Pre-injection Evaluation of CO_2 Sequestration at Dickman Field, Kansas

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Outline

Objective

Introduction

Work Flow

- Seismic Inversion
- Porosity Estimation
- Flow simulation

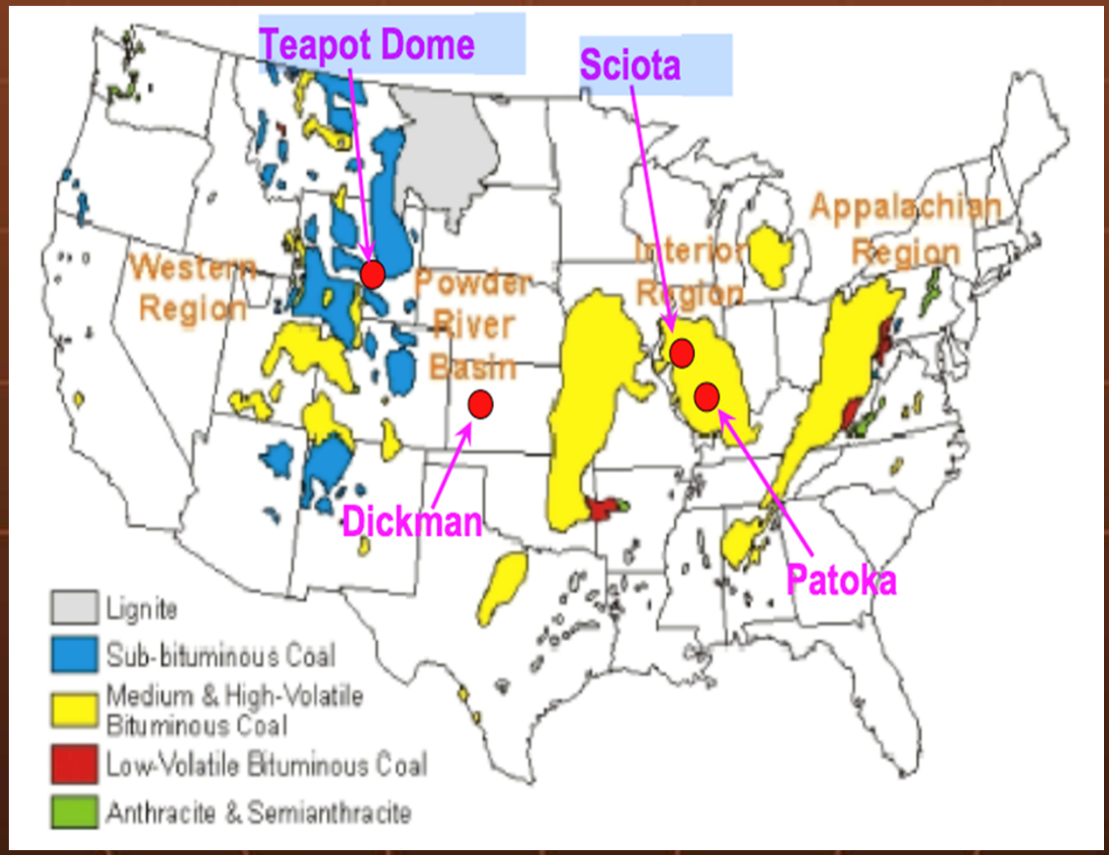
Discussion

Acknowledgement

Objectives

- Estimate reservoir parameters of the Mississippian carbonate brine reservoir in Dickman Field, Kansas using seismic data

- Study the capability of the target formation to contain and trap CO_2



Liner 2009

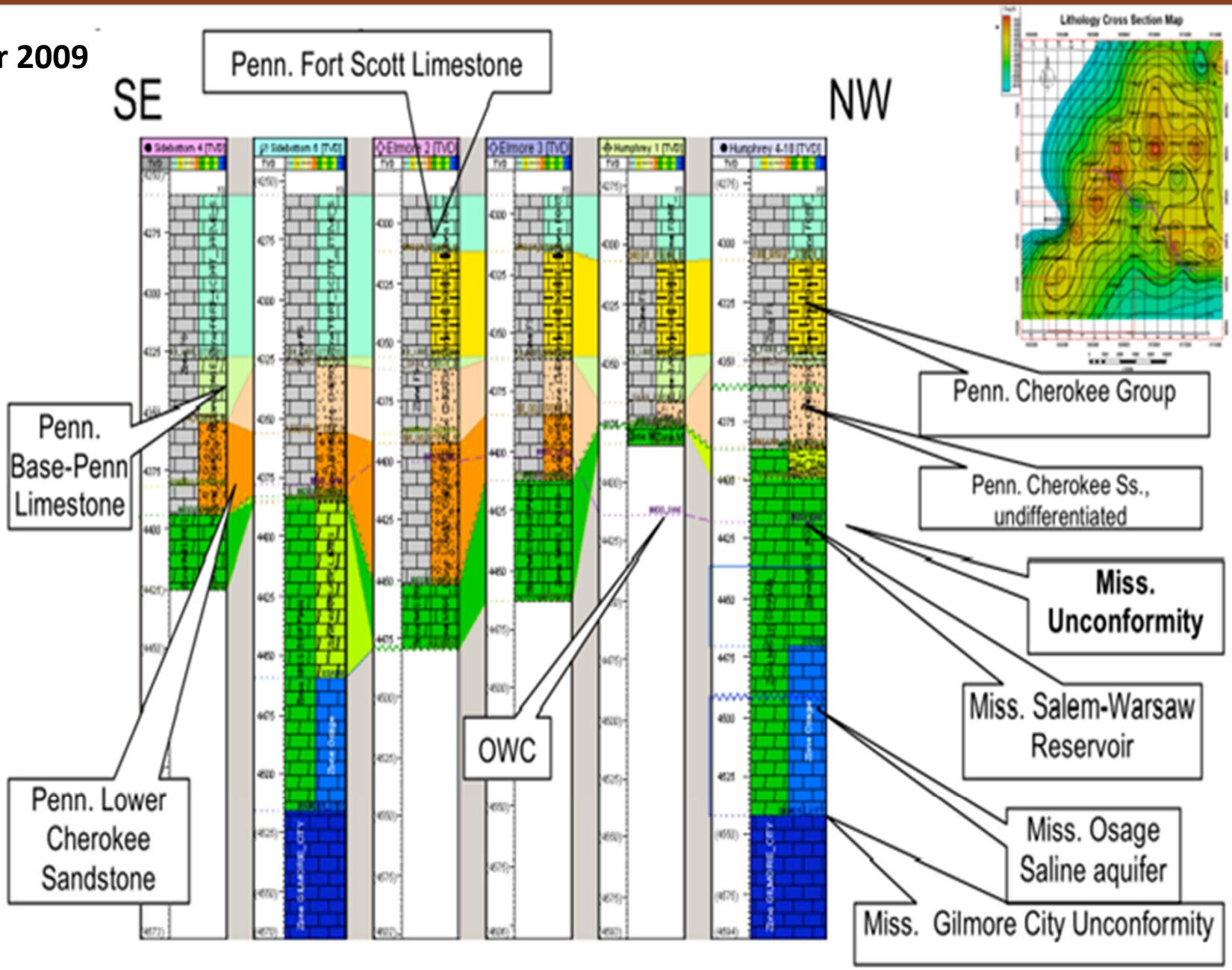
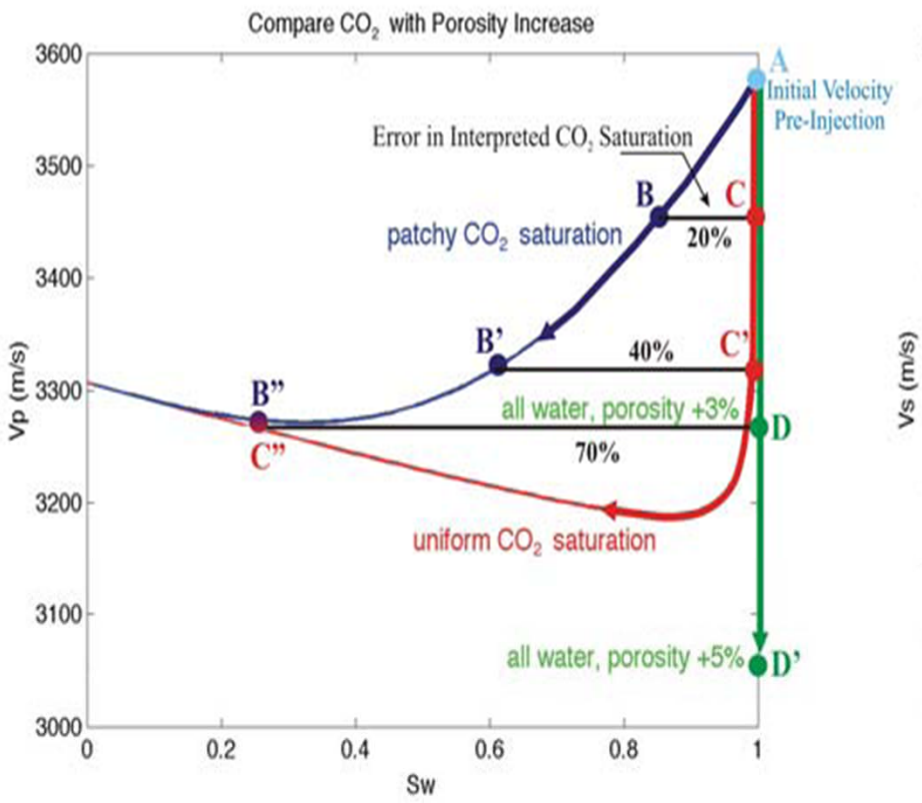
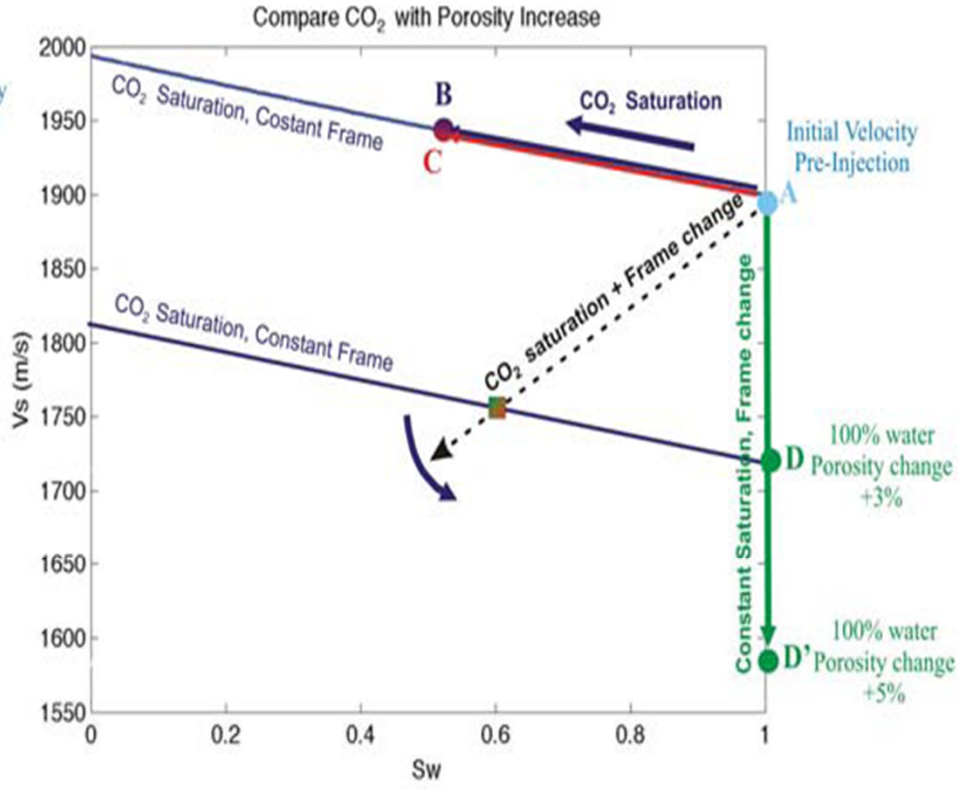


