Testing CO_2 Enhanced Recovery in the Devonian Shales of Kentucky

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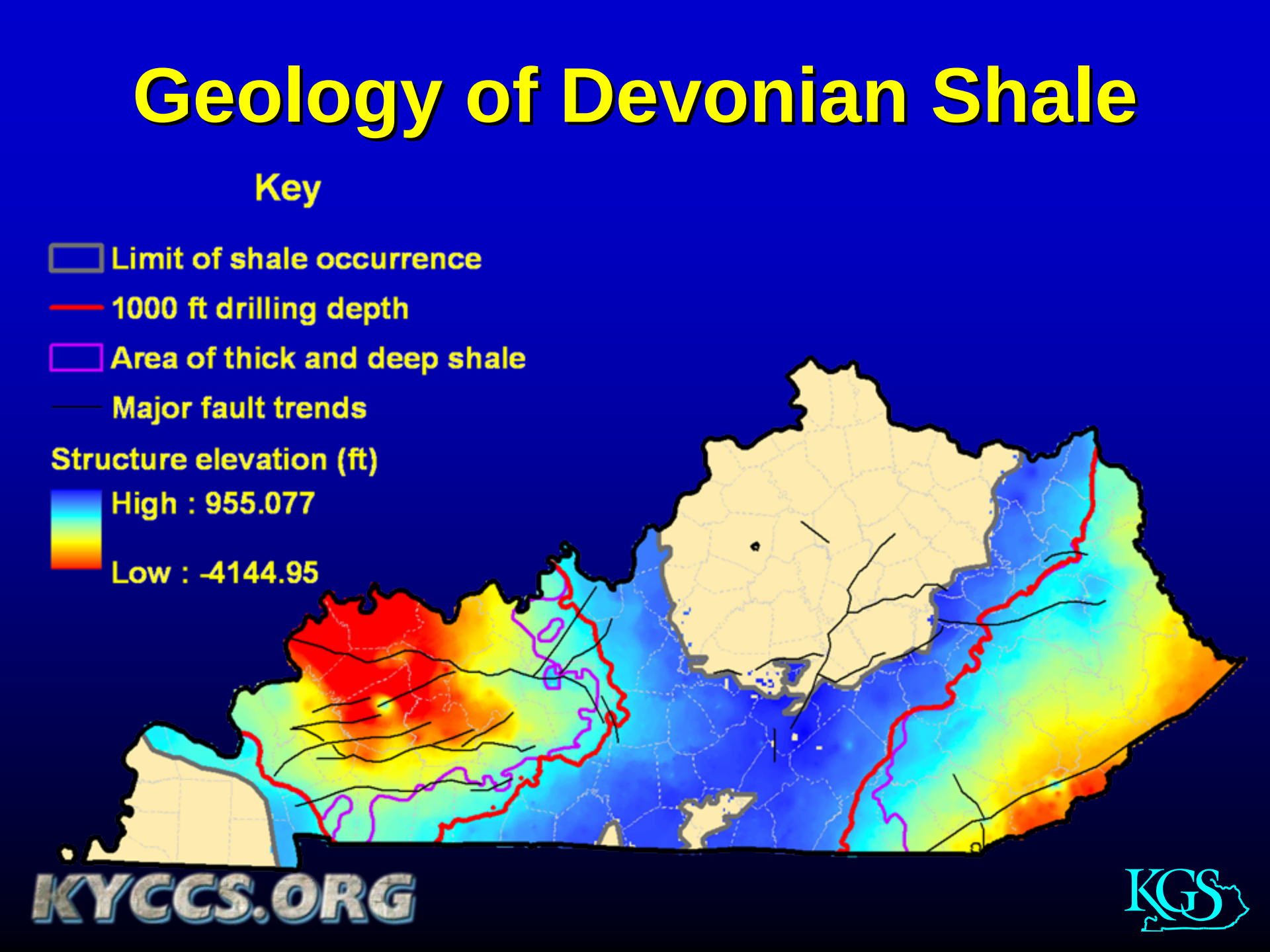
Paradigm

If natural gas can diffuse through the shale matrix to a wellbore, carbon dioxide should be able to diffuse into that same matrix displacing additional gas.

Geology of Devonian Shale



Devonian Shale Reservoir

- Low permeability (microdarcies)
- Micro-porosity
- Organic-rich (up to 25% TOC)
- Thickness
  - > 1,600 feet (eastern Kentucky)
  - > 400 feet (western Kentucky)
- Kentucky's most active and prolific gas producer

