CARBON CAPTURE, UTILIZATION & STORAGE CONFERENCE

JUNE 14-16, 2016 | SHERATON TYSONS CORNER | TYSONS, VA

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Pilot Scale CO_2 EOR at Wellington Field in South-Central Kansas

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Mina Fazelalavi, and Dana Wreath

Participants

BEREXCO

KANSAS GEOLOGICAL SURVEY
The University of Kansas

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DEPARTMENT OF ENERGY · UNITED STATES OF AMERICA

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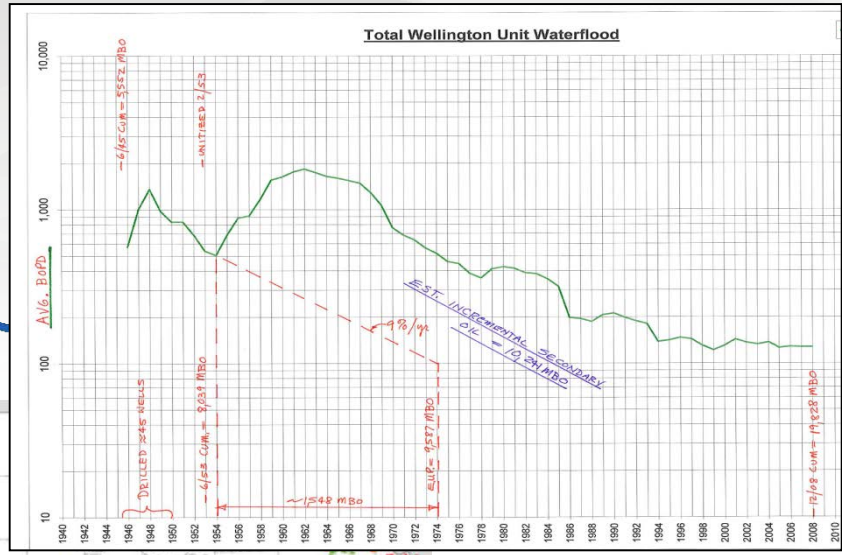
Core Lab
RESERVOIR OPTIMIZATION

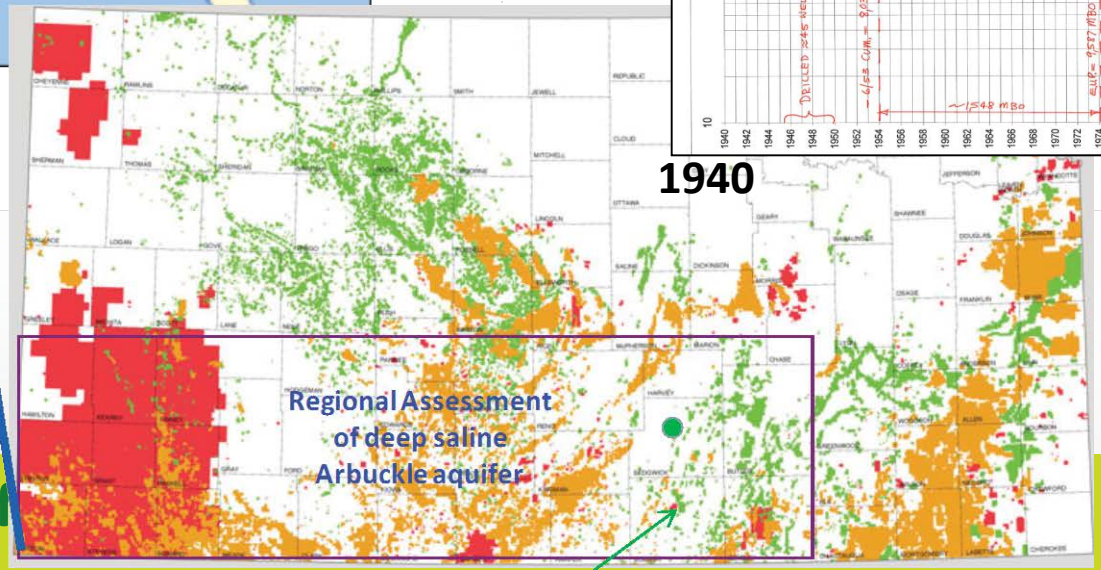
TRILOBITE TESTING, INC.

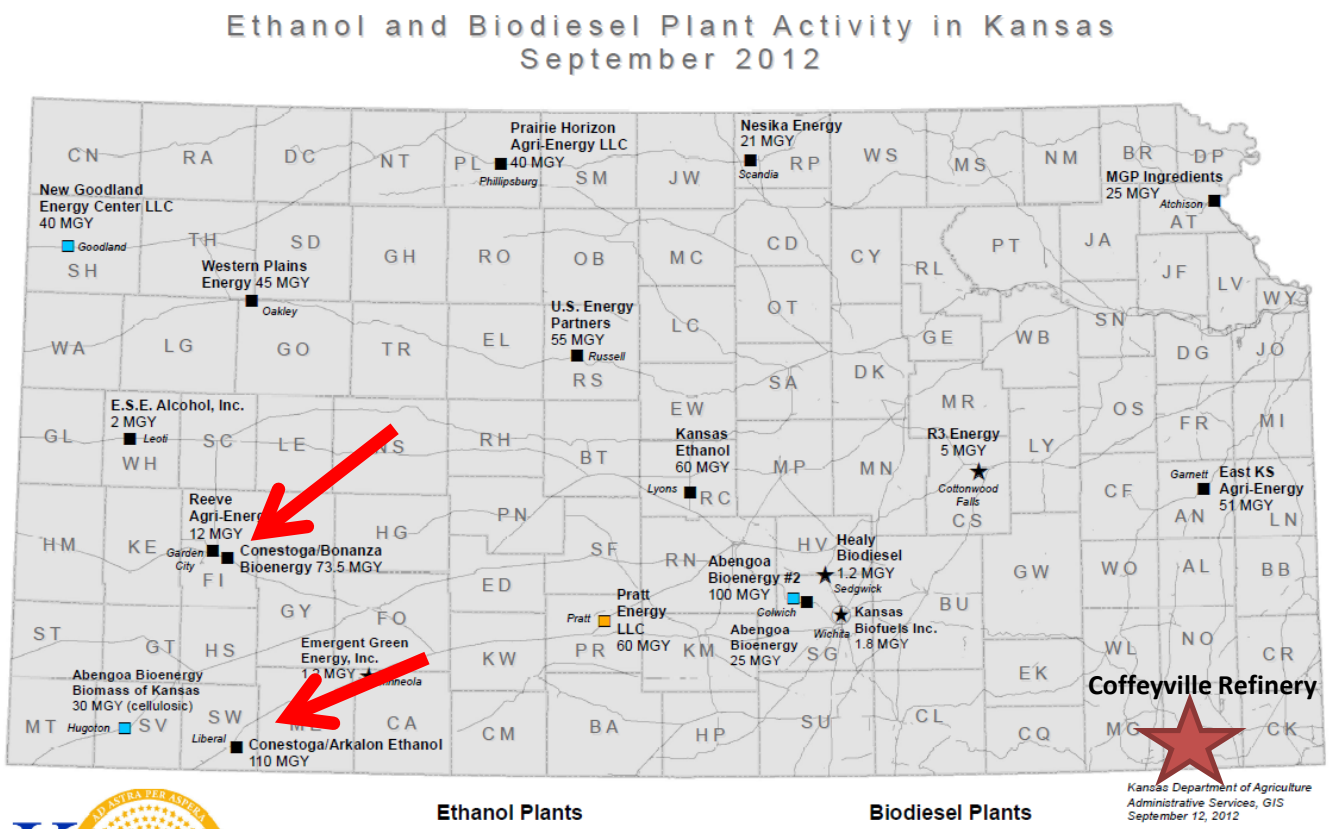
DEVILBISS CORING SERVICE, INC.

Schlumberger
Petrel

Wellington Field, South KS







CO_2 Sources Suitable for EOR

- Kansas holds more than **750 million barrels** of technical CO_2-EOR potential and **~240-370M** metric tons of CO2 is required for recovery
- Economic results based on Hall Gurney field suggest an after-tax project IRR of about 20%
- Access to the significant volumes of ethanol-based CO_2 in Nebraska

