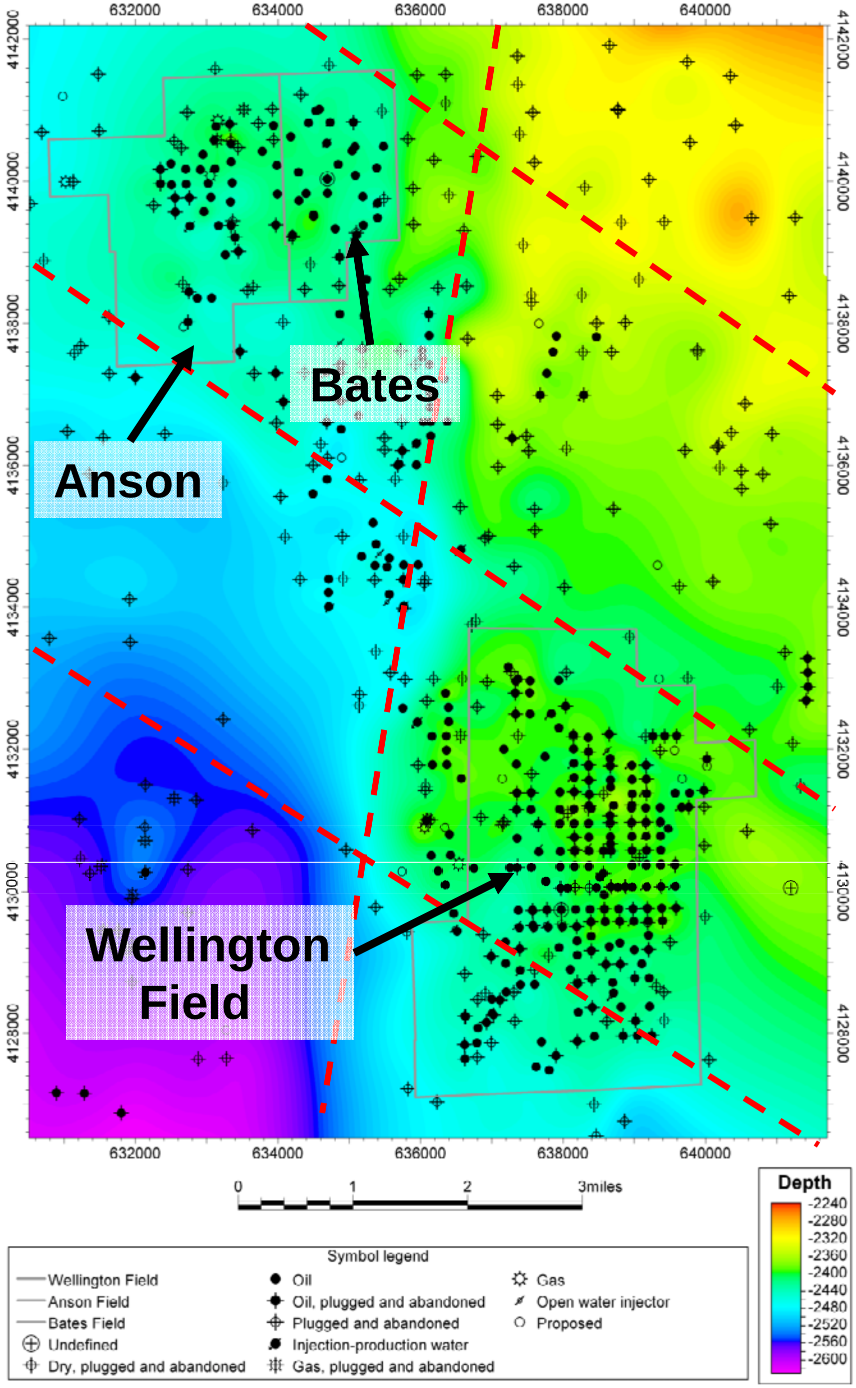


http://maps.kgs.ku.edu/oilgas/index.cfm



Total cumulative is 20.5 million bbls. – BEREXCO

Single pay – Miss. “Chat”



Structure map on top of the Mississippian in Wellington and Anson-Bates Field area. Fields are part of a subcrop play with the Mississippian cherty, dolomitic reservoir preserved in what appears to be structural blocks bounded by NE- and NW-trending lineaments. Warmer colors represent higher elevation. Lineaments added manually (red dashed line).