Figure : Lithologic cross section perpendicular to the axis of the structure across two topographic highs. Section is hung on Fort Scott Limestone top

What Happens as CO_2 Enters The Formation

(Vanorio 2009)





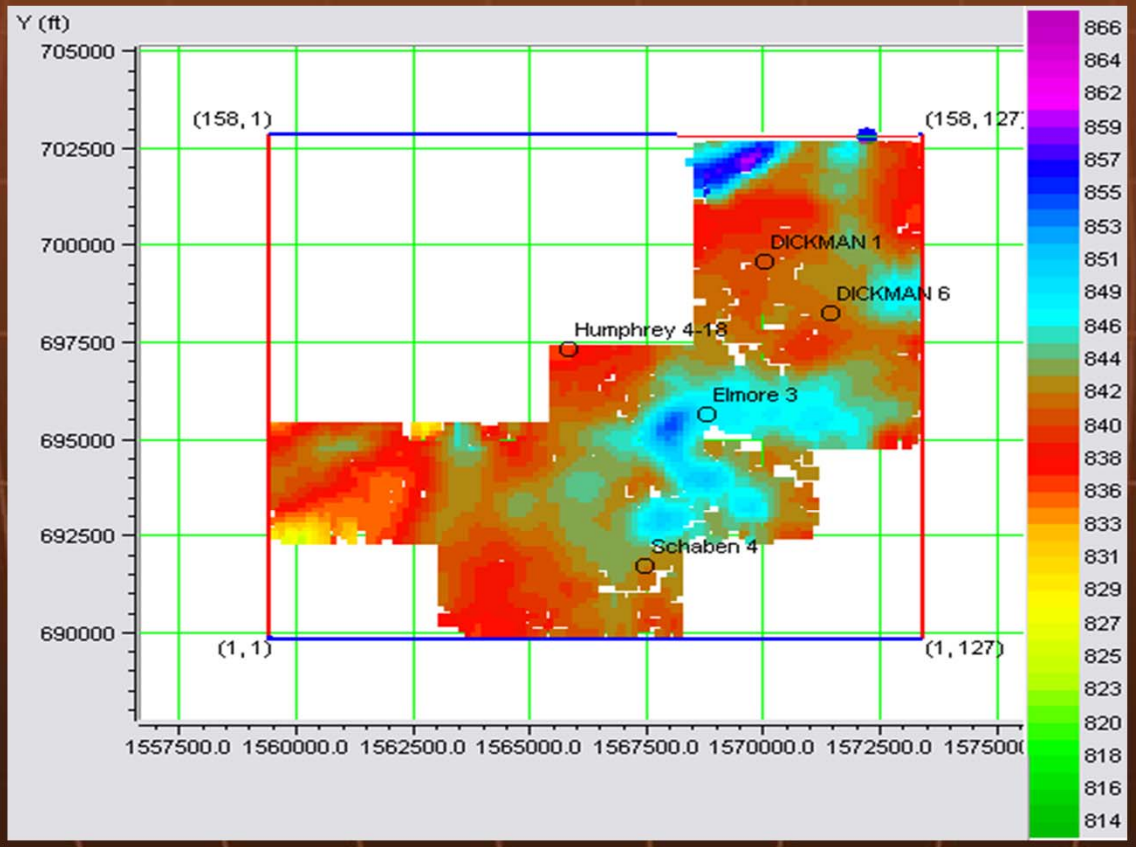
Red: chemically inert uniform saturation

Blue: Chemically inert patchy saturation

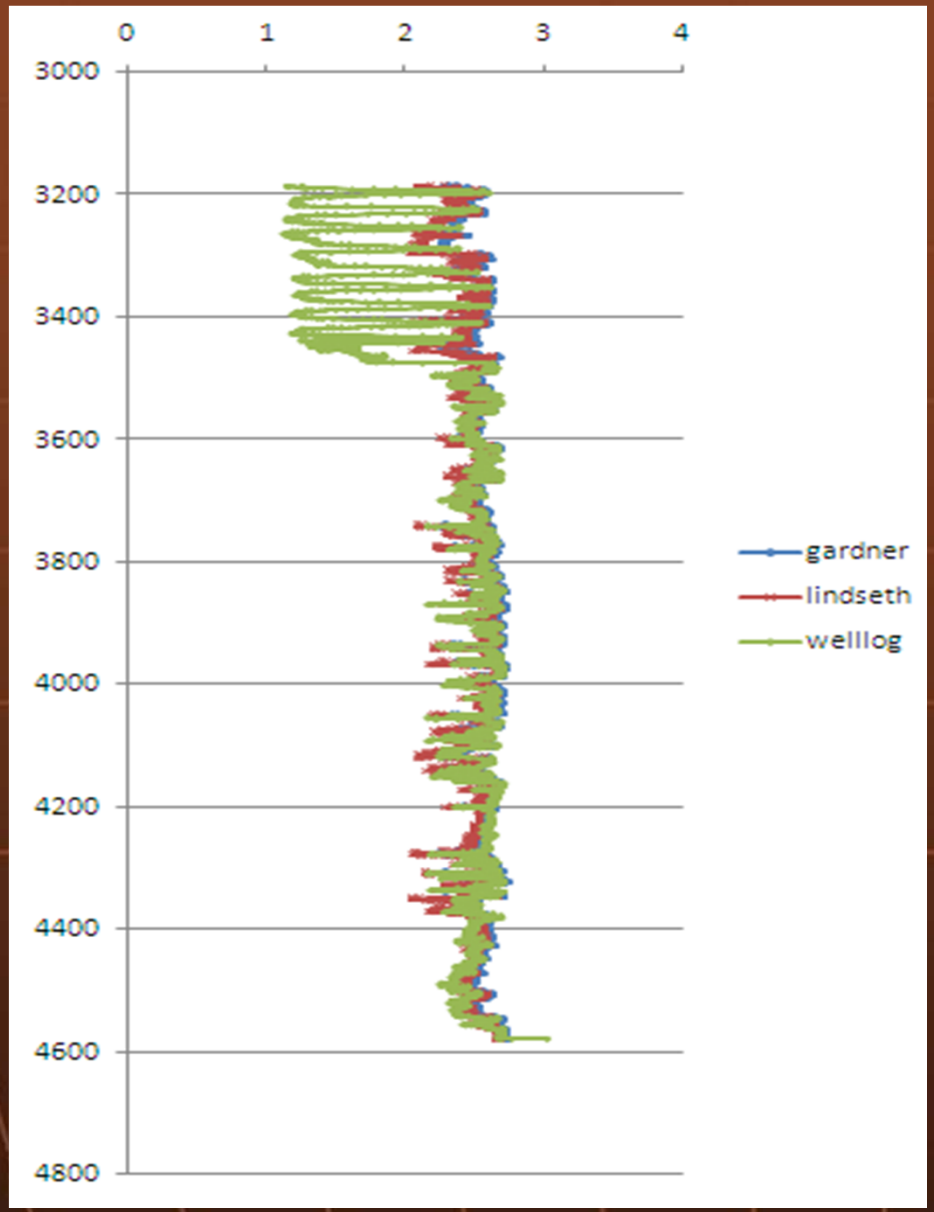
Green: porosity enhancement due to dissolution with 100% water saturation

