Modeling CO_2 Sequestration in Saline Aquifer and Depleted Oil Reservoir to Evaluate Regional CO_2 Sequestration Potential of Ozark Plateau Aquifer System, South-Central Kansas

Funding Opportunity Number: DE-FOA-0000033

CFDA Number: 81.089 Fossil Energy Research and Development

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W. Lynn Watney and Saibal Bhattacharya, PIs
Kansas Geological Survey
Lawrence, Kansas 66047
lwatney@kgs.ku.edu

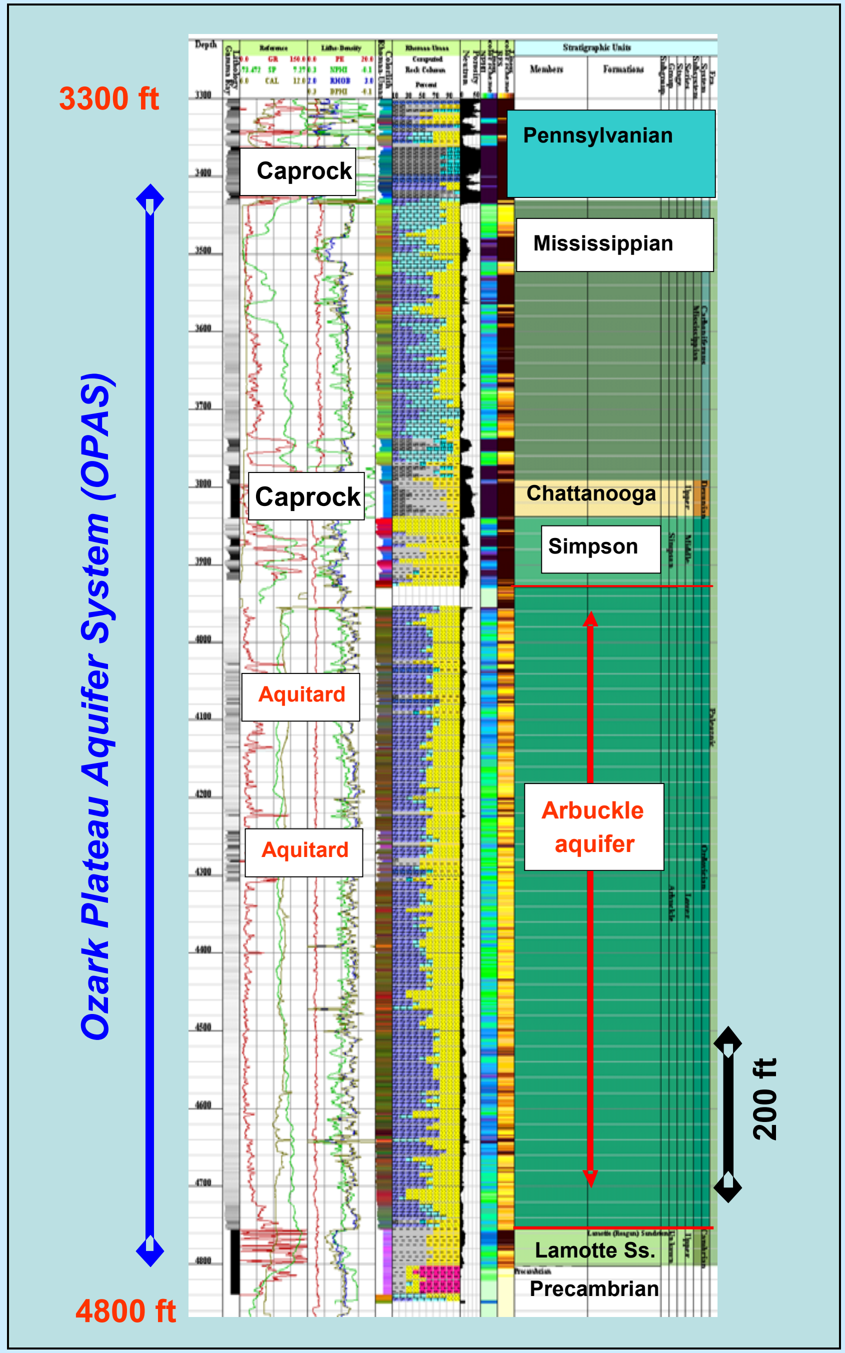
Justin Glier
Project Manager
Carbon Sequestration Division
U.S. Dept. of Energy
National Energy Technology Laboratory

Outline - I

- **Project Description**
- **Local industry cooperation & competitive bidding**
- **How will project results improve current estimates of CO_2 sequestration in OPAS (*Ozark Plateau Aquifer System*)?**
- **Work in progress (time permitting)**

Oil and Gas Industry Partner –

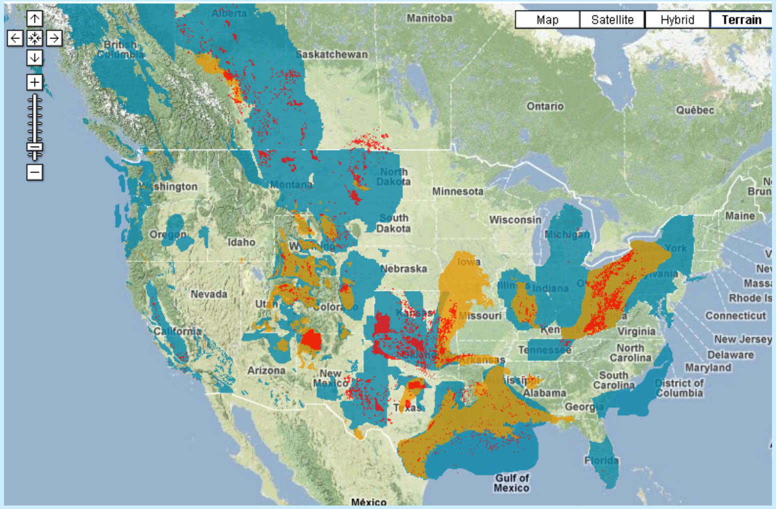
BEREXCO – largest oil producer in Kansas (~1000 wells)



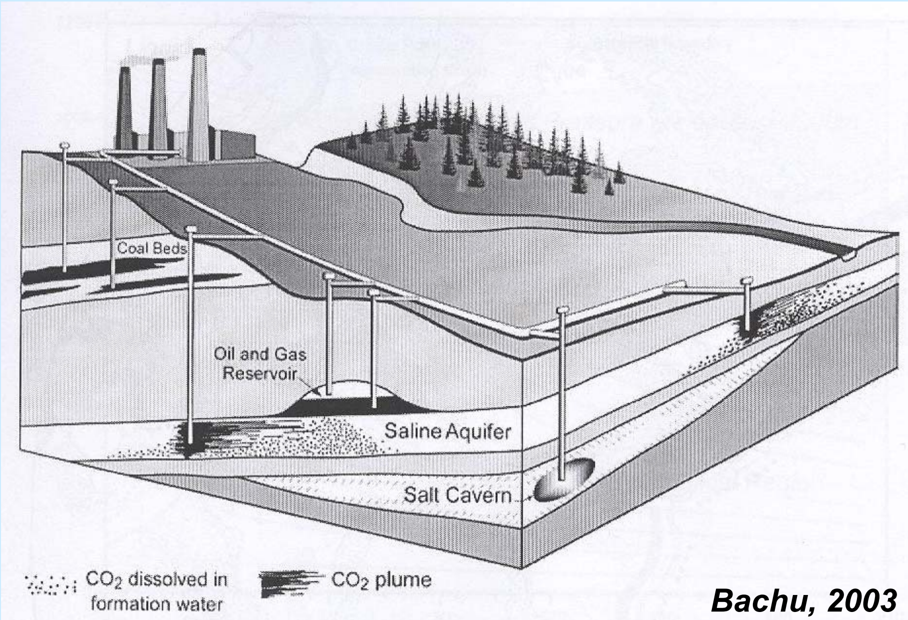
Injector well located 27 miles from Wellington Field

Outline - II

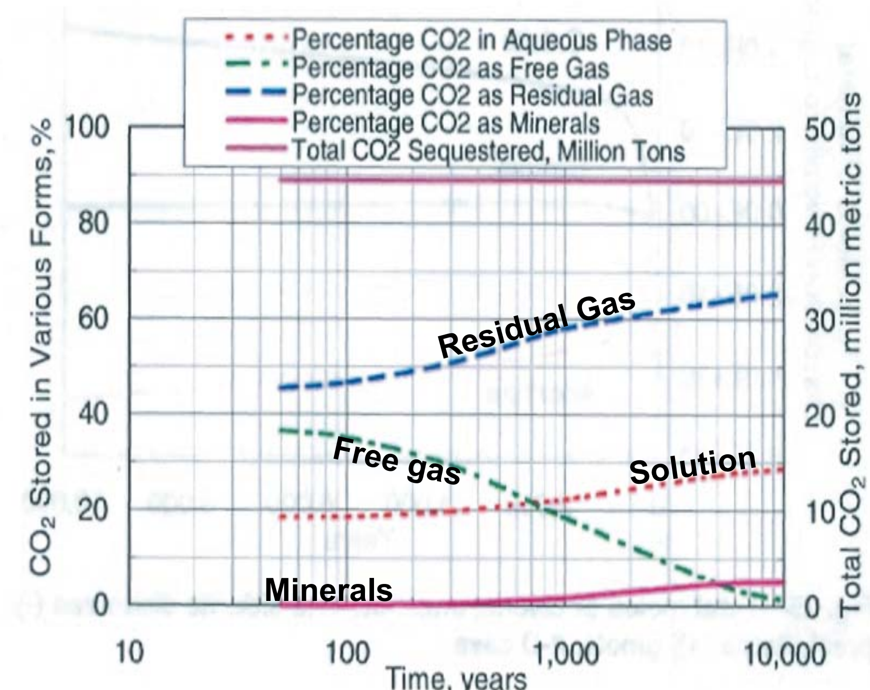
- **Project Description (*official start date – December 8, 2009; completion 12/7/12*)**
  - **Geologic Sequestration of CO_2**
  - **Project Study Area – Wellington field & 17+ counties**
  - **Project Objectives**
  - **OPAS – Target for CO_2 sequestration**
  - **Project Suitability**
    - **Arbuckle Aquifer System – 17+ counties**
    - **Arbuckle Saline Aquifer underlying Wellington field & Wellington depleted oil reservoir**
  - **Data Collection & Analysis**
  - **Approach to Characterization – Wellington field**
  - **Approach to Characterization – Regional (17+ counties in south-central KS)**
    - **Limitations**
  - **Risk Analysis**
  - **Technology Transfer**
  - **Project Timeline**
  - **Budget**
  - **Relevance & Impacts**
  - **Participants**



Geologic Sequestration of CO_2



Bachu, 2003



Ozah, 2005 – after 50 years of injection

Formation Type	*10^9 Metric Tons*	*%*
Saline Aquifers	3,297 – 12,618	91.8 – 97.5
Unmineable Coal Seams	157 – 178	4.4 – 1.4
Mature Oil & Gas Reservoirs	138	3.8 – 1.1
Total Capacity	3,592 – 12,934	100.0