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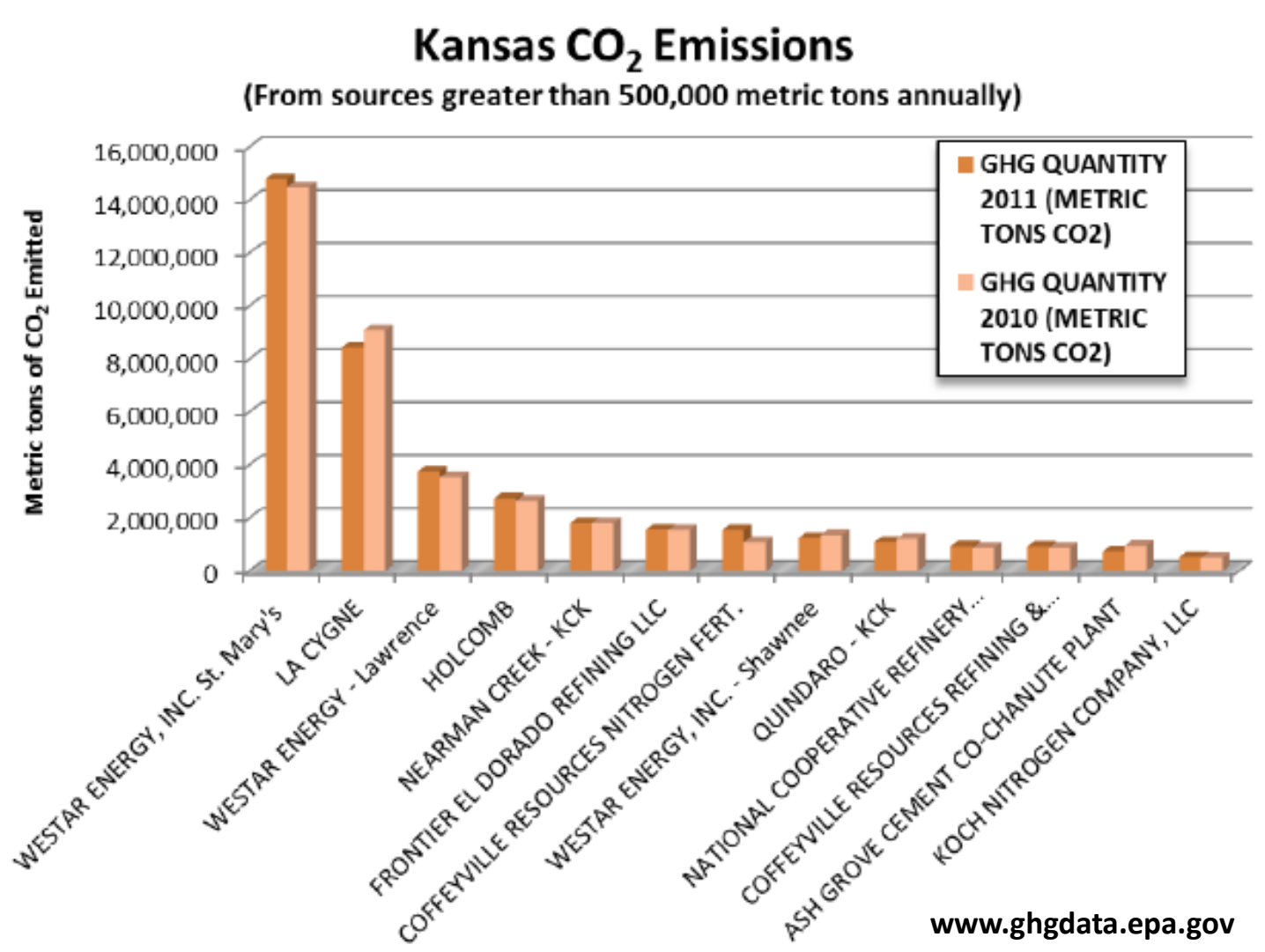

www.ghgdata.epa.gov

CO_2 Sources Suitable for EOR

- Total Kansas 2012 CO_2 emissions from point sources = 44.5M metric tons (846 BCF)/yr.

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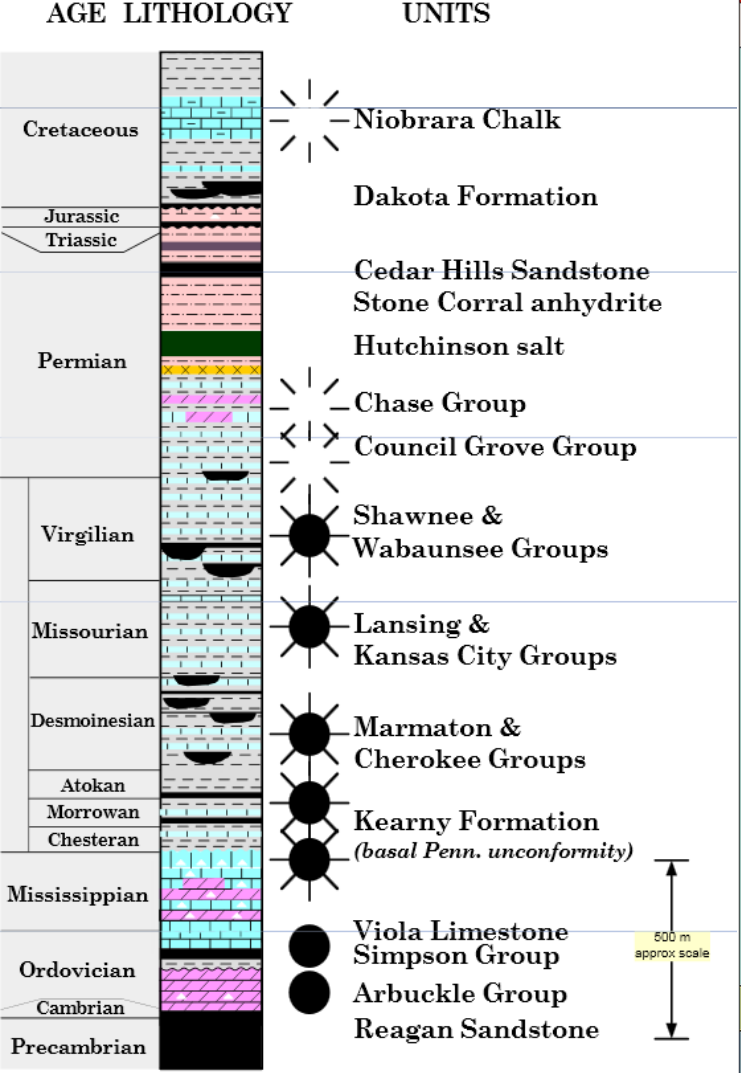
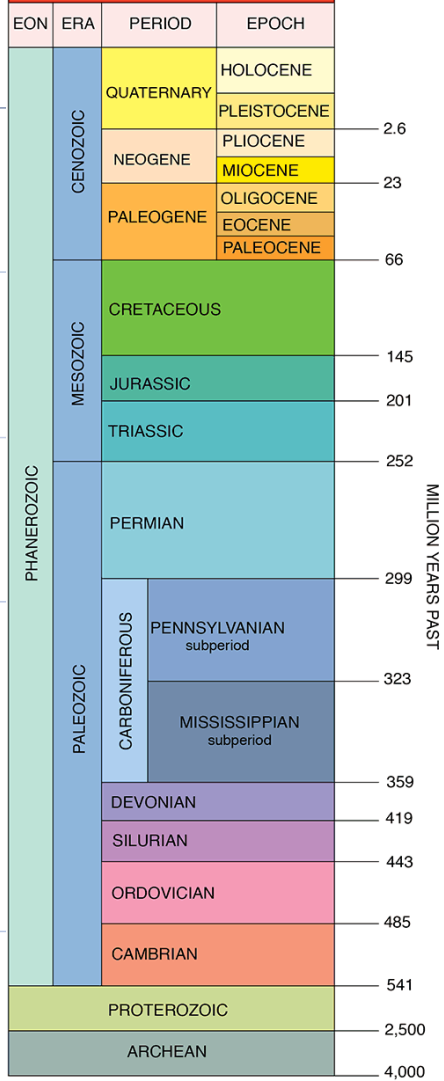
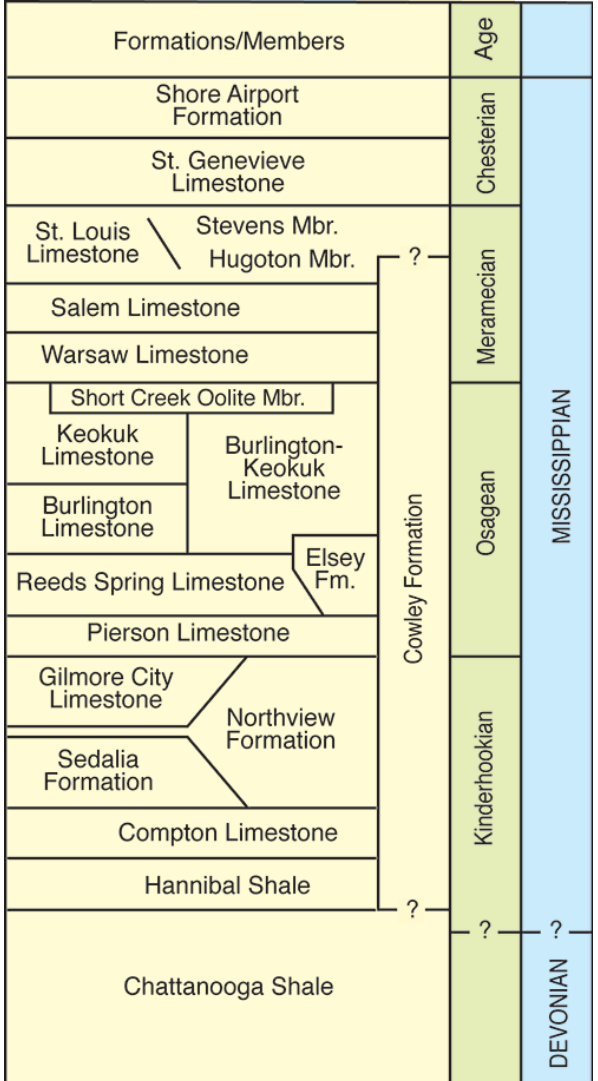
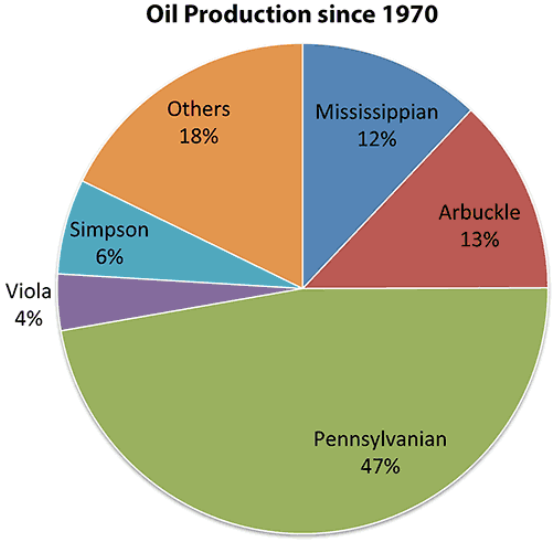
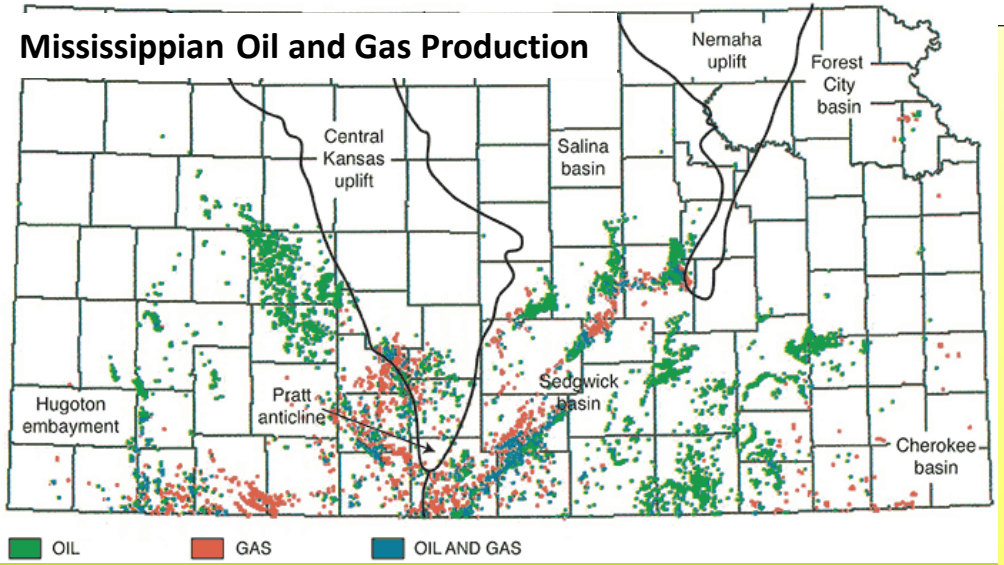