Data

Well name	Density log	Sonic log	Porosity log
Humphrey 4-18	X	X	X
Dickman 1		X	X
Dickman 6		X	X
Elmore 3		X	X



Generating Density Logs from Sonic Logs



Density log generated from Gardner's equation (1974) compared with that of Lindseth's equation (1979)

Gardner's equation

$$\rho = 0.23\ \alpha^{0.25}$$

Work Flow

- Estimate reservoir parameter
  - Invert pre-stack PP seismic data
  - Estimate porosity using multi- attributes
  - Convert time to depth
  - Estimate permeability using Timur (1968) equation
- Simulate CO_2 flow

Porosity Estimation

Well Tie (post-stack)

Angle gather from pre-stack

Starting models

Pre-stack inversion for elastic impedances

Porosity estimation from inversion

Stochastic Inversion

Initial model + wavelets

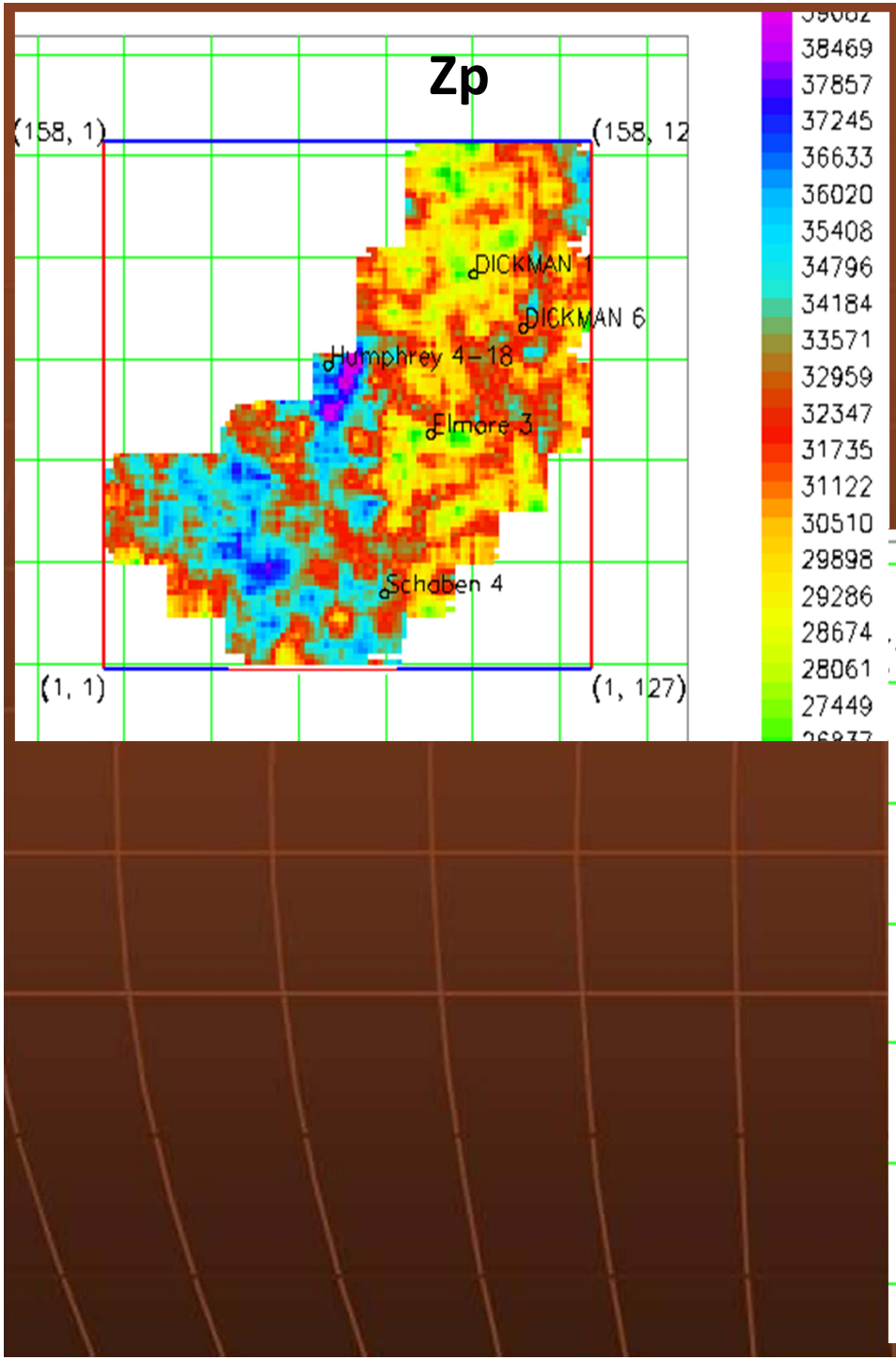
Mean, variance, and Hurst Coeff.

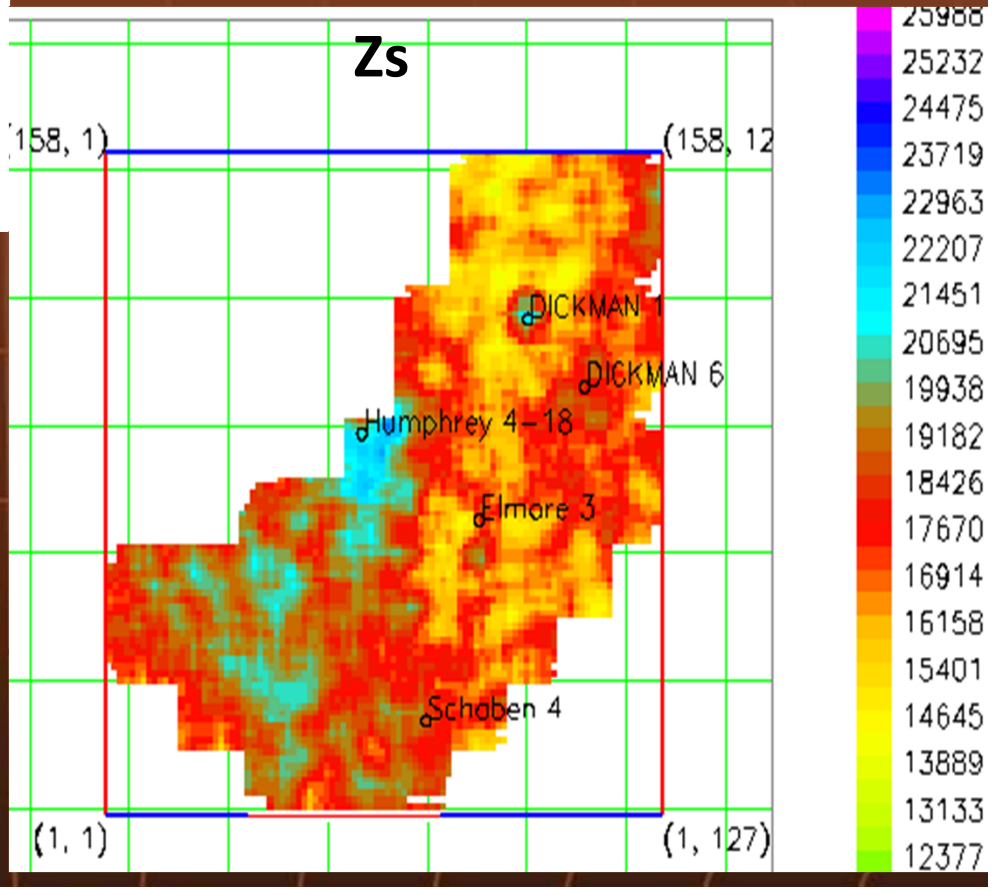
Fractal based prior model of Zp, Zs, and Rho

