Reservoir Engineering Aspects of Pilot Scale CO_2 EOR Project in Upper Mississippian Formation at Wellington Field in Southern Kansas*

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Abstract

A DOE sponsored pilot-scale project has been funded in which 30,000 metric tons of CO_2 will be injected in the upper part of the Mississippian reservoir to verify EOR potential at Berexco Wellington Field in Sumner County, KS. The Mississippian Formation has generated a lot of interest from industry due to tertiary oil and gas recovery potential which became economically feasible in current conditions. Over 2.4 TCF gas and 278 MMBO have been produced in south-central Kansas from Mississippian reservoirs including 20 MMBO at Wellington Field. The main objective of this work is to evaluate reservoir properties, predict reservoir response, evaluate possible risks, and to propose the best CO_2 EOR scenario for the Mississippian reservoir at Wellington Field. Another objective is to test the feasibility for the CO_2 EOR of the larger scale. Mississippian cycles at Wellington Field consist of siliceous or cherty dolomites that range from dark argillaceous dolo-siltites to porous packstone lithofacies. Multicomponent 3D seismic (depth migrated and shear wave) interpretations are being incorporated with log and core data to produce a detailed 3D geological model. The data from this model was upscaled to produce a CMG compositional model. Predictive simulations, sensitivity studies, and historical matching of the water flooding and other stimulation activities in the field were performed with the CMG CMOST and GEM software.

Reference Cited

Doveton, J. and M. Fazelalavi, 2012, Well logs and analysis of Mississippian and Arbuckle: Kansas Geological Society, Lawrence, Kansas presentation at Kansas Geofest. Unpublished.

Website Cited

Kansas Geological Survey, Production plot and decline curve analysis: Website accessed November 22, 2013. http://www.kgs.ku.edu. http://chasm.kgs.ku.edu/Gemini/PlotProduction.html?sType=FIELD&sKID=1000152308

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Project Team

DOE-NETL Contract #FE0006821

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Abengoa Bioenergy : The Global Ethanol Company

Chris Standlee, Danny Allison, Tim Frazer

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Mike Taylor, Ross Black, George Tsoflias

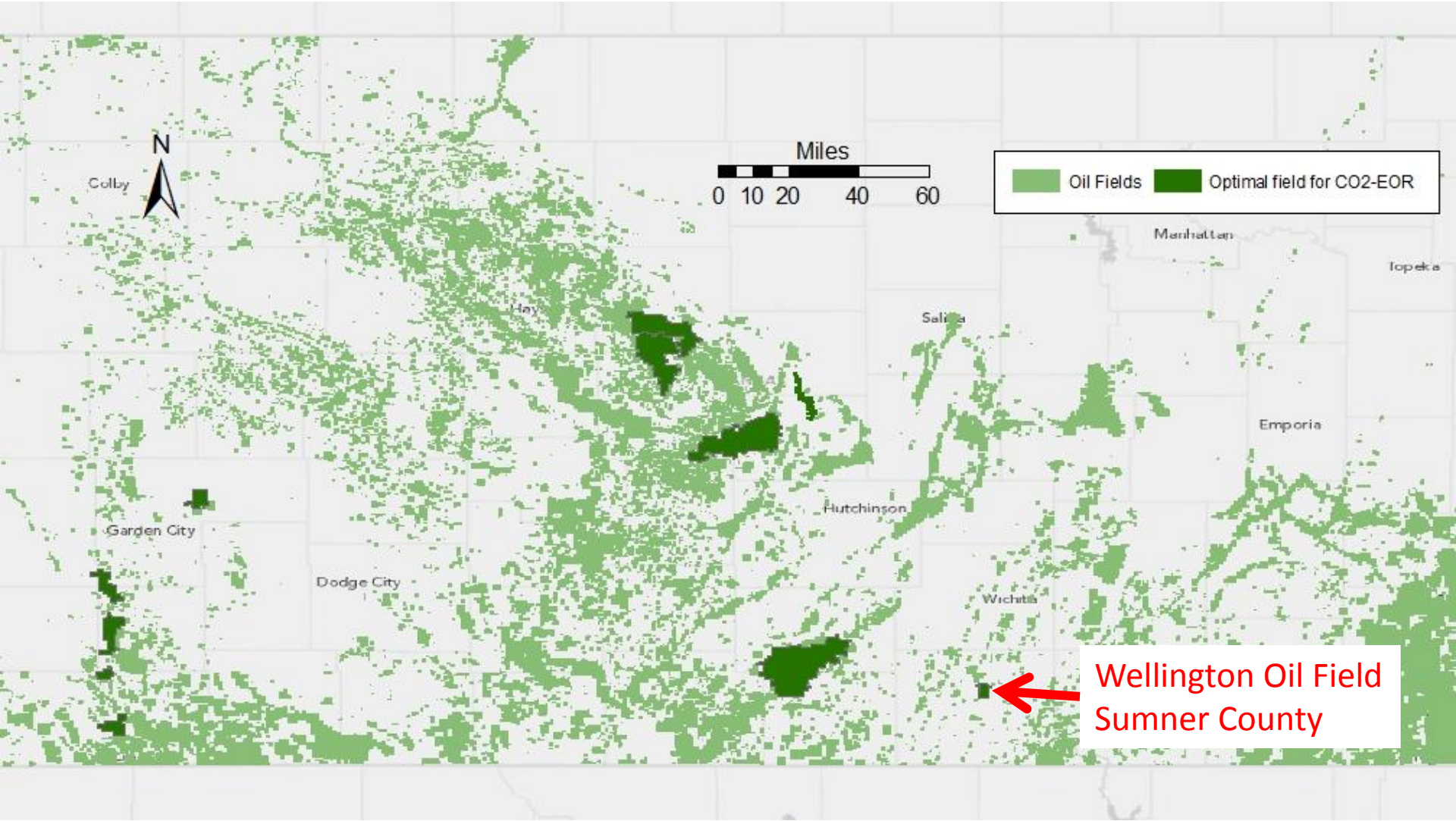
Sandia Technologies, LLC

Dan Collins, David Freeman

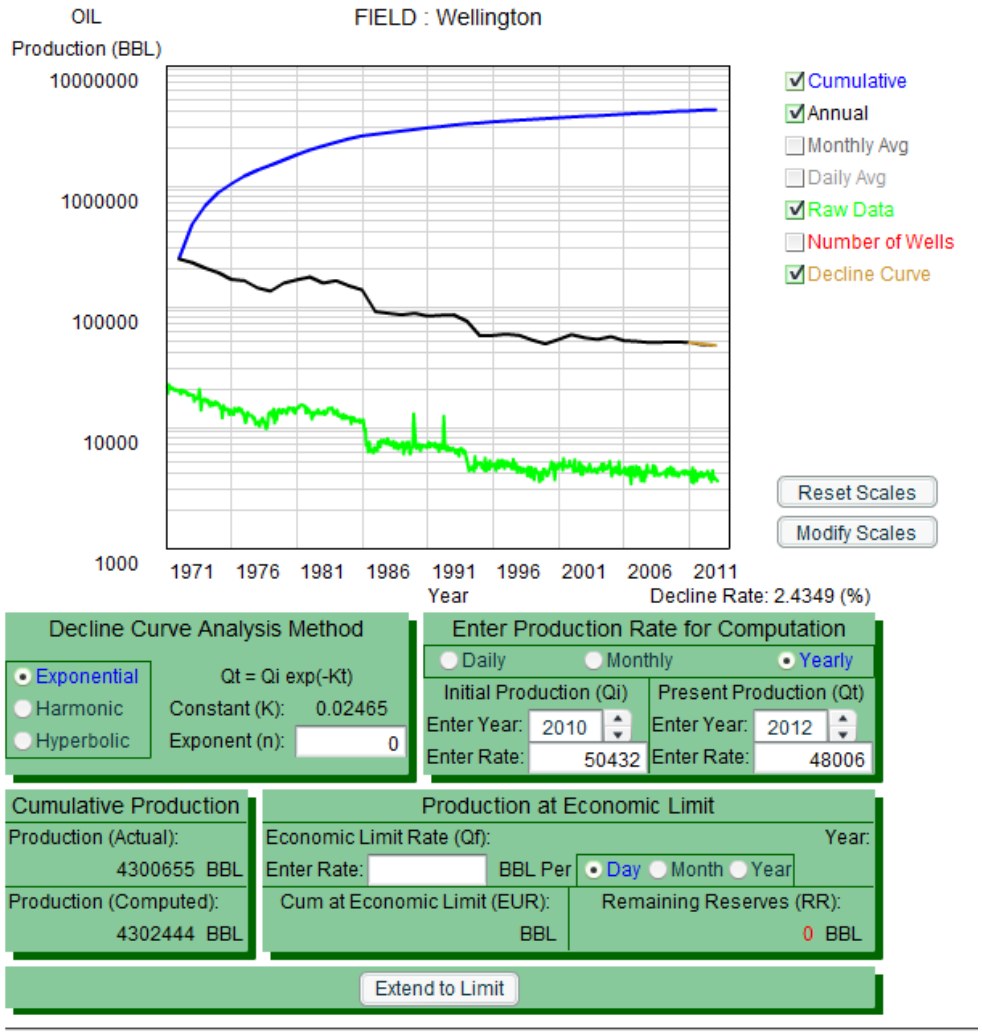
Project Objectives

- Negotiate cost of CO_2 with new source and commence field activities
- Begin injection of 30,000 metric tons of CO_2 into Mississippian oil reservoir at Wellington Field using 5-spot pattern to investigate the viability of CO_2 EOR in Kansas
- Demonstrate 99% assurance of CO_2 storage with MVA and modeling