DOE & NETL, "Carbon Sequestration Atlas of the US and Canada", 2008

Global annual CO_2 emissions ≈ 8 gigatons

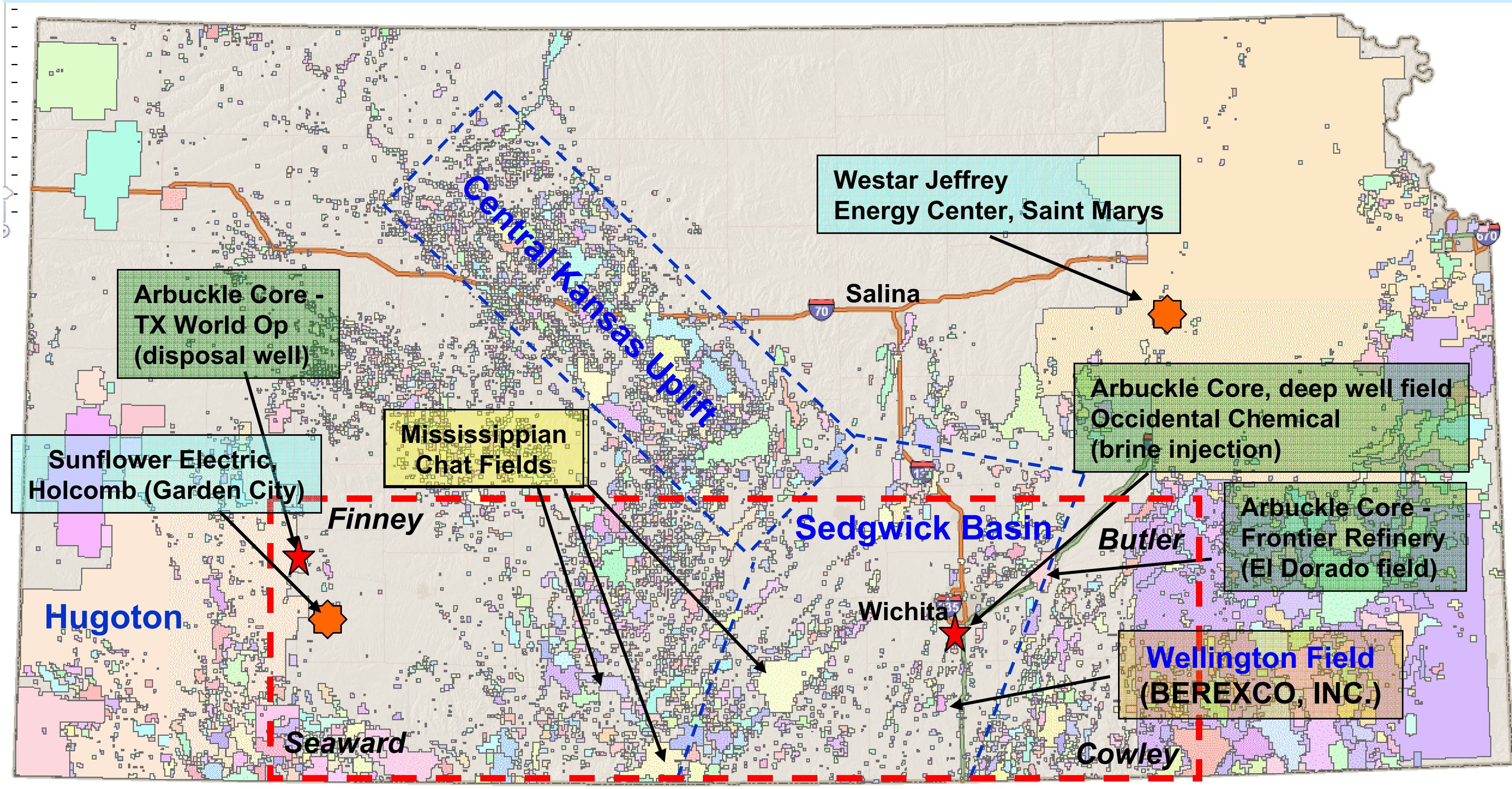
Earth Policy Institute

US emissions ≈ 3.8 gigatons

Carr 2010

Project Study Area

Wellington Field (Sumner County) + 17 Counties



20,000 sq mi. regional study area

50 miles

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

Project Objectives

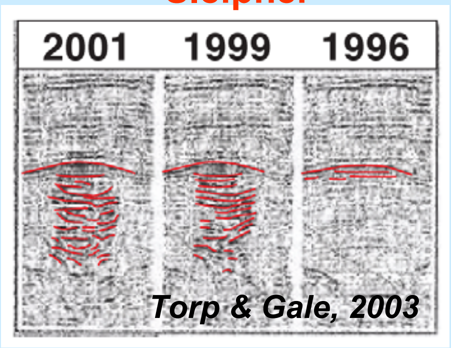
- **Build 3 geocellular models**
  - ***1. Mississippian oil reservoir at Wellington field (Sumner County) - depleted***
  - ***2. Arbuckle saline aquifer underlying Wellington field***
  - ***3. Regional Arbuckle saline aquifer system over 17+ counties***
- **Simulation studies to estimate CO_2 sequestration potential in**
  - ***1. Arbuckle saline aquifer underlying Wellington field***
  - ***2. Miscible CO_2 flood in Wellington field (along with incremental oil recovery)***
- **Identify potential sites for CO_2 sequestration in Arbuckle saline aquifer - 17+ county area**
- **Simulation studies to estimate CO_2 sequestration potential of Arbuckle saline aquifer – 17+ county area**
- **Risk analysis related to CO_2 sequestration**
- **Technology transfer**

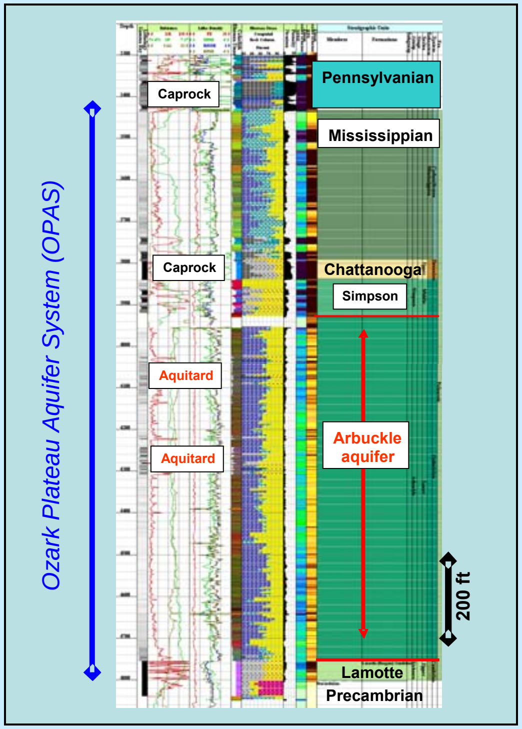
No CO_2 will be injected in this project

OPAS - Arbuckle Aquifer System
Target for CO_2 Sequestration

- **OPAS**
  - **Arbuckle Saline Aquifer System**
    - Thick, deep saline aquifer
    - Interbedded shaly aquitards
    - Estimated sequestration capacity – 1.1 to 3.8 gigatons
    - Propose detailed reservoir characterization & simulation
      - Better estimate sequestration capacity (tonnage) – solution, residual, free phase, minerals & risk analysis
      - Identify prospective sequestration sites in 17+ county study area
  - **Mississippian Chat fields** - overlies
    - Miscible CO_2-EOR
      - Incremental oil recovery
      - CO_2 tonnage sequestered

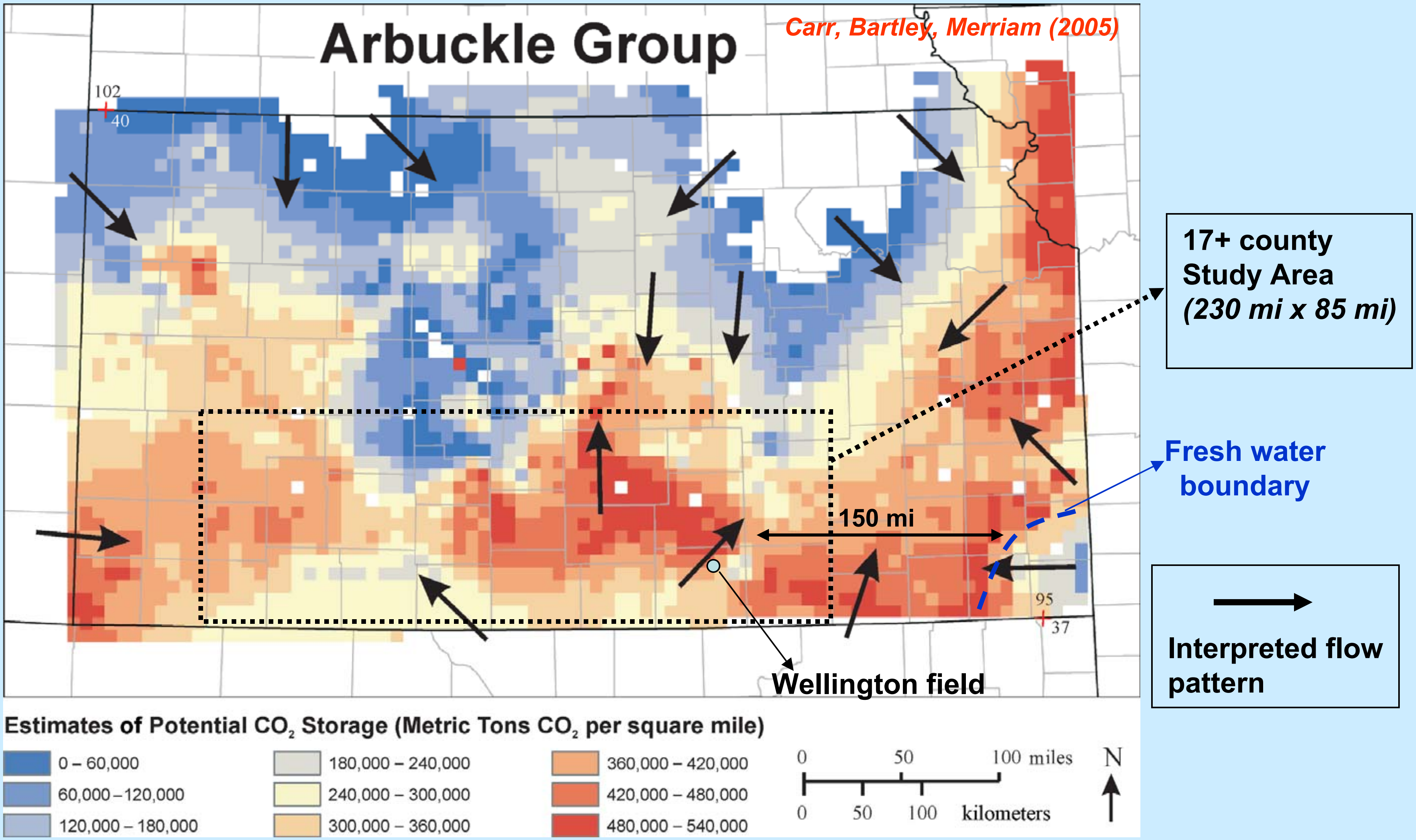
Sleipner





CO_2 Sequestration Target

Arbuckle Saline Aquifer



Red Areas – Sequestration capacity - at least 480,000 metric tons/mi²

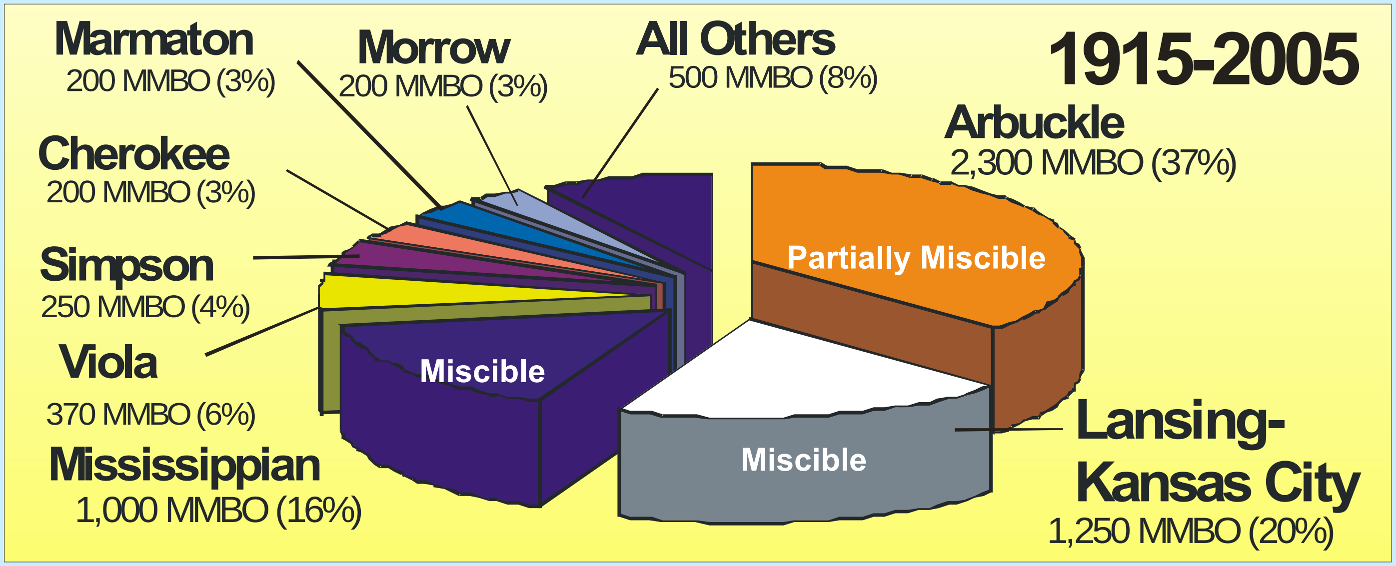
CO_2 Sequestration Target

Depleted Mississippian Chat Reservoirs - EOR

- **6-counties in the regional study area**
  - **Contain six of top 13 Kansas fields (Mississippian chat reservoirs) – candidates for CO_2 EOR**
  - **Multiple fields – produced ≈ 0.47 billion bbls & 3 tcf gas**
  - **Reservoirs characteristics for CO_2-EOR**
    - **Depth – miscible CO_2-EOR**
    - **Lack strong water drive**
    - **Many near depletion**
    - **Some underwent successful waterfloods – Wellington field**
- **CO_2 sequestration potential of CO_2-EOR – minor compared to deep saline aquifers**
  - **Viable CO_2-EOR will encourage KS oil and gas industry to participate in infrastructure development suitable also for CO_2 sequestration in underlying saline aquifers**

CO_2 Sequestration Potential

EOR Potential in Kansas



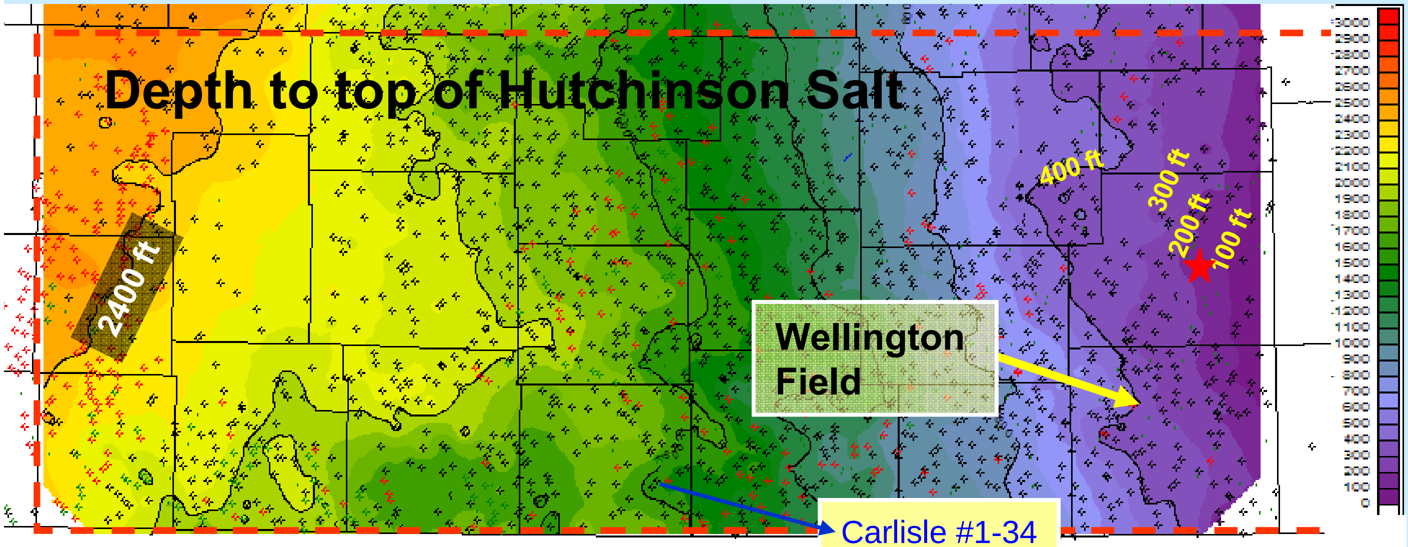
- **4.6 billion barrels crude oil produced – Mississippian, LKC, & Arbuckle**
- **CO_2-EOR could recover substantial incremental oil**
  - ***10% of primary and secondary recovery (technically feasible) ~ 400 MMBO***
  - ***Recovery depends on field readiness, infrastructure, and access to CO_2***
- ***Independent Oil and Gas companies are a primary stakeholder for CCS in Kansas***