VFSA inversion

Inverted Zp, Zs, Rho, and probability volume

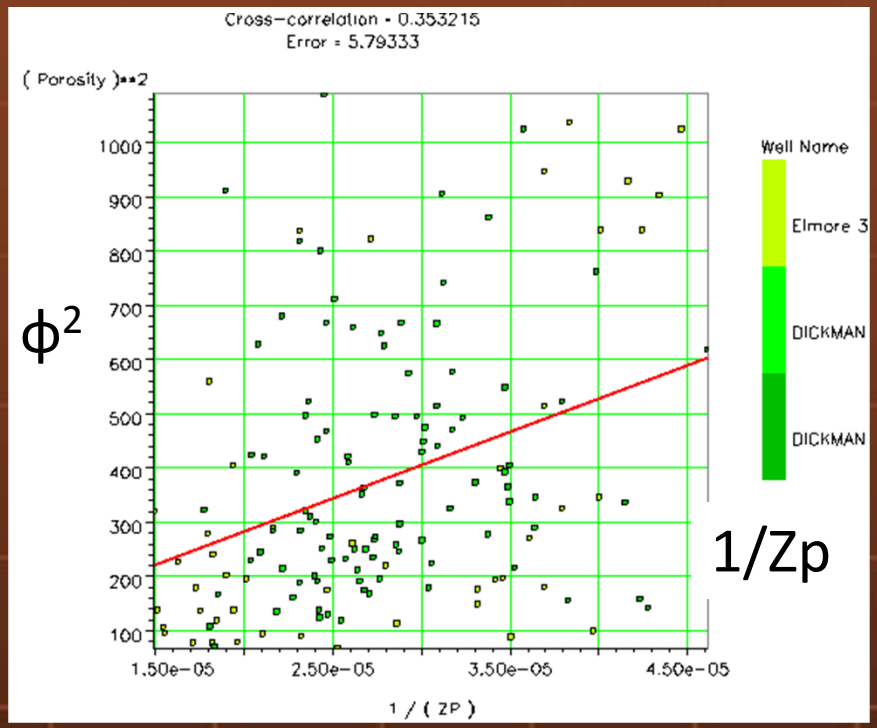
Inverted Elastic Impedances





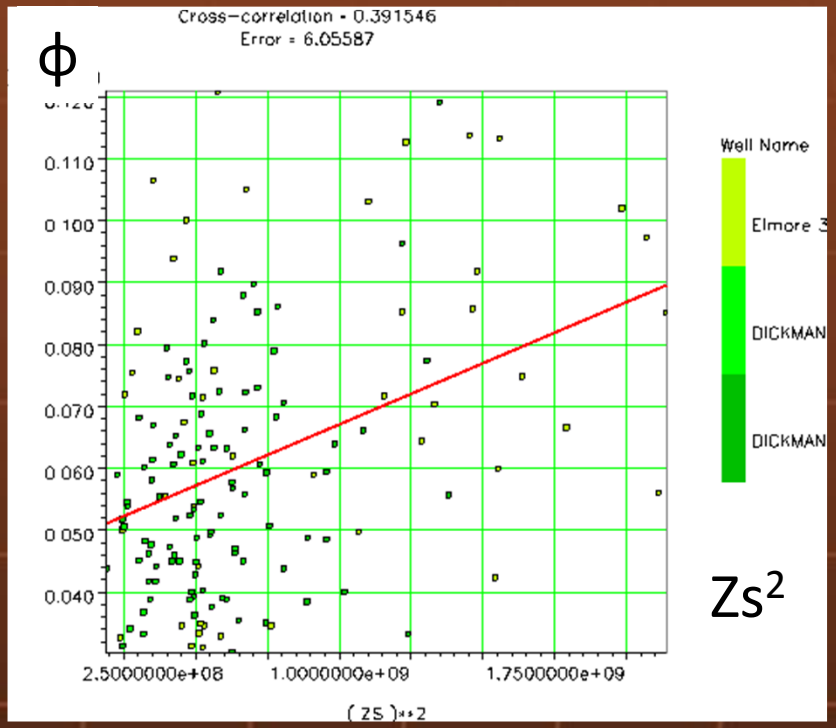
Porosity Estimation

Attribute Correlation



ϕ^2

1/Zp



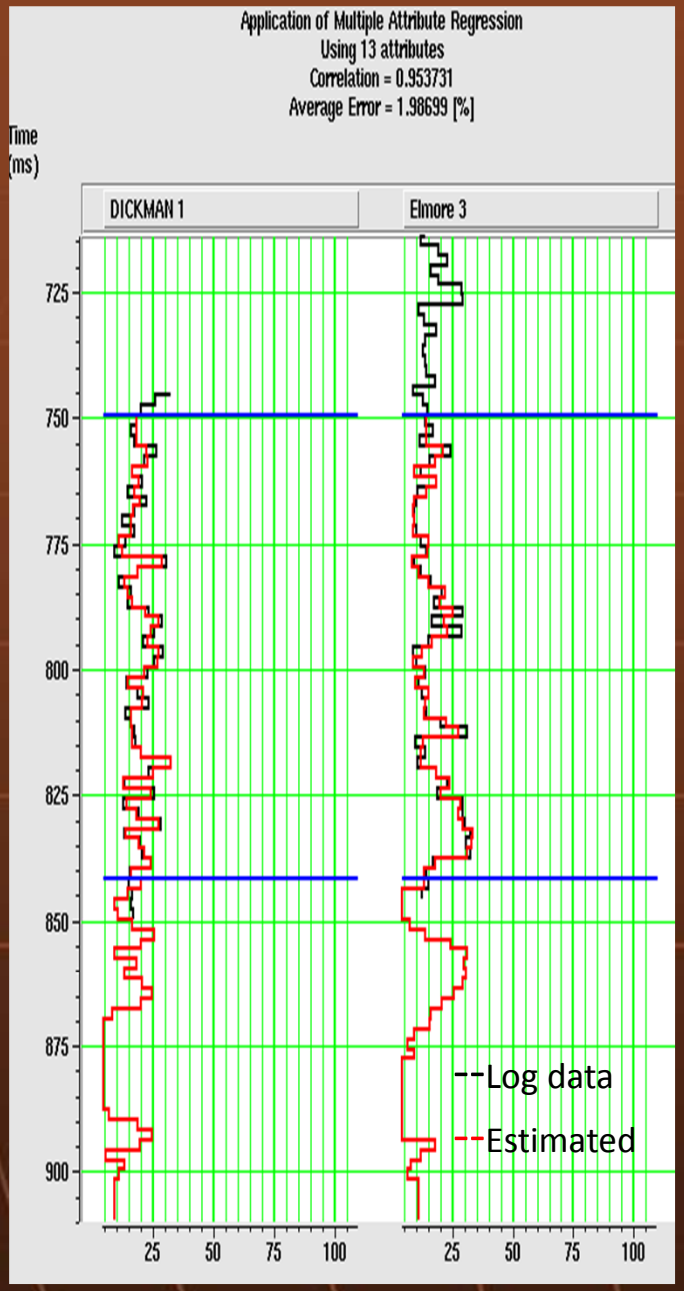
ϕ

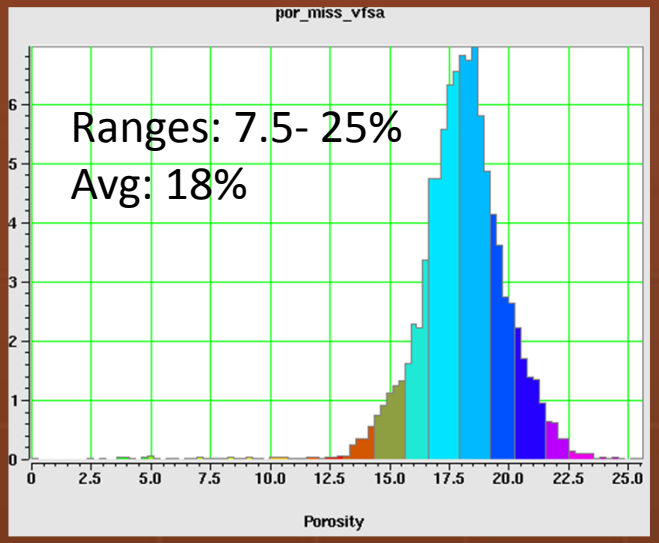
Zs^2

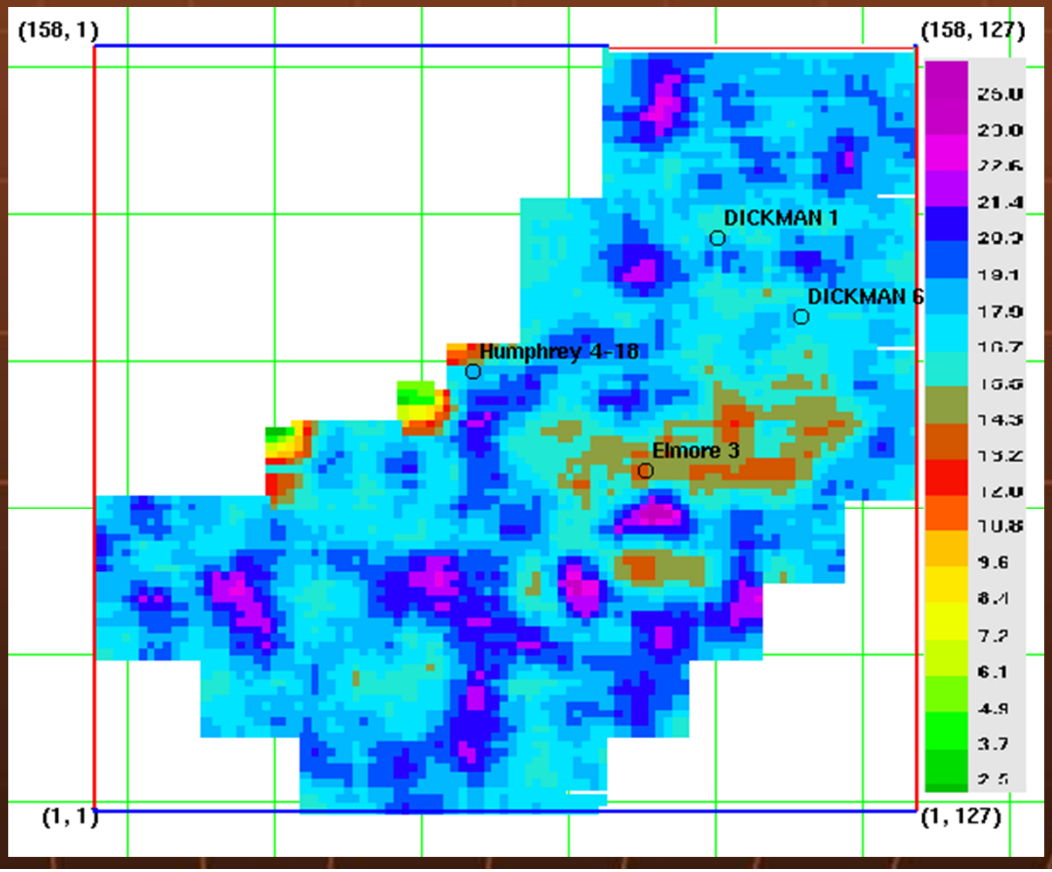
13 attributes excluding density

Target: 8- 25% along Miss. top

Estimated Porosity







Observations

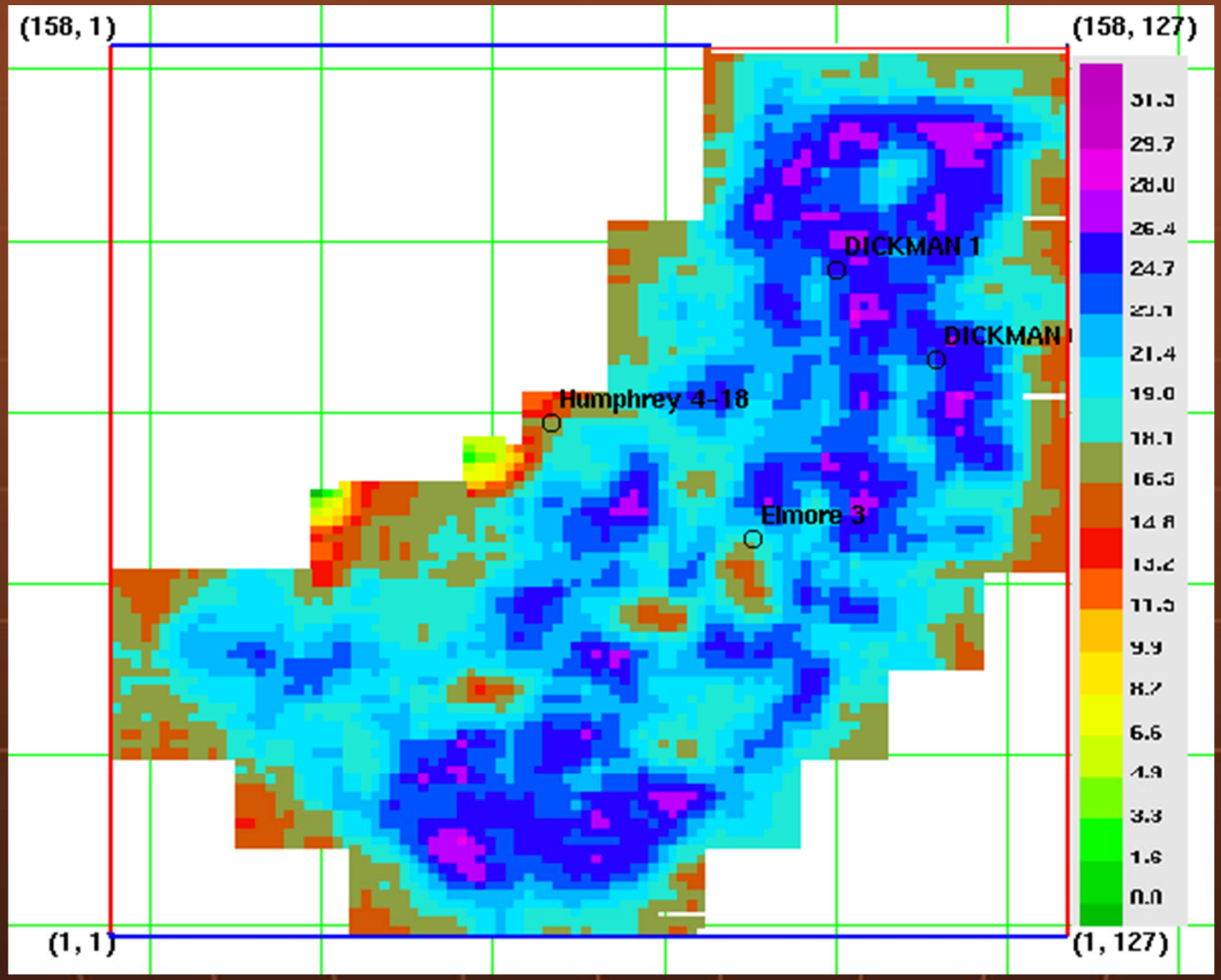