AGE LITHOLOGY UNITS
Cretaceous
Jurassic
Triassic
Permian
Virgilian
Missourian
Desmoinesian
Atokan
Morrowan
Chesteran
Mississippian
Ordovician
Cambrian
Precambrian
Niobrara Chalk
Dakota Formation
Cedar Hills Sandstone
Stone Corral anhydrite
Hutchinson salt
Chase Group
Council Grove Group
Shawnee & Wabaunsee Groups
Lansing & Kansas City Groups
Marmaton & Cherokee Groups
Kearny Formation
(basal Penn. unconformity)
Viola Limestone
Simpson Group
Arbuckle Group
Reagan Sandstone
500 m approx scale

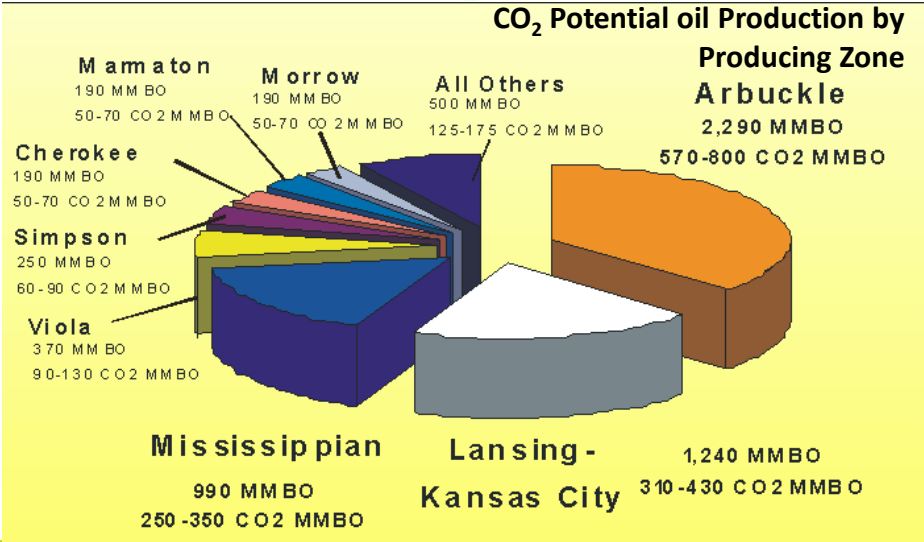

EON
ERA
PERIOD
EPOCH
PHANEROZOIC
CENOZOIC
MESOZOIC
PALEOZOIC
QUATERNARY
HOLOCENE
PLEISTOCENE
NEOGENE
PLIOCENE
MIOCENE
PALEOGENE
OLIGOCENE
EOCENE
PALEOCENE
CRETACEOUS
JURASSIC
TRIASSIC
PERMIAN
CARBONIFEROUS
PENNSYLVANIAN subperiod
MISSISSIPPIAN subperiod
DEVONIAN
SILURIAN
ORDOVICIAN
CAMBRIAN
PROTEROZOIC
ARCHEAN
2.6
23
66
145
201
252
299
323
359
419
443
485
541
2,500
4,000
MILLION YEARS PAST


Formations/Members
Age
Shore Airport Formation
St. Genevieve Limestone
Chesterian
St. Louis Limestone
Stevens Mbr.
Hugoton Mbr.
Salem Limestone
Warsaw Limestone
Meramecian
Short Creek Oolite Mbr.
Keokuk Limestone
Burlington Limestone
Burlington-Keokuk Limestone
Reeds Spring Limestone
Elsey Fm.
Pierson Limestone
Osagean
Gilmore City Limestone
Sedalia Formation
Northview Formation
Compton Limestone
Hannibal Shale
Kinderhookian
Cowley Formation
Chattanooga Shale
MISSISSIPPIAN
DEVONIAN
?


Mississippian Lime Play
Colby
Hays
Great Bend
Garden City
Dodge City
Wichita

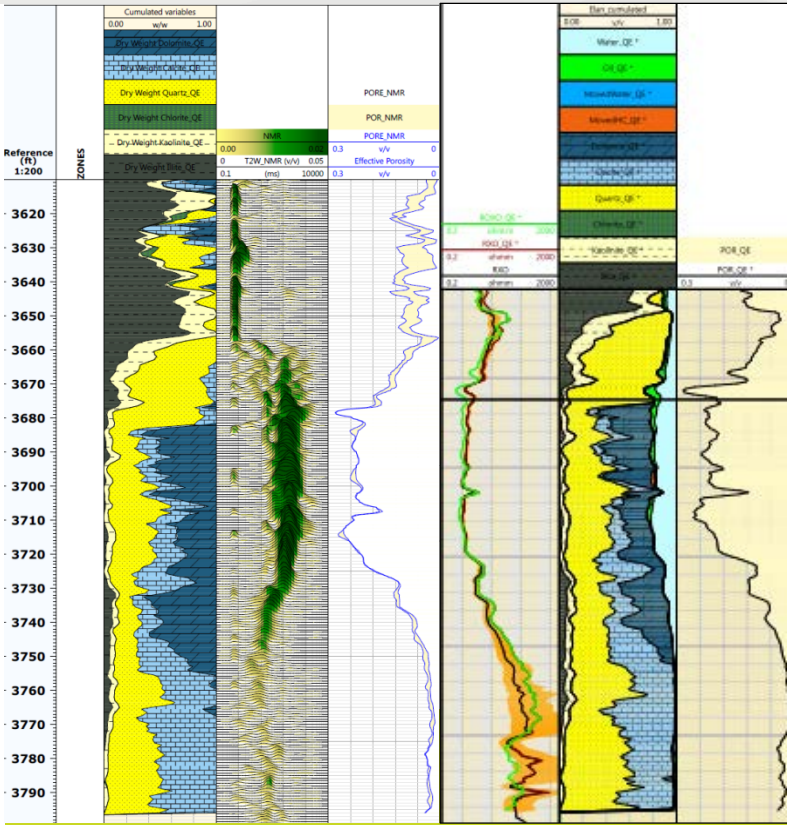

Oil Production since 1970
Others 18%
Mississippian 12%
Arbuckle 13%
Simpson 6%
Viola 4%
Pennsylvanian 47%


Mississippian Oil and Gas Production
Nemaha uplift
Forest City basin
Central Kansas uplift
Salina basin
Hugoton embayment
Pratt anticline
Sedgwick basin
Cherokee basin
OIL
GAS
OIL AND GAS