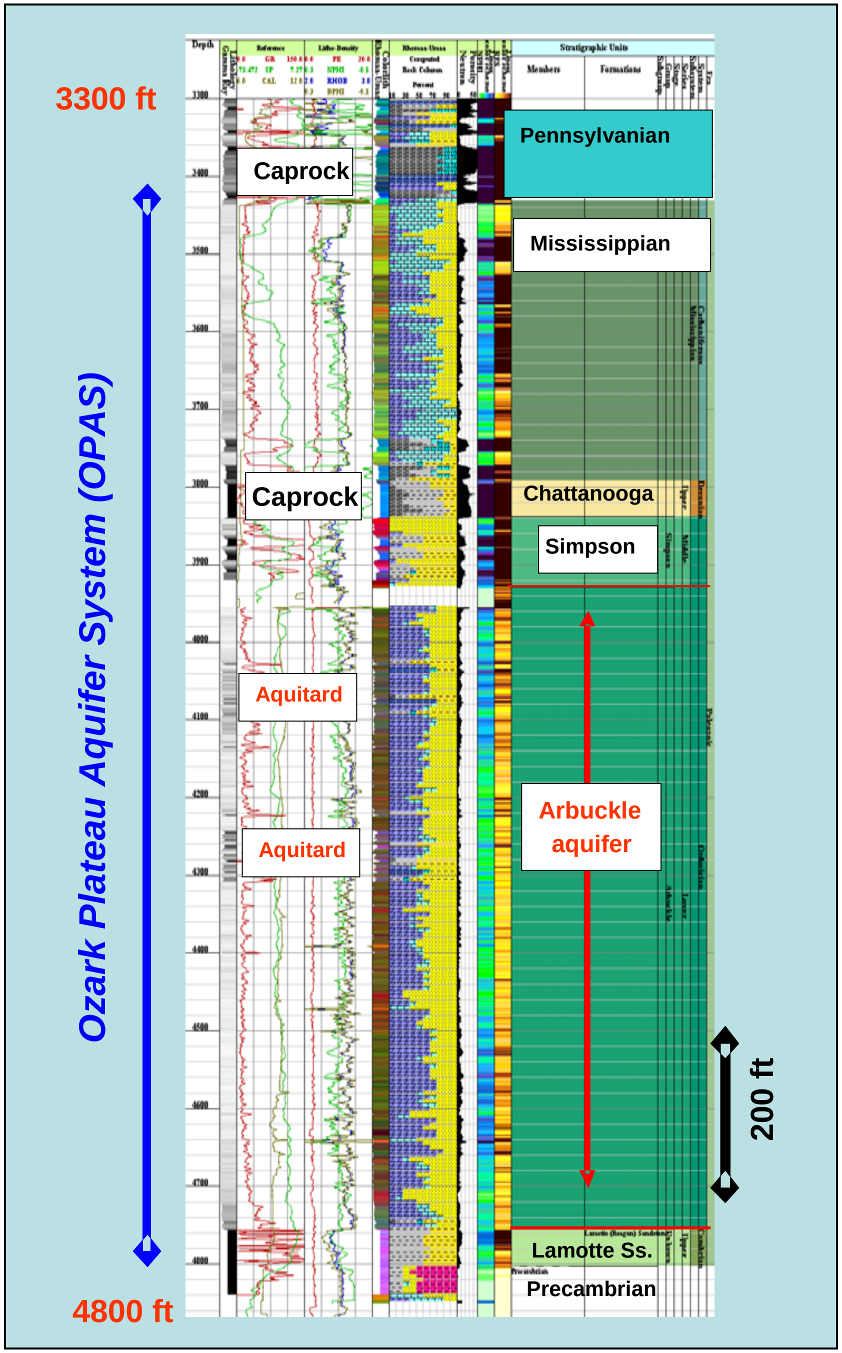
Source: Jason Rush

CO_2-EOR in Mississippian carbonate reservoir & CO_2 sequestration in deep saline Arbuckle aquifer

- **Local industry cooperation & competitive bidding**
- **Improve current estimates of CO_2 storage & sequestration in Kansas**

<u>Oil and Gas Industry Partner</u> –

BEREXCO – largest oil producer in Kansas (~1000 wells)

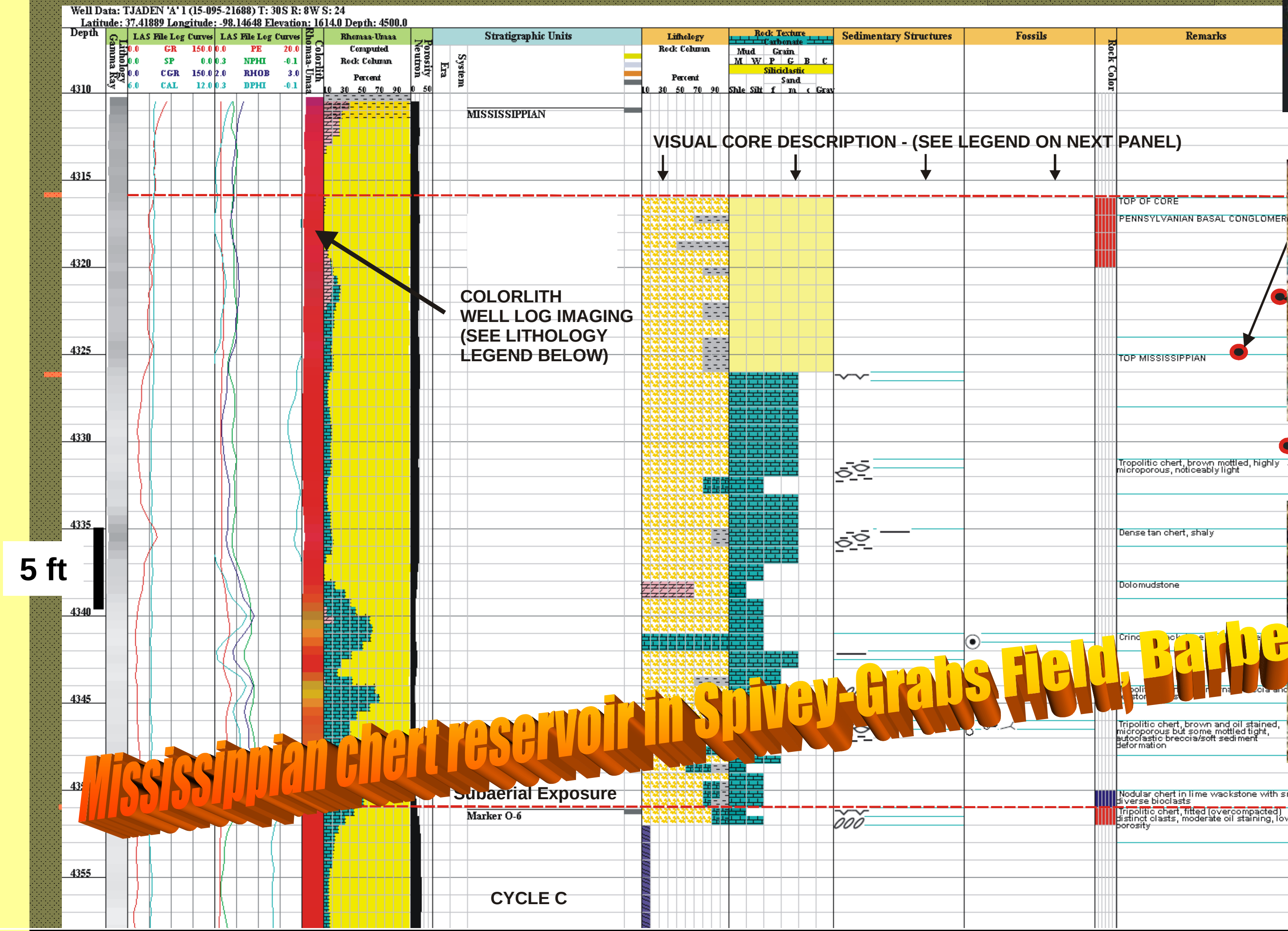


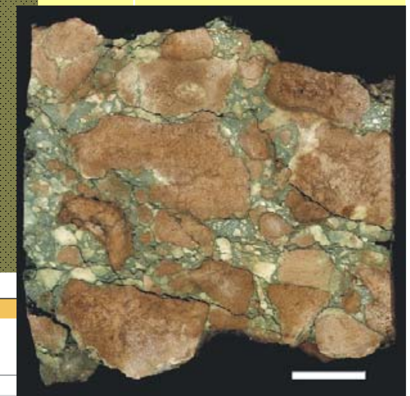
Injector well located 27 miles from Wellington Field

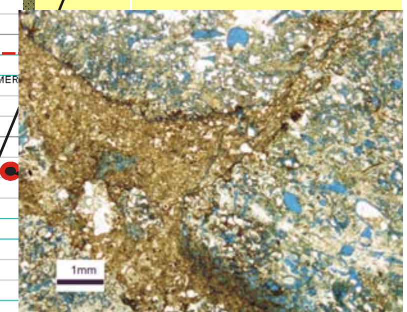
Log-Core Description -
General Atlantic Tjaden A-1
T30S-R8W-Section 24
Barber County, Kansas

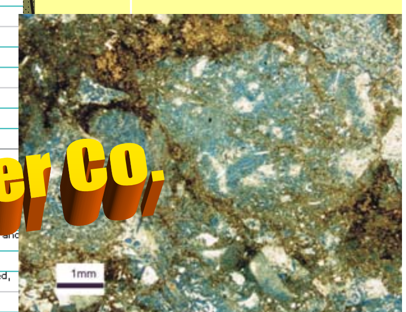
GR = gamma ray, SP = spontaneous potential
CAL = caliper, PE = photoelectric curve
NPHI = neutron porosity, RHOB = bulk density
DPHI = density porosity