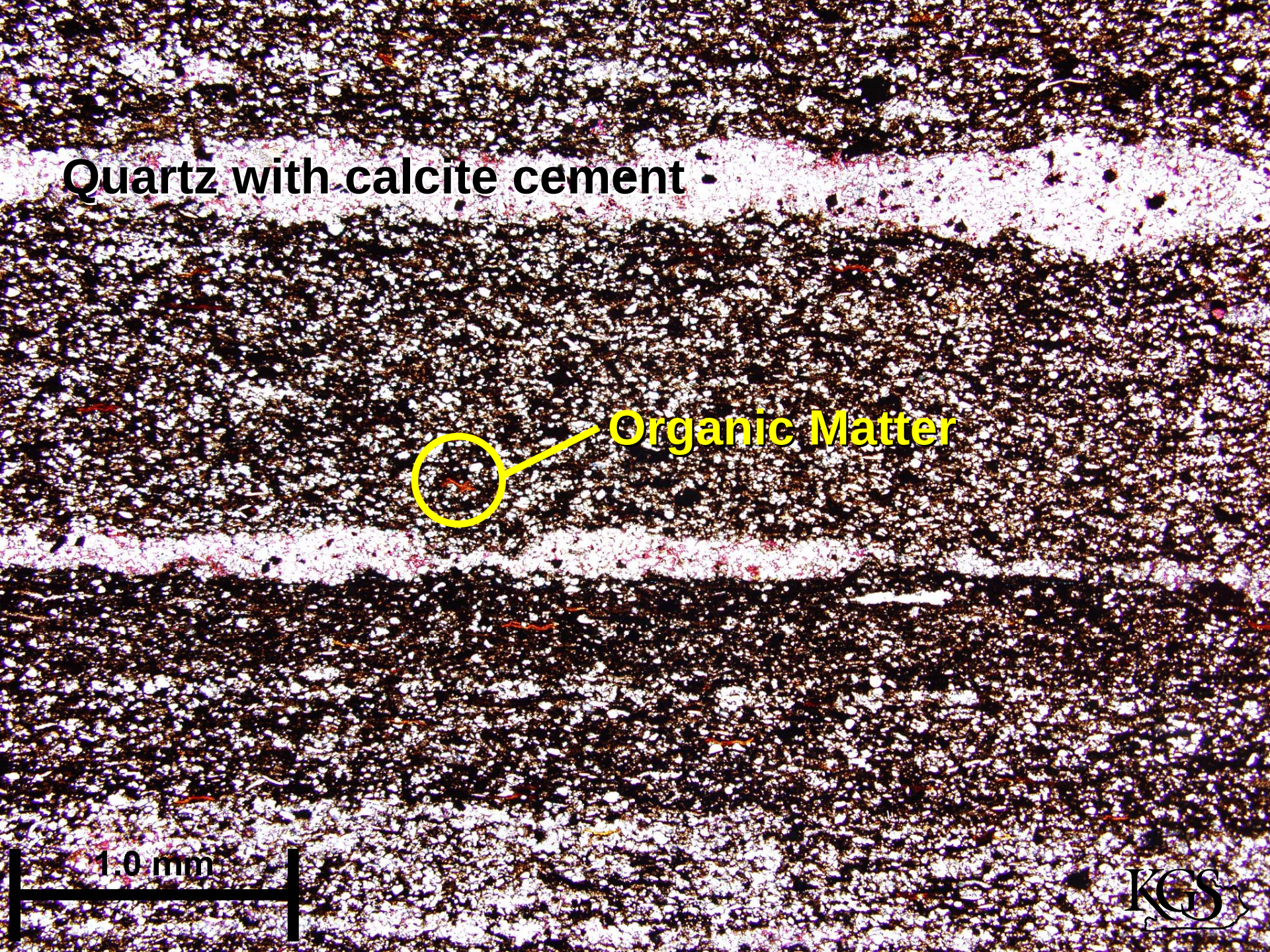
The “Black Shale”

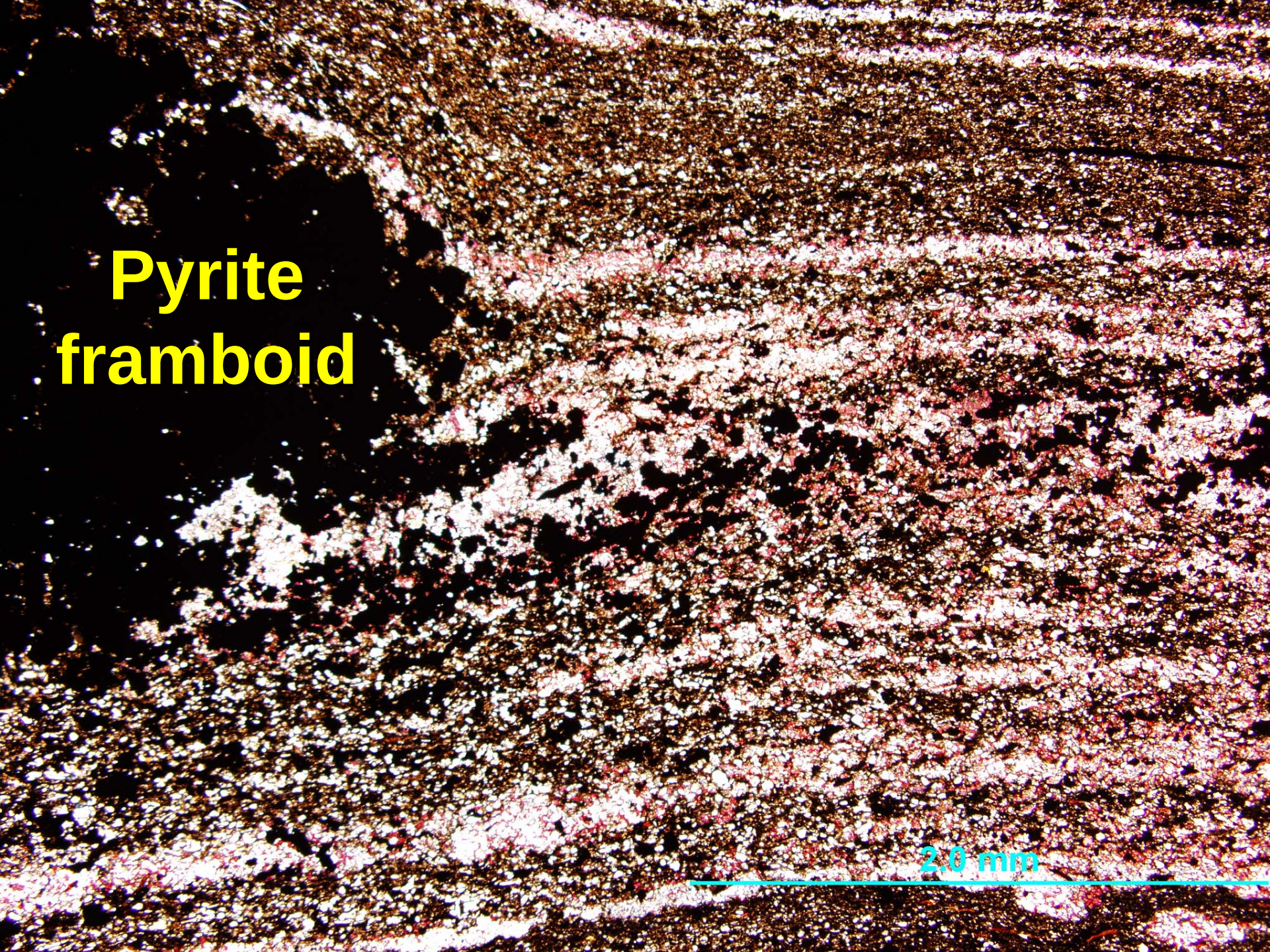
- Fissile
- Alternating
  - Gray (Q+C)
  - Black (organic)