Wellington Field

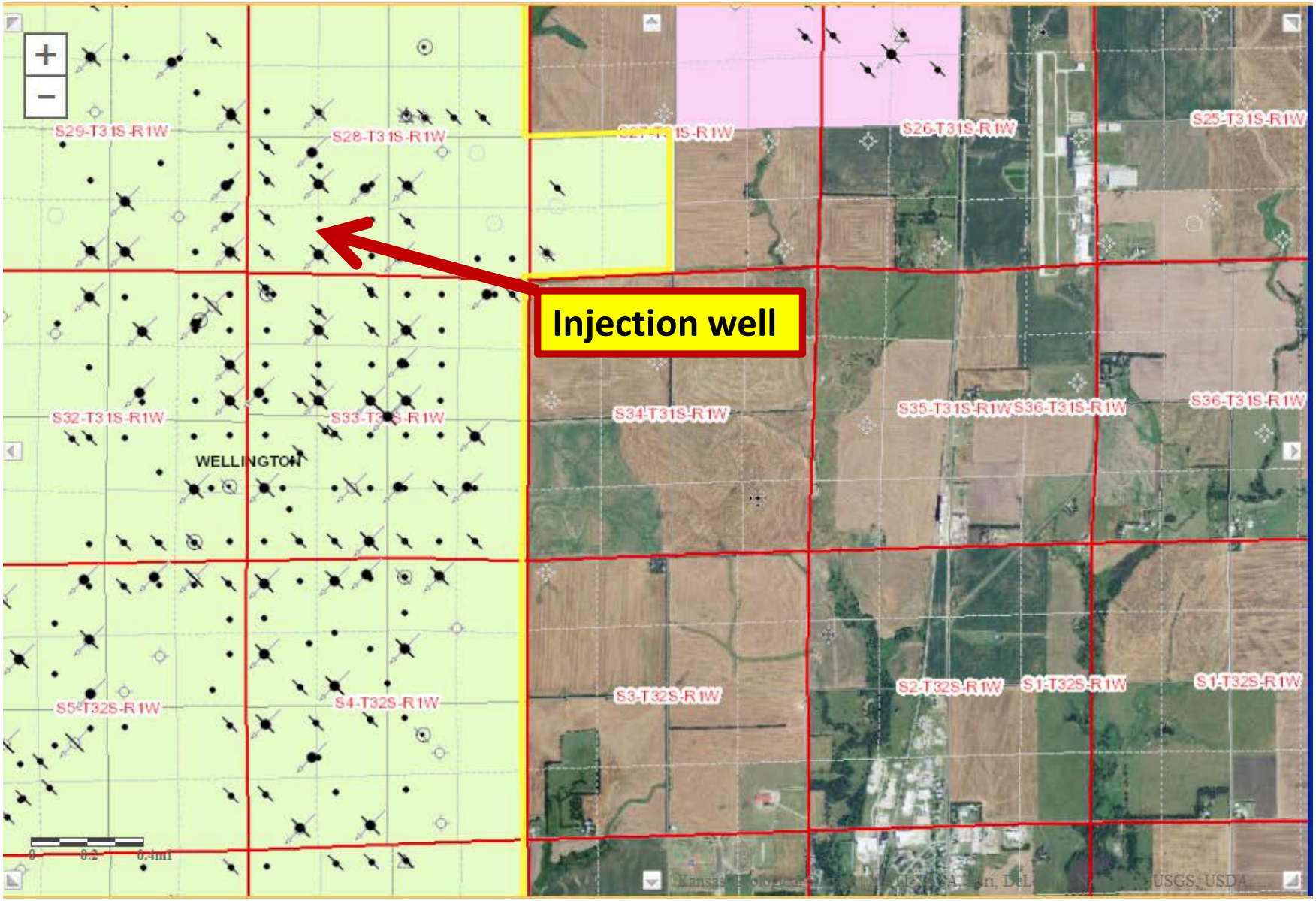


Wellington Field Production History



- http://chasm.kgs.ku.edu/Gemini/PlotProduction.html?sType=FIELD&sKID=1000152308

Wellington Field



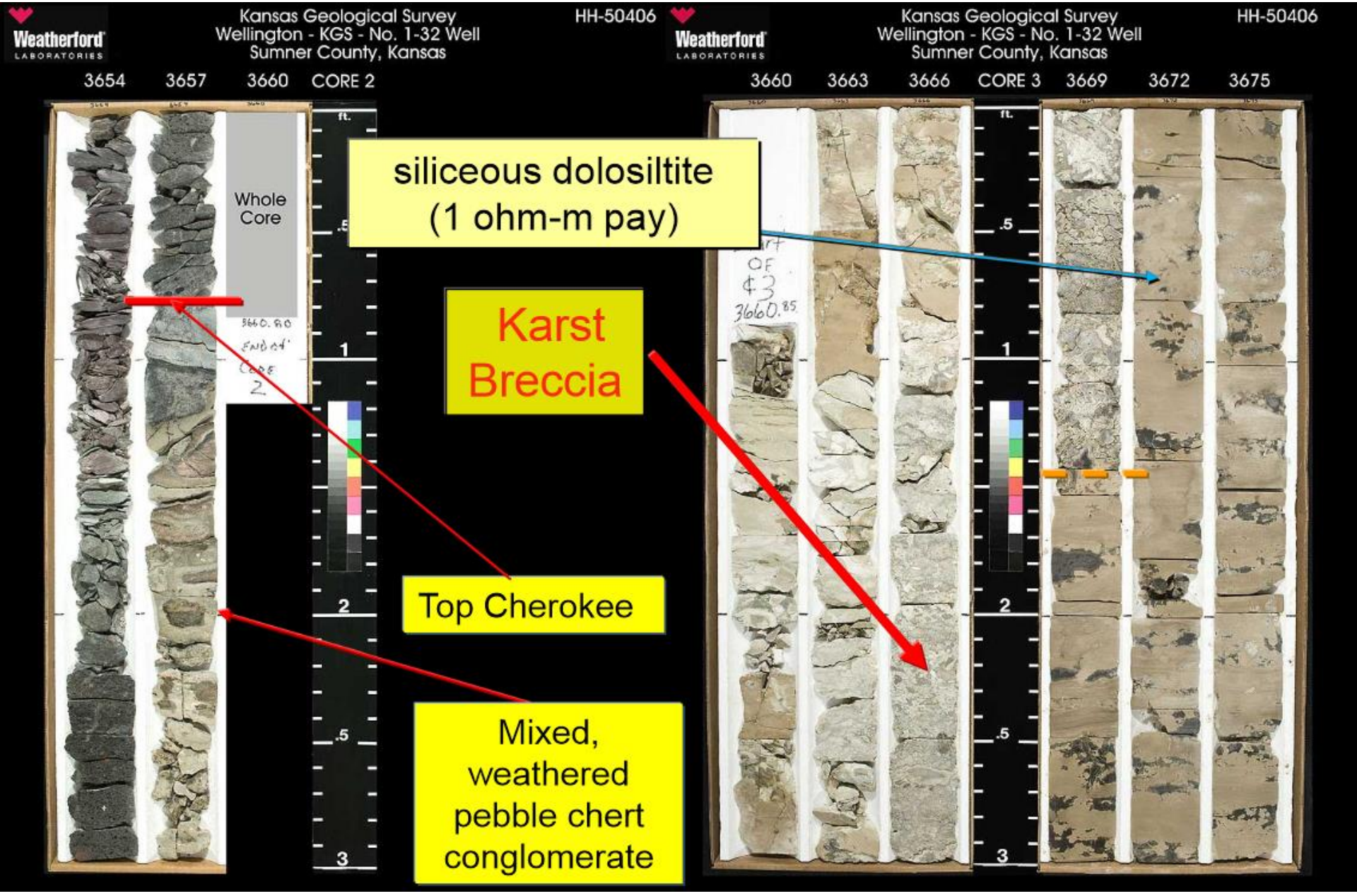
Wellington Field

- Located in S Kansas, Sumner County (T 31-R1W)
- Production started is 1929
- Water flooding started in early 1950s
- Production continues with very high water-cuts (up to 99. %)
- 3 lithofacies sequences:
  - Chat sand
  - Dolomitic sequence
  - Carbonate interval