API: 15-095-21688
Spud Date: Jan-18-1994
Completion Date: Feb-26-1994
Plugging Date:
Well Type: INJ
Status: Well Drilled
Total Depth: 4500





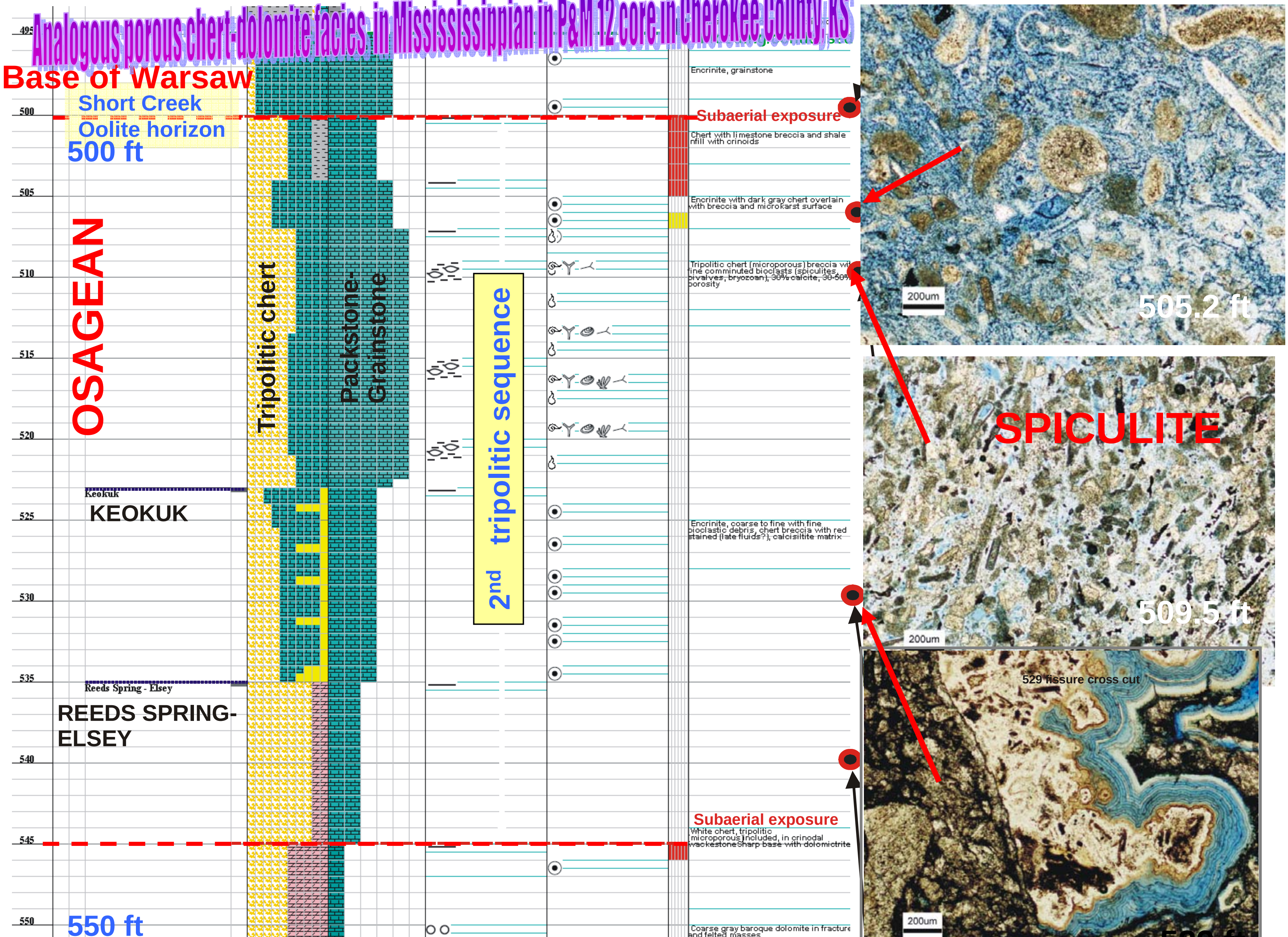




Mississippian chert reservoir in Spivey-Grabs Field, Barber Co.

Watney et al. (2001)

Analogous porous chert-dolomite facies in Mississippian in P&M 12 core in Cherokee County, KS



Watney et al. (2009)