Estimated Zp, Zs and Vp/Vs match the well logs

Estimated porosity falls within reported range (Liner 2009)

Estimated density is unreliable due to the quality of input seismic data

High porosity throughout the Gilmore formation makes it a good candidate for CO_2 injection

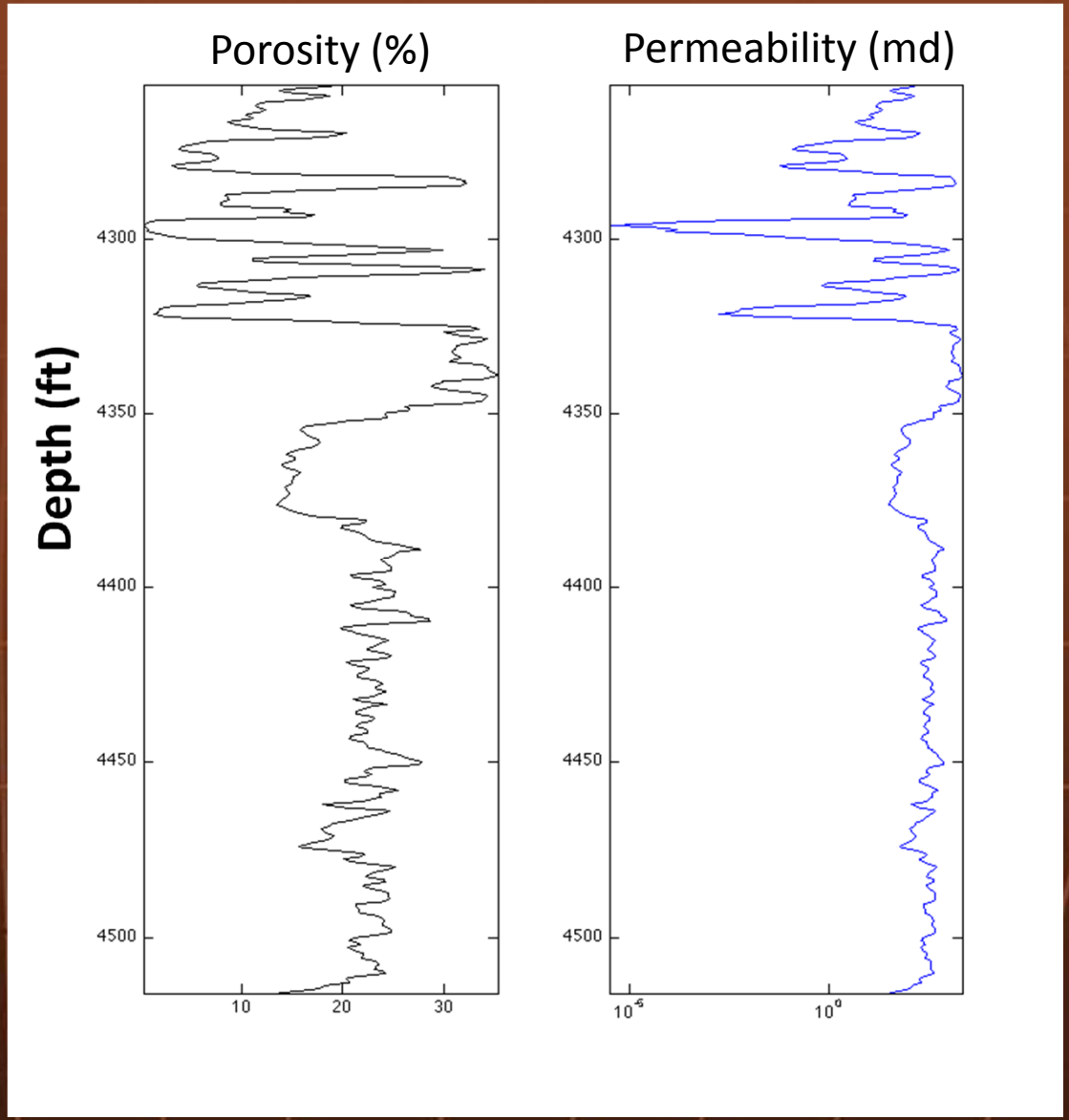
Porosity Distribution of the Gilmore Formation



Permeability Estimation

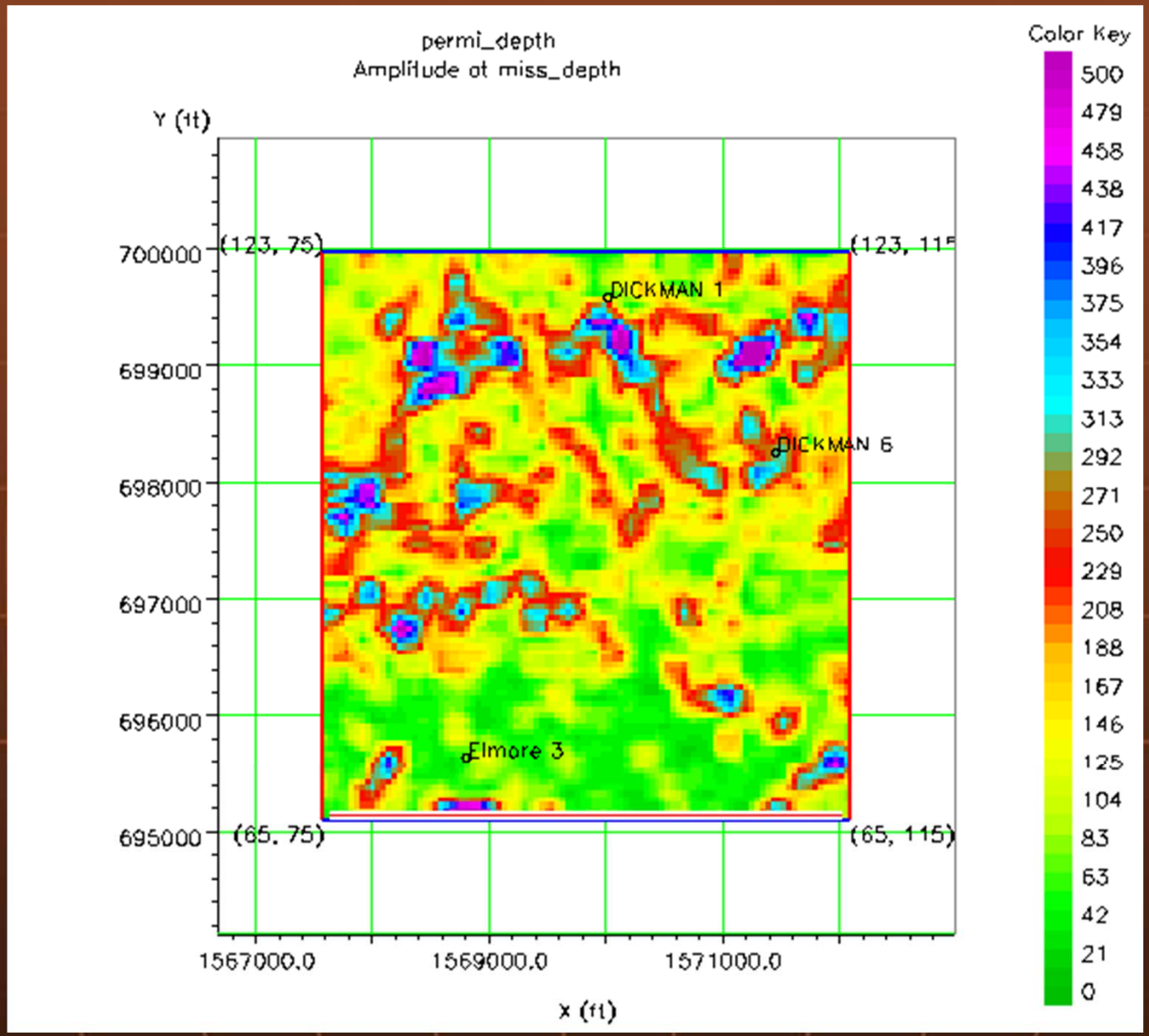
Timur (1968) equation for k- Φ relationship, S_{wir} = 20%