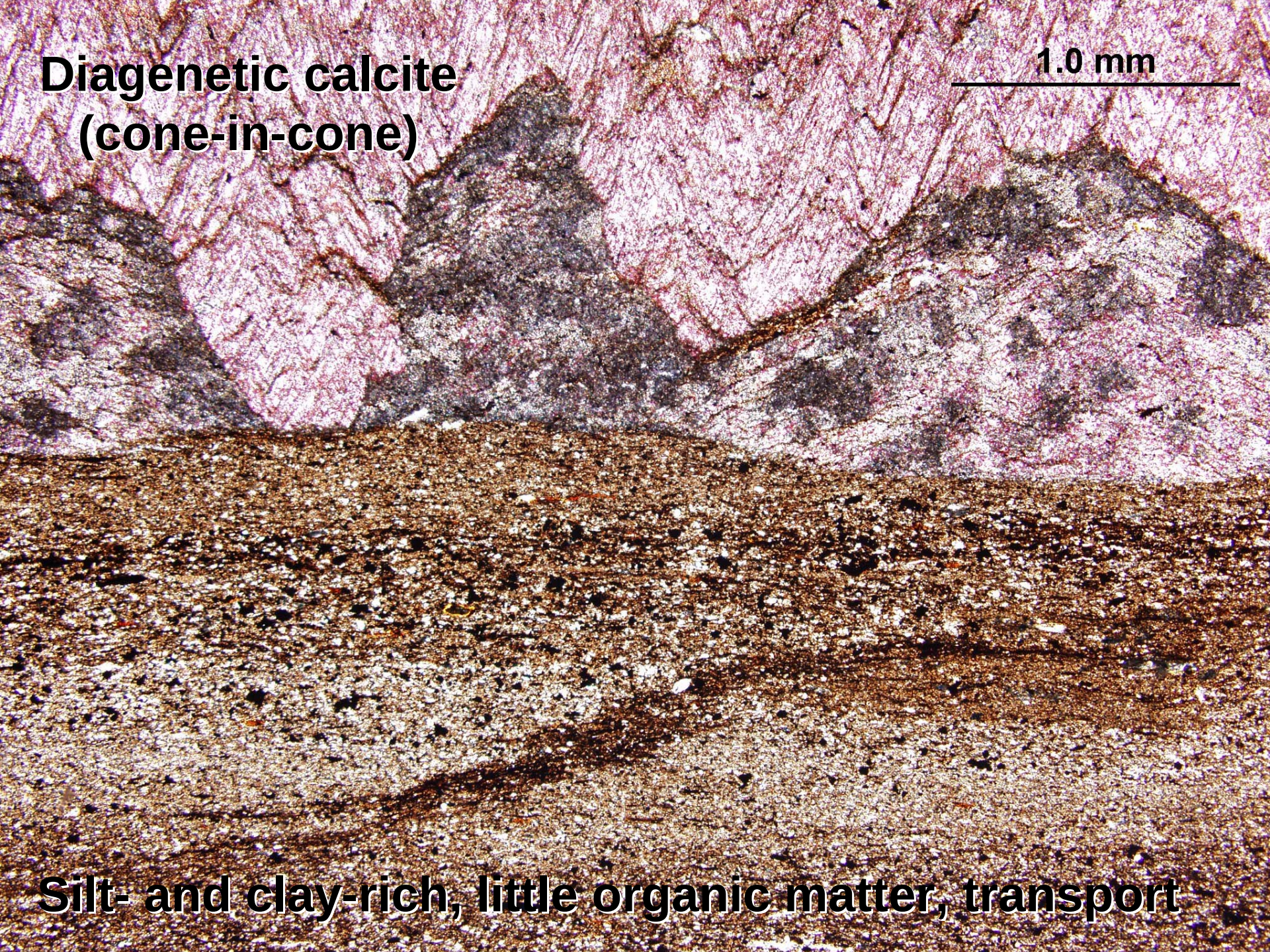
(Not to scale)