Interbedded porous and tight zones in the Arbuckle saline aquifer

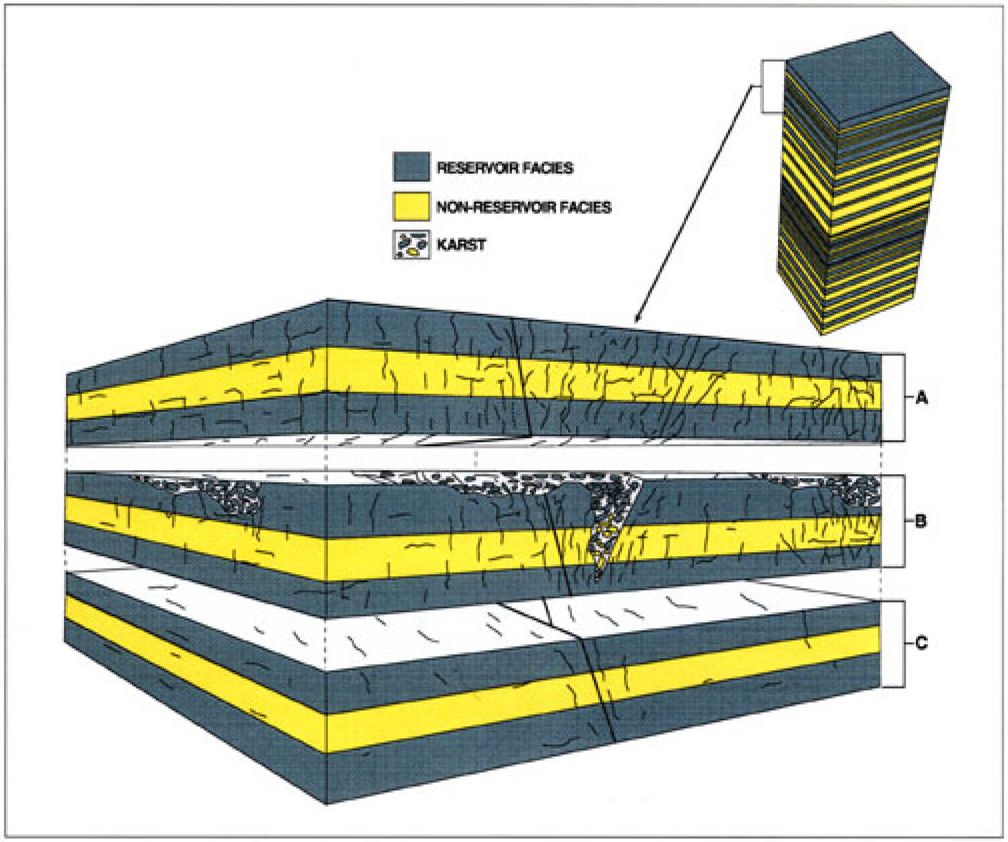
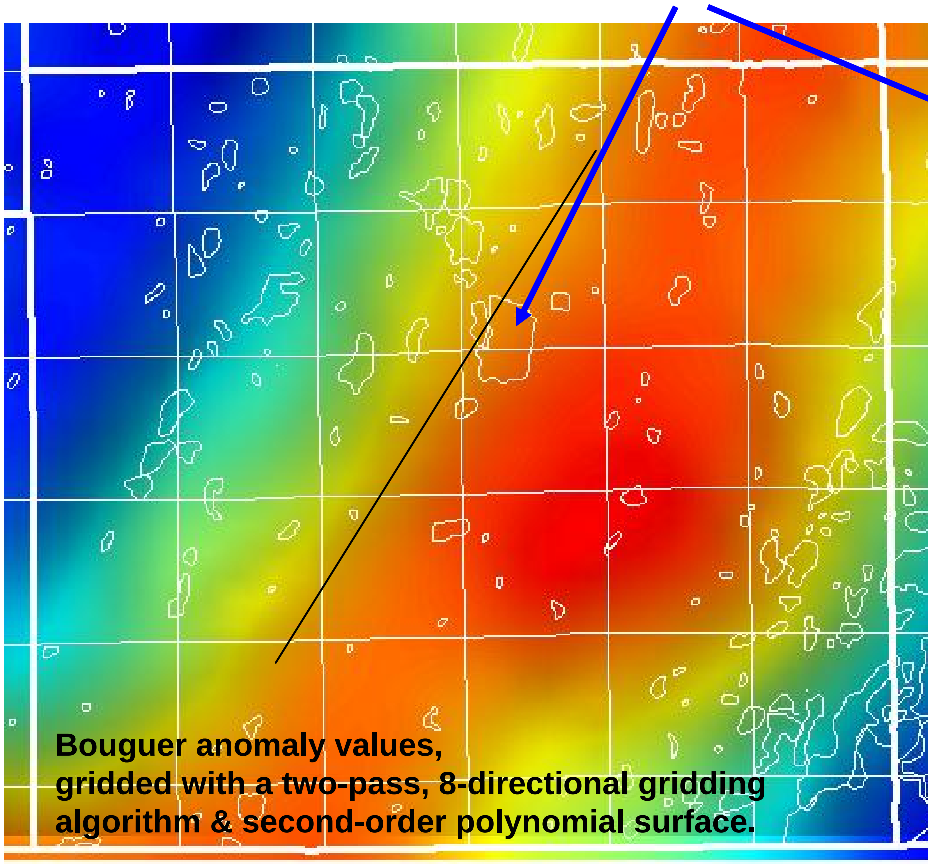


Figure 31--End-member Arbuckle reservoir types. **A)** Abundant fracturing of strata. Lithofacies control porosity and permeability within individual layers (beds), but fractures dominate overall permeability. **B)** Karst overprinting on lithofacies and fractures, resulting in complex porosity and permeability. Karst overprinting can vary laterally from insignificant to extensive. Even where extensively developed, karst processes can both enhance and destroy reservoir properties. **C)** Lithofacies control porosity and permeability, and laterally persistent stratal packages may exert significant control on flow properties.

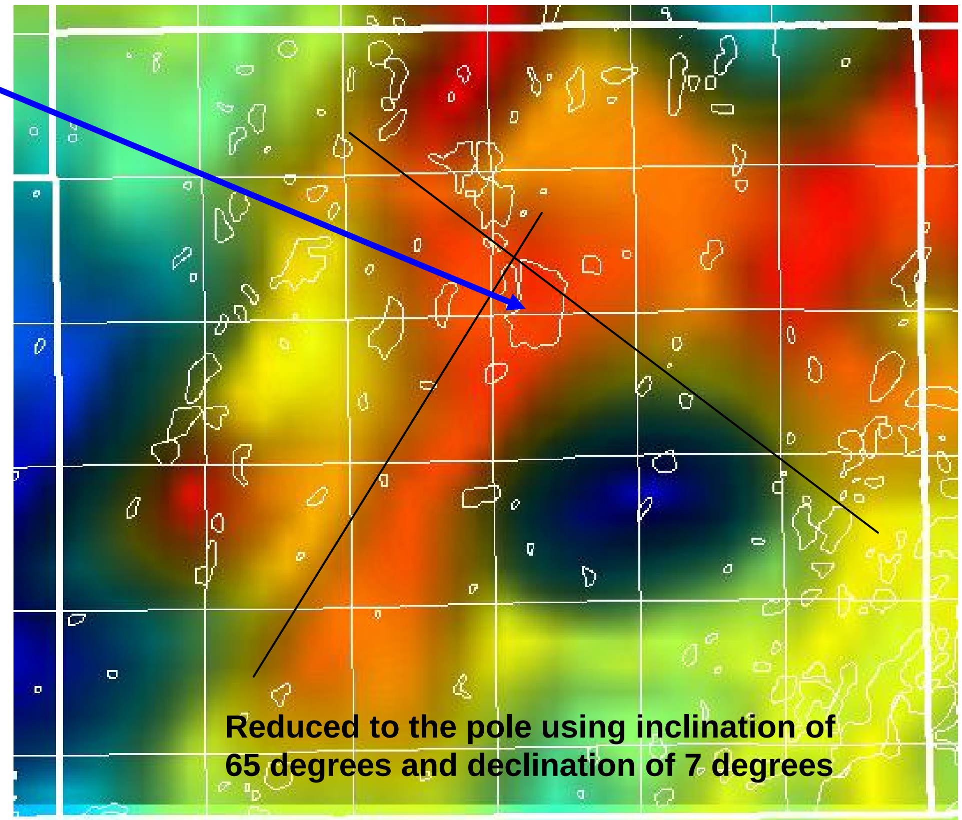
Franseen et al. (2004)