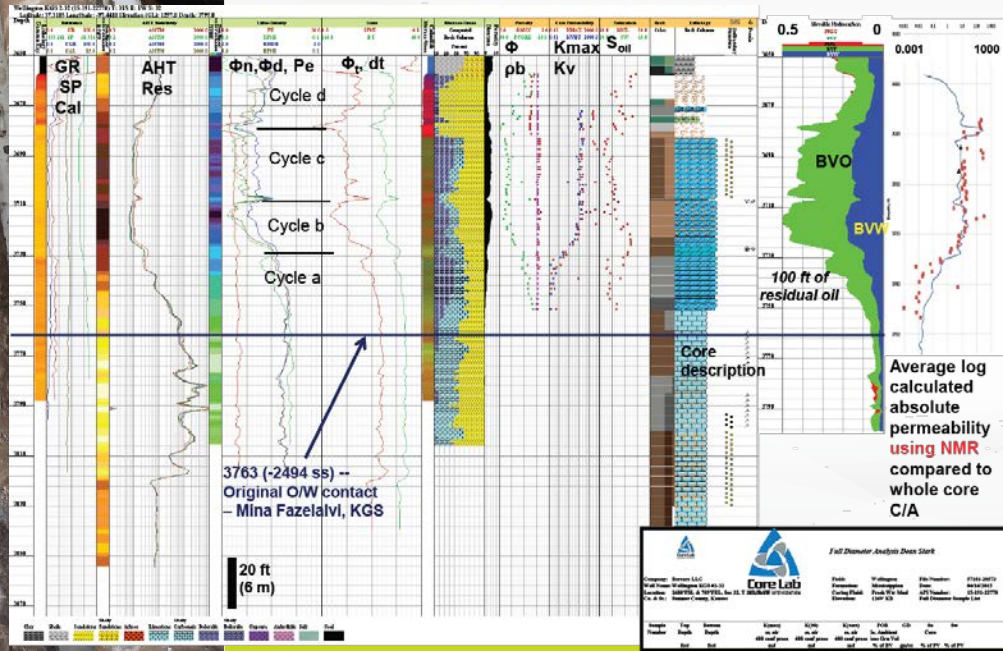

CO2 Potential oil Production by Producing Zone
Marmaton
190 MM BO
50-70 CO2 MMBO
Morrow
190 MM BO
50-70 CO2 MMBO
All Others
500 MM BO
125-175 CO2 MMBO
Arbuckle
2,290 MMBO
570-800 CO2 MMBO
Cherokee
190 MM BO
50-70 CO2 MMBO
Simpson
250 MMBO
60-90 CO2 MMBO
Viola
370 MM BO
90-130 CO2 MMBO
Mississippian
990 MMBO
250-350 CO2 MMBO
Lansing-Kansas City
1,240 MMBO
310-430 CO2 MMBO