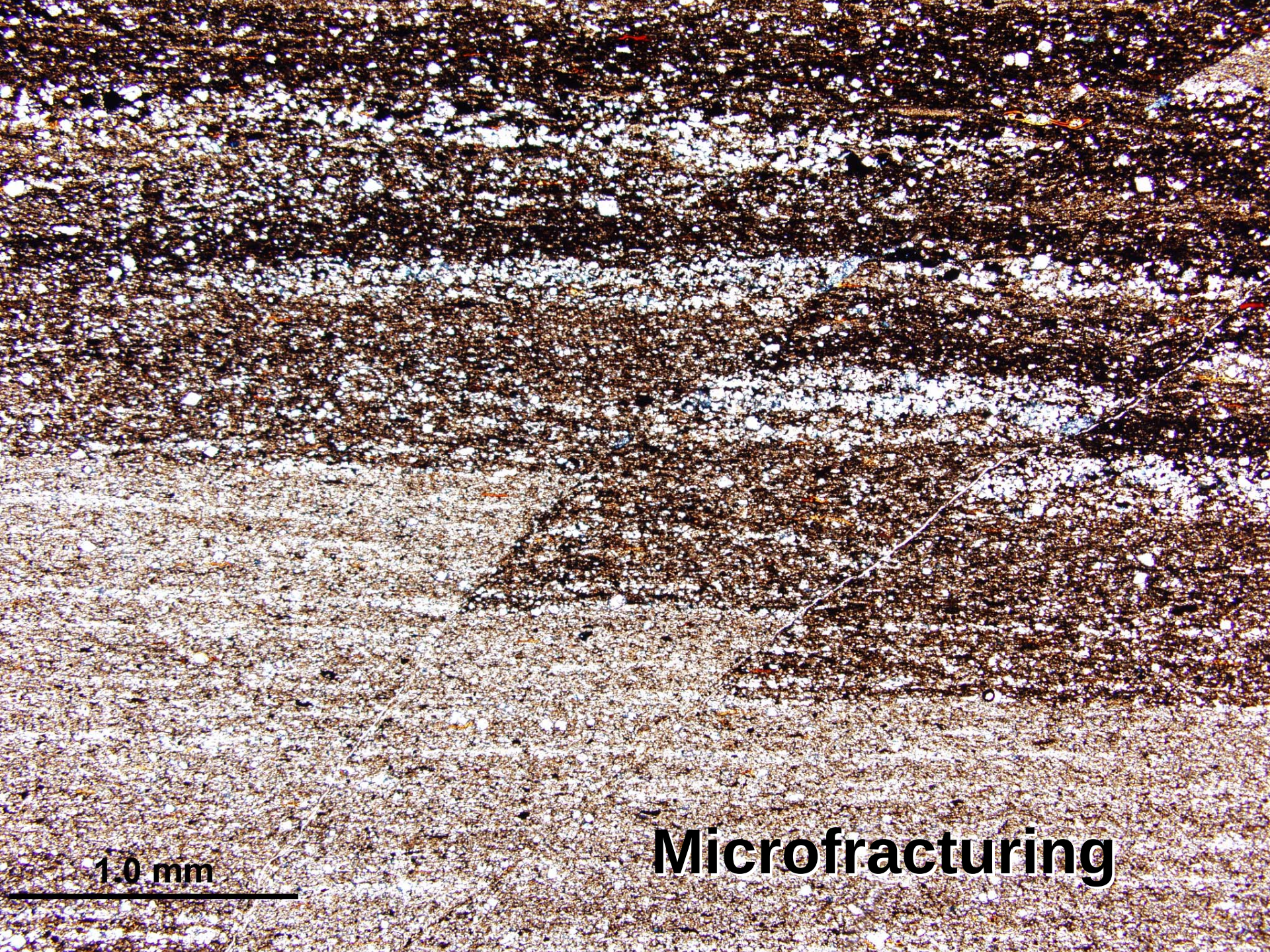
New Albany

Ohio

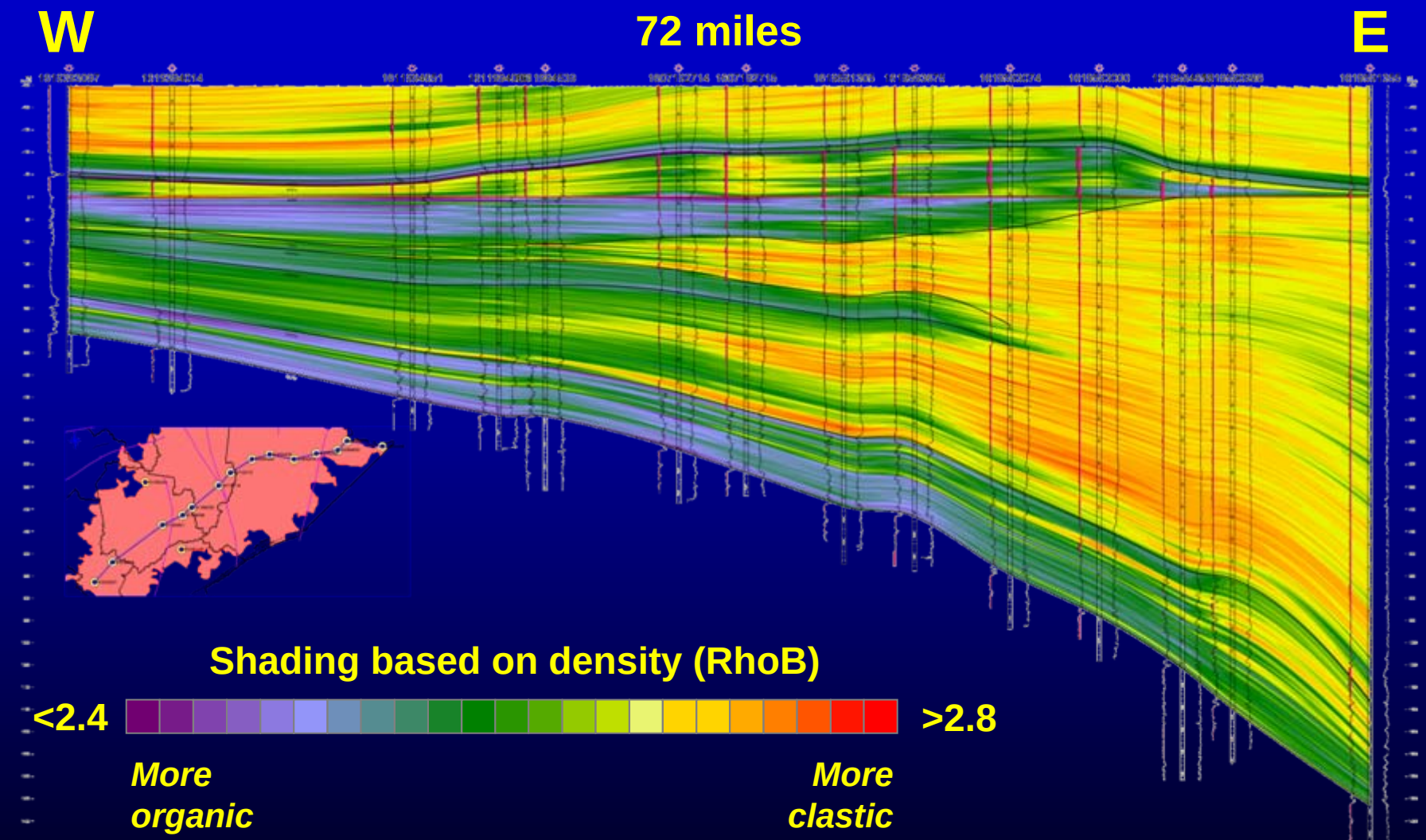

Quartz with calcite cement
Organic Matter
1.0 mm


Pyrite framboid
2.0 mm


Diagenetic calcite
(cone-in-cone)
1.0 mm
Silt- and clay-rich, little organic matter, transport