Potential Fields in Wellington Field Area

Wellington Field



Sumner County Kansas
Gravity with oil and gas fields



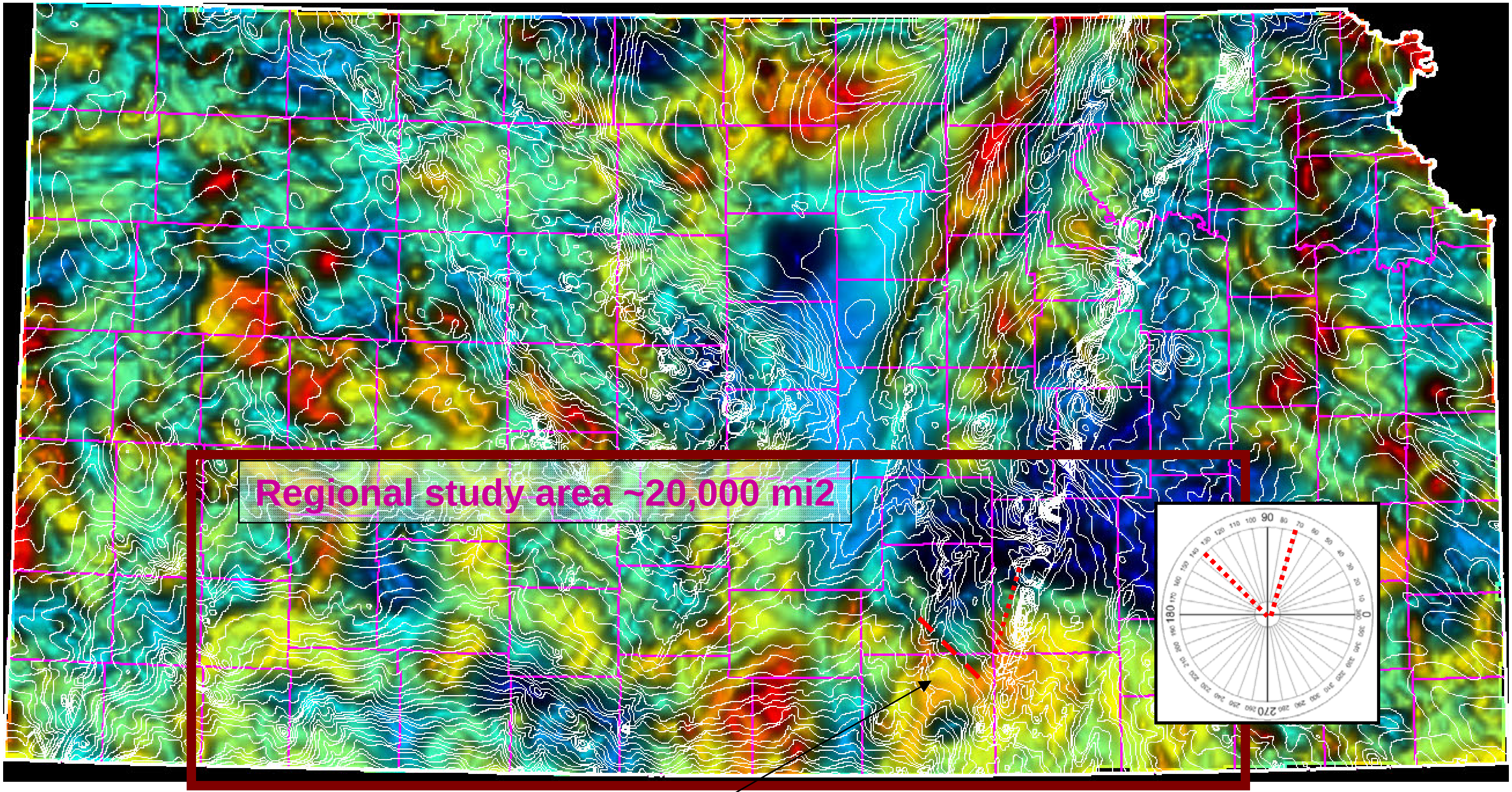
6 mi.

Sumner County Kansas
Magnetics with oil and gas fields

http://www.kgs.ku.edu/PRS/PotenFld/County/rs/sumnerMagOg.html

http://www.kgs.ku.edu/PRS/PotenFld/County/rs/sumnerGravOg.html

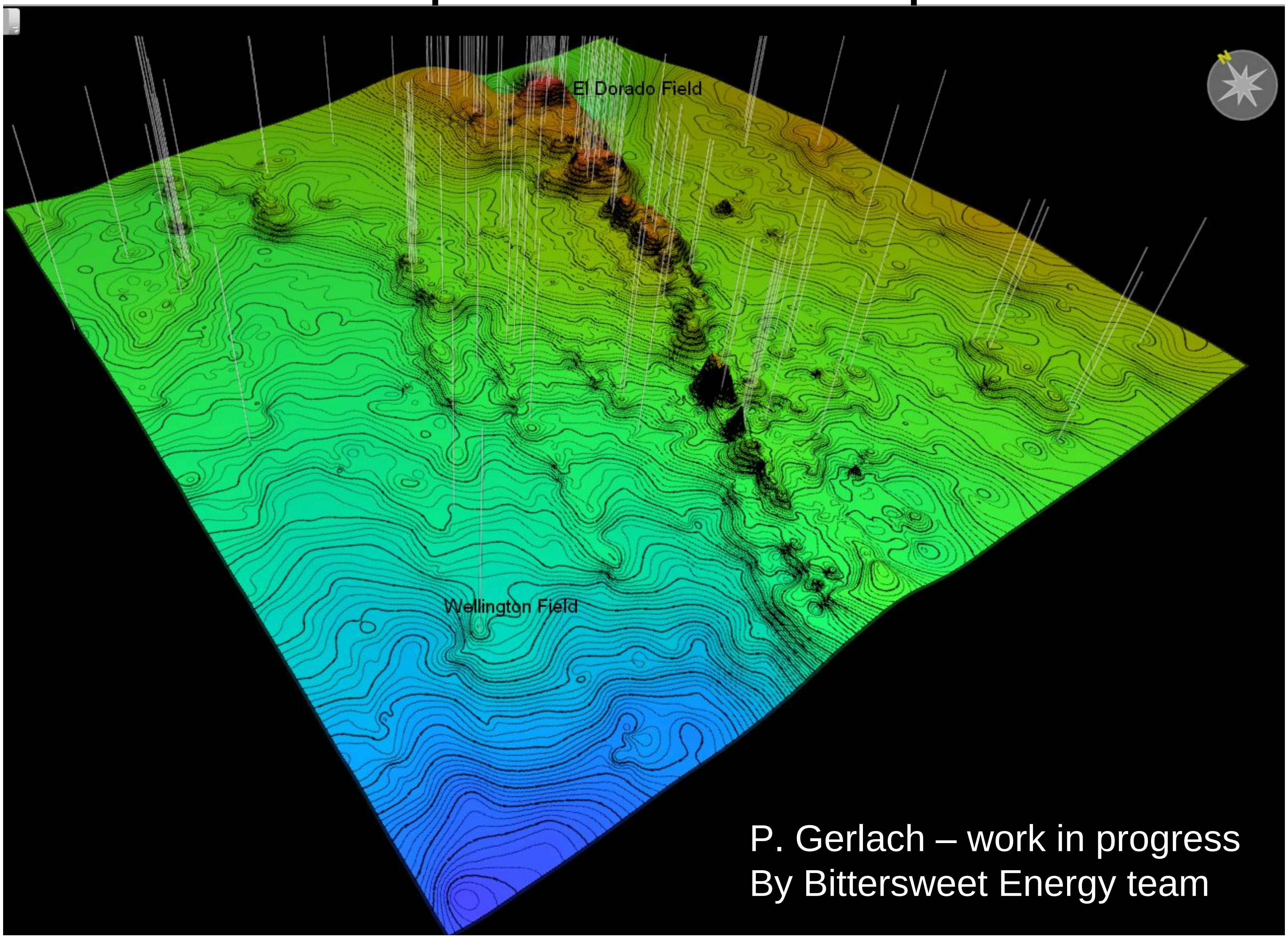
Magnetic – reduced to pole, overlain with *configuration of Precambrian surface* (Cole, 1976; Kruger, 1999)