Reservoir Characterization

- 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

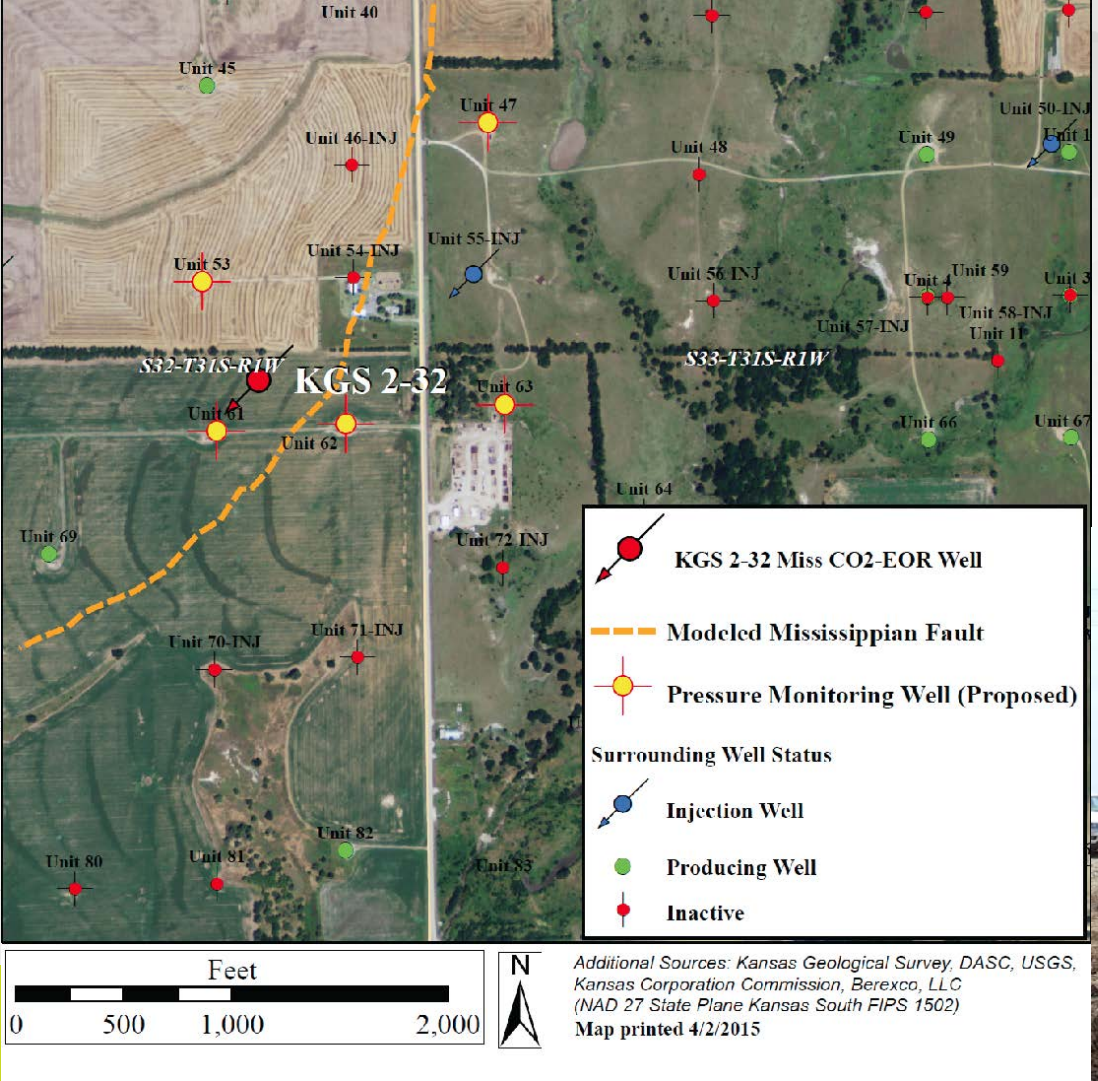


Injection Well Drilling, Coring, and Logging

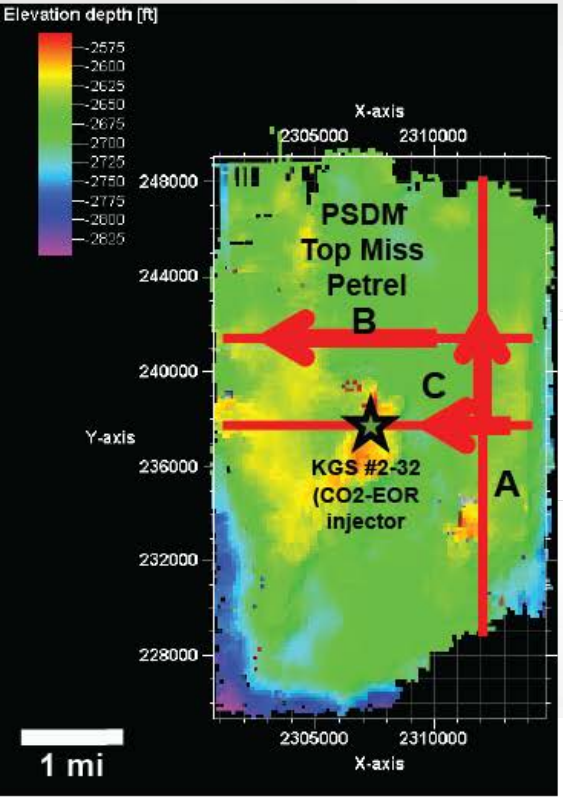


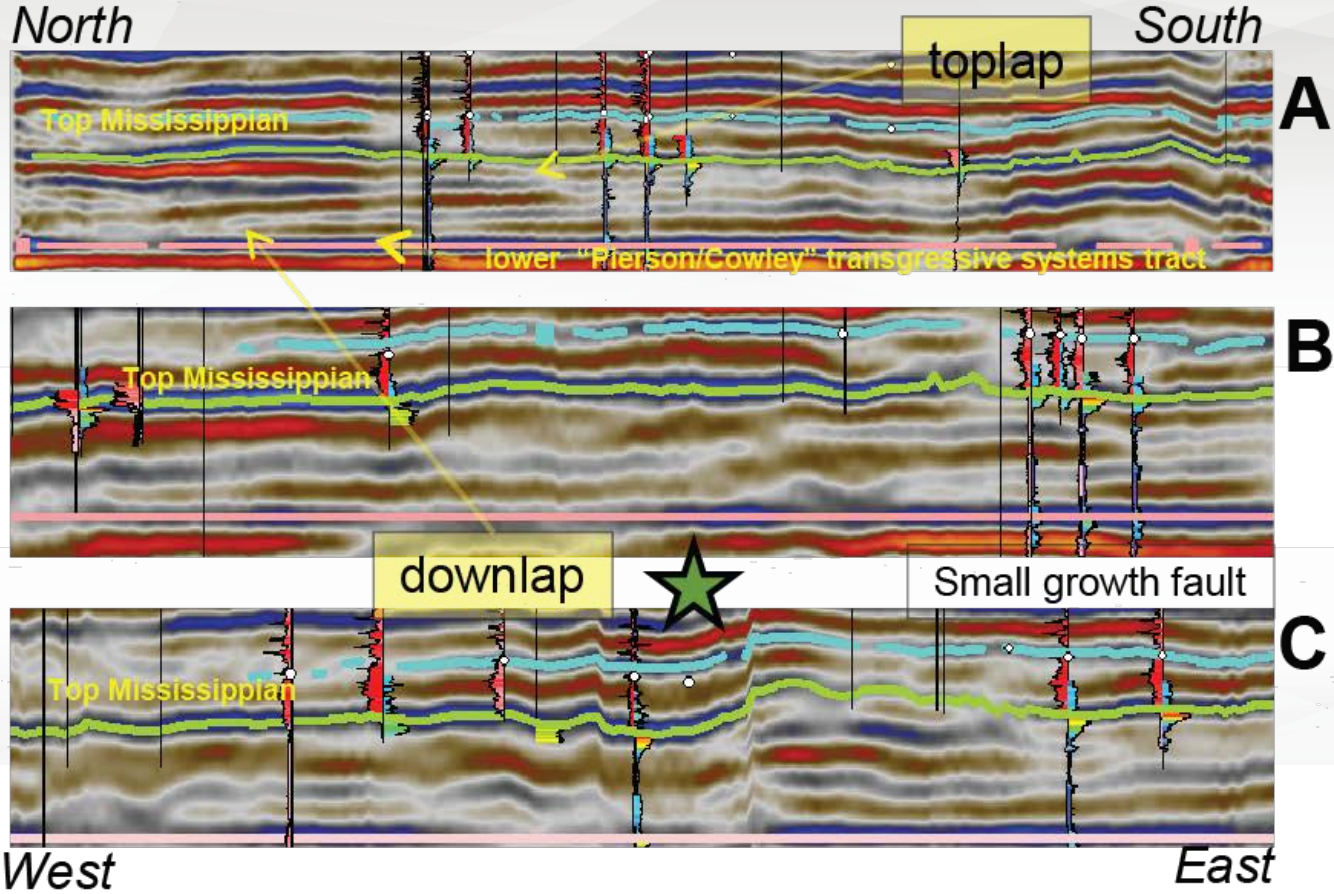
Well Testing

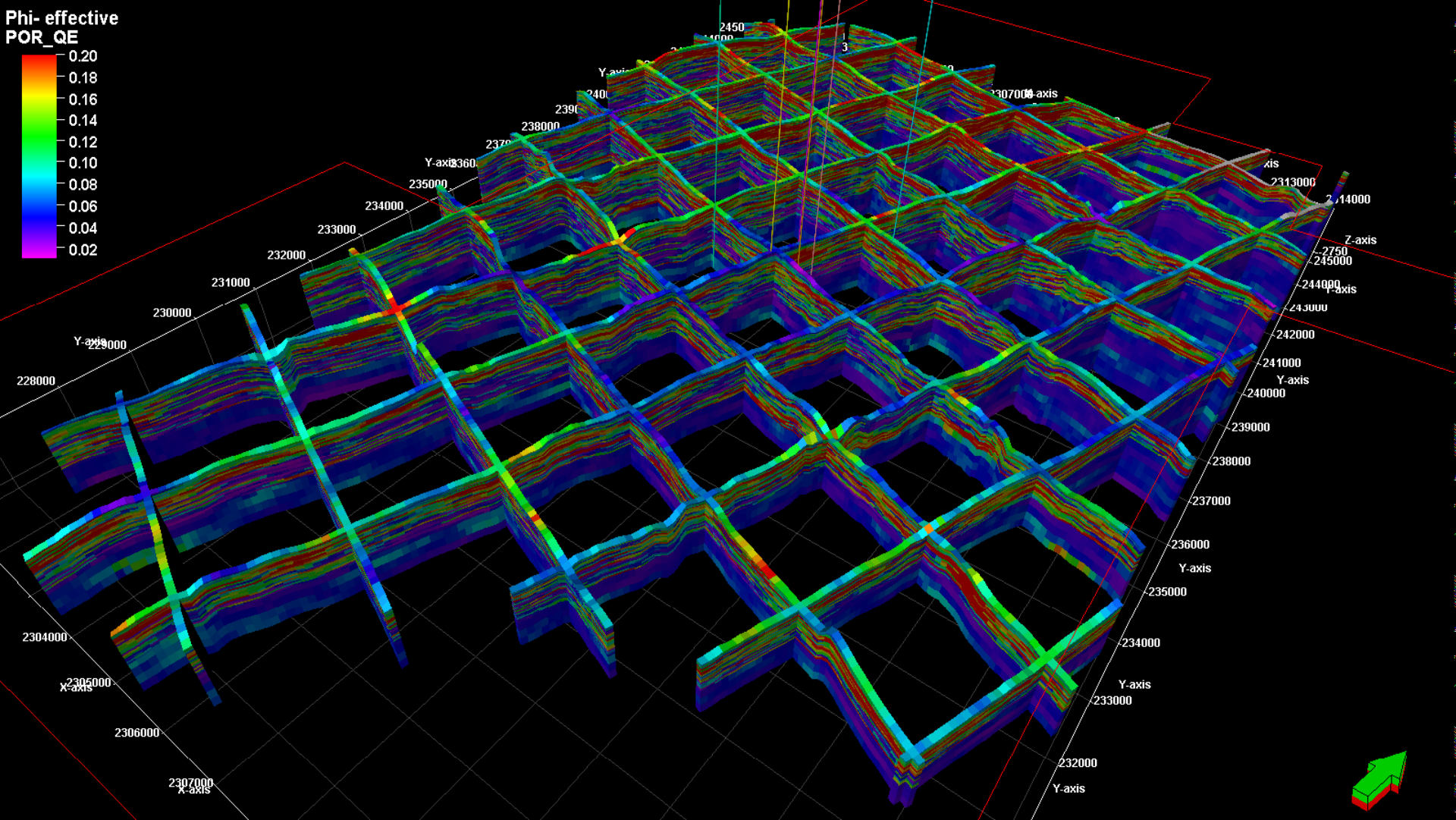
- Drill stem test
- Step rate test
- Interference test



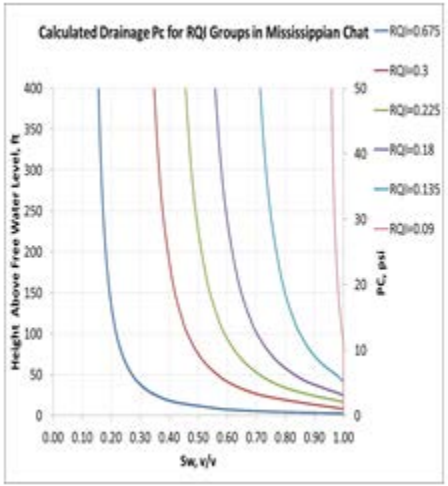
Seismic Stratigraphy Using PSDM

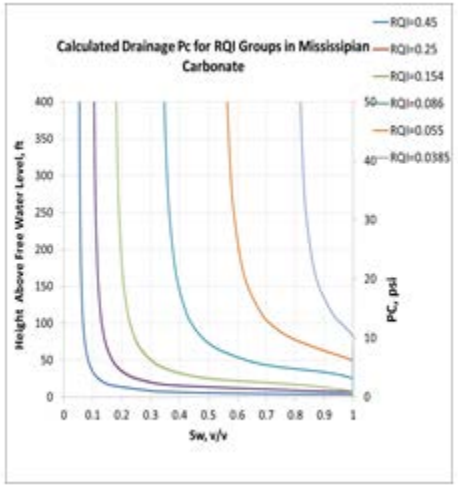


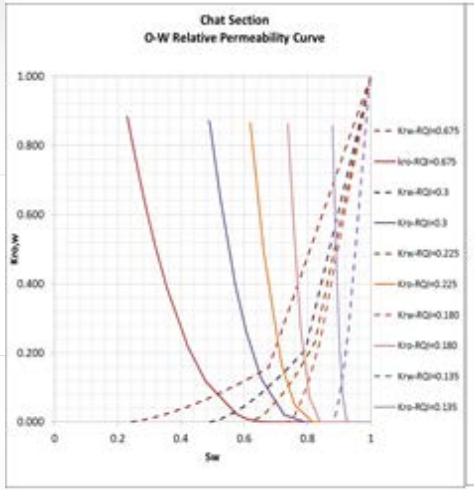


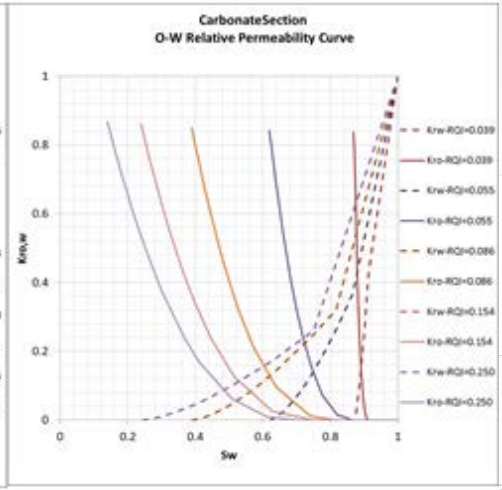

Phi- effective
POR_QE
0.20
0.18
0.16
0.14
0.12
0.10
0.08
0.06
0.04
0.02
X-axis
Y-axis
Z-axis