Suitability of Project
Arbuckle Aquifer System

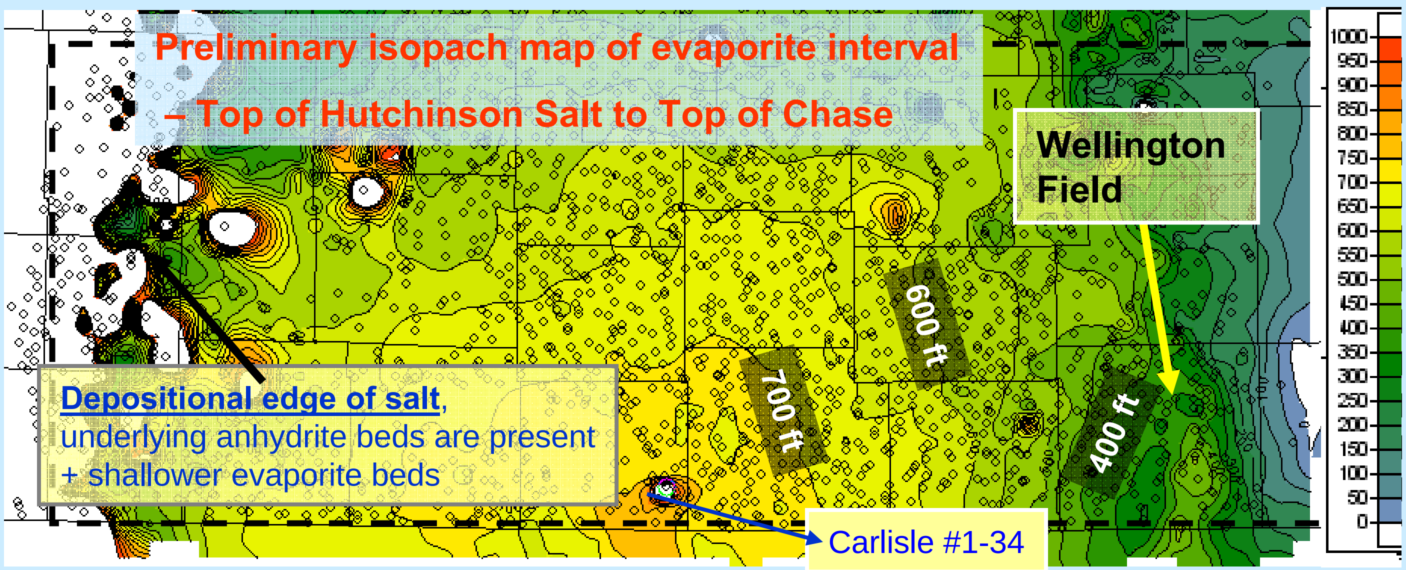
- **Arbuckle Aquifer System**
  - **"Excellent opportunity of large-scale CO_2 sequestration with hydrodynamic trapping, long isolation (>1000 yr) from the atmosphere, and protection of underground sources of drinking water supplies" …… Carr et al. (2005)**
  - **Extensive brine geochemical database – NatCarb (3700 samples)**
  - **Other factors**
    - **Depth > 3500 ft, thickness > 800 ft**
    - **Remoteness from freshwater > 150 mi to east**
    - **Vertically isolated from shallow freshwater – aquitards & <u>evaporites</u> (salt)**
    - **Arbuckle Group – Class I & II disposal zone since 1950s**

Suitability of Project

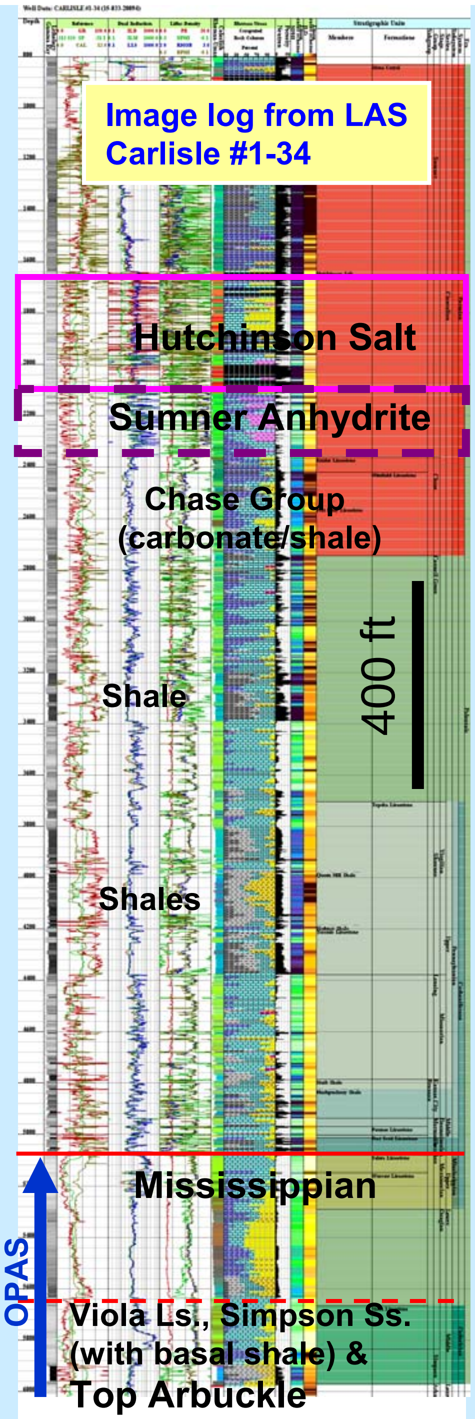
Evaporite seal overlying Arbuckle Saline Aquifer



Data from Watney and Paul (1981); Watney et al. (1989)

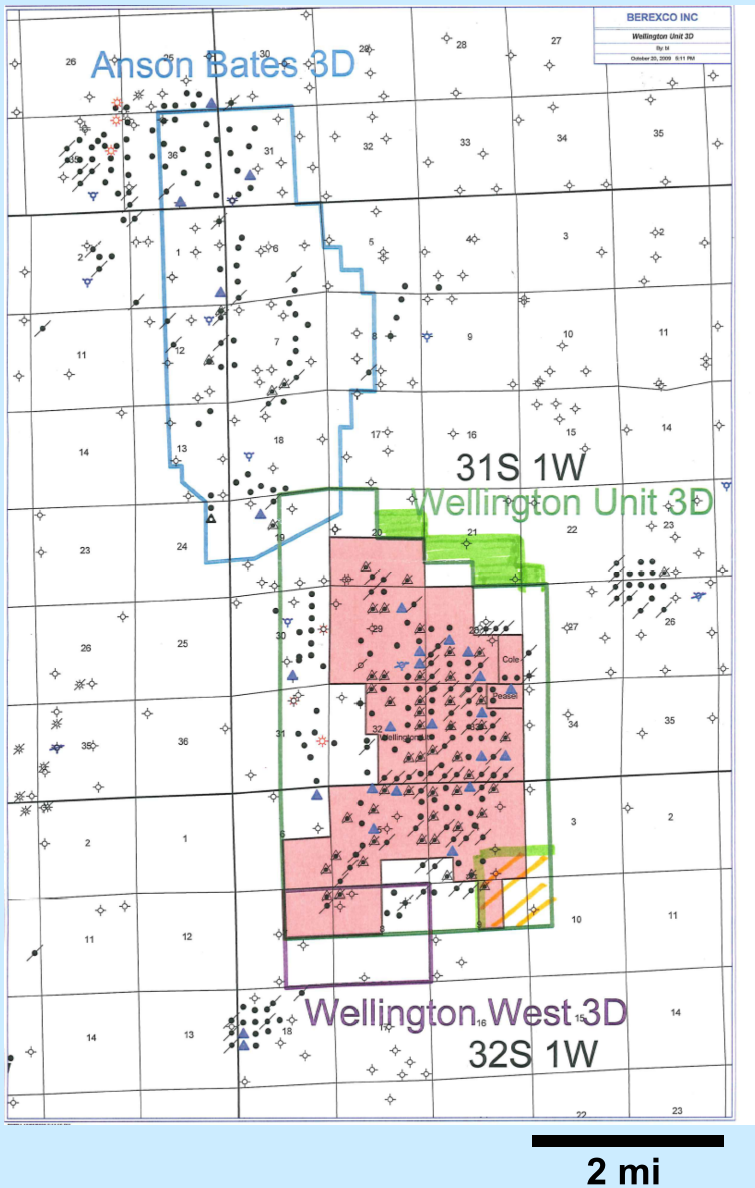


Regional study area: 230 mi x 85 mi



Suitability of Project

Wellington field, Sumner County



- **Wellington field**
  - **Discovered 1922 (134+ wells)**
  - **44 active wells, 20.5 MM BO**
  - **Unitized and owned by BEREXCO**
  - **Excellent waterflood – ideal for CO_2-EOR**
  - **Arbuckle aquifer (1050 ft thick, top 4150 ft)**
  - **Considered for CO_2-EOR (Coffeyville refinery)**
- **Anson & Bates fields**
  - **Mississippian chat reservoir**
  - **6 MM BO**
  - **3D donated by Noble Energy**
- **3 fields could sequester ≈ 30 MM tons CO_2 (MidCarb Sequestration Vol. calculator)**

Data Collection & Analysis

- **Geophysical surveys at Wellington field**
  - **Gravity & magnetics begin Feb. 4th**
  - **3D multicomponent (converted wave) seismic (~10 mi^2) begins Feb. 10th**
  - **2- 2D shearwave surveys (8 linear miles)**
- **Well #1 - Drill, core (*1600 ft from base of Pennsylvanian*), log, case, perforate, and test to basement (~5100 ft)**
- **Well #2 - Drill, log, case, perforate, and test to basement**
- **Core Analysis (Mississippian and Arbuckle core - Well #1) & PVT**
- **Geochemical studies on Arbuckle water – KSU Geology Dept.**
  - **Major reactive pathways and reaction kinetics**
- **17 county regional study – OPAS**
  - **Regional geomodel – Arbuckle Aquifer**
  - **Flow-unit mapping (aquitards, caprock, & overlying salt bodies)**
- **Cap rock integrity and micro-biological studies – KU Geology Dept.**
- **Reservoir simulation**
  - **Wellington field – Arbuckle Aquifer & Mississippian Chat depleted field**
  - **Compartments in 17+ county study area**

Approach to Characterization

Wellington - Arbuckle Saline Aquifer & Mississippian Chat Reservoir - I

- **Integrated Reservoir modeling – geocellular Petrel© models**
  - **Multicomponent 3D seismic survey**
  - **Routine and special core analysis**
  - **Water chemistry analysis – flow-unit specific**
  - **Cap rock competency analysis**
  - **Hydrogeologic studies**
    - Lateral continuity of aquifer & aquitards
    - Aquifer velocity, direction, and gradient
- **Reservoir simulation – CMG - GEM©,WINPROP©, & CMOST©**
  - **Simulator**
    - Multiphase multicomponent
    - Phase and chemical equilibrium
    - Rate dependent mineral dissolution/precipitation modules

Approach to Characterization

Wellington - Arbuckle Group Saline Aquifer & Mississippian Chat Reservoir - II

- **Reservoir simulation**
  - **Inputs**
    - Integrated reservoir geomodel – fracture/fault trends
    - Facies-specific - relative-permeability, hysteresis curves, K - Phi trends
    - Aquifer/aquitard specific – water chemistry and pressure
  - **Anticipated results - Arbuckle Group Saline Aquifer**
    - Plume movement and spread
    - Tonnage of CO_2 sequestered (25 & 50 yrs)
    - Optimum injection pressure
    - Pressure of free-phase CO_2 under cap rock
    - Sequestration enhancement - simultaneous brine injection from upper horizons
    - Porosity changes due to mineralization - location of maximum porosity change