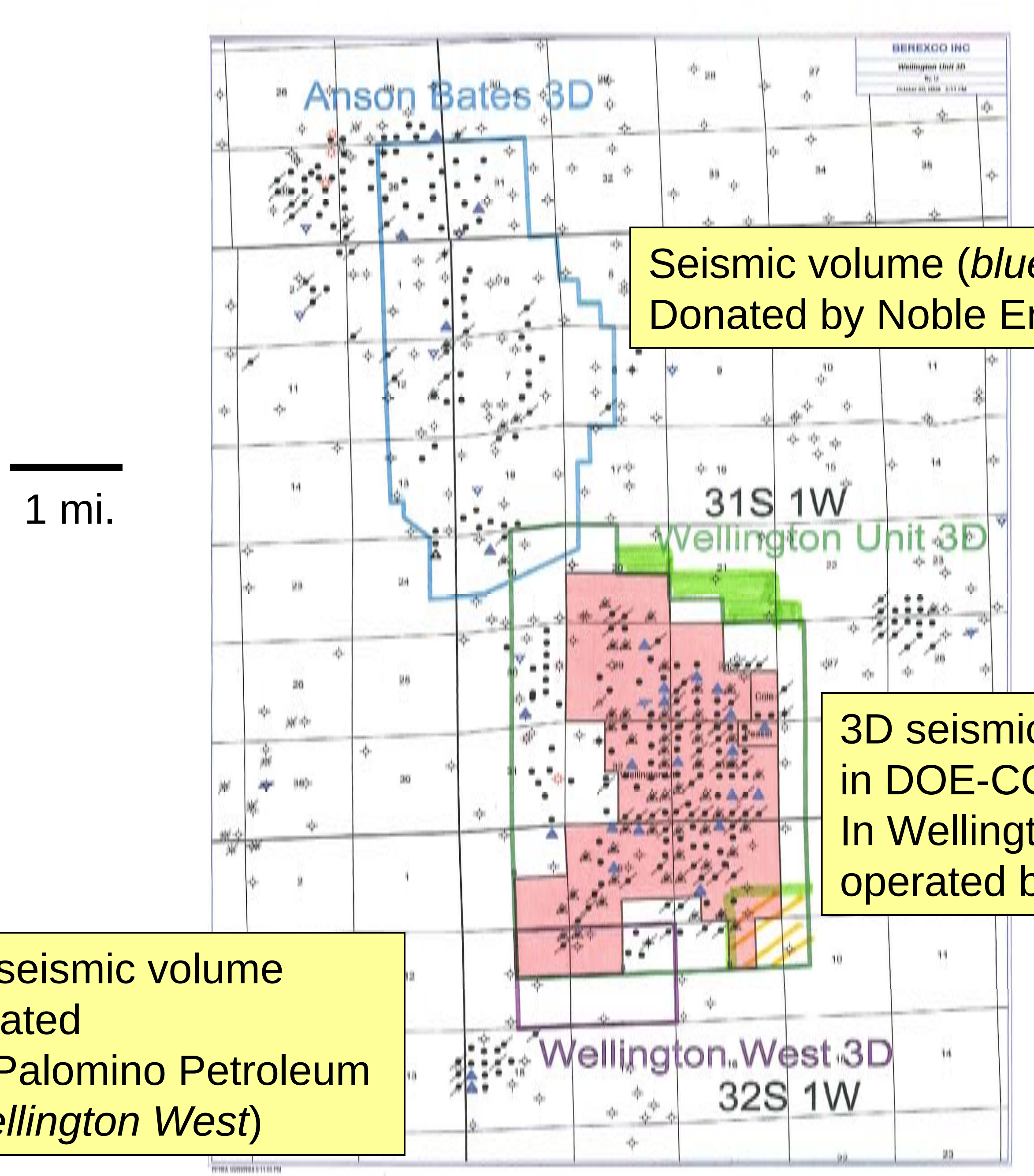


Wellington Field
~18 mi west of the Nemaha Uplift

Nemaha Uplift in vicinity of Wellington Field -- ~N19°E
Secondary lineaments -- N46°W