Capillary Pressure and Relative Permeability



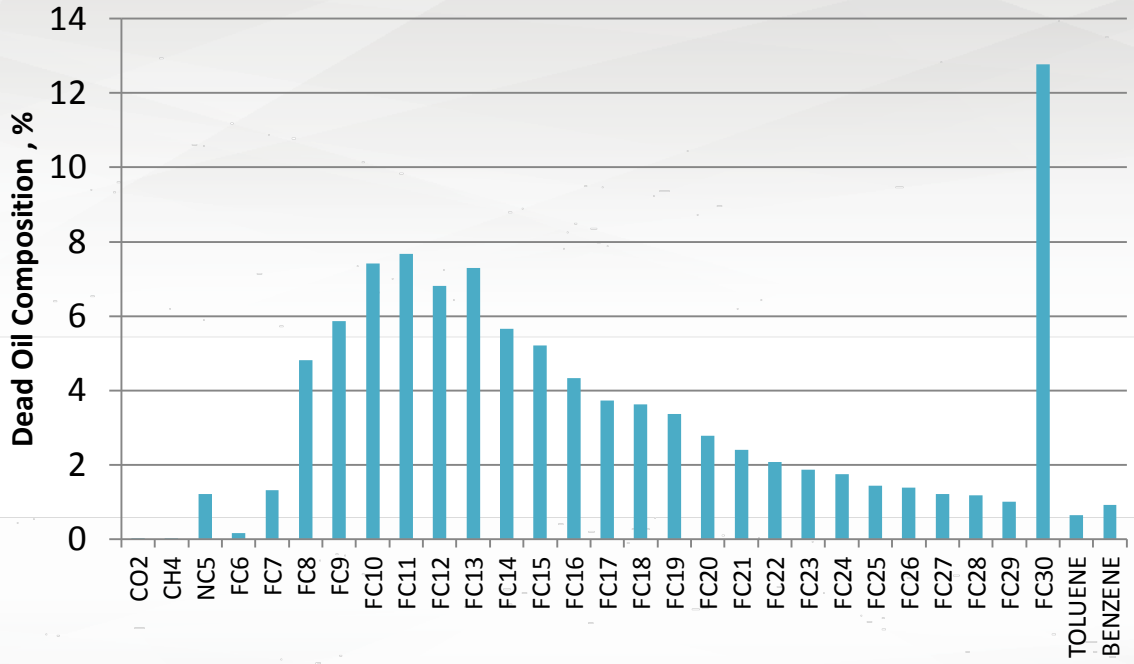






Fluid Analysis

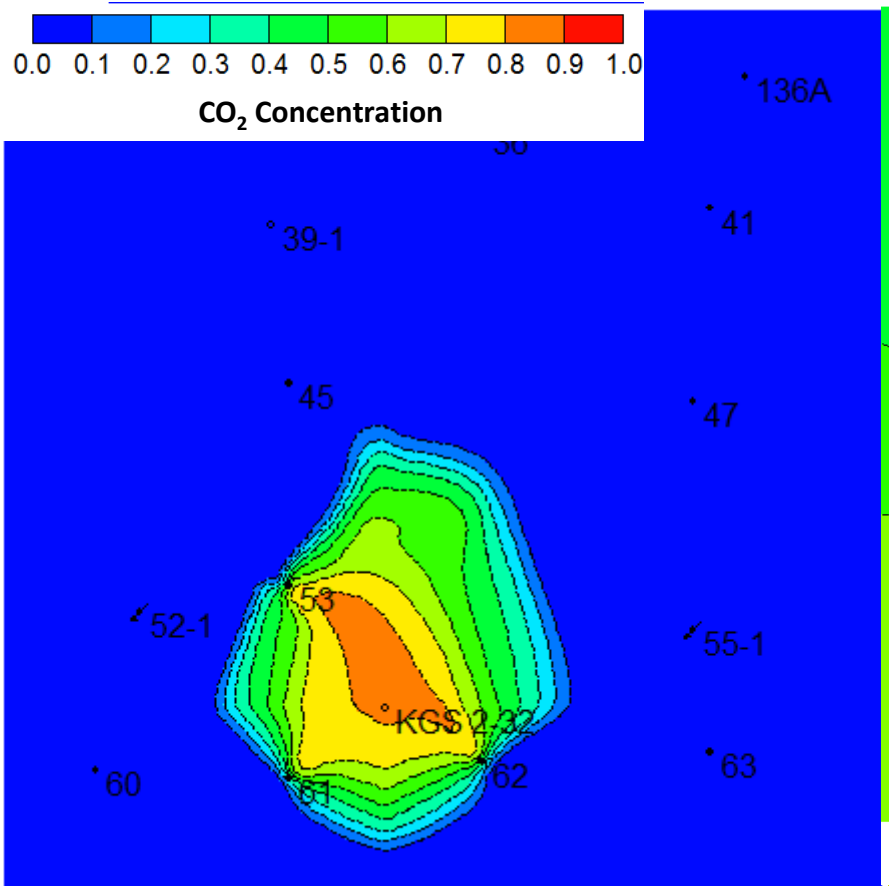
- CO_2 Miscibility pressure is ~1650 psi
- Oil API gravity is 30°
- Oil composition
- Water composition
- PVT