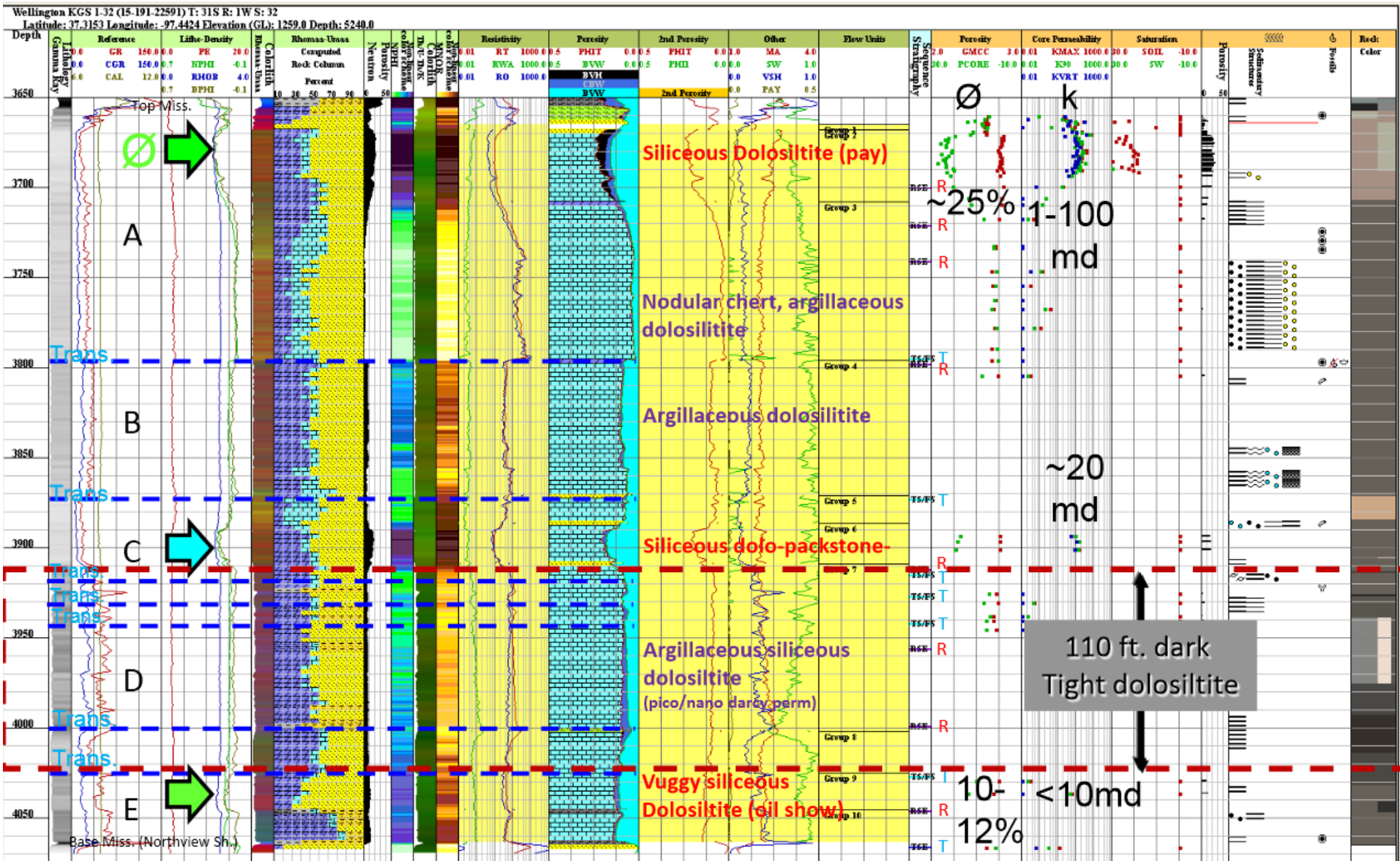
Data Availability

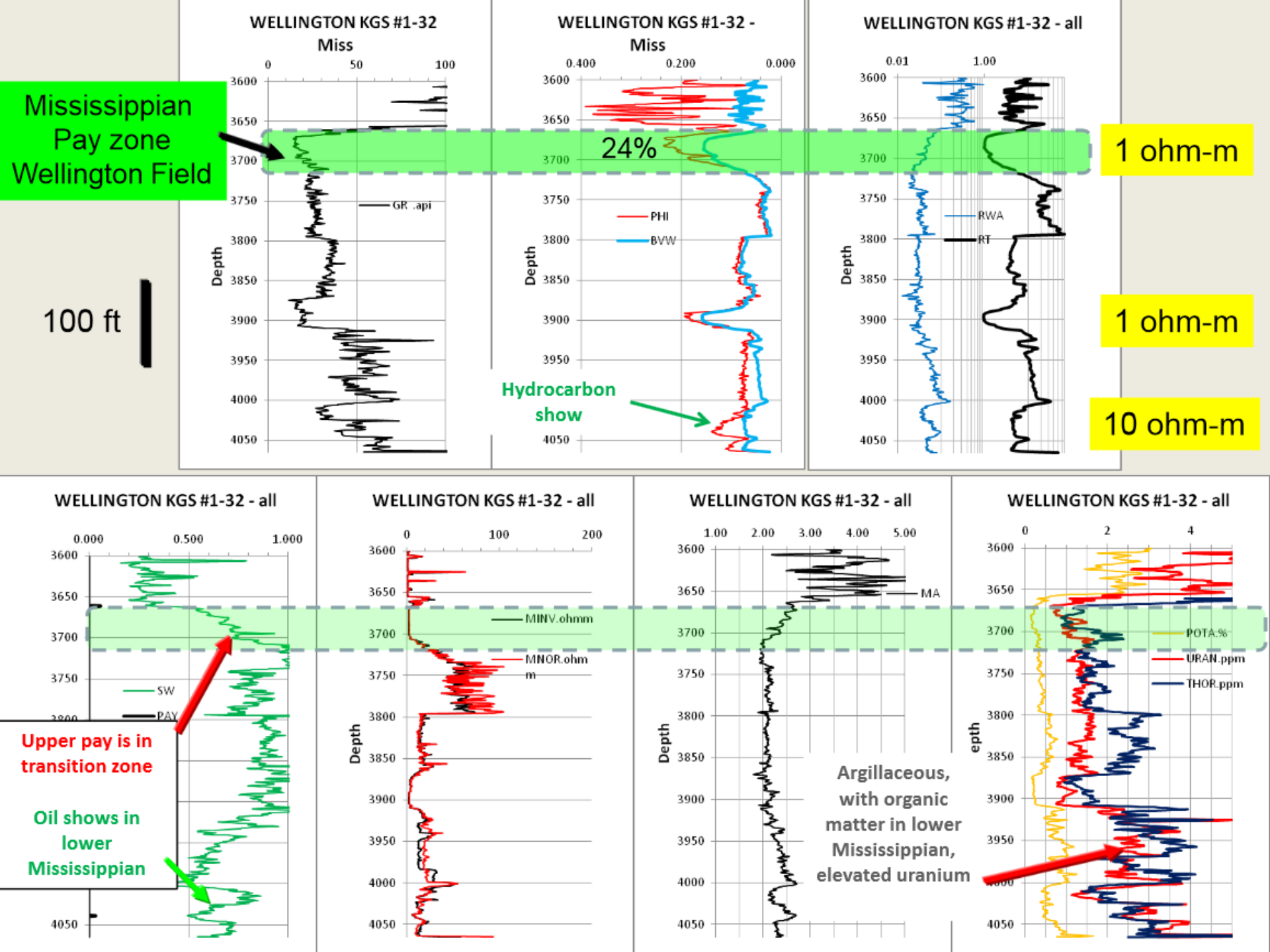
- Very old Neutron logs with or without resistivity logs for all wells
- 16 wells with complete suites of resistivity and porosity logs
- New wells drilled by KGS have a full set of modern logs
- Core is available from KGS #1-32
  - Porosity/permeability
  - Geochemistry
  - Geomechanical data
- 3D Seismic
- Formation fluids analysis