East side of regional study area
Top Arbuckle Group



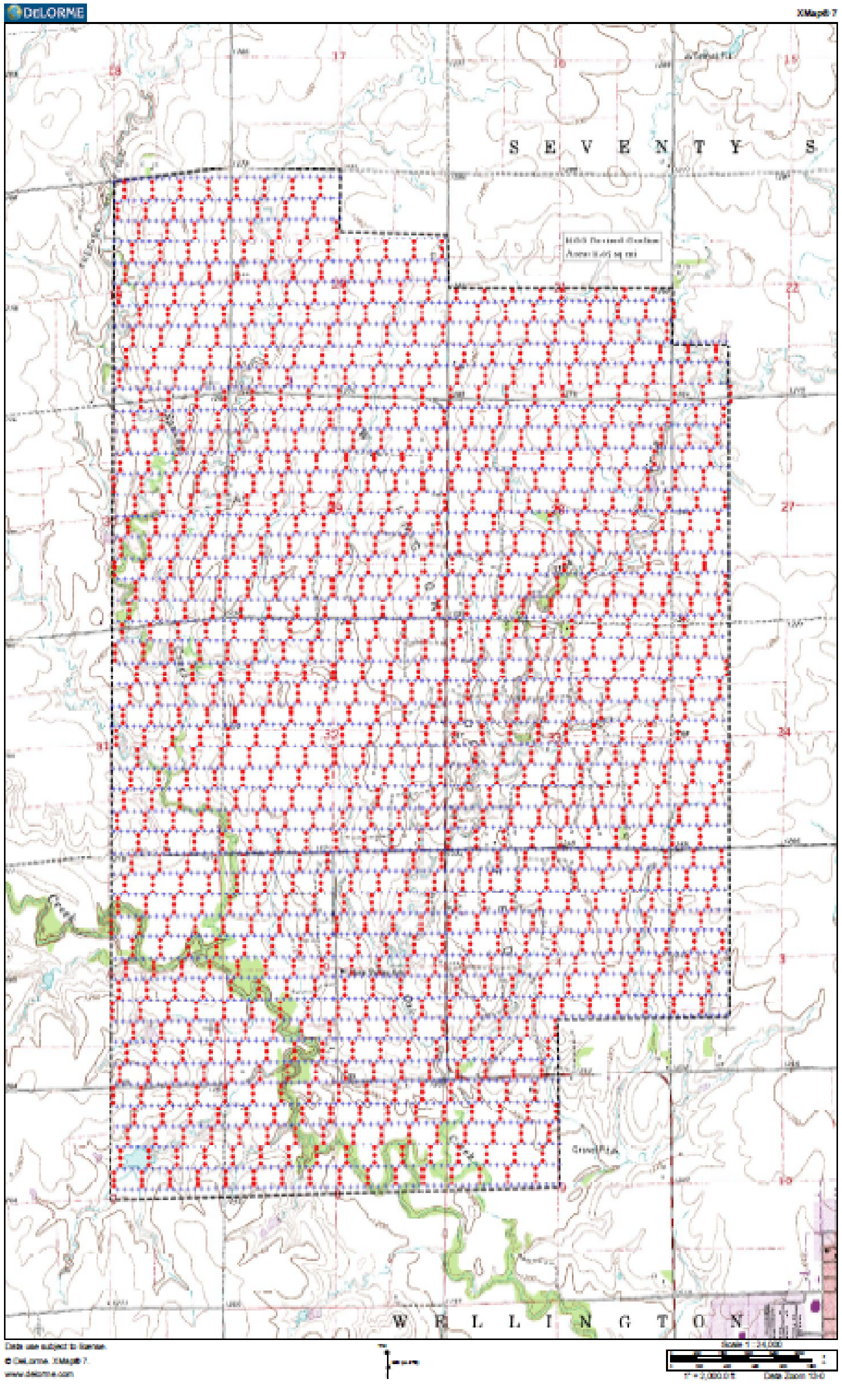


Seismic volume (*blue outline*)
Donated by Noble Energy Corporation

3D seismic volume being acquired in DOE-CO2 study (*green outline)*
In Wellington Field
operated by BEREXCO

3D seismic volume donated
By Palomino Petroleum
(*Wellington West*)

Revised 3D Preplot (1/29/10)



1 mi.

Seismic Acquisition Parameters

Recording System	**ION Scorpion**
Number of active channels	1152
Number of active lines	18
Number of active channels per line (max)	64
Receiver interval	165'
Receiver line interval	495'
Geophone type	Single 3C Digital Phone
Energy source	2 - 62,000 lbsVibrators
Sweeps Parameters	4 Sweeps, 12 Seconds
Source Interval	165'
Source line interval	660'
Record length	5 seconds
Sample rate	**2 milliseconds**
Shooting technique	Roll Line by Line
Recording tape format	SEG D
Subsurface bin spacing	82.5' x 82.5'
Approximate total lines	49
Approximate total receiver groups	3831
Approximate total source points	2811
Surveying and Field Layout total Stations	6642

PARAGON
GEOPHYSICAL SERVICES, INC

Prior sweep test now being updated 3/5/10

Sweep Tests			Wellington 3D					
			February 18, 2010					
Number of Vibs Vary			**Revision 1**					
Listen time 2 sec								
Start Taper = varies			**3D3C P-Wave**					
End Taper .300 sec								
Number of Vibs	**File #**	**Test #**		**Sweep Frequencies**	**Sweep Length**	**# of Sweeps**	**Low end Taper Length**	**High end Taper Length**
Low end Frequency tests & sweep length								
2 vib	**?**	1	(+3db/oct)	**Sweep 10-130**	10 Seconds	8	**0.3 Seconds**	0.3 Seconds
2 vib	**?**	2	(+3db/oct)	**Sweep 10-130**	**20** Seconds	4	**0.3 Seconds**	0.3 Seconds
2 vib	**?**	3	(+3db/oct)	**Sweep 10-130**	**20** Seconds	4	**0.6 Seconds**	0.3 Seconds
2 vib	**?**	4	(+3db/oct)	**Sweep 10-130**	**20** Seconds	4	**1.2 Seconds**	0.3 Seconds
2 vib	**?**	5	(+3db/oct)	**Sweep 10-130**	**40** Seconds	2	**0.3 Seconds**	0.3 Seconds
2 vib	**?**	6	(+3db/oct)	**Sweep 10-130**	**40** Seconds	2	**0.6 Seconds**	0.3 Seconds
2 vib	**?**	7	(+3db/oct)	**Sweep 10-130**	**40** Seconds	2	**1.2 Seconds**	0.3 Seconds
2 vib	**?**	8	(+3db/oct)	**Sweep 10-130**	**40** Seconds	2	**2.4 Seconds**	0.3 Seconds
High Frequency tests								
2 vib	**?**	9	(+3db/oct)	**Sweep 10-110**	**40** Seconds	2	**0.3 Seconds**	0.3 Seconds
2 vib	**?**	10	(+3db/oct)	**Sweep 10-120**	**40** Seconds	2	**0.3 Seconds**	0.3 Seconds
2 vib	**?**	11	(+3db/oct)	**Sweep 10-140**	**40** Seconds	2	**0.3 Seconds**	0.3 Seconds
2 vib	**?**	12	(+3db/oct)	**Sweep 10-150**	**40** Seconds	2	**0.3 Seconds**	0.3 Seconds
2 vib	**?**	13	(+3db/oct)	**Sweep 10-160**	**40** Seconds	2	**0.3 Seconds**	0.3 Seconds
Test number of vibs								
1 vib	**?**	14	(+3db/oct)	**Sweep 10-130**	**40** Seconds	2	**0.3 Seconds**	0.3 Seconds
3 vib	**?**	15	(+3db/oct)	**Sweep 10-130**	**40** Seconds	2	**0.3 Seconds**	0.3 Seconds
4 vib	**?**	16	(+3db/oct)	**Sweep 10-130**	**40** Seconds	2	**0.3 Seconds**	0.3 Seconds
Test db/octs								
2 vib	**?**	17	**(+1db/oct)**	**Sweep 10-120**	**40** Seconds	2	**0.3 Seconds**	0.3 Seconds
2 vib	**?**	18	**(+1db/oct)**	**Sweep 10-130**	**40** Seconds	2	**0.3 Seconds**	0.3 Seconds
2 vib	**?**	19	**(+1db/oct)**	**Sweep 10-140**	**40** Seconds	2	**0.3 Seconds**	0.3 Seconds
2 vib	**?**	20	**(+5db/oct)**	**Sweep 10-120**	**40** Seconds	2	**0.3 Seconds**	0.3 Seconds
2 vib	**?**	21	**(+5db/oct)**	**Sweep 10-130**	**40** Seconds	2	**0.3 Seconds**	0.3 Seconds
2 vib	**?**	22	**(+5db/oct)**	**Sweep 10-140**	**40** Seconds	2	**0.3 Seconds**	0.3 Seconds
Additional Low Frequency Test								
2 vib	**?**	23	**Linear**	**Sweep 10-130**	**40** Seconds	2	**0.3 Seconds**	0.3 Seconds
2 vib	**?**	24	**(+3db/oct)**	**Sweep 6-130**	**40** Seconds	2	**0.3 Seconds**	0.3 Seconds
2 vib	**?**	25	**Linear**	**Sweep 6-130**	**40** Seconds	2	**0.3 Seconds**	0.3 Seconds

3D DATA PROCESSING SEQUENCE (P-Wave)