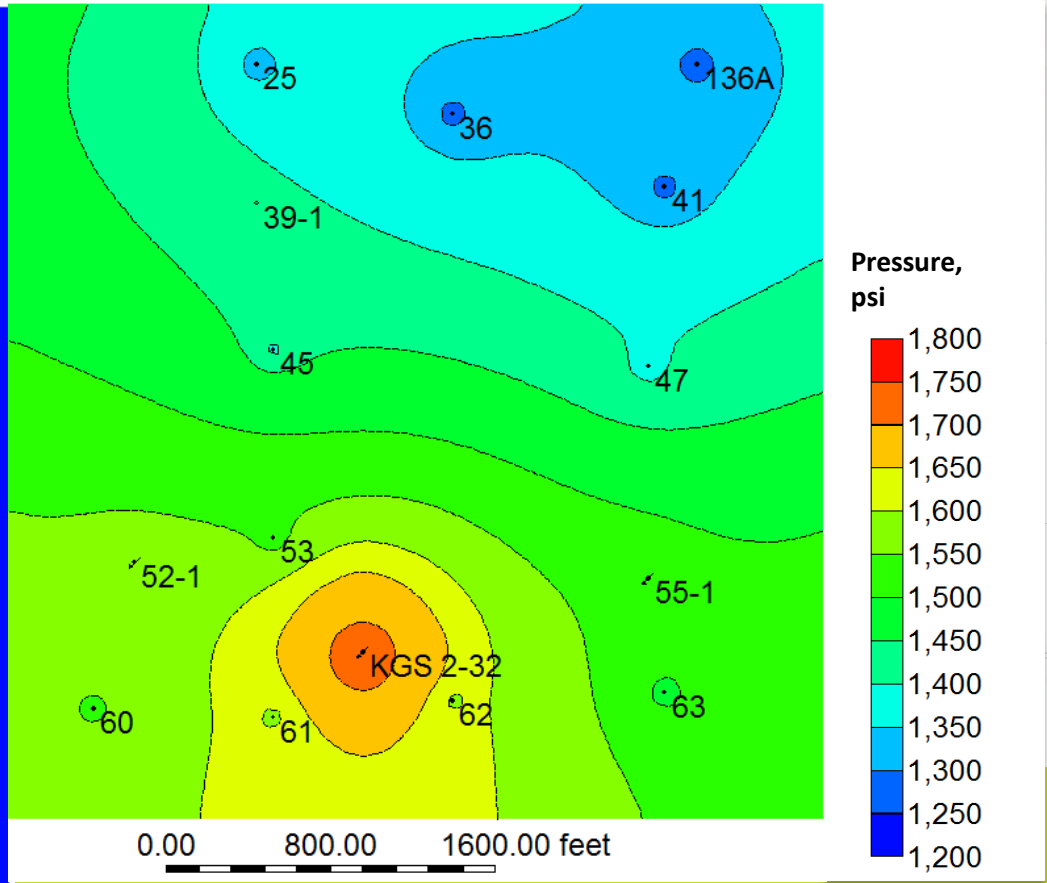
Reservoir Modeling

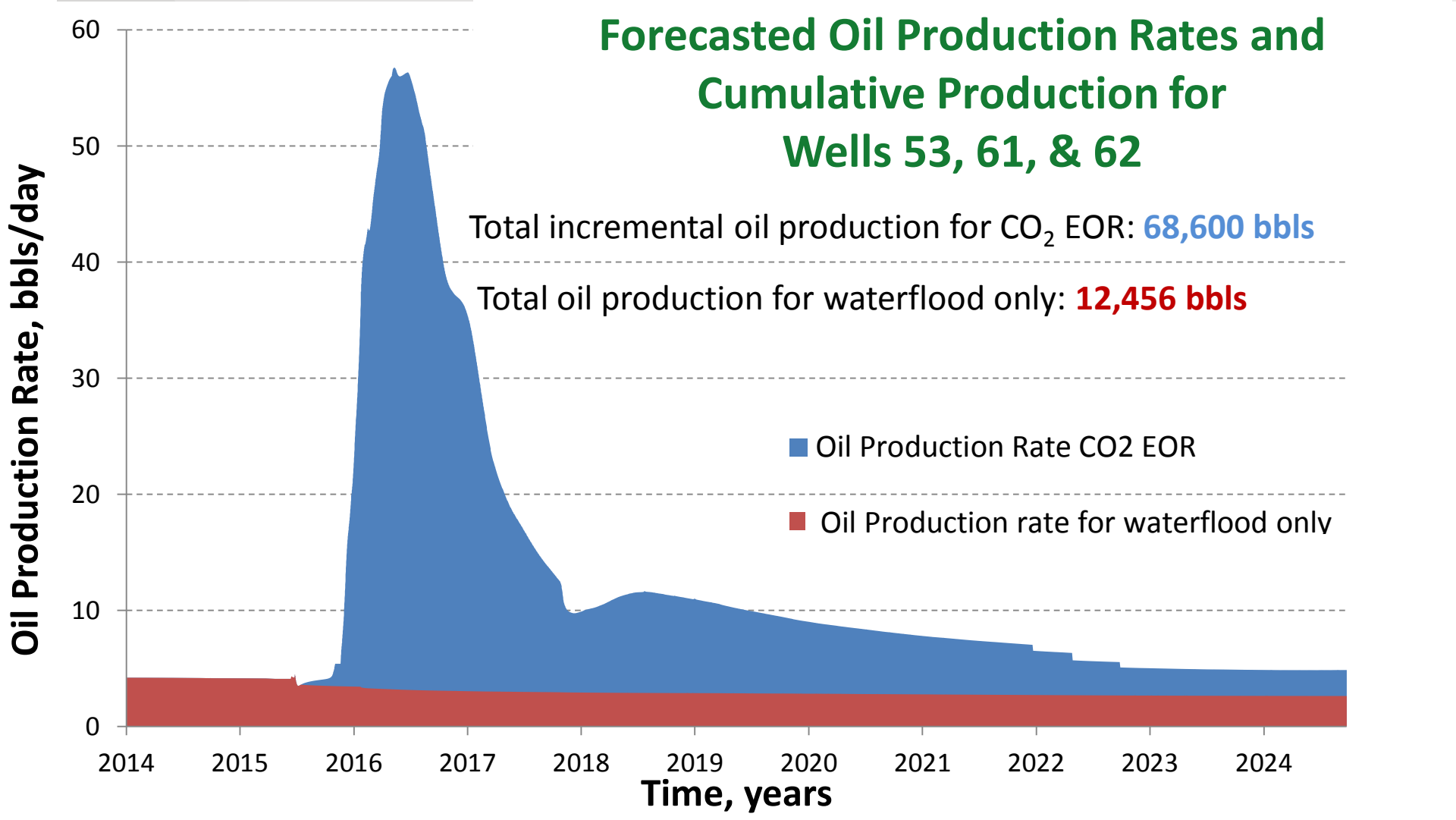
- Strategy for a flood
  - Monitoring optimization
  - Re-pressurization strategy for miscibility
  - CO_2 movement
- Economic forecast
  - Sweep efficiency
  - Oil production
  - CO_2 production

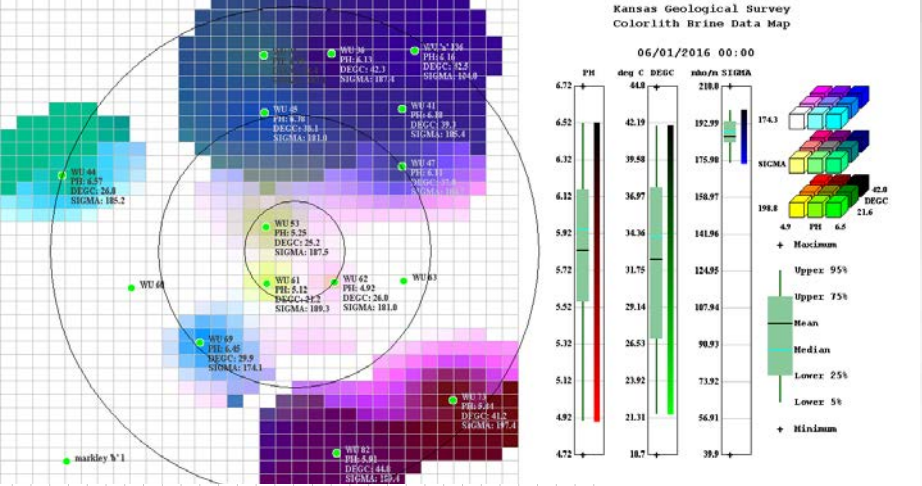
Forecasted CO_2 Movement in Reservoir

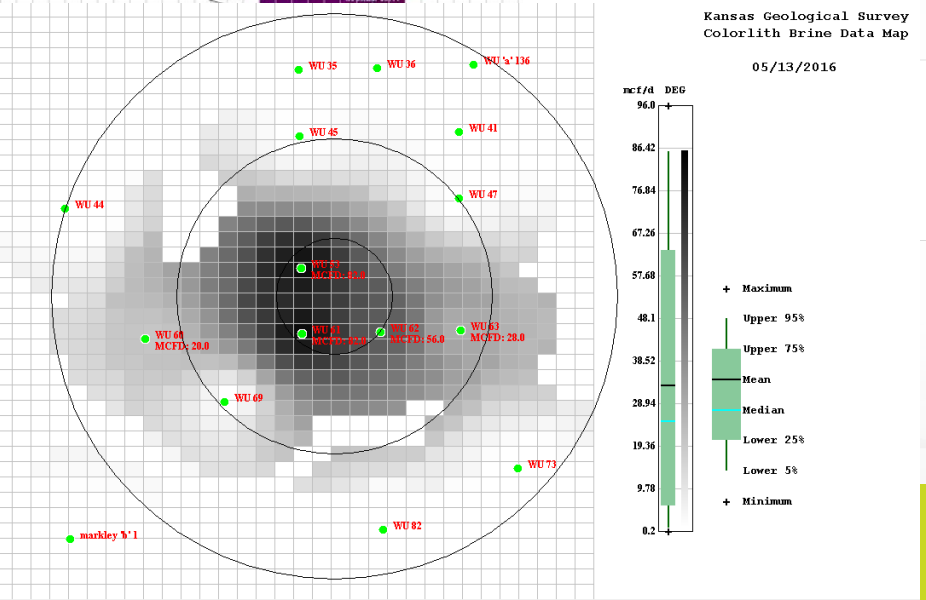


Forecasted Pore-Pressure Distribution at the Start of CO_2 Injection
Required miscibility pressure is ~1650




Forecasted Oil Production Rates and Cumulative Production for Wells 53, 61, & 62
Total incremental oil production for CO_2 EOR: 68,600 bbls
Total oil production for waterflood only: 12,456 bbls
Oil Production Rate CO2 EOR
Oil Production rate for waterflood only
Oil Production Rate, bbls/day
Time, years
0
10
20
30
40
50
60
2014
2015
2016
2017
2018
2019
2020
2021
2022
2023
2024





Fluid Monitoring

- Water chemistry
  - Alkalinity
  - pH
  - Cations/anions
  - Microbial
- Production history
  - Oil/water
  - CO_2 account

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Seismic Monitoring

Housing setup for Sercel (Mark Products) L-22D-3D sensors, ~5 ft below surface to minimize surface noise; installed below frost line in bedrock