Mississippian Pay Zone Core



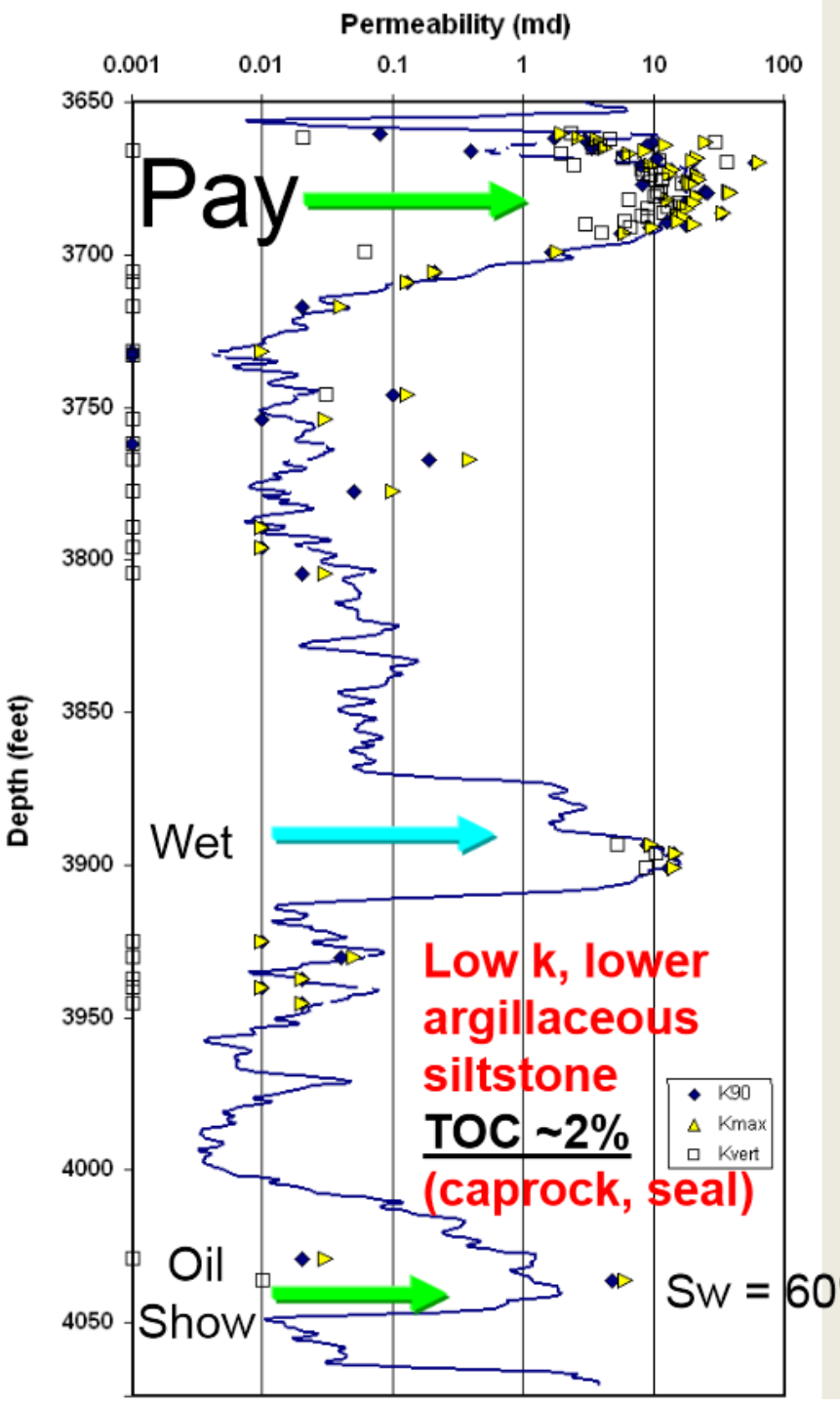
Cored Well, Berexco Wellington KGS#1-32
Top Mississippian to Kinderhook Shale (410 ft)




Mississippian
Pay zone
Wellington Field
100 ft
WELLINGTON KGS #1-32
Miss
GR .api
WELLINGTON KGS #1-32 -
Miss
PHI
BVW
24%
Hydrocarbon
show
WELLINGTON KGS #1-32 - all
RWA
RT
1 ohm-m
1 ohm-m
10 ohm-m
WELLINGTON KGS #1-32 - all
SW
PAY
Upper pay is in
transition zone
Oil shows in
lower
Mississippian
WELLINGTON KGS #1-32 - all
MINV.ohmm
MNOR.ohm
m
WELLINGTON KGS #1-32 - all
MA
Argillaceous,
with organic
matter in lower
Mississippian,
elevated uranium
WELLINGTON KGS #1-32 - all
POTA.%
URAN.ppm
THOR.ppm
Depth

Permeability profile entire Mississippian

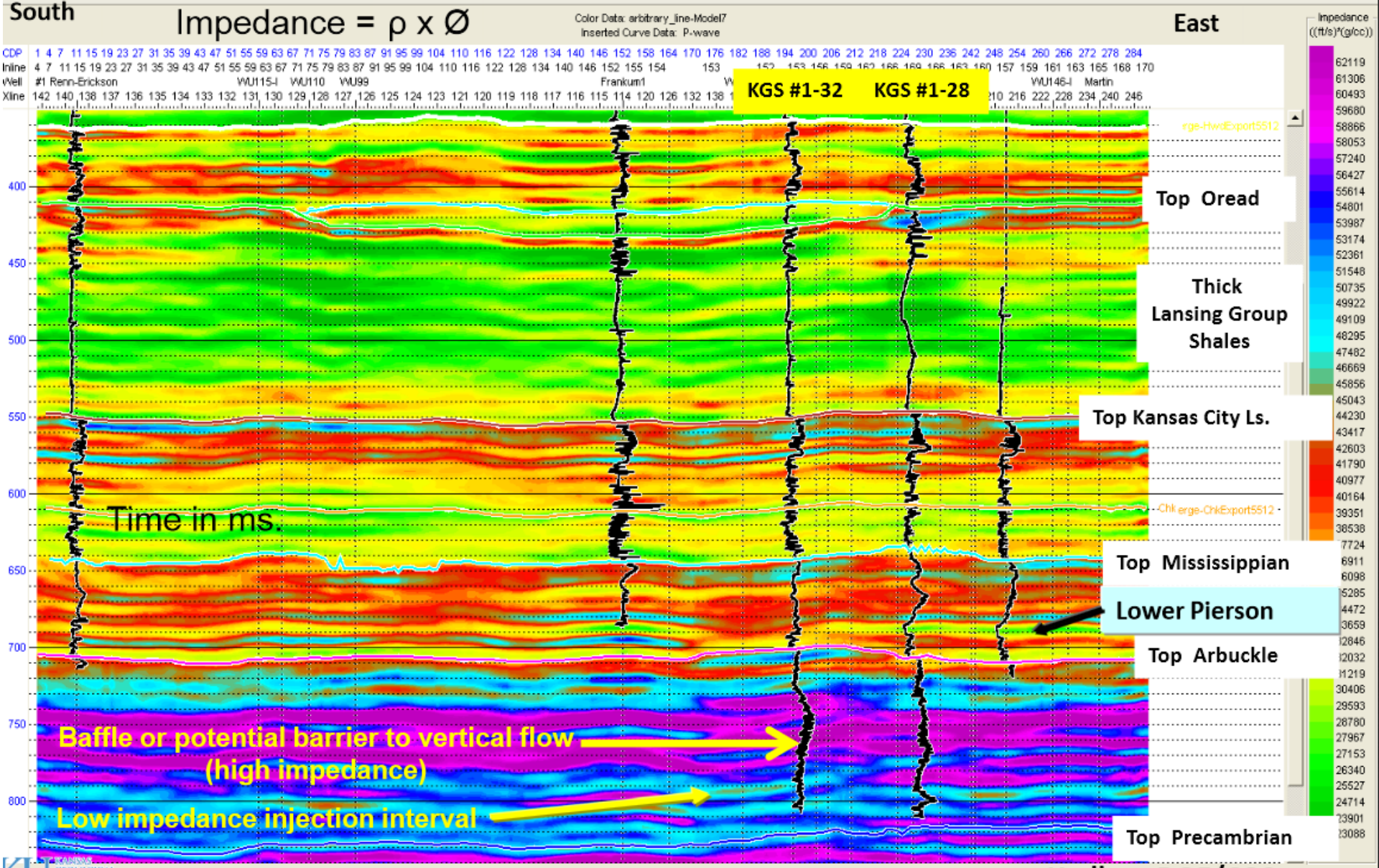
KGS #1-32 Wellington : Estimation of permeability based on *magnetic resonance imaging (MRIL^{tm})* using porosity and T2 center-of-gravity versus core Kmax, K90, and Kvert core permeabilities