Approach to Characterization

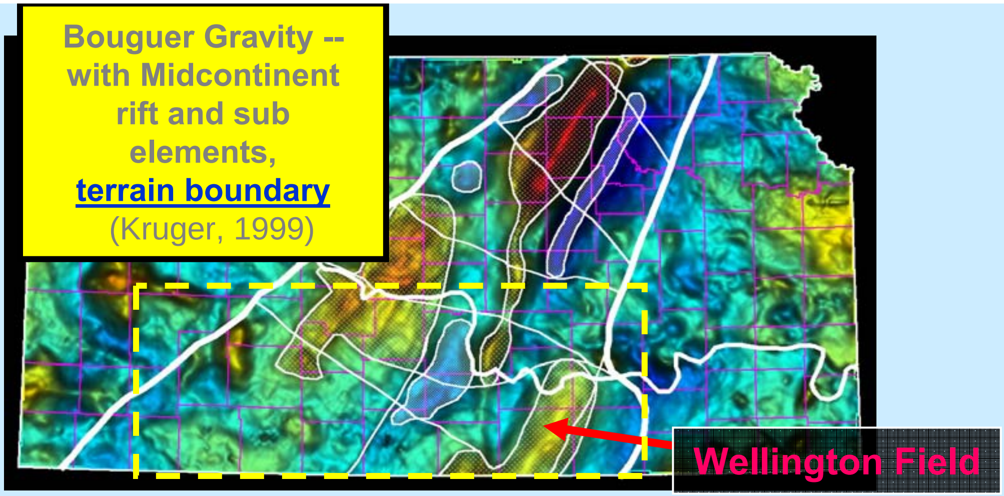
Wellington - Arbuckle Group Saline Aquifer & Mississippian Chat Reservoir - III

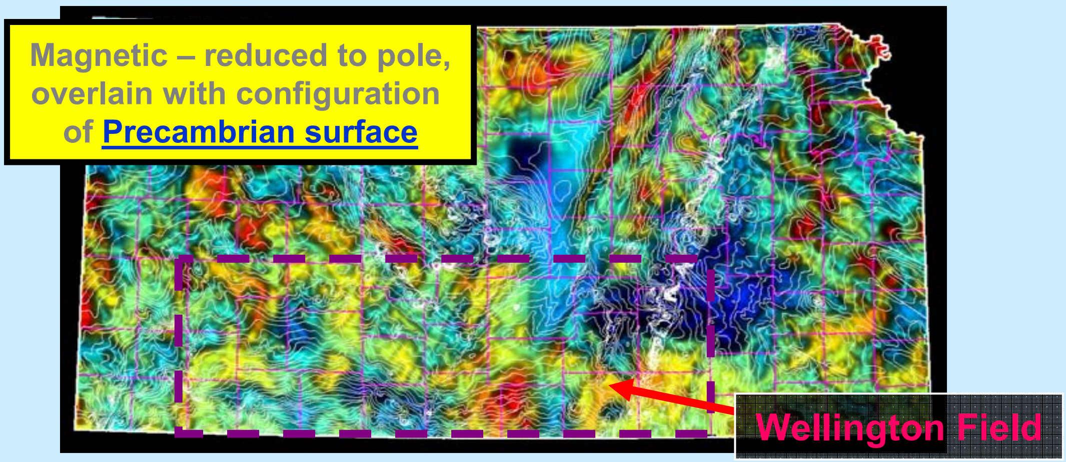
- **Anticipated results (cont.) - Mississippian Chat reservoir**
  - **Identify areas with significant residual oil saturation**
    - **Model 5-spot patterns**
      - Incremental oil recovery
      - Tonnage CO_2 sequestered - solution, residual gas saturation, minerals
      - Tonnage CO_2 injected for recovery of 1 incremental barrel oil
      - Tonnage CO_2 recycled
    - **Other injection patterns – optimize oil recovery**
    - **Field-scale EOR model – maximum oil recovery with minimum up-front investment**
      - Identify areas viable for multiple pattern EOR implementation
      - Total incremental oil recovery
      - Tonnage of CO_2 sequestered - solution, residual gas saturation, minerals
      - Tonnage CO_2 recycled

Approach to Characterization

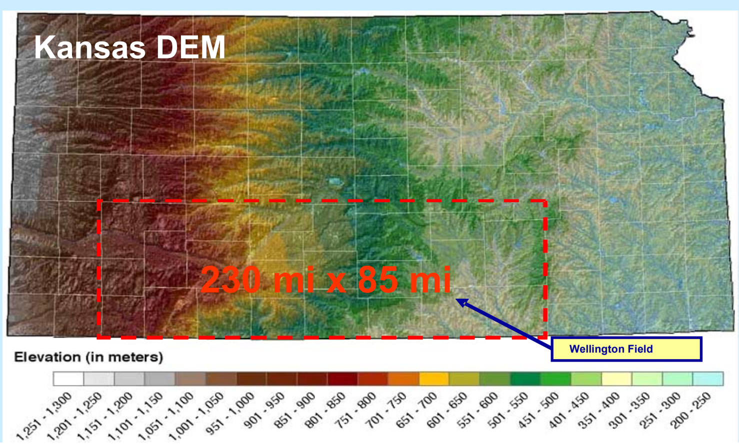
Arbuckle Saline Aquifer (17+ county area)

- **Detailed saline aquifer characterization**
  - **Storage, flow, and composition changes due to CO_2 injection**
- **Proposed studies for regional Arbuckle Saline Aquifer**
  - **Inventory all available data – select key deep wells**
    - **Database of 95,000+ wells, 1413 deep wells, 147 wells to basement**
  - **Integrated data analysis – identify reservoir compartments**
    - **Structural and derivative mapping**
    - **Petrophysical catalog (4 Arbuckle cores) – facies-specific rock catalog**
    - **Water chemistry database – aquifer/aquitard specific database**
  - **Simulation of select large compartments**
    - **Use stratigraphic & facies-specific data**
      - Water chemistry
      - Petrophysical data
    - **Tonnage of CO_2 that can be sequestered before plume reaches boundaries**
  - **Estimate total tonnage of CO_2 that can be sequestered**





New algorithm will be developed to interpret gravity and magnetic data in the 17+county study area to delineate depth to basement, basement faults and fractures



High resolution satellite imagery maps will be interpreted to map surface faults and lineaments

Kansas – 200 mi x 400 mi

Approach to Characterization - Limitations

Arbuckle Saline Aquifer (17+ county area)

- Uneven distribution of wells penetrating Arbuckle – per section
- *Current* assessment
  - 1413 wells > 100 ft penetration in Arbuckle
  - 276 wells – full Arbuckle penetration (basement test)
- Cores – 4 Arbuckle cores available
  - Ideally – more cores would help better characterize flow-units
- Wellington field area – data rich
  - Facies specific – petrophysical and water chemistry catalog
- Regional geomodeling
  - Use all available Arbuckle well data – identify pore-types, facies/flow-units
  - Quantify petrophysical properties of flow units using data from Wellington area catalog
  - Access subsurface information collected from USGS's Anadarko Basin Resources Assessment Project
- Ongoing efforts to encourage operators to donate additional 3D data
  - Noble Energy donated 3D data for Anson-Bates field
  - Palomino Petroleum donated 3D data for Wellington West field

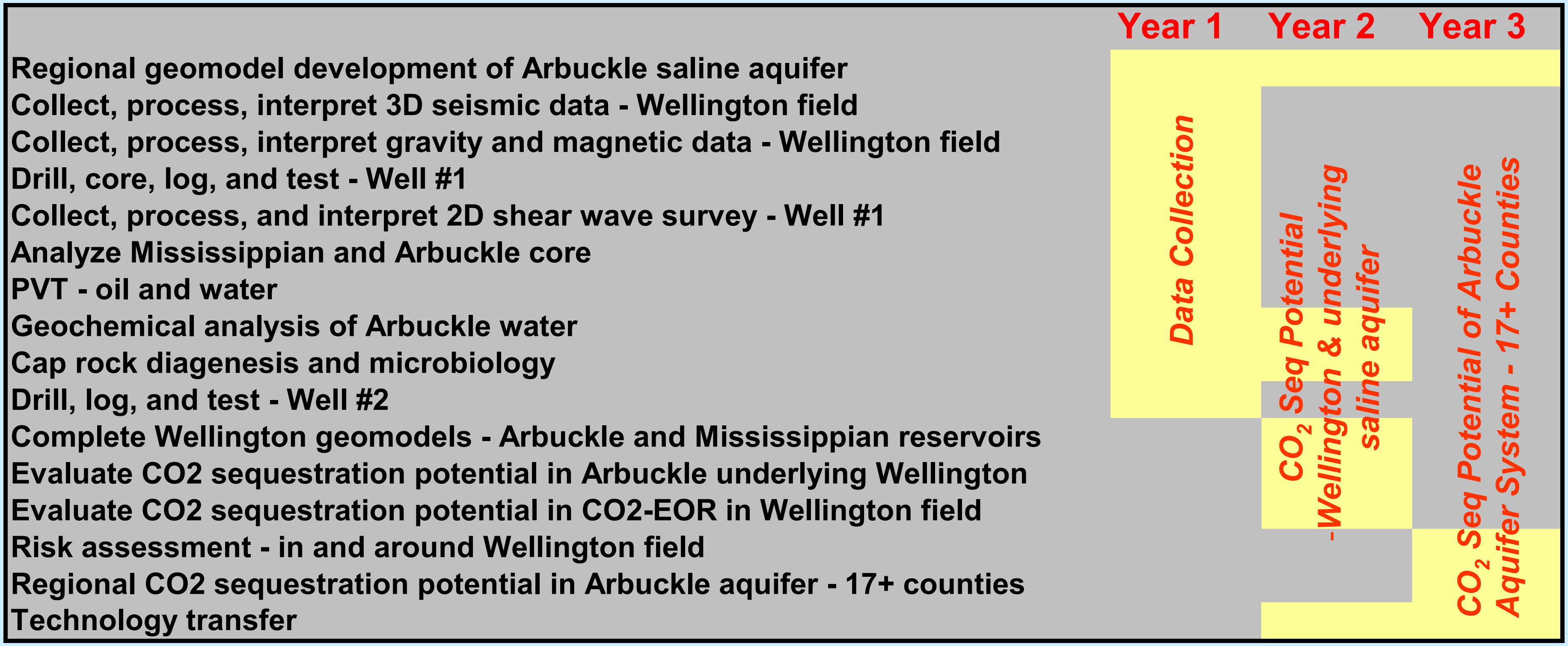
Risk Analysis
Wellington Field

- **Arbuckle saline aquifer underlying Wellington field**
  - **Free-phase CO_2 plume growth and attenuation over time**
    - **How close will the plume be to the nearest fault/fracture trend ? (time frame)**
    - **Will the plume migrate outside the risk-assessment area (10-mile radius around Wellington field)? (time frame)**
    - **Effects of sealing or transmitting faults on plume migration and attenuation**
    - **How long will it take for free-phase CO_2 to become negligible?**
    - **Plume growth and pressure under cap-rock**
      - CO_2 injected deep and rising plume travels through multiple aquitards
- **Wellington Mississippian Chat CO_2-EOR**
  - **Given the age of wells and quality of cement**
    - **How many wells in Wellington likely to fail?**
    - **Upon failure – amount of CO_2 (% injection) leaking to shallow horizons (surface)**

Technology Transfer

- KGS has a successful history of technology transfer
- Huge amount of data will be collected, analyzed, and generated
  - Project website - hosted by KGS
    - Repository of all data, analyses, and reports
    - Linked to NatCarb databases – NatCarb hosted at the KGS
  - Easy access & download from project website
    - Interactive GIS-based online mapping system, developed at the KGS, will be modified to display, filter, and query cross-sections and maps from the study areas
- Best-practices manual for site selection and characterization for CO_2 sequestration will be developed
- Disseminate lessons learned
  - Core workshops
  - Presentations at industry conferences
  - Peer-reviewed journal articles

Project Time Line



Budget

	$ 4,974,299.00	$ 1,359,020.00	$ 6,333,319.00

	Budget - DOE	Match	Total
Berexco - Drilling (2 wells)	$ 1,659,895.00	$ 288,000.00	$ 1,947,895.00
Berexco - Geophysics*	$ 624,687.00	$ 175,305.00	$ 799,992.00
Berexco - Logging (2 wells)**	$ 207,240.00	$ -	$ 207,240.00
Berexco - Coring (1 well)	$ 272,000.00	$ 10,000.00	$ 282,000.00
Weatherford - Core Analysis	$ 365,873.00	$ 105,015.00	$ 470,888.00
KS State Geology	$ 225,167.00	$ 82,966.00	$ 308,133.00
CMG (reservoir simulation support)	$ 212,432.00	$ 152,108.00	$ 364,540.00
Bittersweet Energy (regional support)	$ 703,900.00	$ 70,096.00	$ 773,996.00
Log Digi	$ 38,000.00	$ -	$ 38,000.00
Noble Energy (An.-Bates 3D seis.)	$ -	$ 274,856.00	$ 274,856.00
Remote Sensing	$ 41,000.00	$ -	$ 41,000.00
KGS & KU Geology	$ 383,490.00	$ 159,265.00	$ 542,755.00
Others - Supplies & Travel	$ 55,470.00	$ -	$ 55,470.00
GRA Tuition	$ 21,355.00	$ -	$ 21,355.00
KU - F&A	$ 163,790.00	$ 41,409.00	$ 205,199.00

* Geophysical acquisition & processing by Paragon (3D), Lockhart (2D and gravity/mag), Fairfield & Echo (seis. Processing)
Geophysical post processing and analysis by Hedke-Saenger Geosciences, Geo-Textures, Nissan, Miller, Raef, Xia

** Logging by Halliburton

Relevance & Impact

- **Proposed Project**
  - **"Shovel ready" – BEREXCO INC (sole owner and operator of Wellington field) is very interested in evaluating the viability of CO_2-EOR and follow-up with field implementation if viable**
    - Wellington field along with nearby Anson-Bates field – potential of sequestering 30 million tons of CO_2
    - Nearby CO_2 sources – refineries at El Dorado (50 miles), Coffeyville (120 miles)
  - **Will create and retain jobs in Kansas and elsewhere in the US**
    - Seismic surveys
    - Drilling 2 wells
    - Logging 2 wells and coring 1 well
    - Routine and special core analysis
    - Geologic consultants – regional study
    - Reservoir simulation consultants
  - **Viability of CO_2 sequestration in deep, thick, Arbuckle saline aquifer in KS**
    - Has potential of developing into a major industry in Kansas
  - **Viability of CO_2-EOR in depleted Mississippian chat reservoirs**
    - Encourage KS O&G operators to develop CO_2-EOR infrastructure – beneficial to CO_2 sequestration in Arbuckle saline aquifer
  - **Share best practices in characterization, modeling, and forecasting fate of injected CO_2 in aquifers and depleted oil fields**
    - Southwestern Regional Sequestration Partnership, NatCarb, & industry
    - Develop regional expertise in CO_2 sequestration

Participants

Kansas Geological Survey, Univ. of KS, & KS. State Univ.