$$k = 0.136 \frac{\Phi^{4.4}}{S_{wir}{}^{2}}$$

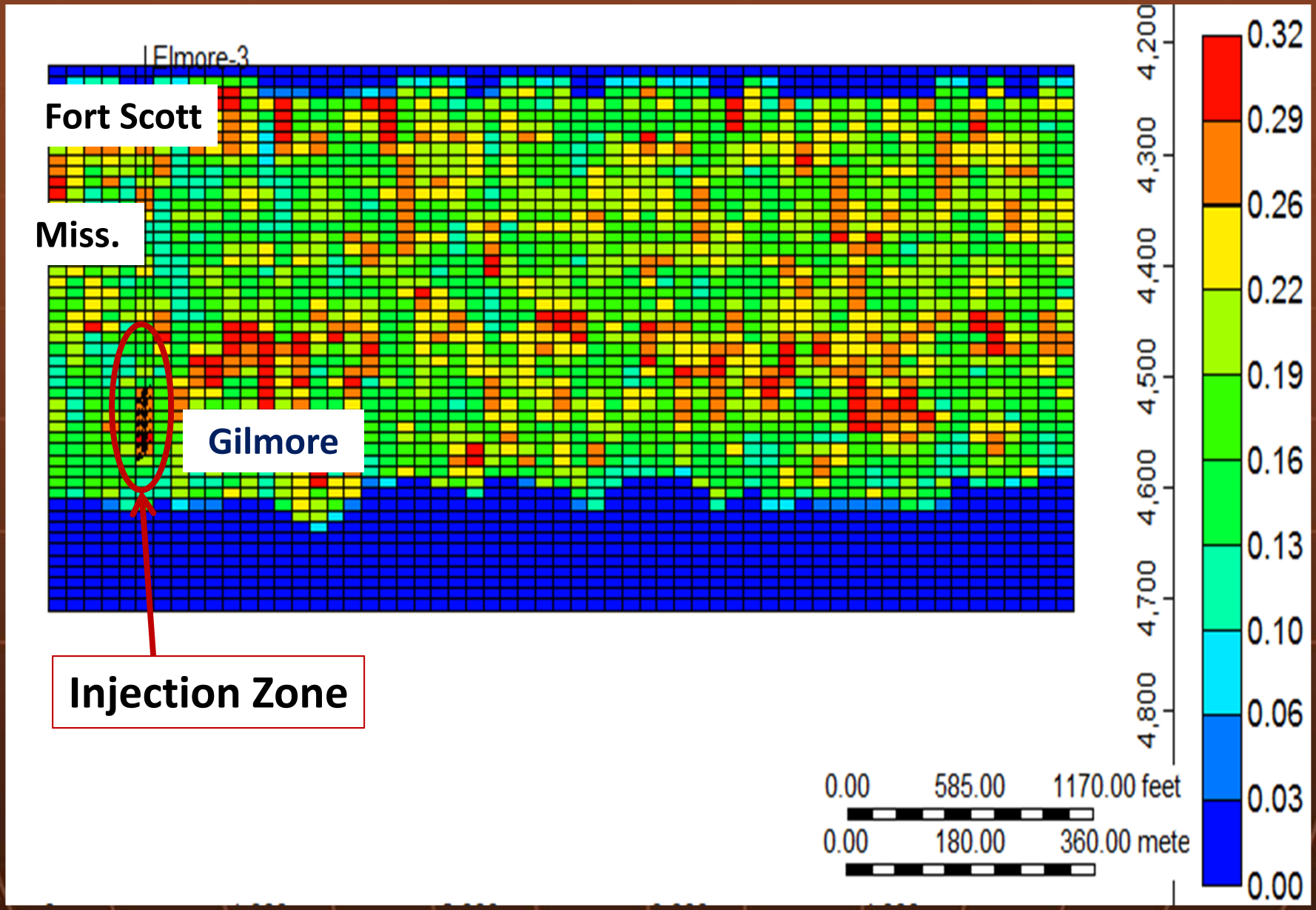


Flow Simulation

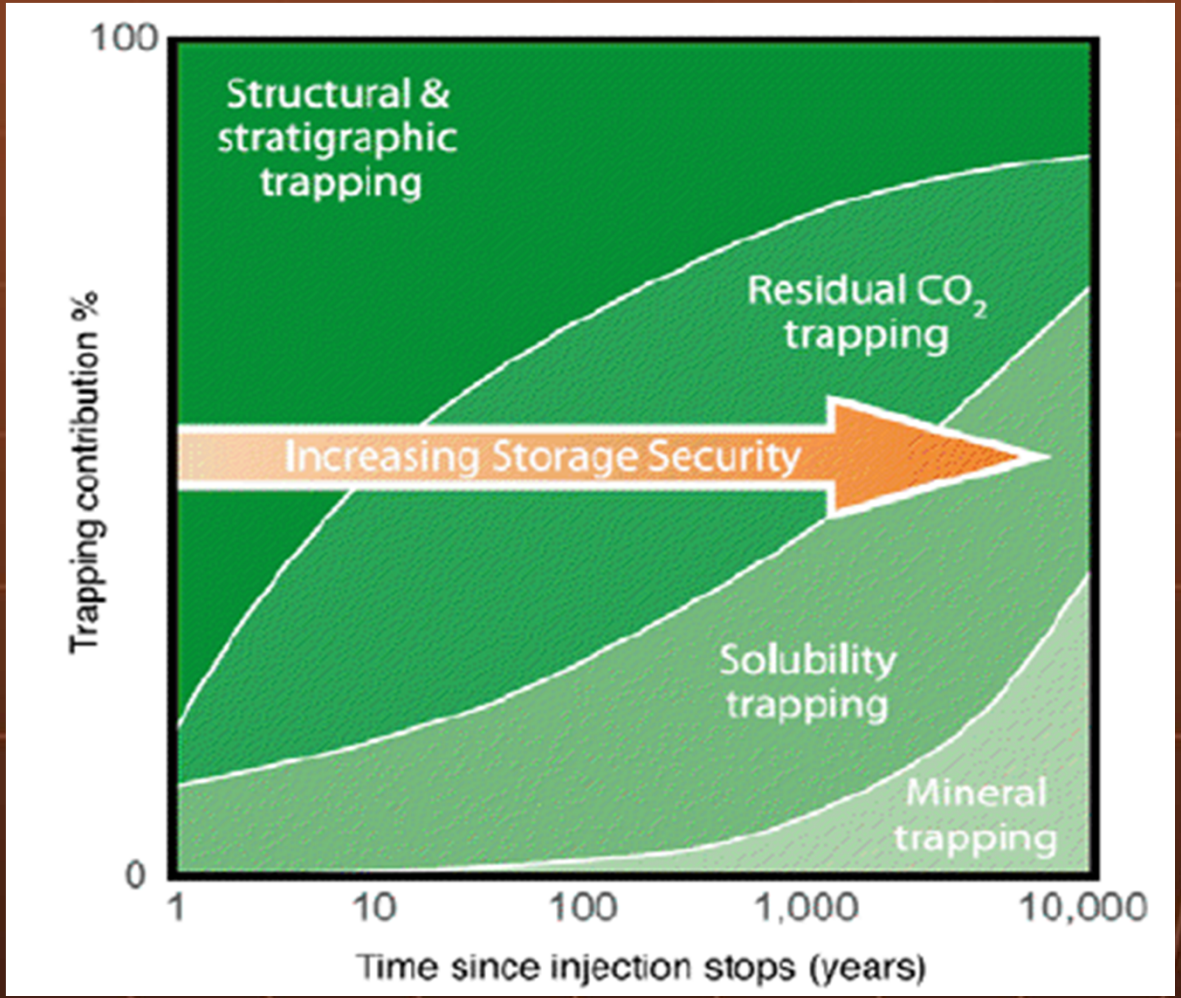
Injection Area



Injection Zone – Vertical View



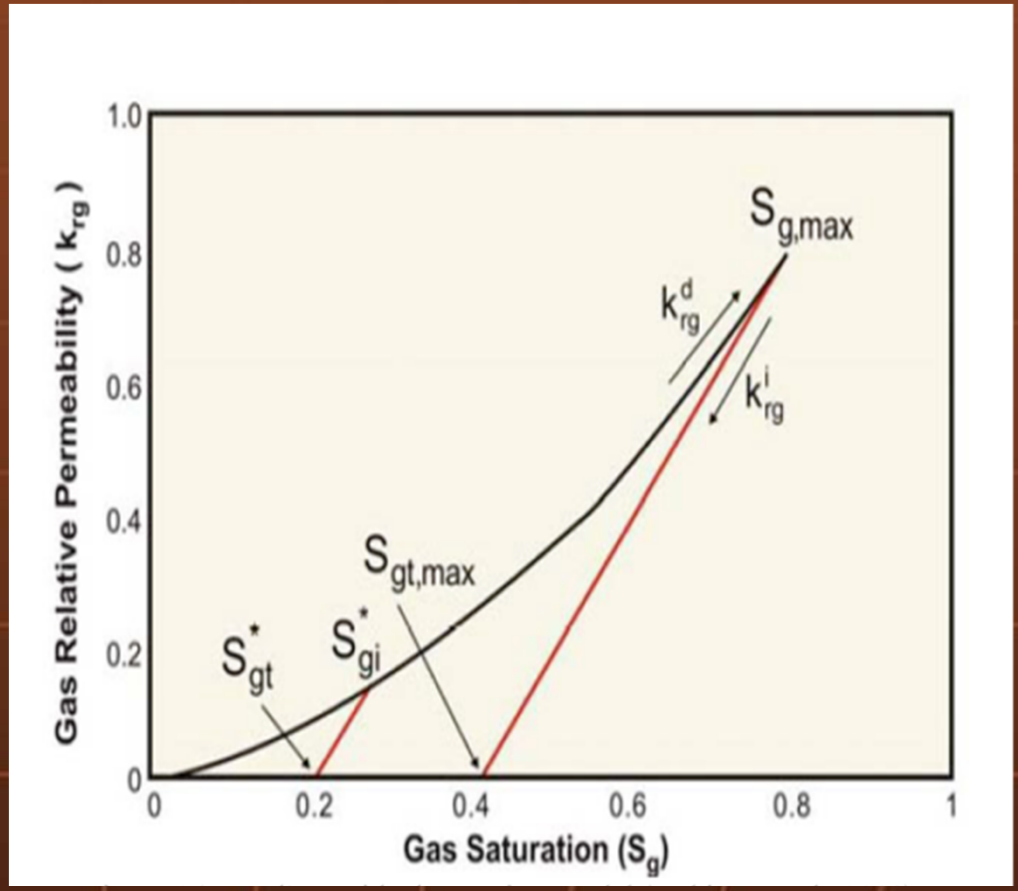
Trapping Mechanisms



Trapping Effectiveness through time (ICCP 2005)

Residual Gas Trapping

- CO_2 is trapped as immobile gas in porous media
- Safe



Typical Land's residual Trapping model (Nghiem 2009)

Solubility Trapping

Fugacity equation to calculate solubility of CO_2

$$f_{CO2,aq} = f_{CO2,g}$$

Equation of state

$$f_{CO2,aq} = H_{CO2,aq}\ Y_{CO2,aq}$$

$H_{CO2,aq}$ is Henry Constant

$Y_{CO2,aq}$ mole fraction of CO_2 in brine

Safe as migration rate 40 ft/ ma (Timothy et al 2008)

Trapping Mechanisms

- Mineral Trapping

  $CO_2 + H_2O = H^+ + HCO_3^-$

  $CaCO_3 + H^+ = Ca^{++} + HCO_3^-$

  Requires thousands of years, and is considered safe

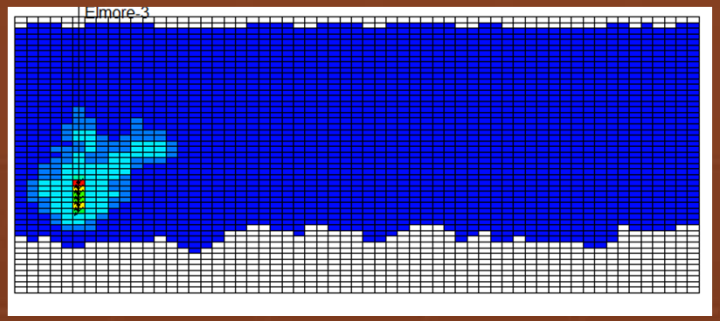
- Structural Trapping

  Theoretical well pipe corrosion rate at 80-84F: 30-60 mm/yr (Han et al 2009)

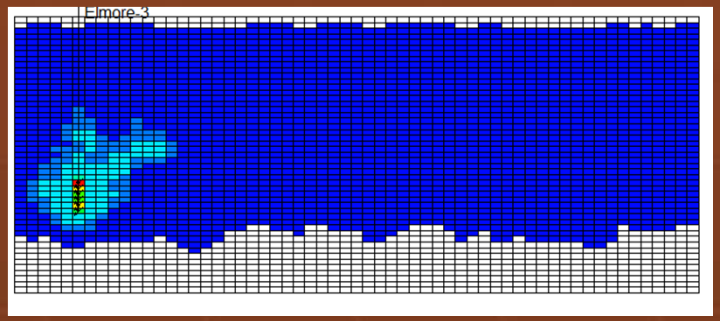
Important Reservoir Conditions

- ***Injection rate: 346 ton/day or 6.67 x 10^6 ft^3/day***
- Water Oil Contact = 4581 ft MD
- The reservoir temperature = 113 F
- Total Dissolved Solid Salinity = 45,000 ppm