Doveton & Fazelalavi, July 2012

Arbitrary seismic impedance profile – Wellington Field

distinct caprock, mid-Arbuckle tight, lower Arbuckle injection zone

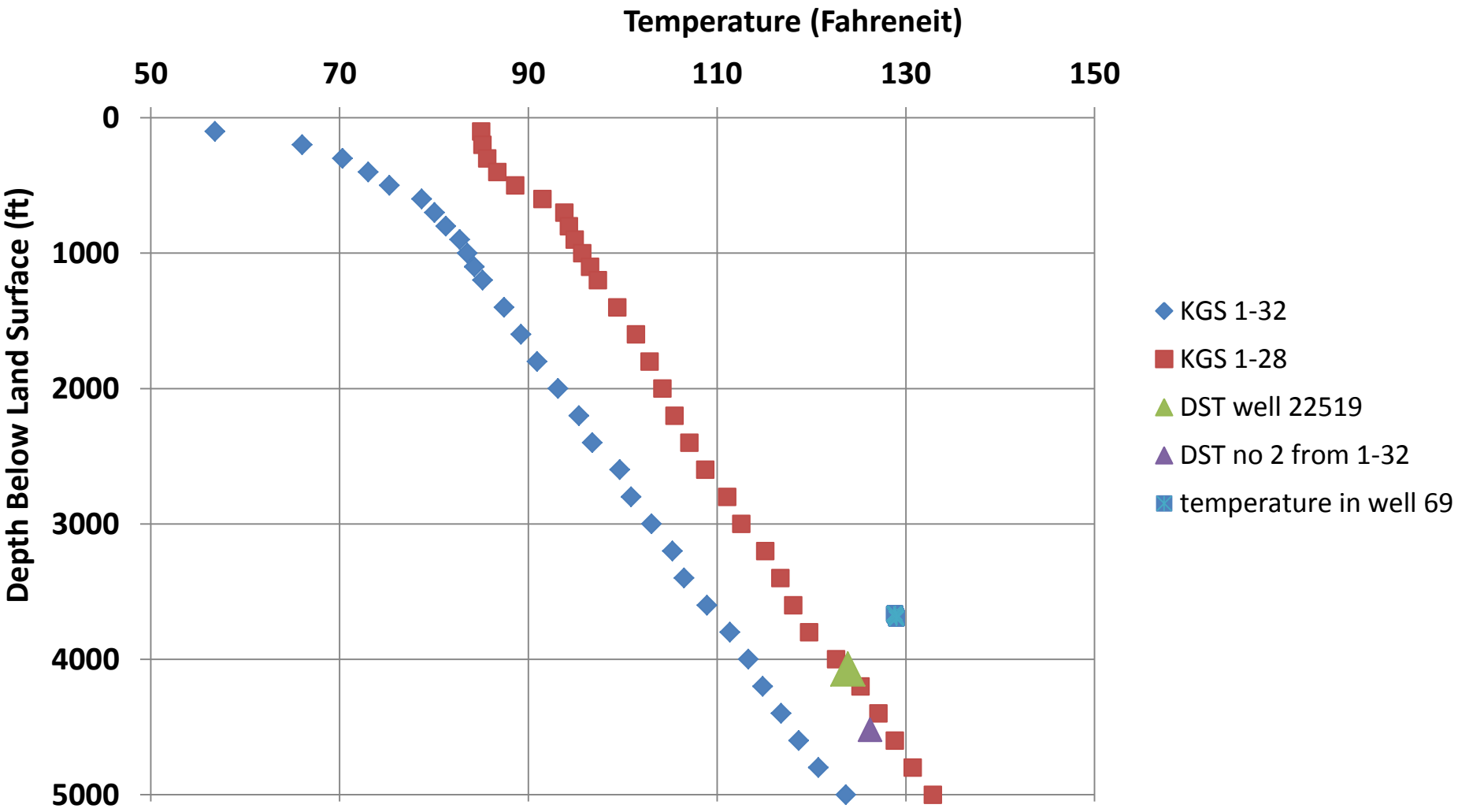


Hedke – DOE/CO2

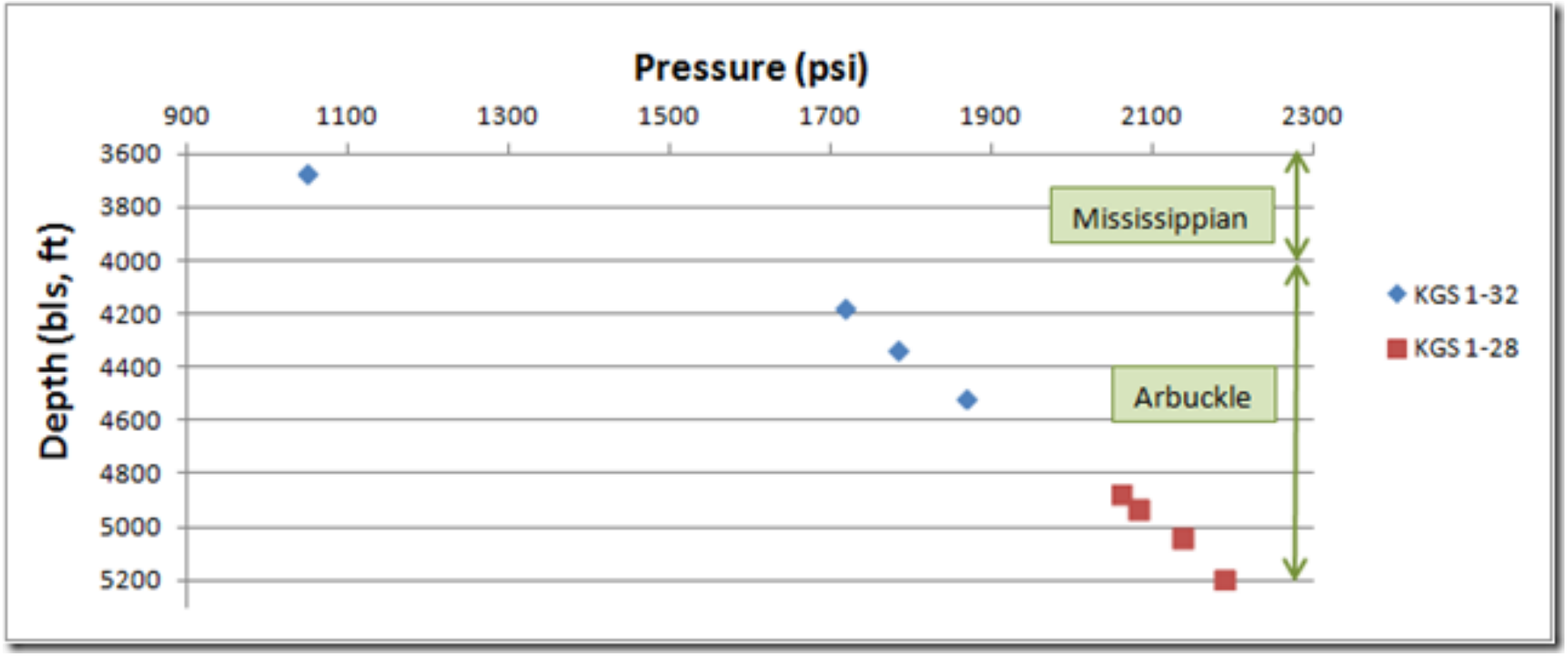
Log and Core Data Analysis

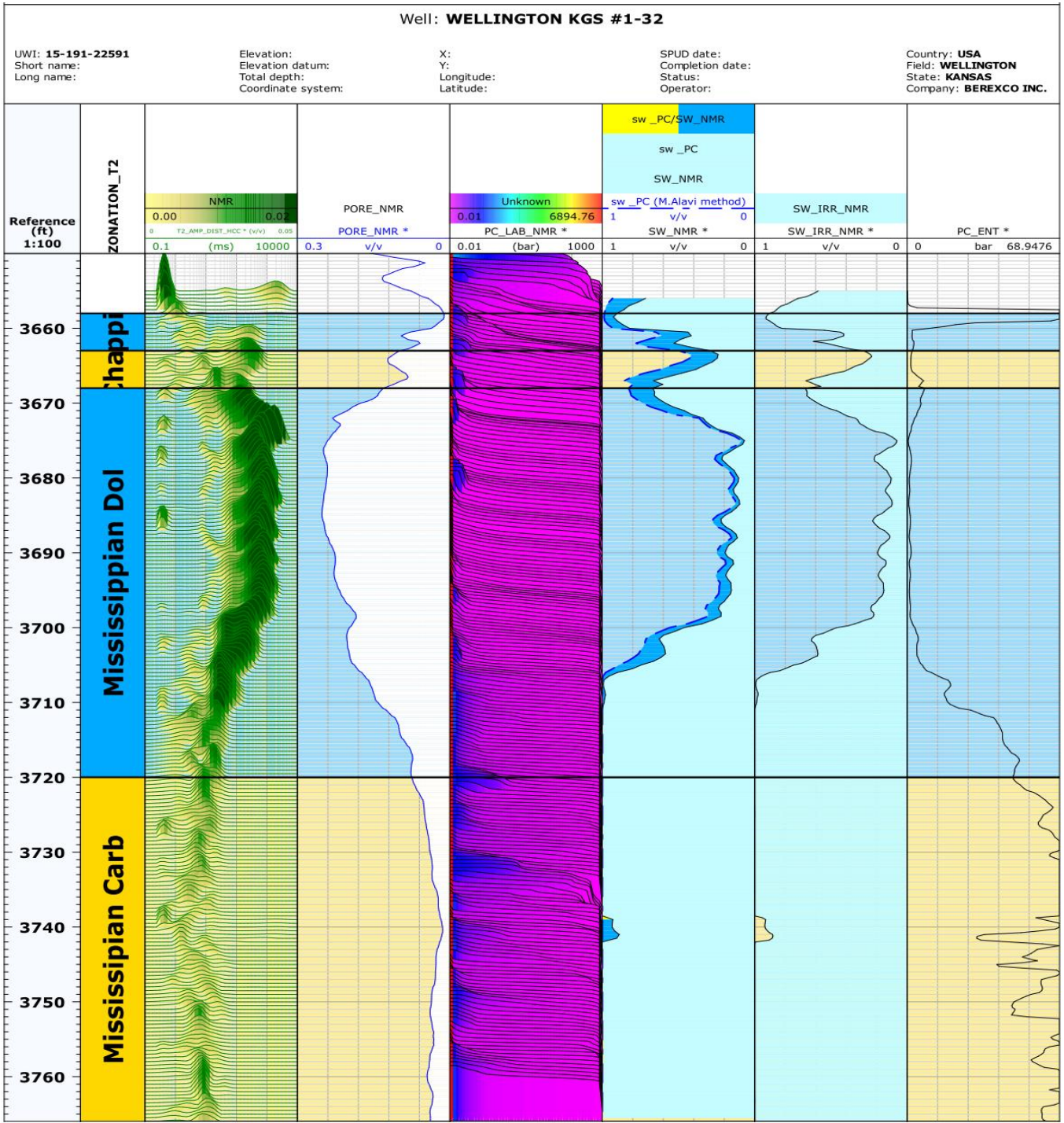
- Routine core analysis
  - Porosity
  - Permeability (max and 90°)
  - Matrix density
  - Interval: 3657 - 3801
- 6 Discrete Rock Types were determined
- NMR log was analysed by TechLog
  - Porosity
  - Irreducible water saturation
  - CO_2 Entry pressure
  - Capillary pressure