1.0 mm
Microfracturing

Cross Section



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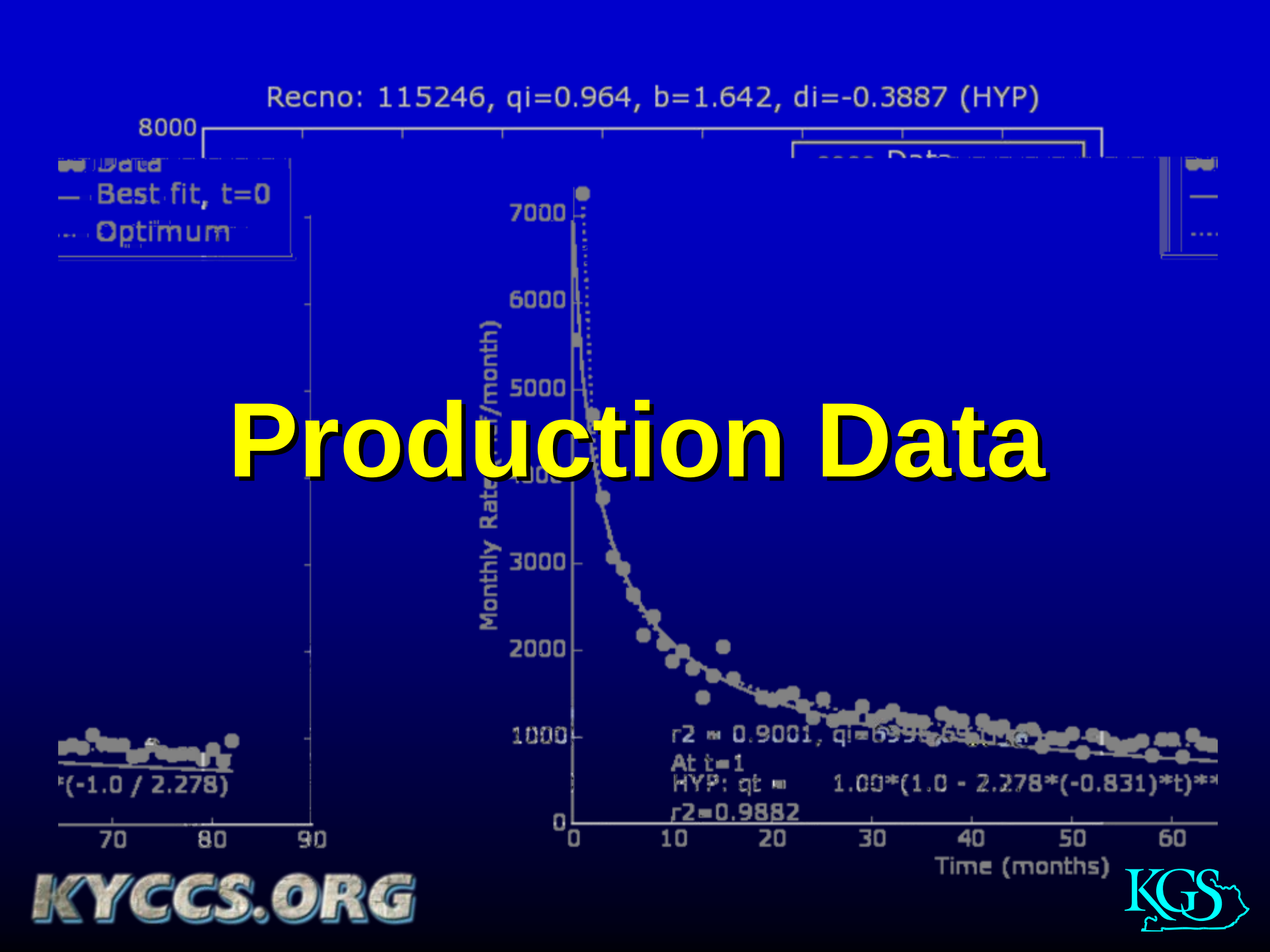
Lines of Evidence Favoring CO_2 EGR

- Analogous to coal
- Production data
- Preferential adsorption
- CO_2 frac study

DOE Regional Carbon Sequestration Partnerships

- Midwest Geologic Sequestration Consortium (Illinois Basin)
- Midwest Regional Carbon Sequestration Partnership (Appalachian Basin)



Production Data

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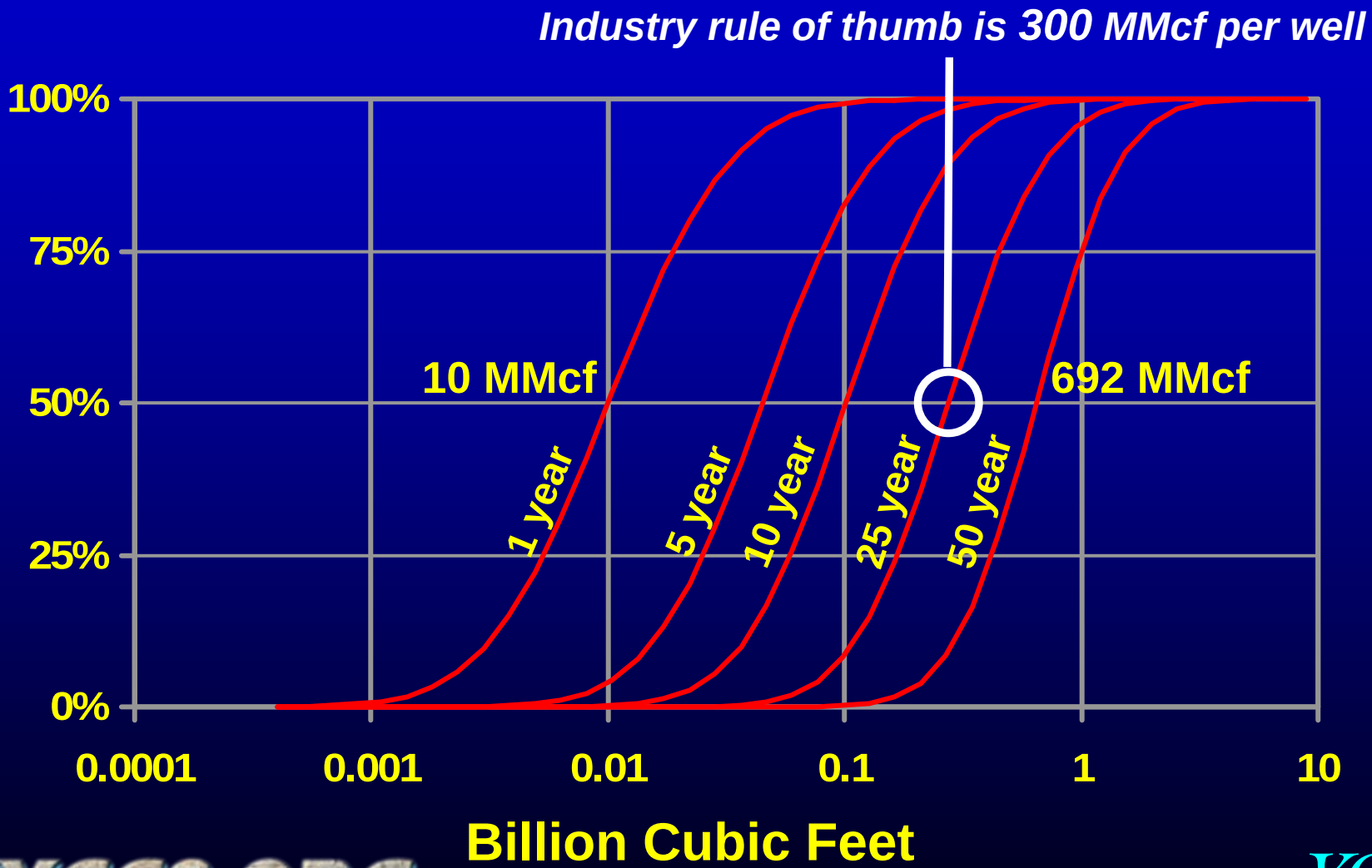
Cumulative Production