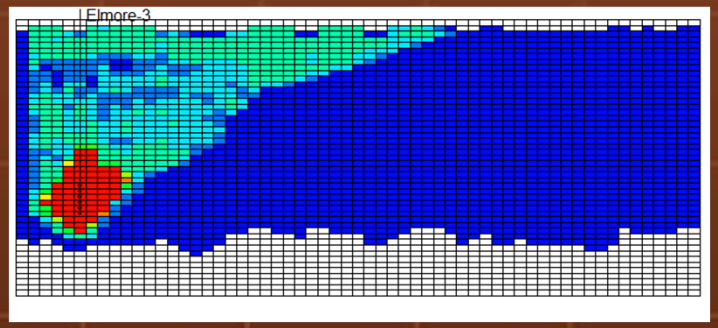
CO_2 Migration



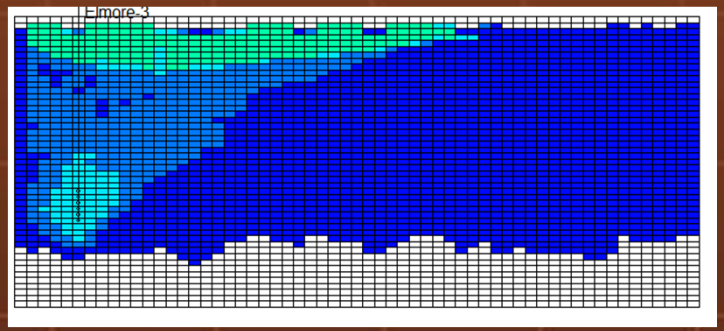
1 year



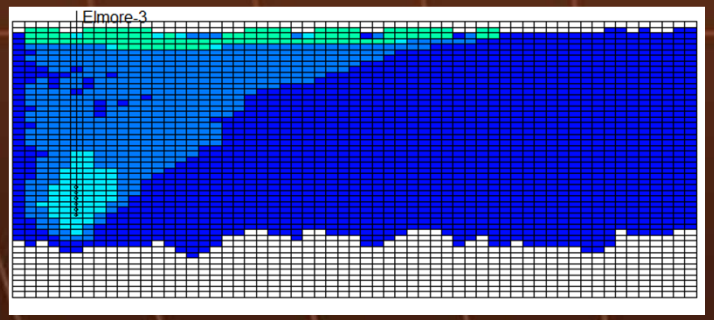
10 years



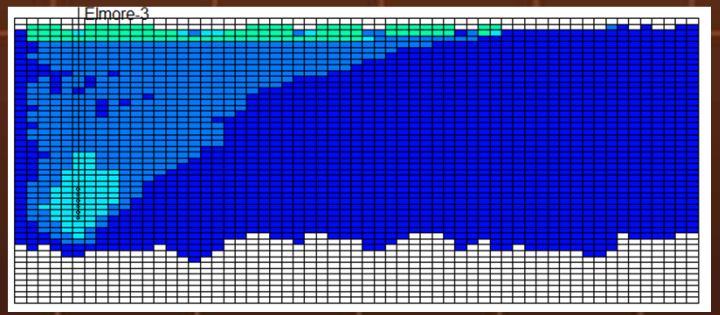
25 years



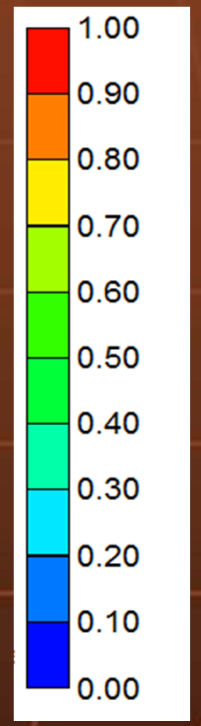
40 years



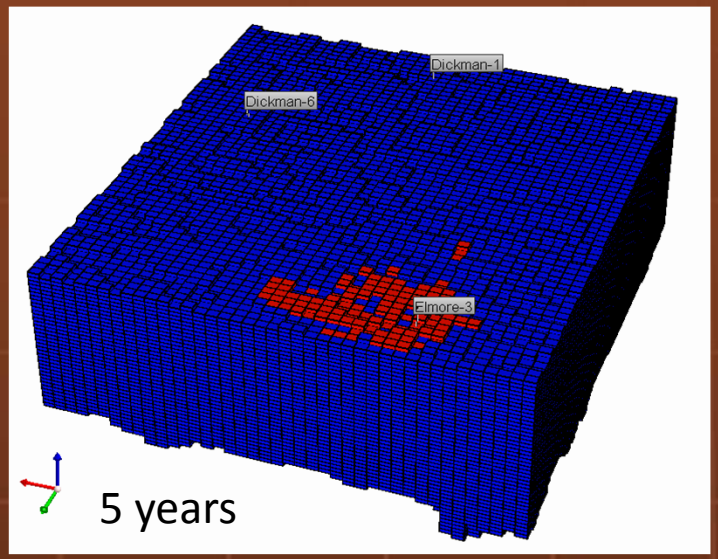
100 years

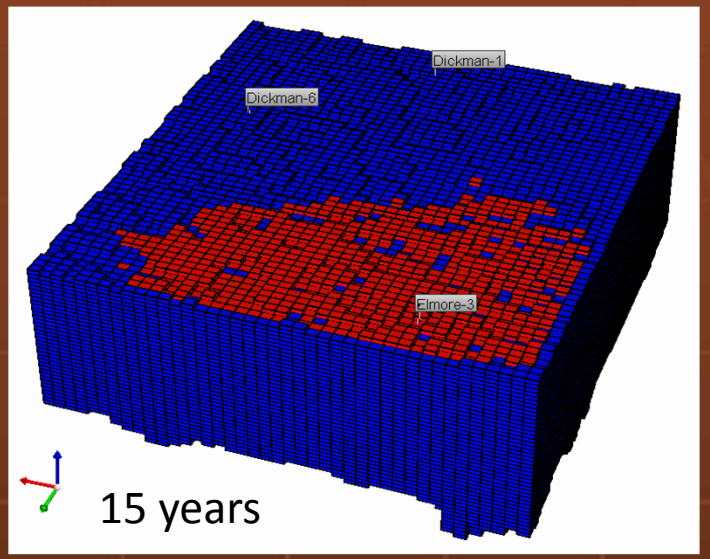


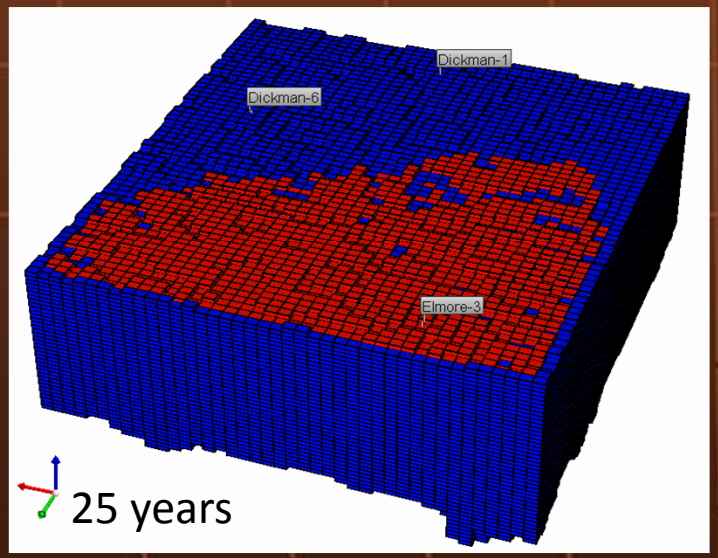
275 years

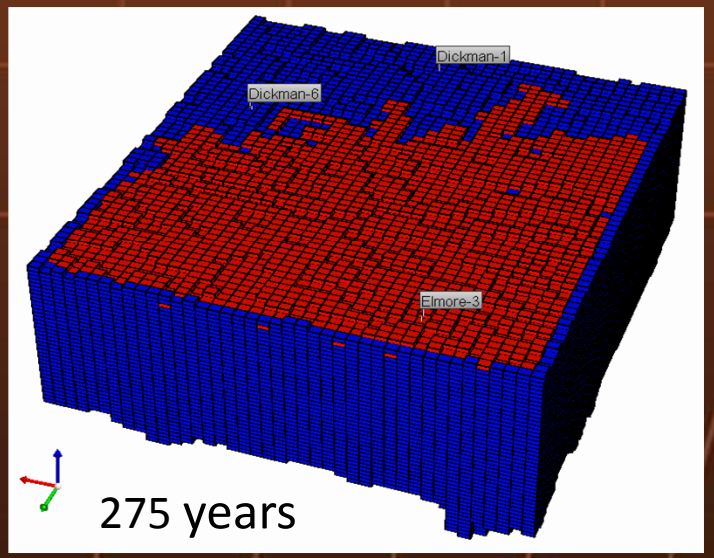


CO_2 Migration Plain View









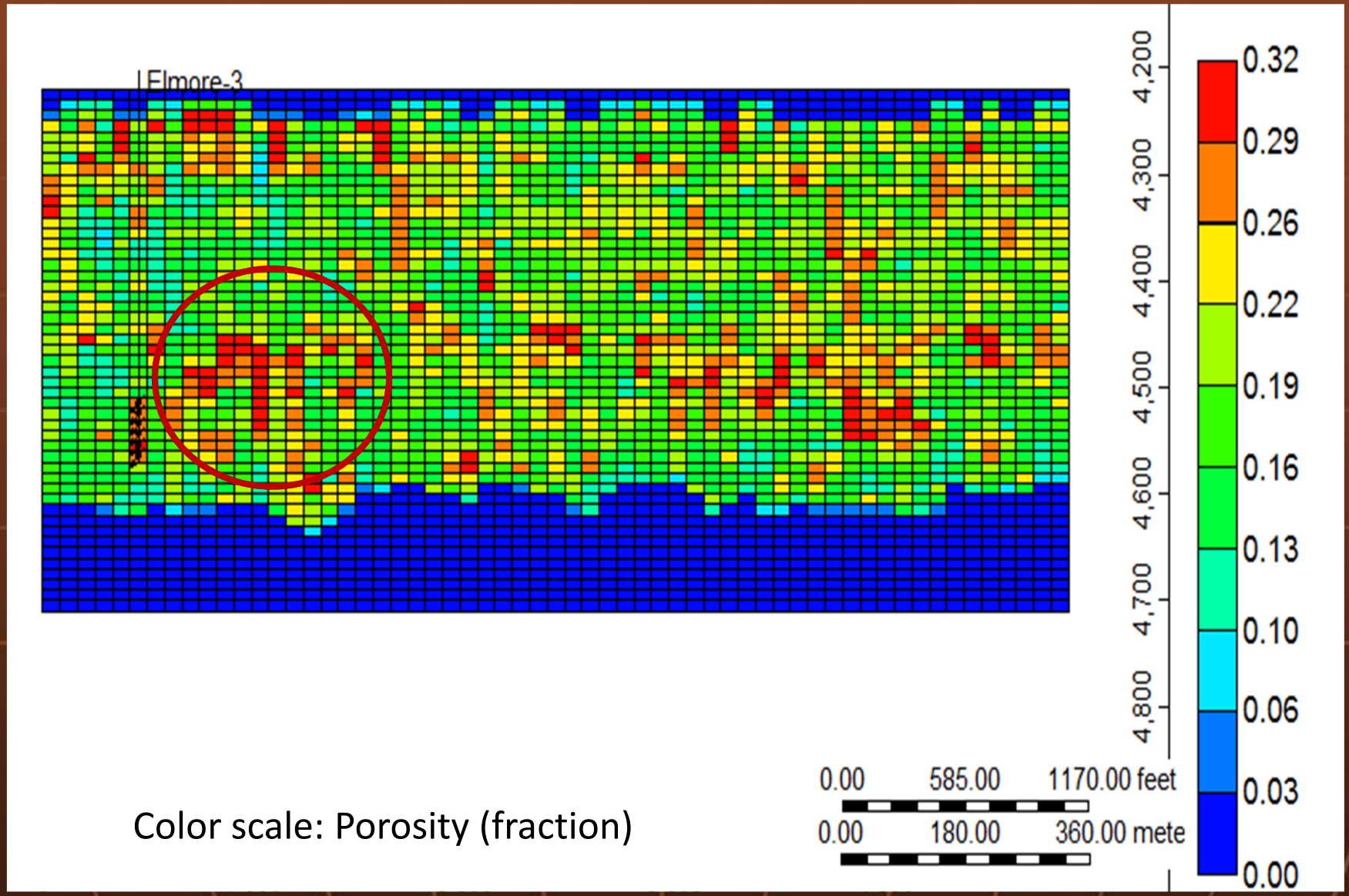
Flow Simulation Observations

- K and Φ do not changes significantly during injection
- CO_2 migrates upward quickly in the first 100 years
- Slow lateral spreading
- There is a high possibility that CO_2 migrates through Fort Scott

Further Investigations

- Simulate flow with higher injection pressure to force CO_2 into higher porosity zone
- Model water injection above perforation zone during CO_2 injection to keep it away from the borehole

High Porosity Zone Near Well Bore



Color scale: Porosity (fraction)

General Conclusion

- Pre-stack inversion can be used reliably to estimate elastic impedances
- Estimated porosity falls within desirable range
- High porosity throughout Gilmore Formation, which makes it a good candidate for CO_2 injection

General Conclusions (cont.)

- Flow simulation predicts CO_2 moves upward quickly within the first 100 years and then spreads laterally
- Low trapping efficiency (also reported in Liner 2009)
- *Possible migration through sealing rock (Fort Scott)*

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