Reservoir Temperature



Reservoir Pore-Pressure

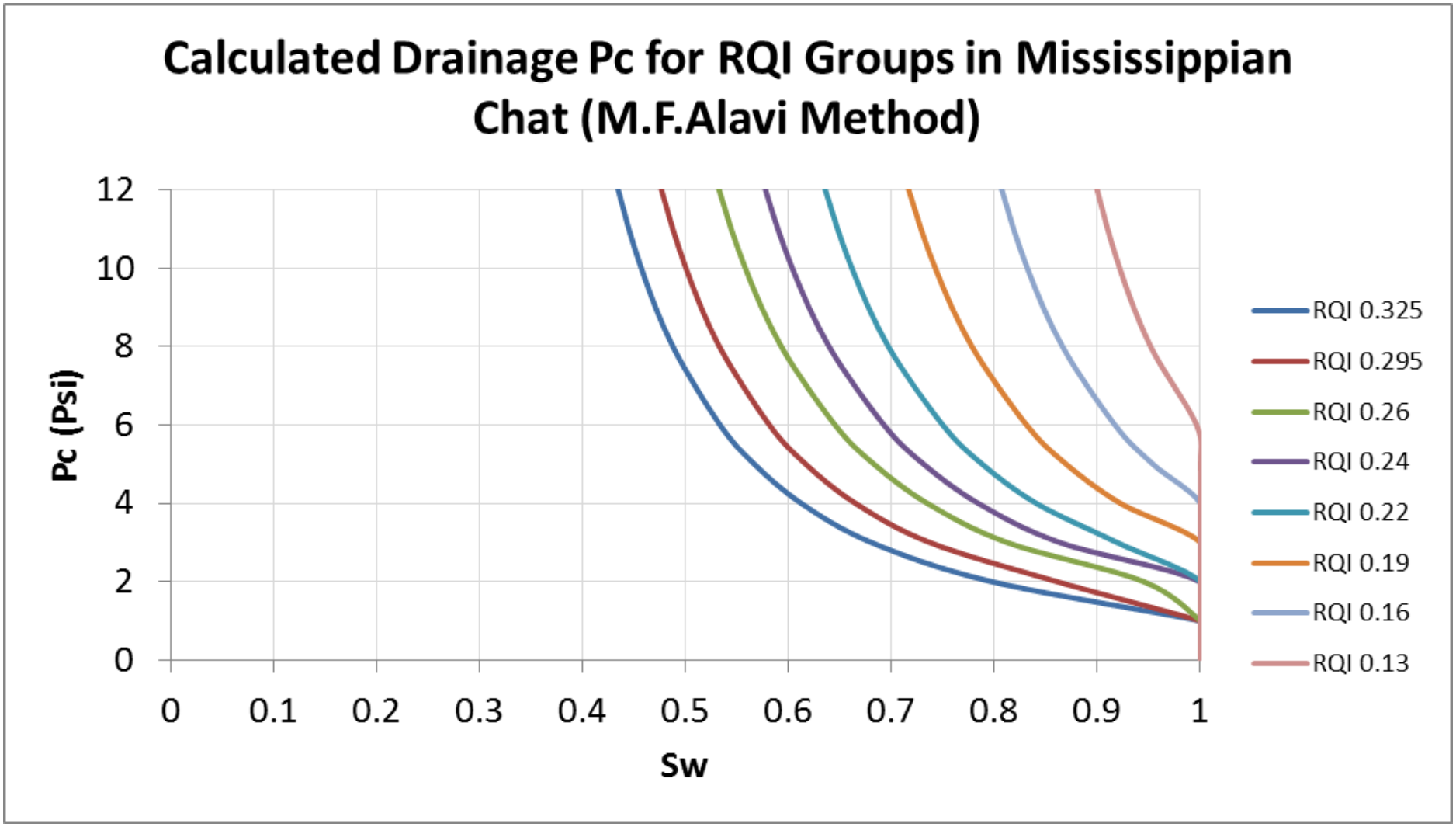




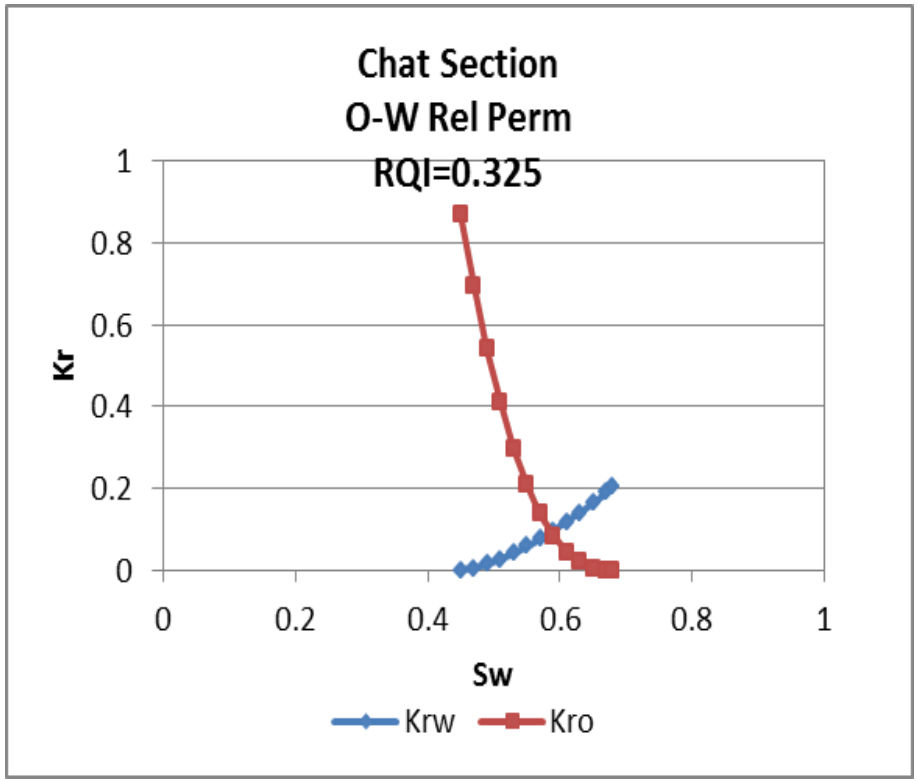
Calculated initial water saturation

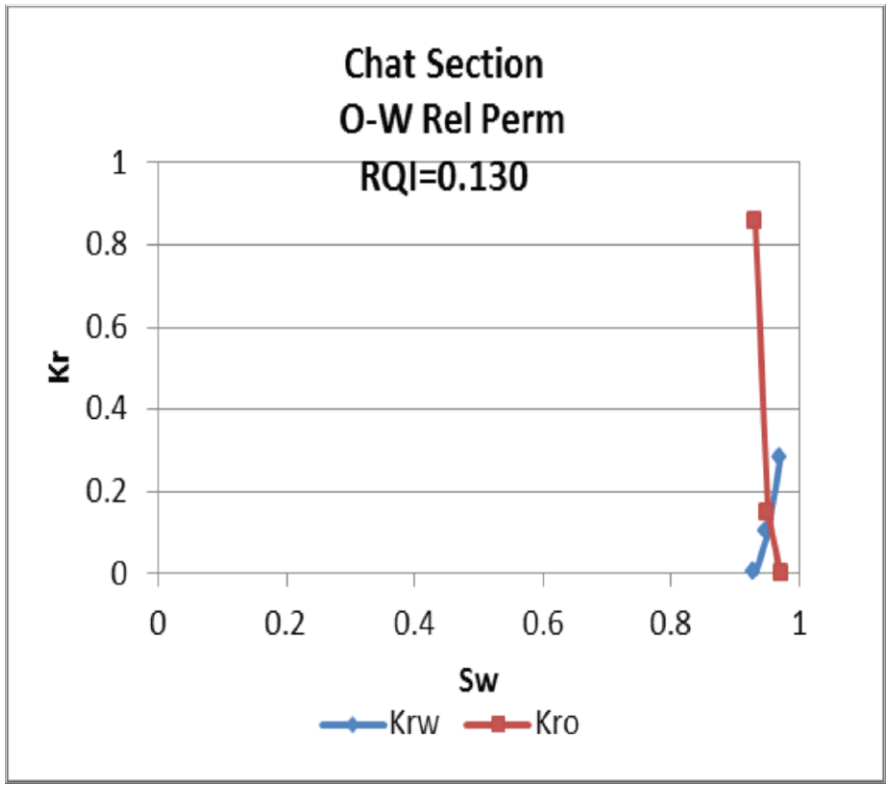
Water Composition

	mg/l			mg/l
PH	5.92		Ni	0.01
Li	3.90		Cu	0.09
Na	58000.00		Ag	0.04
K	702.00		Zn	1.78
Be	0.00		Al	0.10
Mg	1890.00		Pb	0.18
Ca	11300.00		F	10.00