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Proprietary GTI data

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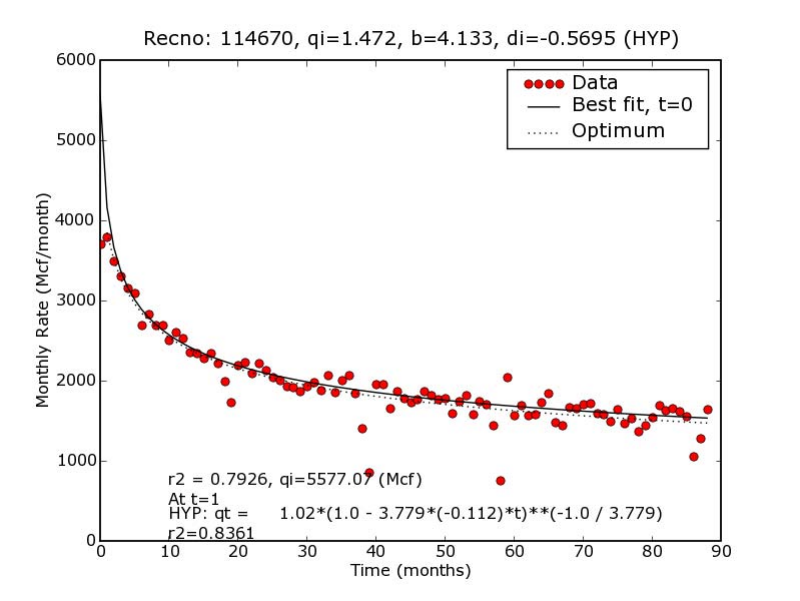
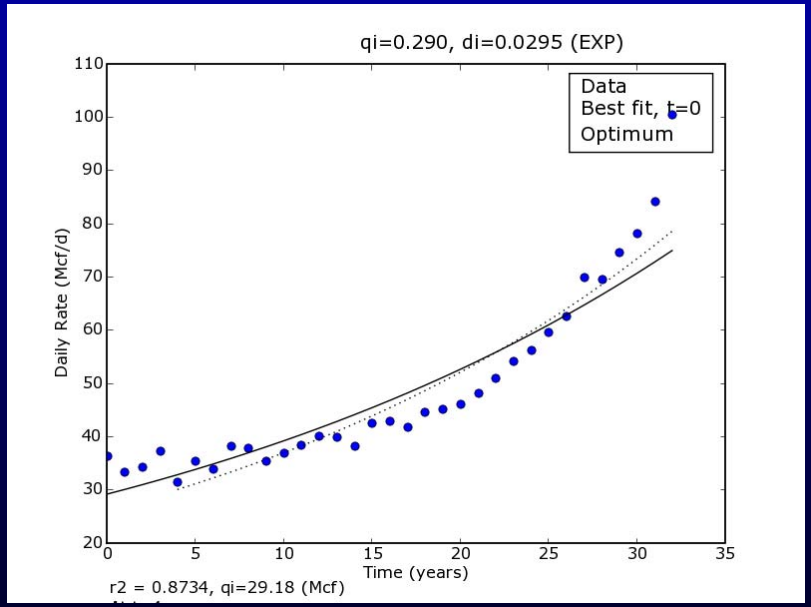
Well “Declines”



Long-term, nearly flat decline

Production for some wells inclines



GTI Proprietary Data

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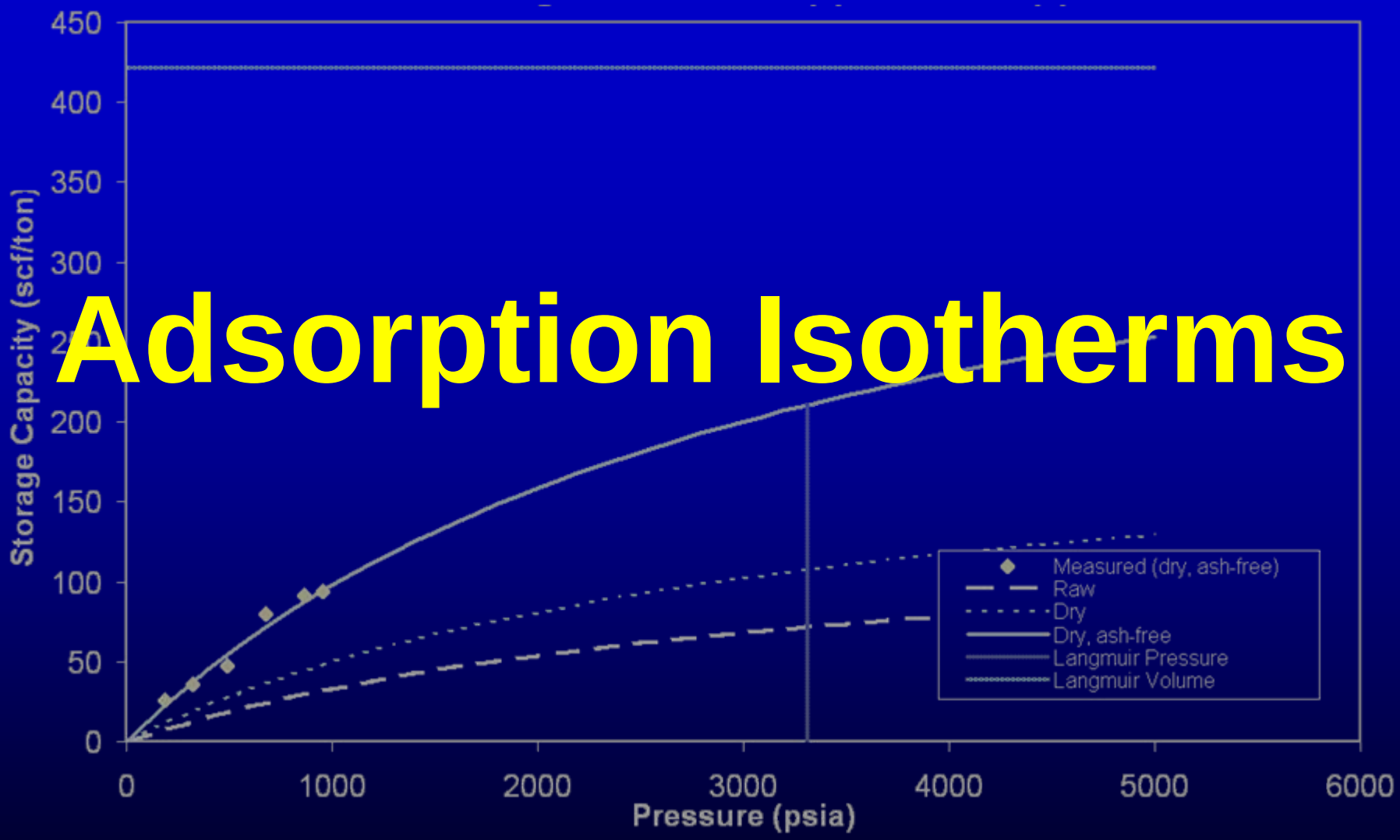
Adsorption Isotherms