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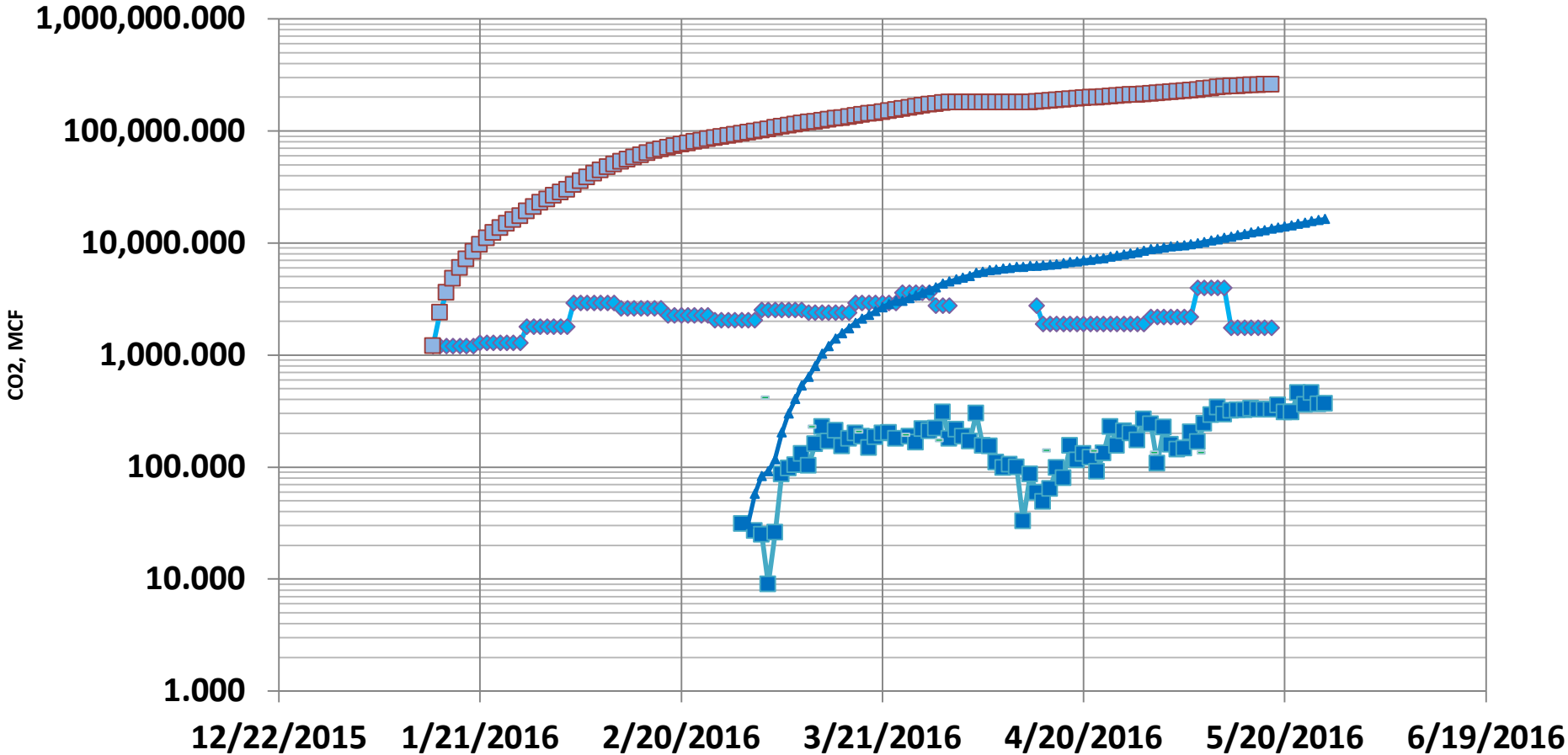
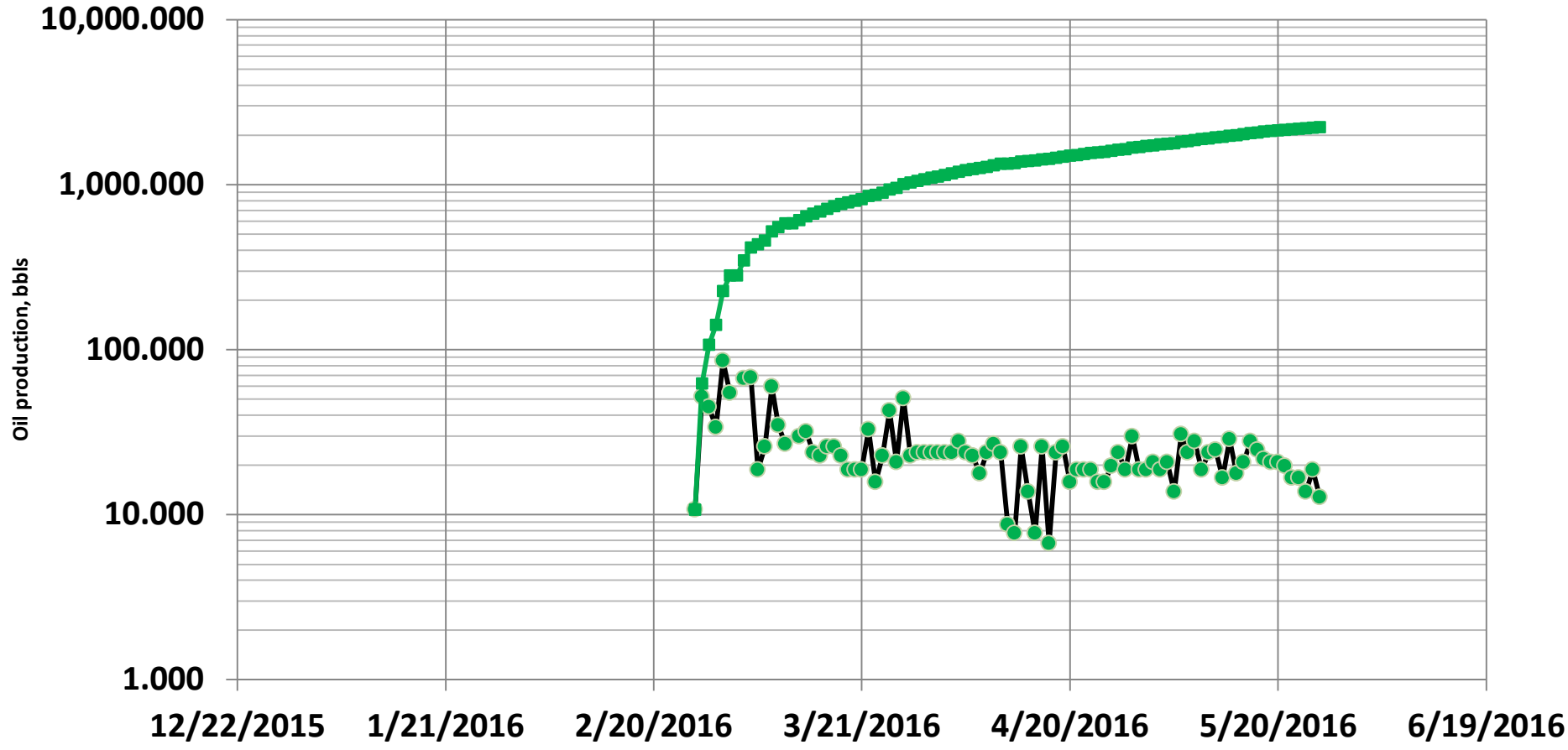
Operations

Injected vs. Produced CO_2

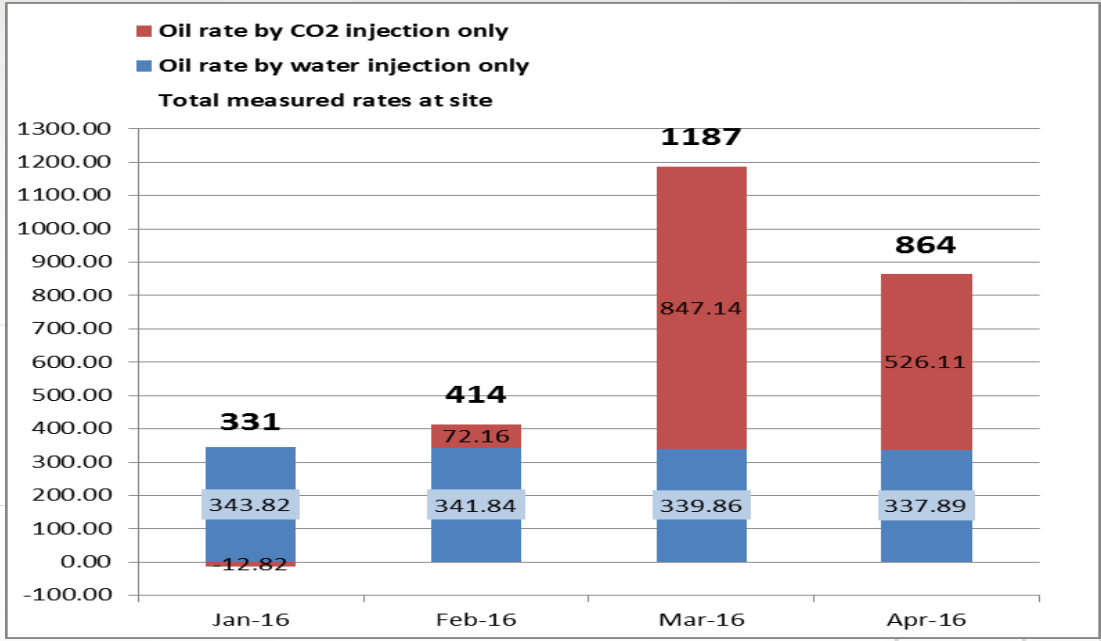


Produced Oil



Decline Curve Analysis

- One battery production - East Nelson
- The exponential function, where Di is the decline rate
- Using the exponential function, oil rates by water injection only are forecast for Jan, Feb, March and April 2016 .



Summary and Future Work

- No substantial deviations due to unforeseen circumstances (carbonate fracturing, temperature, pressure, etc.)
- Successful oil recovery
- Low CO_2 losses due to venting or reservoir properties
- Manage CO_2 plume and finalize CO_2 injection
- 2D seismic to confirm CO_2 plume

Acknowledgements & Disclaimer

Acknowledgements

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