- **Project Manager & PI – Dr. Lynn Watney**
  - **Geologist** - 33 yrs experience in KS geology
- **2nd PI – Saibal Bhattacharya**
  - **Reservoir Engineer** – 12 yrs reservoir simulation experience in KS fields
- **Other KGS Co-PIs**
  - Dr. D. Newell – Structure & diagenesis
  - J. Rush – Petrel geomodeling and data integration
  - Dr. R. Miller – Seismic interpretation
  - Dr. J. Doveton – Log petrophysics and core modeling
  - Dr. J. Xia – Gravity-magnetic modeling and interpretation
  - Dr. M. Sophocleous – Aquifer modeling and well testing
  - **Others**
    - **J. Victorine – Java web application**
    - **D. Laflen – core curation**
    - **M. Killion – ESRI GIS**
    - **K. Look, G. Gagnon, D. Suchy, D. Stewart – manage data**
- **Department of Geology – University of KS**
  - Dr. E. Franseen – Stratigraphy & diagenesis
  - Dr. R. Goldstein – Cap rock integrity (Fluid inclusions and diagenesis)
  - Drs. Roberts & Fowle – experiments in microbial-CO_2 interactions
- **Department of Geology – Kansas State University**
  - Dr. S. Datta – Aquifer geochemistry
  - Dr. A. Raef – Seismic analysis and modeling

Participants

Industry & Consulting Partners

- **BEREXCO INC. – owner/operator of Wellington field**
  - Dana Wreath – Divisional Engr – Supervise all field operations
  - Randy Koudele – Reservoir Engr
  - Bill Lamb – Petra database management and data transfer
  - Evan Mayhew – Operations Engr – drilling, completion, and well testing
  - Robert Hefner – Geophysicist – 3D acquisition, processing, and interpretation
  - Phyllis Shahin – Landman – landowner negotiations and contracts
  - Charles Spradlin – VP and Land Manager
  - Adam Beren – President
- **Hedke-Saenger Geosciences Ltd. – Seismic acquisition & initial interpretation**
  - Paragon Geophysical, Lockhart Geophysical, Fairfield, Echo, Geotextures & Susan Nissen
- **Bittersweet Energy Inc. – Geologic Consultants (17+ county regional geomodel)**
  - Tom Hansen – Arbuckle aquifer geomodeling
  - Ken Cooper – Arbuckle aquifer simulation and coring
  - John Lorenz – Fracture characterization
  - Paul Gerlach - Arbuckle aquifer geomodeling
  - Larry Nicholson - Arbuckle aquifer geomodeling
- **Weatherford Laboratories - Routine & Special core, Rock Mechanics, PVT**
- **Computer Modeling Group**
  - Bob Brugman – Simulation Engineer – CMG WINPROP & GEM-IMEX simulation
- **David Koger – Satellite imagery analysis – surface lineaments and fractures**
- **Noble Energy – 3D seismic donation (Anson Bates field),** David DesAutels, contact
- **LogDigi – Log digitization**
- **Halliburton – Well logging**

Co-operation with Local Industry & Competitive Bidding

- **Long history of KGS's close interaction with KS O&G industry**
  - **2009 calendar**
    - **Organized RPSEA Small Producer meeting**
    - **KGS forum to identify research problems**
    - **Presentations at industry meetings – KIOGA**
    - **Helped identify research subjects relevant to KS O&G industry**
      - Regional Arbuckle characterization
    - **Contentious issues – risk, liability, global warming**
- **BEREXCO INC. – largest KS O&G company**
  - **Helped negotiate best quotes**
    - **Logging – Reduced costs by half, helped circumvent restrictions imposed on KGS by another vendor regarding software use**
    - **Seismic – best quotes with significant cost-match**
    - **Coring – competitive coring, supervision of coring, core storage**
    - **Used leverage on other sub-contractors**
  - **Independent KS O&G industry – prefers to use local companies**
    - **Knowledge base, relationships, comfort level, & cost-effectiveness**
- **Data donation from industry – Hugoton Project**
  - **Data confidentiality respected – results available for publication**

Existing CO_2 storage methodology
2008 DOE Carbon Sequestration Atlas

- **Volumetric Method**
  - **Porosity, area, and thickness**
  - **Efficiency terms – heterogeneity, fraction PV contacted by CO_2**
    - **Net to total area (A_{ntg})**
    - **Net to gross thickness (H_{ntg})**
    - **Effective to total porosity (Phi_{ntg})**
    - **Efficiencies**
      - Areal displacement (E_A)
      - Vertical displacement (E_I)
      - Gravity – density difference (CO_2 & water) – (E_g)
      - Microscopic displacement - E_d

$$E_{saline} = A_{ntg} * H_{ntg} * Phi_{ntg} * E_A * E_I * E_g * E_d$$

Assume injection wells placed regularly throughout basin – “maximum storage”

Existing CO_2 storage methodology
2008 Carbon Sequestration Atlas

- **Compressibility method - Monte Carlo**
  - **Applicable for single phase (constant compressibility)**
    - **Ex: single phase oil reservoir, confined saline formations**
  - **CO_2 injection into saline aquifer – 2 phases**
    - **Approximation – apply formula to water phase only**
    - **Original water volume (V_{wo}) compressed by pressure increase ($P – P_o$)**
      - P - maximum capillary pressure to breach seal or pressure to activate fault
      - P - average water pressure over entire V_{wo}
    - **Compressed water volume (ΔV_w or G_{CO2}) – occupied by CO_2**
      - **ΔV_w or $G_{CO2} = V_{wo} * c_t * (P-Po)$**
      - **Vwo = A * H * phi**
      - **$c_t = c_f + c_w$ (sum of formation and water compressibility)**
    - **Closed system – V_{wo} can be defined (water contained by compartment)**
      - **How many aquifers are closed systems?**
    - **Open system – V_{wo} is infinite and can not be defined**

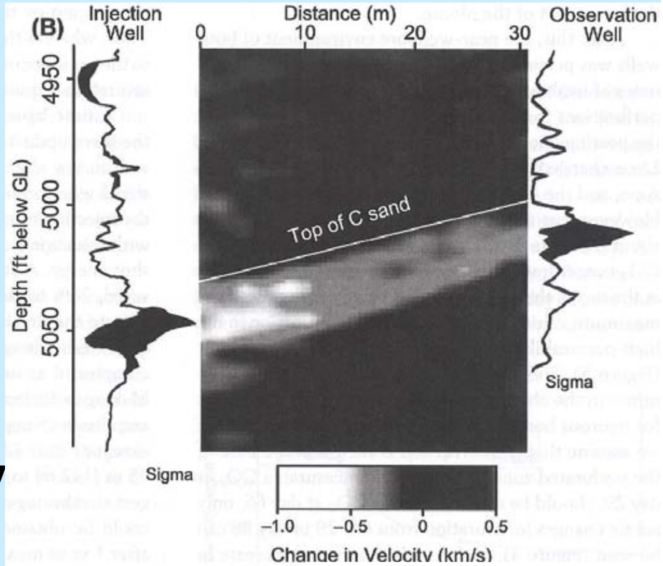
• Neither method provides plume description or spread, CO_2 entrapment by residual saturation, solution, and mineralization

• Free phase CO_2 plume – highest risk

Proposed Project

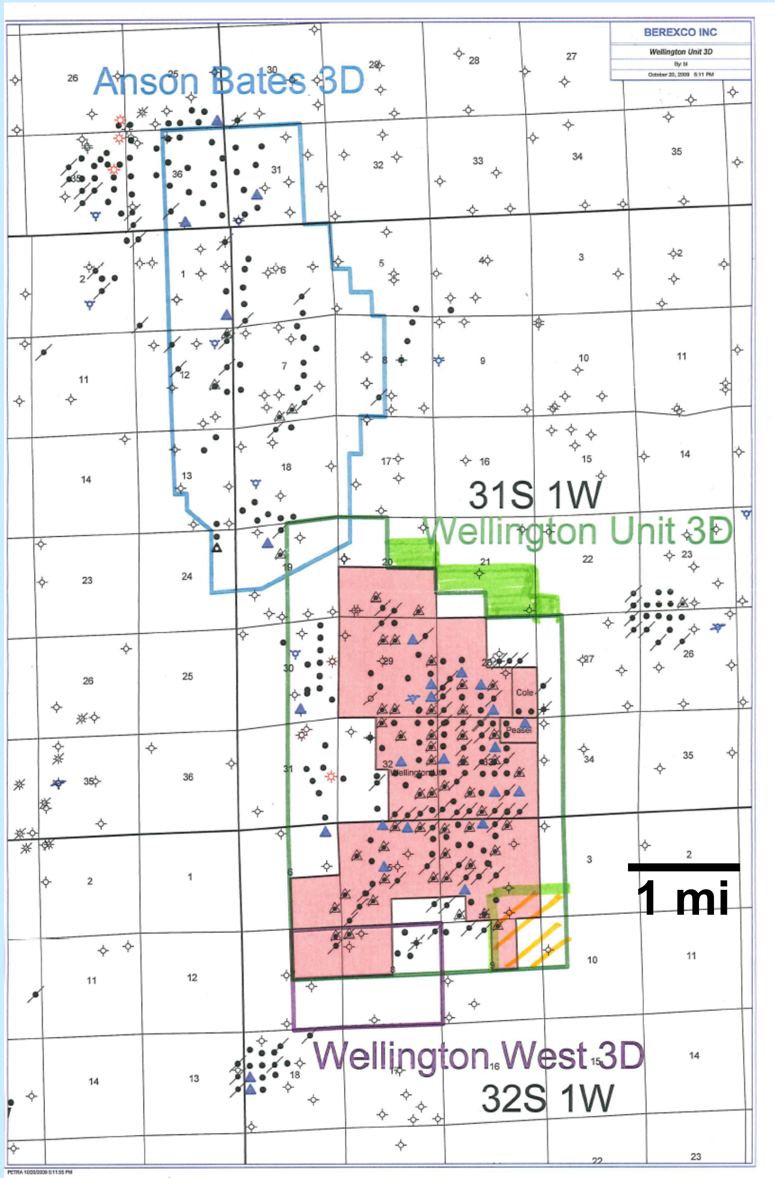
Improve Current Sequestration Estimates

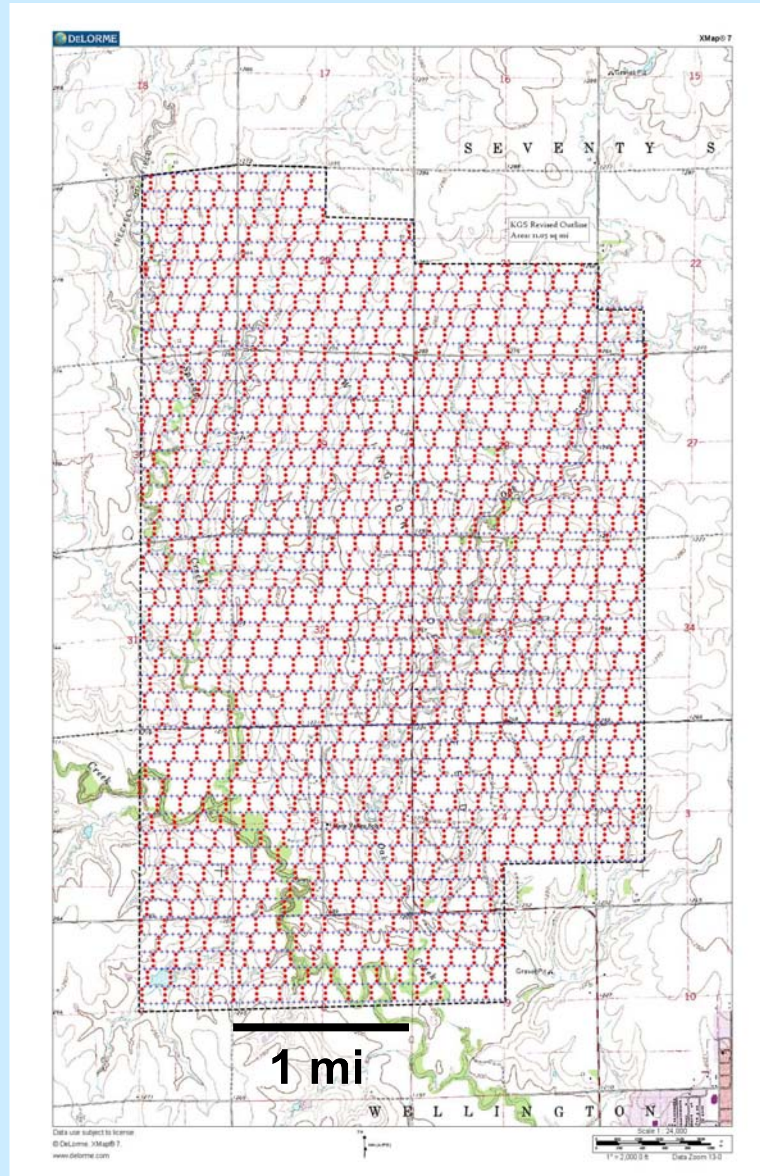
- **Geocellular model – incorporates variation in**
  - **Layering – flow-units/facies**
    - **Porosity**
    - **Thickness**
    - **Permeability**
    - **Seal continuity**
  - **Fracture and fault boundaries**
- **3D reservoir model includes**
  - **Facies specific petrophysical properties**
  - **Aquifer/aquitard specific water geochemistry**
- **Compositional reservoir simulation**
  - **Dynamic modeling of *in situ* CO_2 flow and entrapment**
  - **Model CO_2 entrapment by different mechanisms**
    - **Solution, residual gas, free phase, and minerals**
    - **Convective current due to CO_2 dissolution in brine**
  - **Model plume shape, migration with time – compartment boundaries**
    - **Include aquifer velocity and direction**
  - **Model if free phase pressure under cap/seal has potential to breach**
    - **Time frame when free phase CO_2 becomes negligible**