Sr	417.00		Cl	119000.00
Ba	0.73		Br	464.00
Cr	0.02		CO3	42.00
Mn	0.89		P	0.02
Fe	0.29		Se	0.02
Co	0.01		SO4	703.00

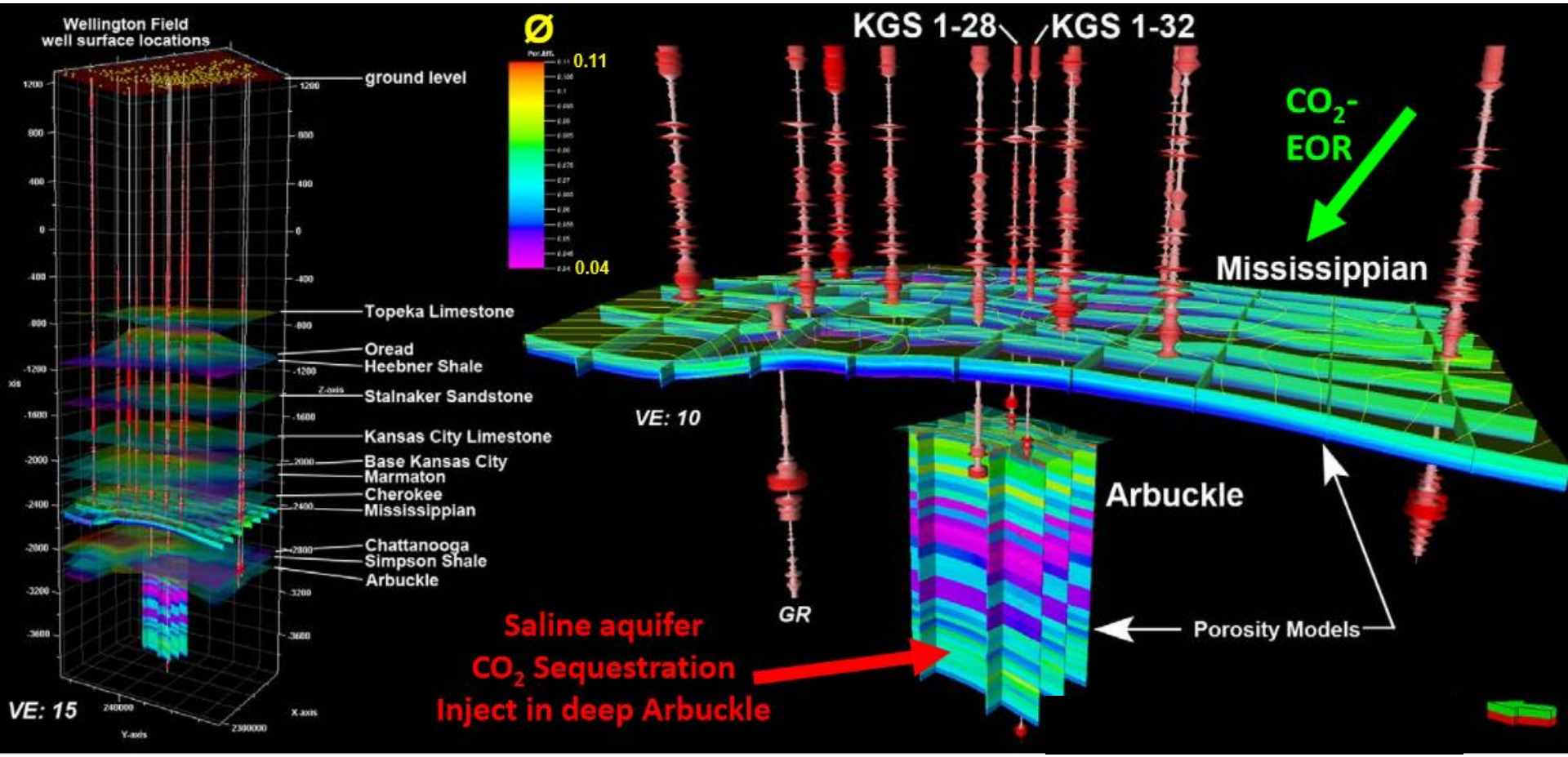

Calculated Drainage Pc for RQI Groups in Mississippian Chat (M.F.Alavi Method)
Pc (Psi)
12
10
8
6
4
2
0
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Sw
RQI 0.325
RQI 0.295
RQI 0.26
RQI 0.24
RQI 0.22
RQI 0.19
RQI 0.16
RQI 0.13