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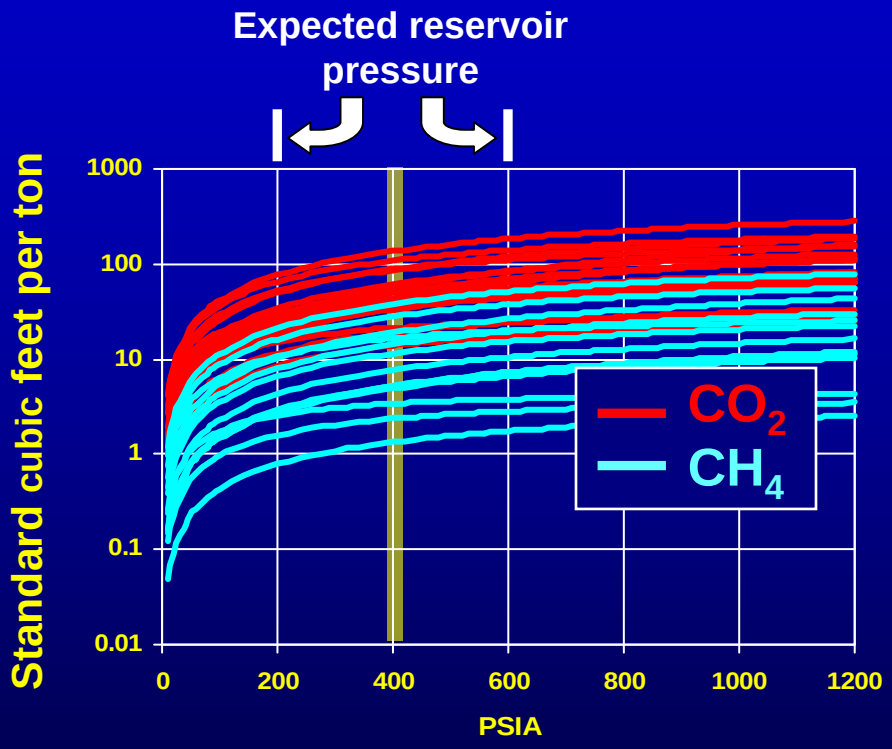
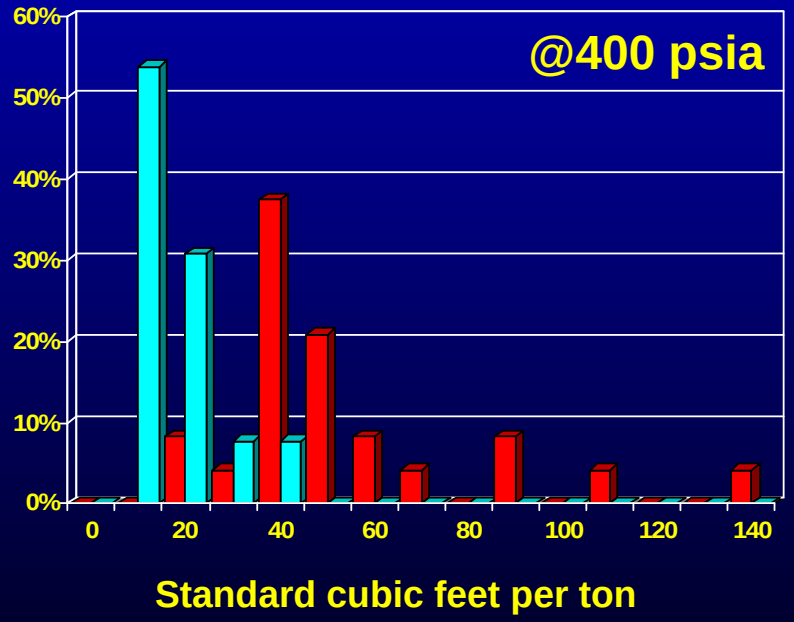
Isotherms Indicate Preferential Adsorption