Frio crosshole
Tomography of CO_2 plume
Source: BEG

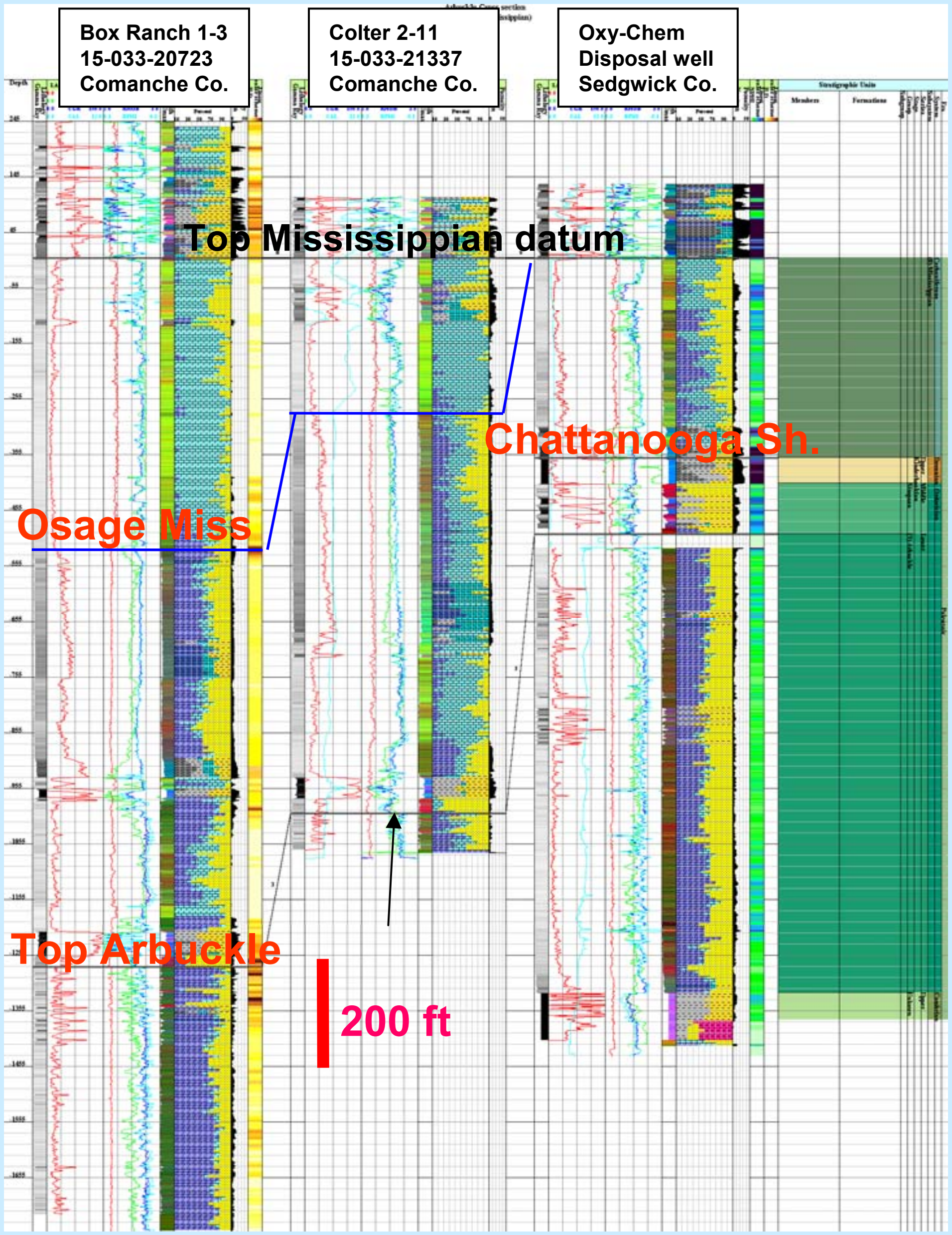
Work in Progress – 3D Seismic Survey & High Resolution Gravity/Magnetic





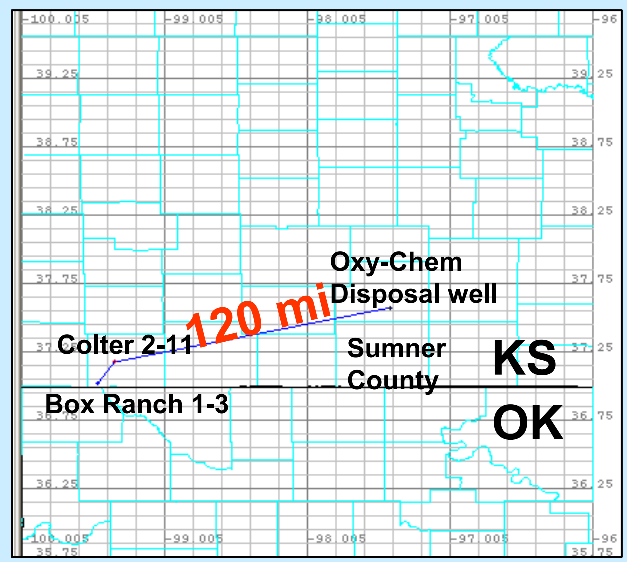
Work in Progress

Modifying Web-based Well Profile & Cross Section Java Codes



<u>Three well stratigraphic cross section with datum on top of the Mississippian carbonates</u> showing color images of gamma ray (gray scale), lithology track (multicolor image column), and color lithology percentage.

Index map, South-Central KS & North-Central OK



All well data saved in <u>LAS 3.0 format</u>

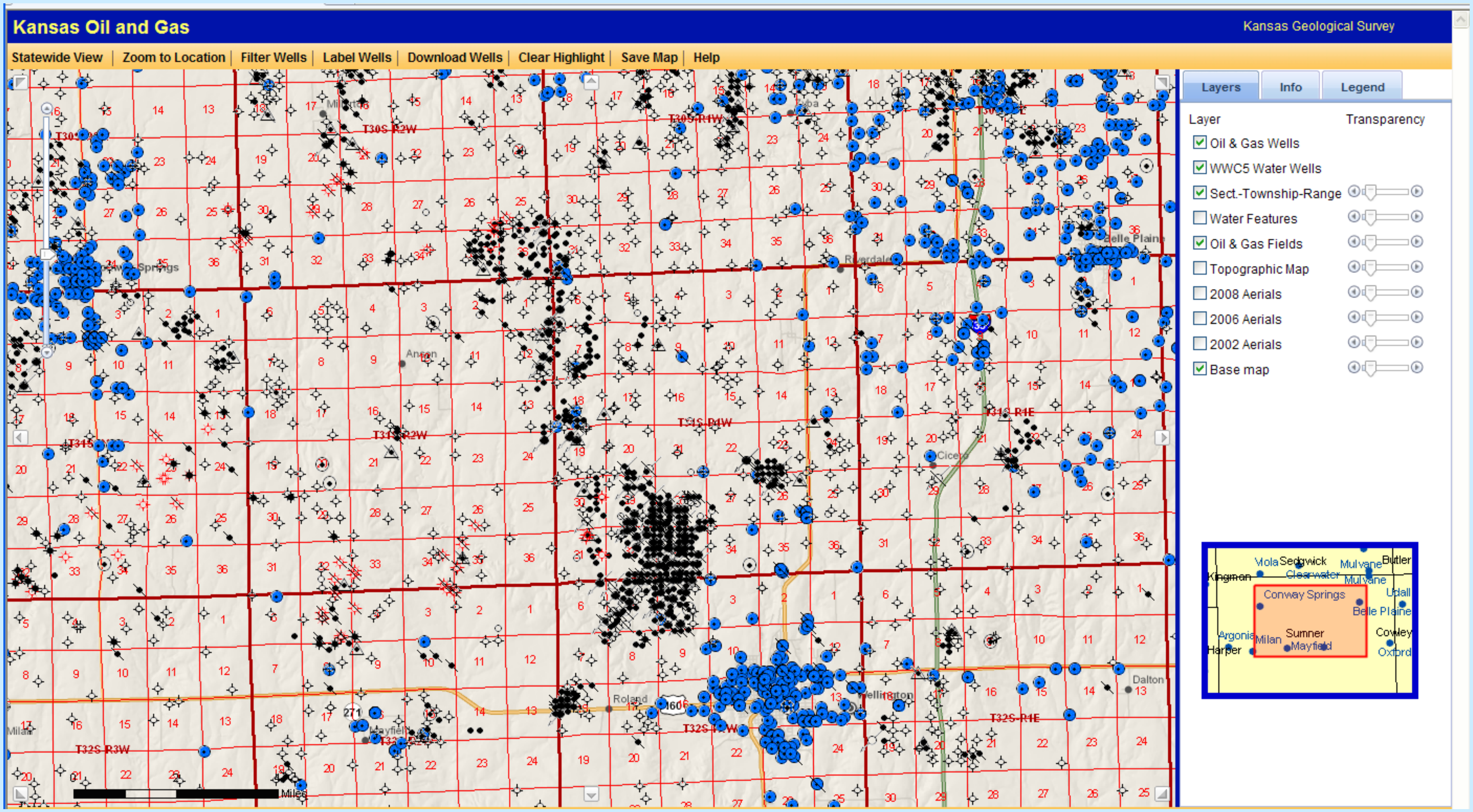
Work in Progress

Adapting Oil and Gas Map Viewer for Project

- Google-type map interface to pan and zoom

- Display <u>ALL</u> wells, access well data, launch well profile and cross section web tools

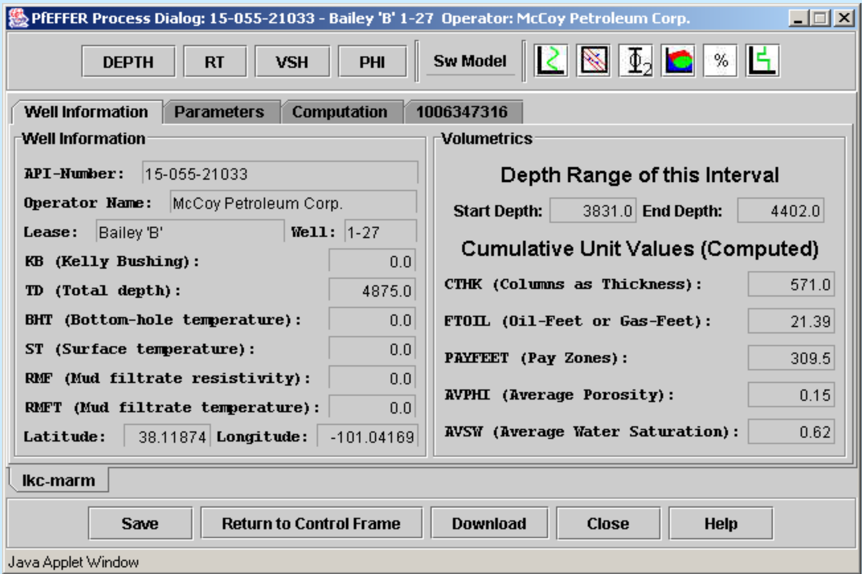
- Display georeferenced maps and simulations