1. Reformat and resample to 2 milliseconds
2. QC plot all records for trace edits
3. Merge survey data with seismic data
4. Spherical divergence and inelastic attenuation compensation
5. Refraction static analysis and application, as required
6. Relative amplitude preservation
7. Initial parameter analysis (trace, shot and surface consistent deconvolution tests plus bandwidth analysis)
8. Deconvolution (as determined from tests)
9. Spectral balance (frequency compensation, if required)
10. 3D CDP bin assignment and sort (plot source/receiver XY locations)
11. 3D velocity analysis (one mile grid)
12. QC brute stack entire data volume
13. QC time slices of brute stack data volume
14. Surface consistent 3D residual statics

fairfieldnodal

<u>3D DATA PROCESSING SEQUENCE</u> (P-Wave) *(continued)*

15. QC stack control lines with residual statics applied
16. Intermediate parameter analysis (Post NMO-mute, pre-stack scaling and bandwidth)
17. Prestack Noise Attenuation (if needed)
18. Second pass of 3D velocity analysis (half mile grid)
19. Stack all lines for QC over static analysis window
20. Second pass of 3D surface consistent residual statics
21. QC stack selected lines
22. Velocity analysis (half mile grid)
23. Final 3D bin stack
24. 3D noise suppression, if required
25. Paper QC plots of stack volume
26. Paper QC time slices
27. Final parameter analysis (filtering, scaling, spectral balance)
28. 3D migration velocity analysis
29. 3D migration
30. 3D noise suppression (FX Decon), if required
31. Filtering and Balance

P to S-WAVE , CONVERTED, PROCESSING SEQUENCE (C-WAVE)

1. QC brute ACP stack entire data volume
    - Compare with P-wave volume to maintain regional structural integrity
2. QC time slices of brute ACP stack data volume
3. First Pass velocities (2 mile grid)
4. Surface consistent 3D residual statics
5. QC ACP stack control lines with residual statics applied
6. Intermediate parameter analysis (Post NMO-mute, pre-stack scaling and bandwidth)
7. Pre-stack noise attenuation (TXY Dip Filter or 3D Beam Steer) (if needed)
8. Second pass of 3D velocity analysis (one mile grid)
9. ACP Stack all lines for QC
10. Second pass of 3D surface consistent residual statics
11. ACP stack all lines
    - Create super gathers at velocity locations for azimuth analysis
12. First attempt to register C-wave Radial ACP stack with P-wave stack
13. Third pass of 3D velocity analysis (half mile grid)
14. Third pass of 3D surface consistent residual statics
15. ACP stack all lines
    - Create super gathers at velocity locations for azimuth analysis
16. Second attempt to register C-wave Radial ACP stack with P-wave stack
17. Gamma scans for common conversion point binning
18. CCP Stack
19. 3D migration velocity analysis
20. 3D migration
21. 3D noise suppression (FX Decon), if required
22. Filtering and Balance

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3D PRE-STACK TIME MIGRATION

1. Input decon gathers with all statics applied
2. 3D Kirchhoff prestack time migration of velocity target lines at 1320 feet
3. Velocity analysis (1/2 mile grid)
4. 3D Kirchhoff prestack time migration of full volume processed at 2 milliseconds

   Aperture 7,000 feet (one side)
   Output 50 fold CDP gathers
   Output binning 82.5 x 82.5 feet

5. Velocity analysis (1/2 mile grid)
6. Stack prestack migrated data to produce full offset volume
7. Filtering and balance

fairfieldnodal

3D Seismic Post-Processing and Interpretation

Hedke-Saenger Geoscience, Ltd.,
KGS (*Rick Miller*),
KSU (*Abdelmoneam Raef*),
Geo-Texture Technologies,
Susan E. Nissen, Geophysical Consultant

Seismic post processing

- Impedance inversion, elastic inversion, spectral decomposition, and AVO characterization to estimate reservoir porosity / lithology (impedance and elastic inversion), possible hydrocarbon signature (spectral decomposition), and indirect corroboration of Vp/Vs ratio (AVO).
- Process and interpret the converted wave (C-wave) that is acquired in multi-component acquisition.
- Elastic inversion of the C-Wave data and subsequent independent calculation of Vp/Vs ratio.

HEDKE-SAENGER GEOSCIENCE, LTD

Principal Component Data Conditioning, 3D Volume-Based Curvature Analysis, Workstation-Ready SEG-Y Volume Creation and Preliminary Interpretation of Wellington/Sumner Deep DOE 3D Survey

Susan E. Nissen
Geophysical Consultant

Workstation-Ready SEG-Y Deliverables

Curvature Volumes

Primary Outputs
- EnerComp
- PCA
- K_max_long
- K_neg_long
- K_pos_long

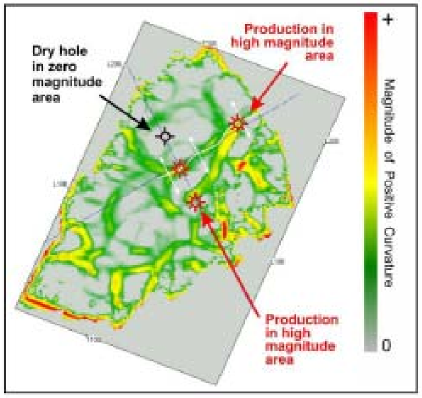
Secondary Outputs
- PCAmv
- Dip_azim
- Dip_mag
- Grad_mag
- K_max_high
- K_gauss_long
- K_min_long
- K_min_azim_long

Curvature - High Resolution
- K_curvedness_high
- K_dip_high
- K_gauss_high
- K_min_azim_high
- K_min_high
- K_neg_high
- K_pos_high
- K_strike_high

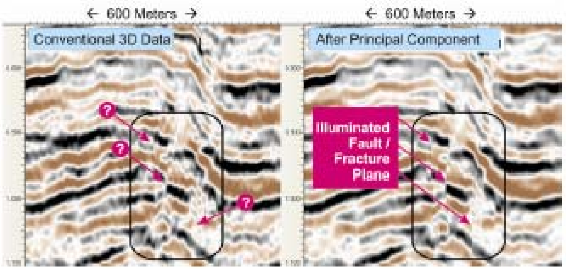
Curvature - Long Wavelength
- K_curvedness_long
- K_dip_long
- K_strike_long

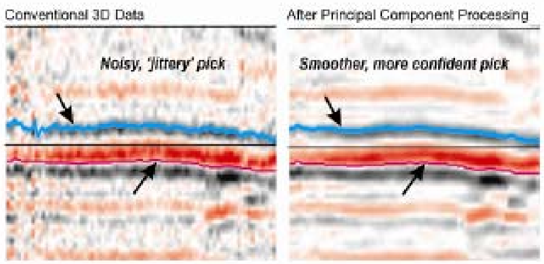
Shapes
- K_bowl_ long
- K_dome_ long
- K_line_ long
- K_ridge_ long
- K_saddle_ long
- K_valley_ long

SMT Project File



Correlation of Curvature with Production





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www.geo-texture.com • mstevenson@geo-texture.com