Relative Permeability Curves

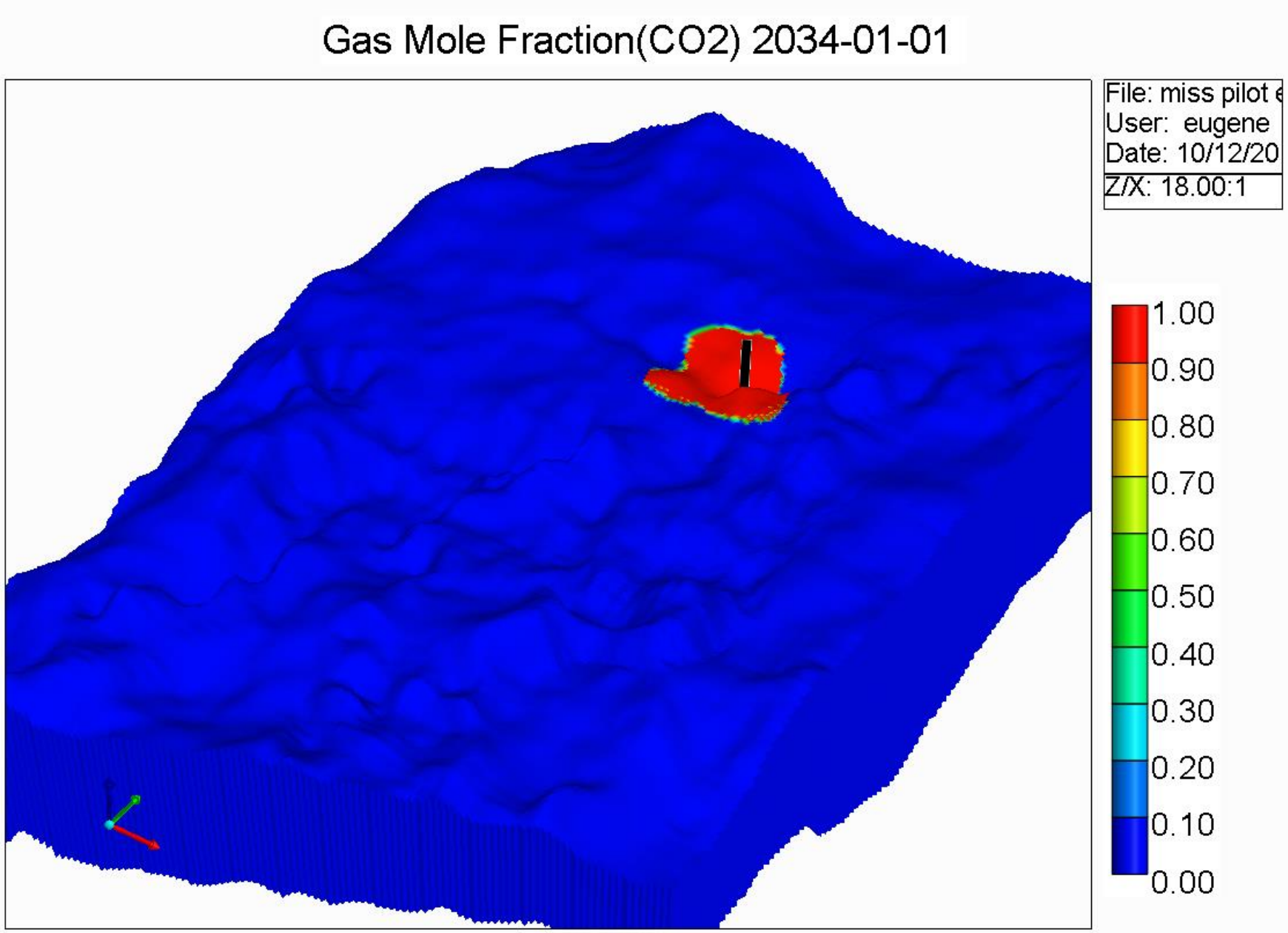




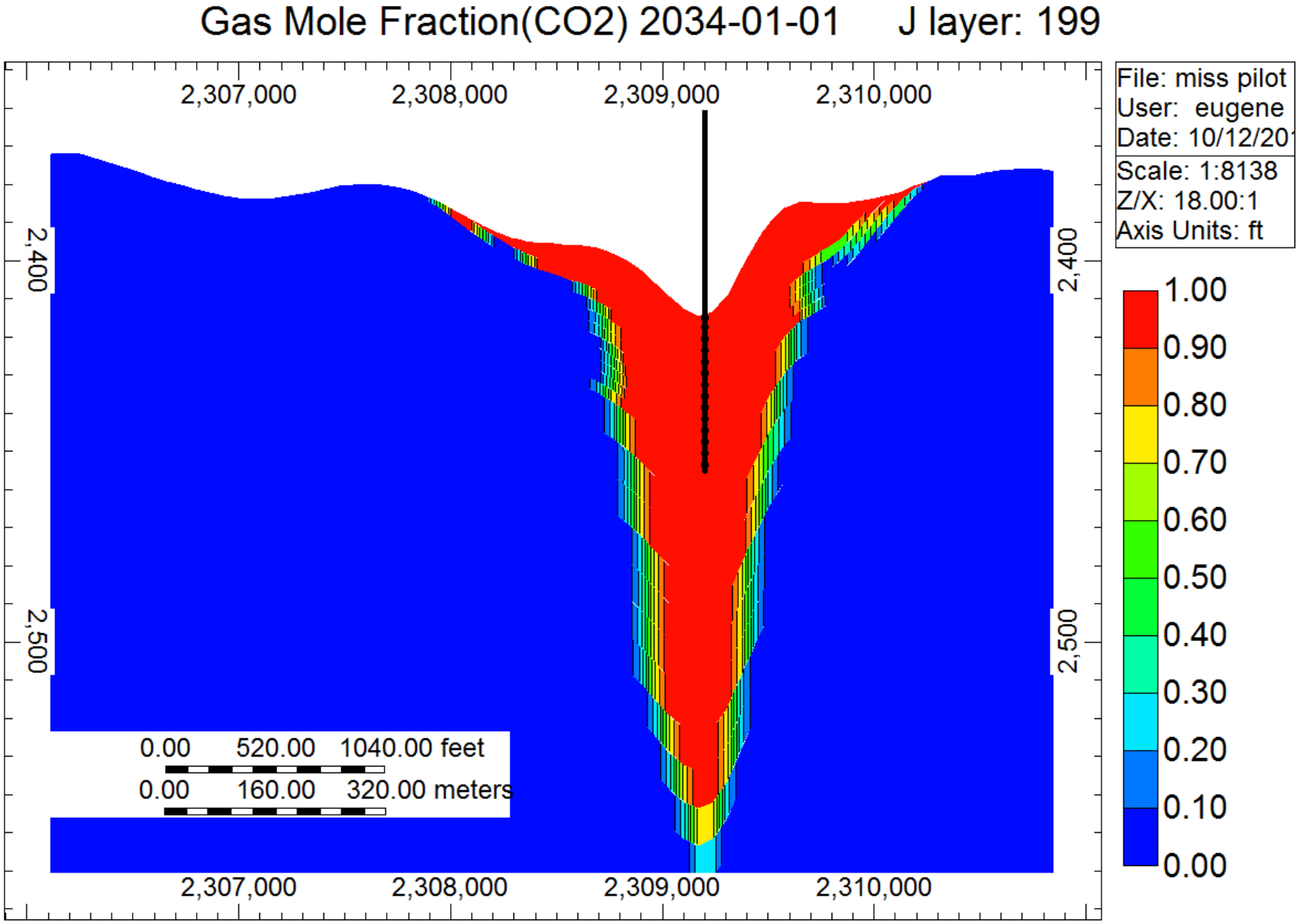
Wellington Field – Geological Model



Initial Dynamic Simulations



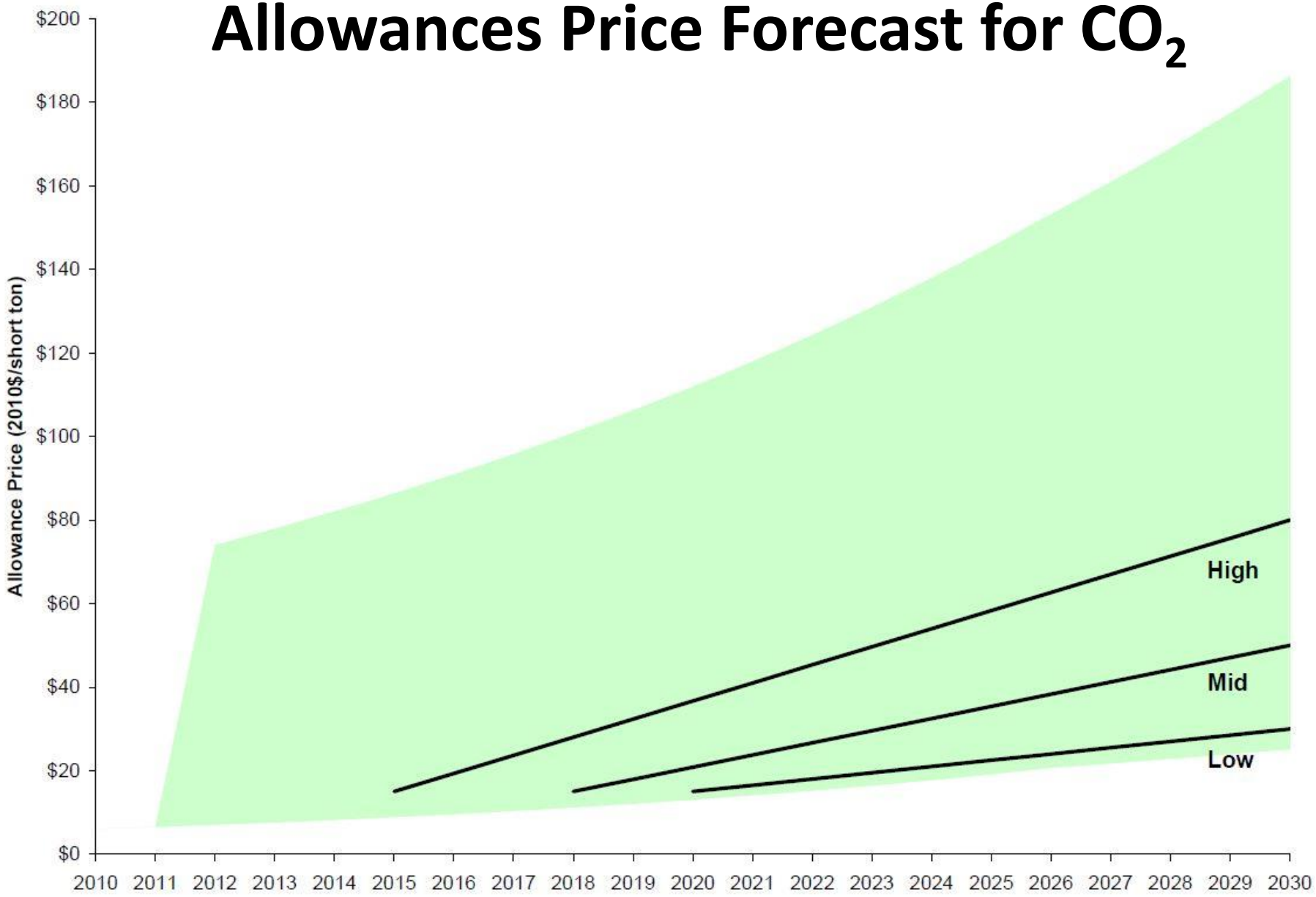
Initial Dynamic Simulations



Future Directions

- Implementation of the miscibility data
- Production and water-flood history matching
- Predictive modeling for CO_2 EOR
  - Engineering optimization
  - Accounting for CO_2

Allowances Price Forecast for CO_2



Questions?