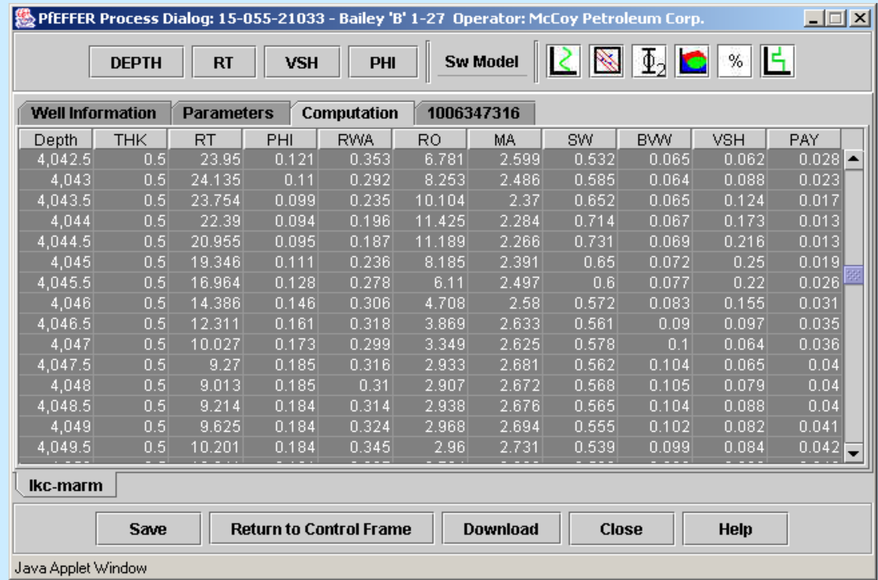


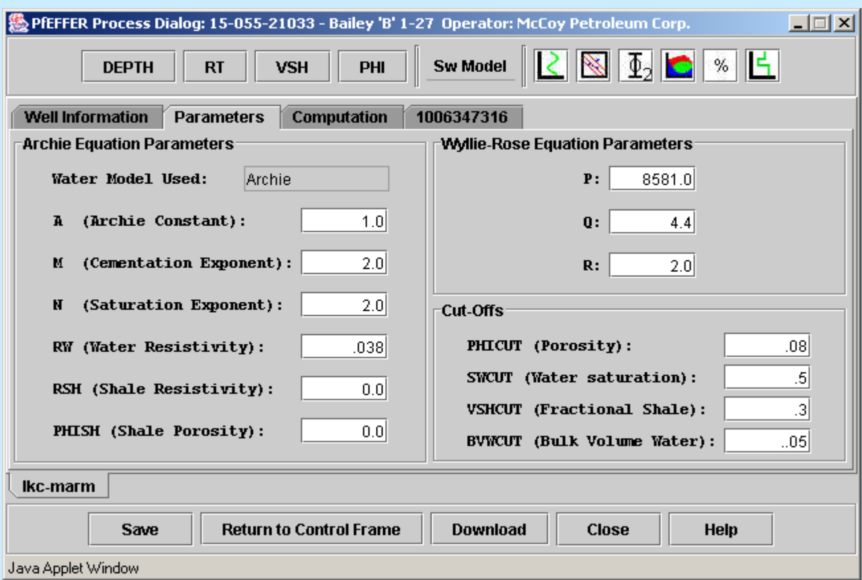
4 mi

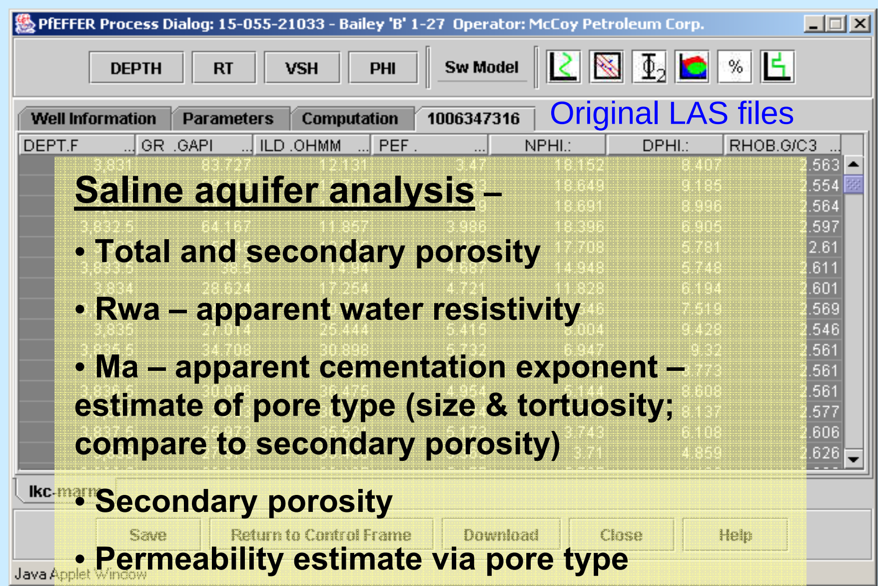
Work in Progress

PfEFFER – Java-based log analysis program







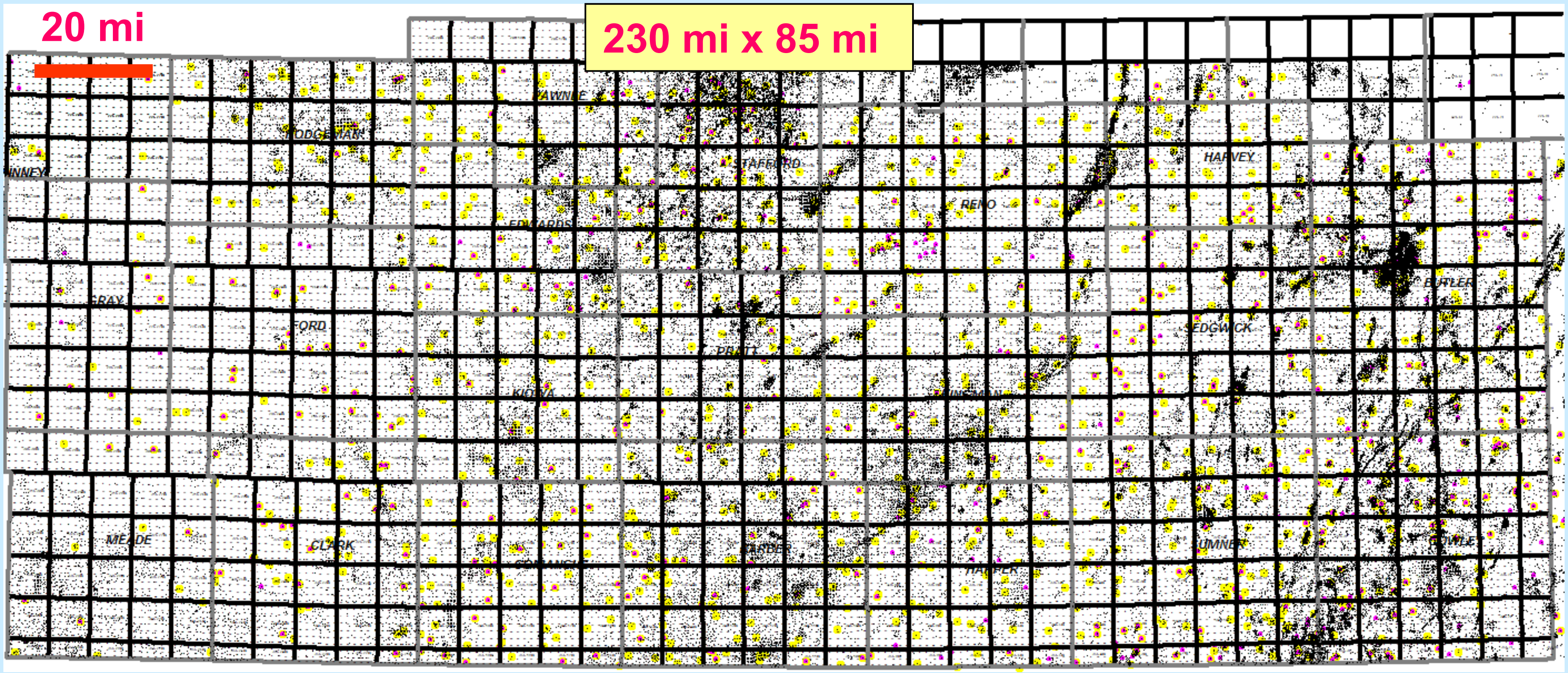


Saline aquifer analysis –

- Total and secondary porosity
- Rwa – apparent water resistivity
- Ma – apparent cementation exponent – estimate of pore type (size & tortuosity; compare to secondary porosity)
- Secondary porosity
- Permeability estimate via pore type

Work in Progress

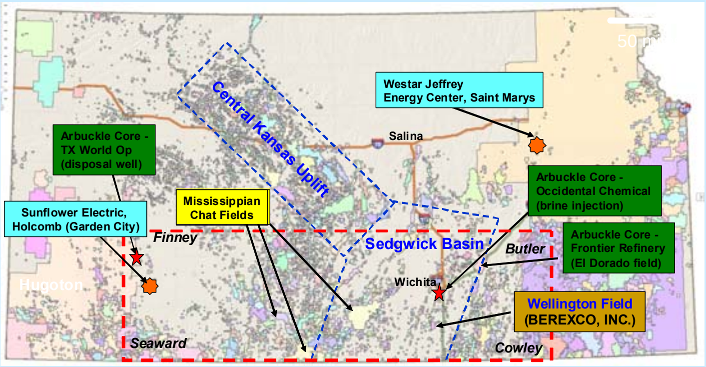
Status of identifying key wells in regional study area



YELLOW SQUARE = Potential TYPE WELLS
MAGENTA CIRCLE = Well with elog (raster) downloaded and depth registered in Geographix

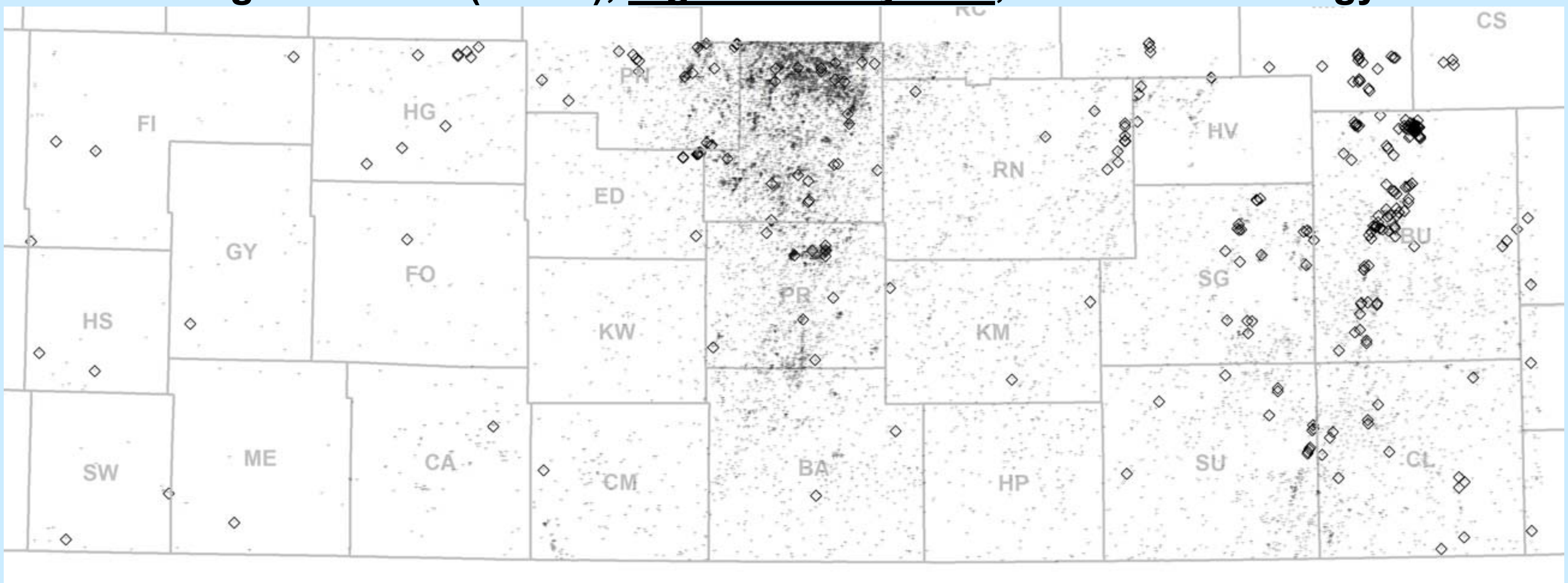
As of 2-1-10:

Total wells available ~95,000
KEY WELLS to date = 1413
Pre-Camb Tests = 276



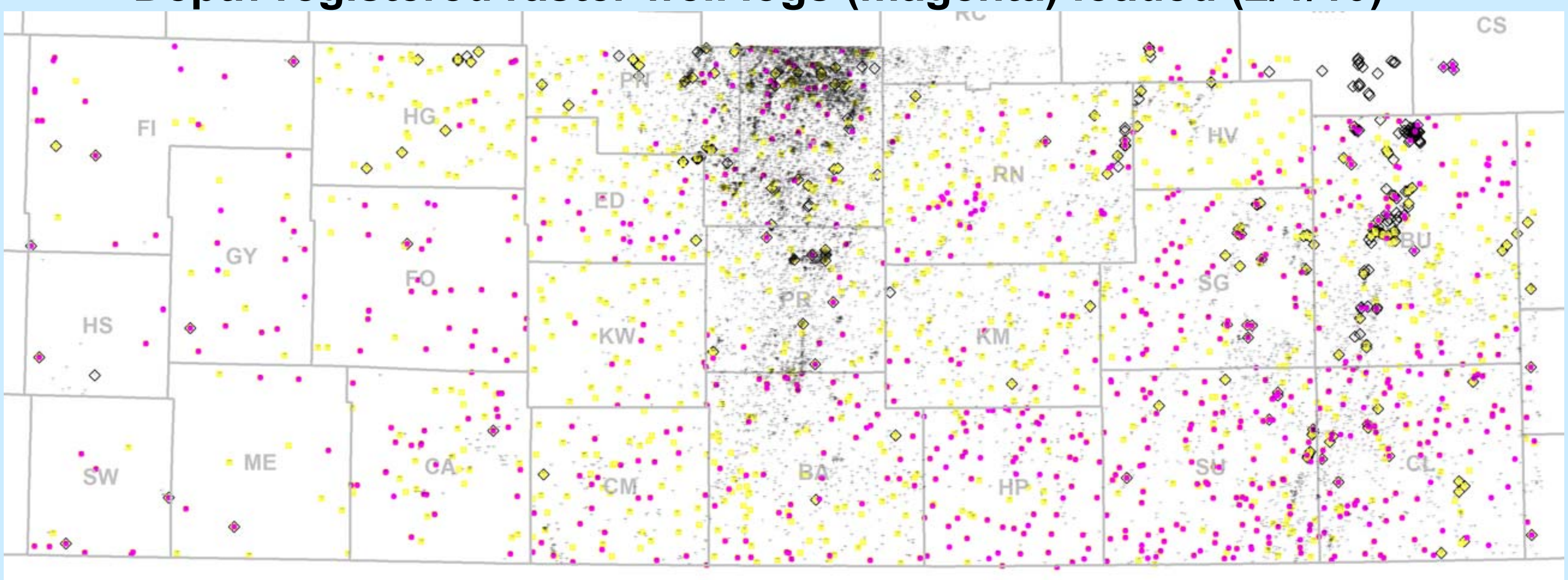
Work in Progress

Wells Penetrating Basement (2/1/10), regional study area, Bittersweet Energy subcontractor



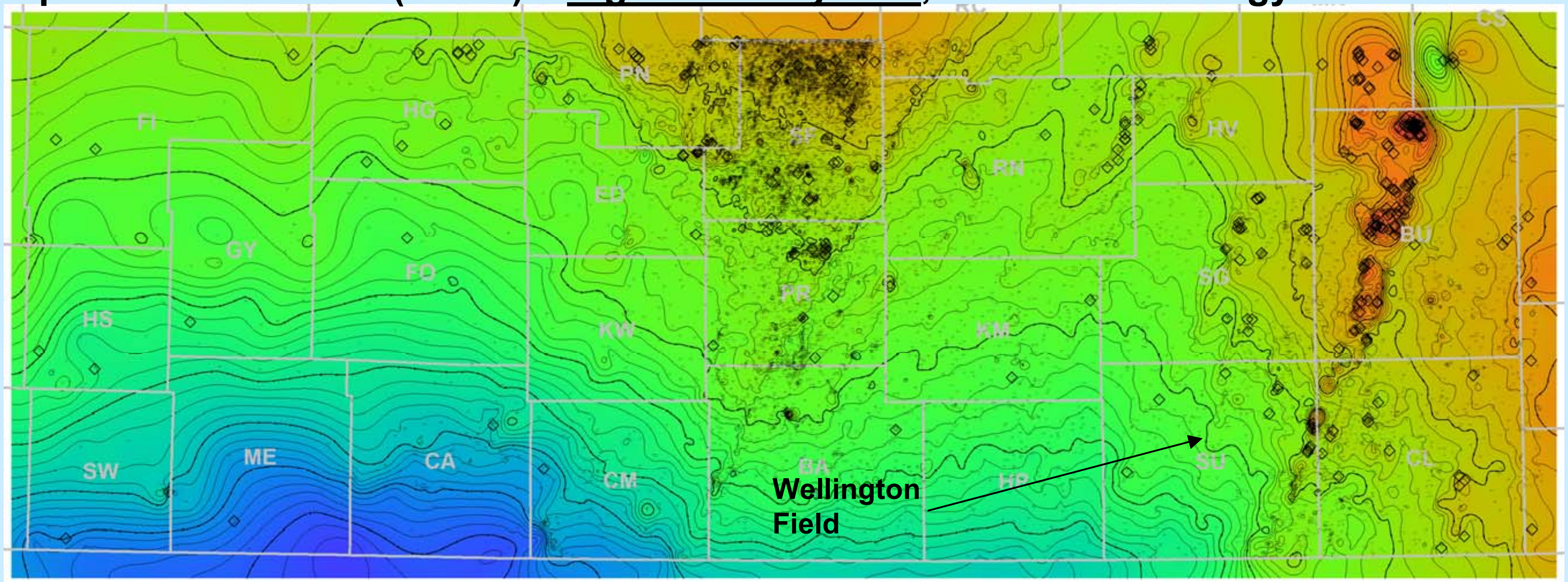
20 mi

Depth-registered raster well logs (magenta) loaded (2/1/10)



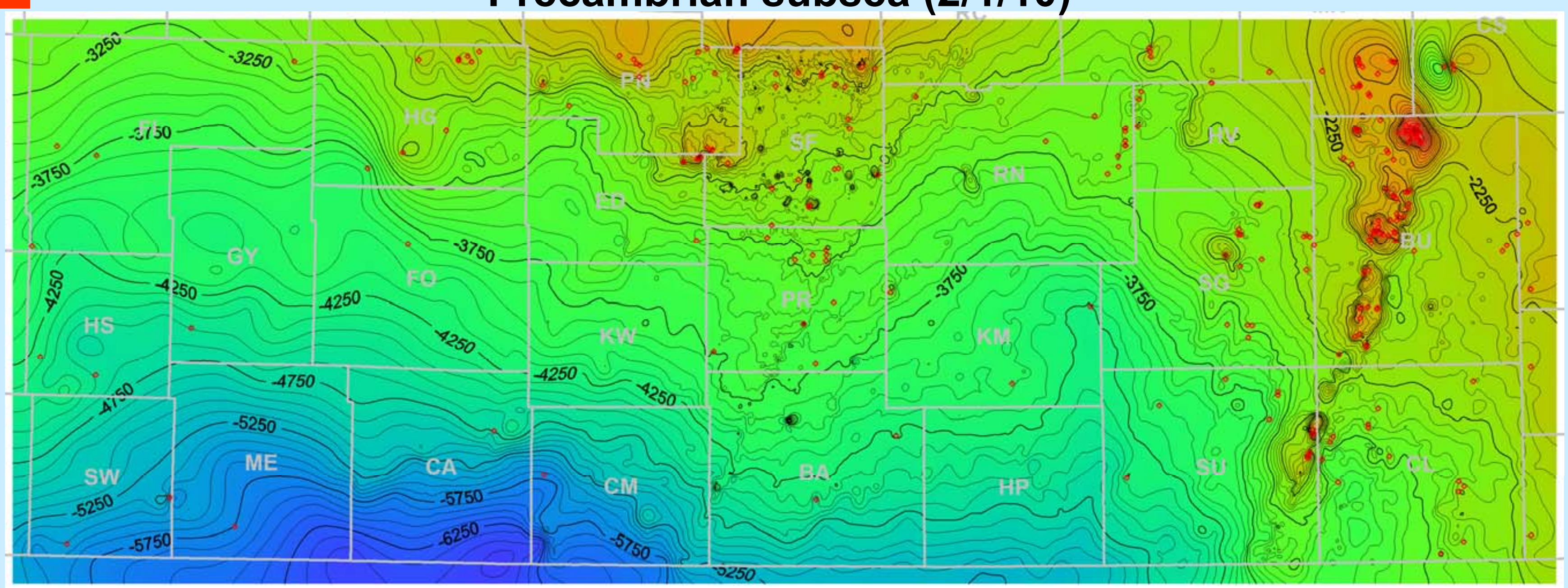
Work in Progress

Top Arbuckle subsea (2/1/10) – regional study area, Bittersweet Energy subcontractor



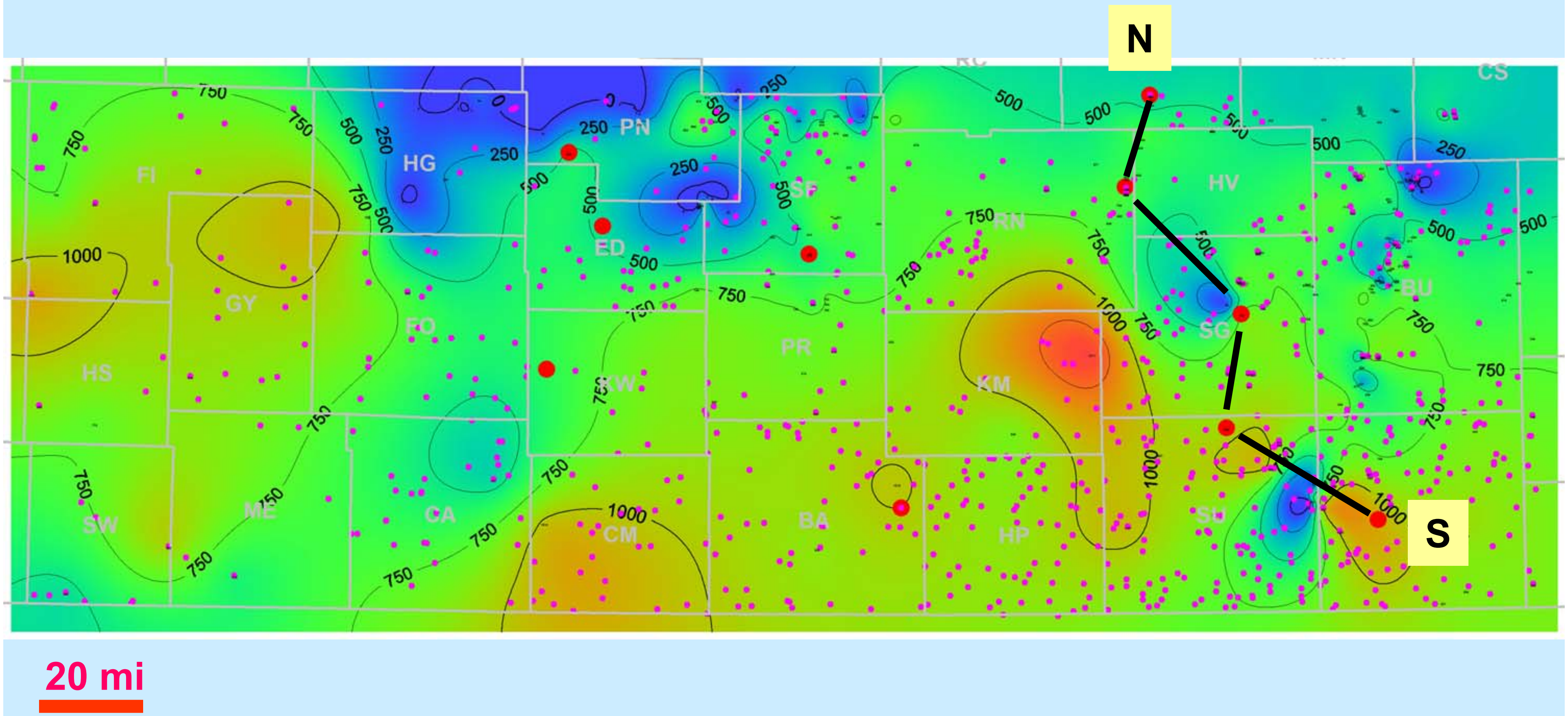
20 mi

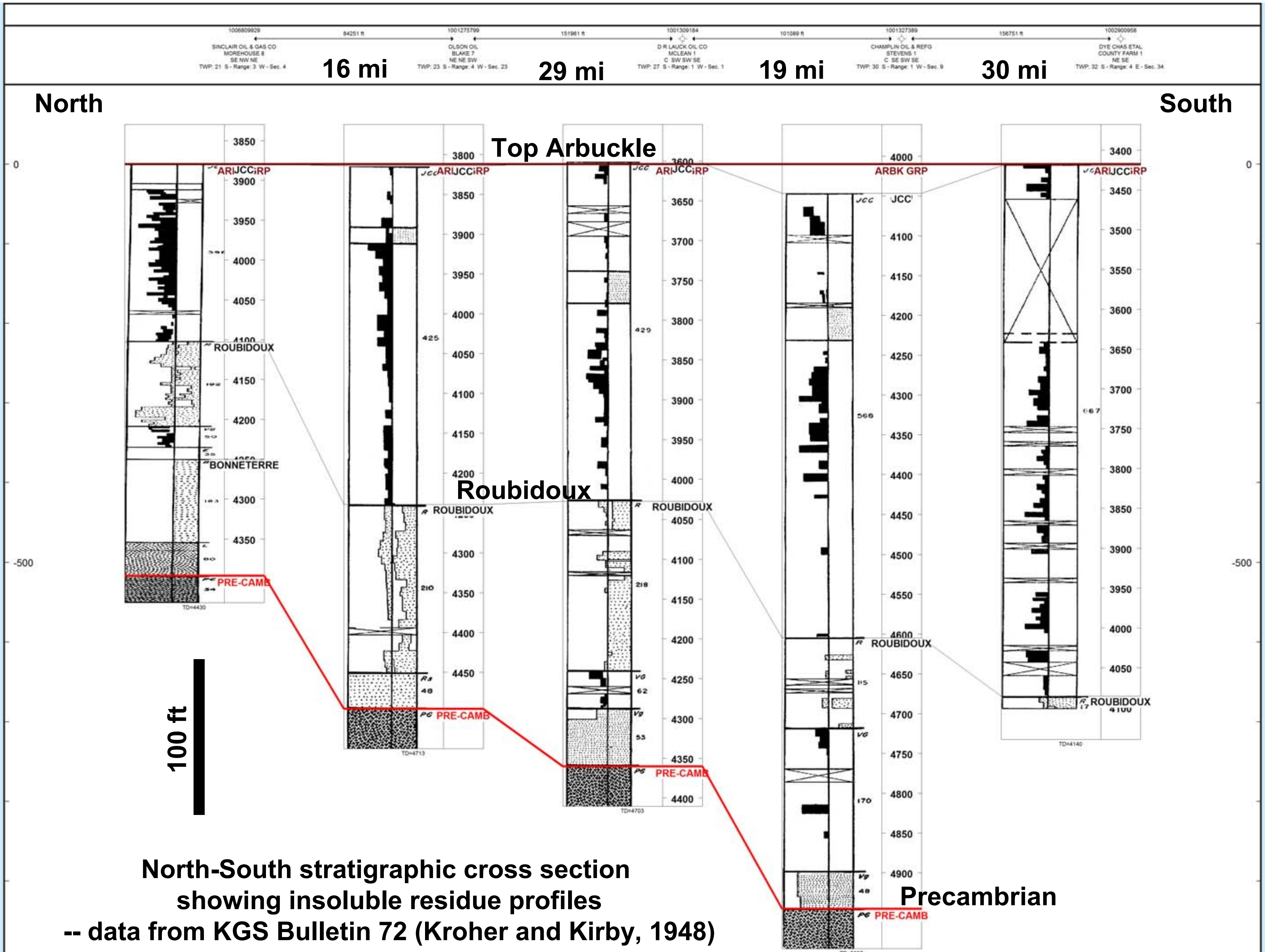
Precambrian subsea (2/1/10)



Work in Progress

Arbuckle Isopach based on key wells (small magenta dots)
Insoluble Residue Wells (large red dots) with index for cross section (2/1/10)
Bittersweet Energy subcontractor





North-South stratigraphic cross section
showing insoluble residue profiles
-- data from KGS Bulletin 72 (Kroher and Kirby, 1948)
index on previous map