$CO_2 = 5.3 \times CH_4$

Average CO_2: 42.9 scf/ton

Average CH_4: 8.1 scf/ton



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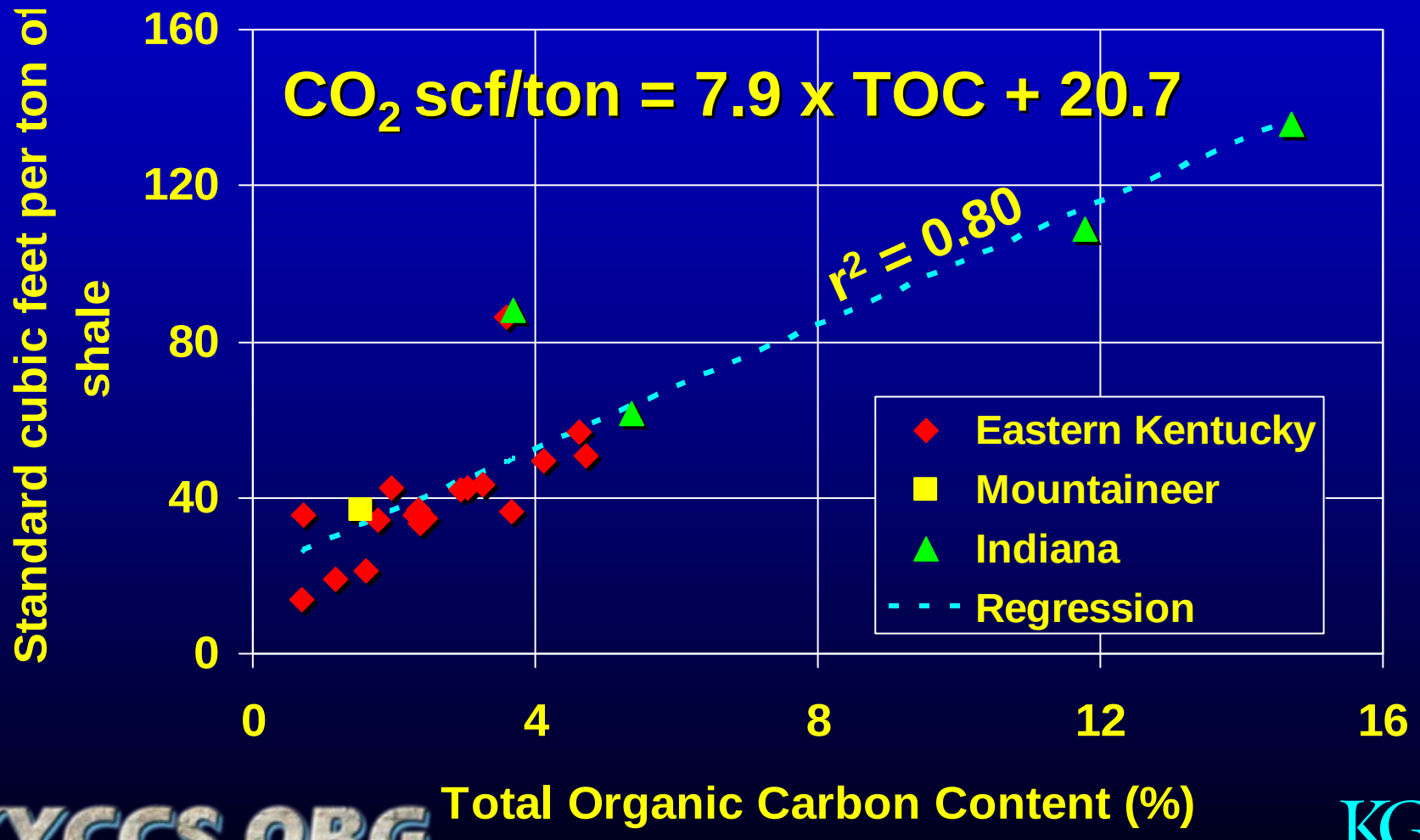
CO_2 Adsorption at 400 PSIA



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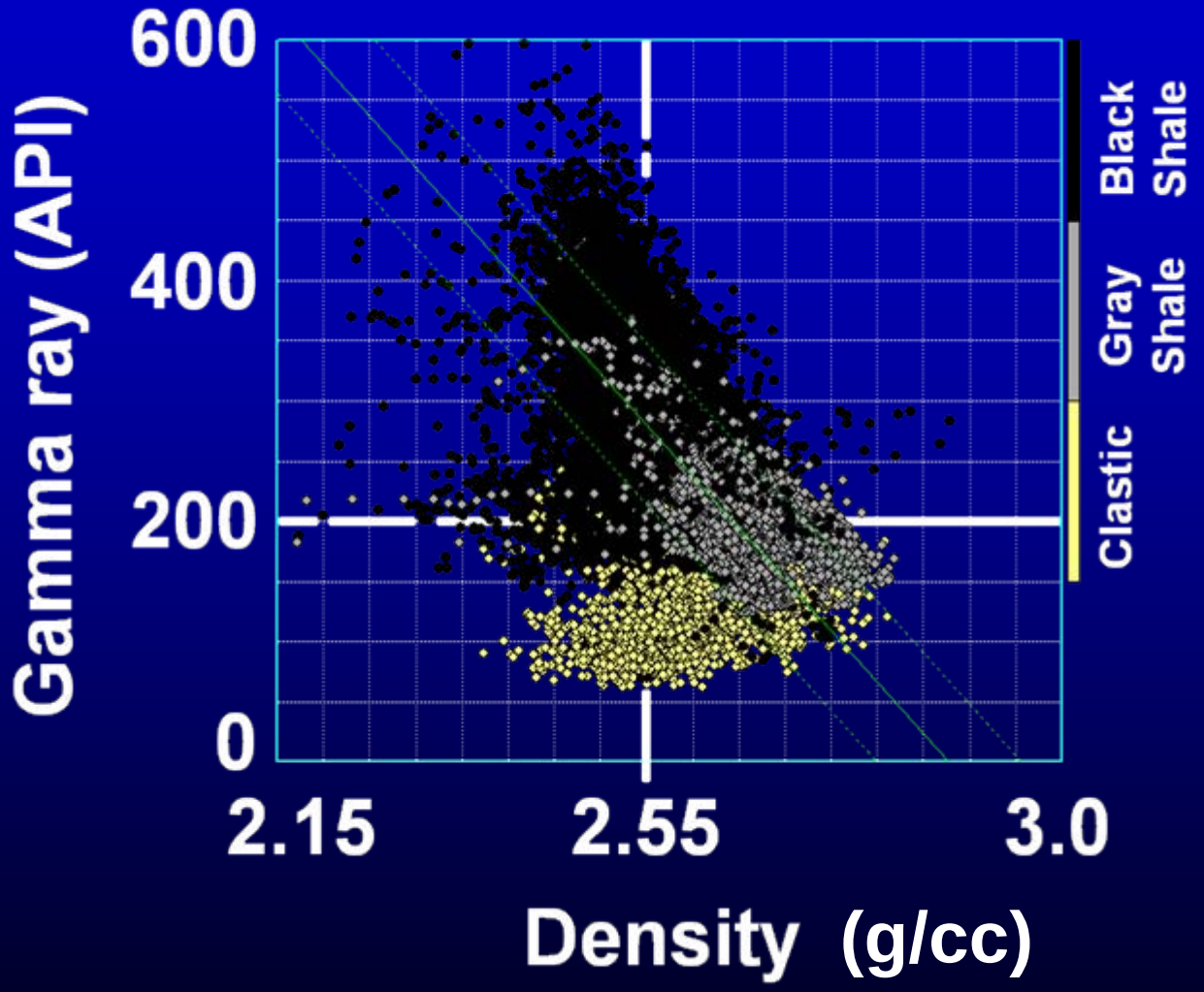
Crossplot



Lower density
&
Higher GR
=
More organic

$RhoB_{max}$ gray shale = 2.82 g/cc

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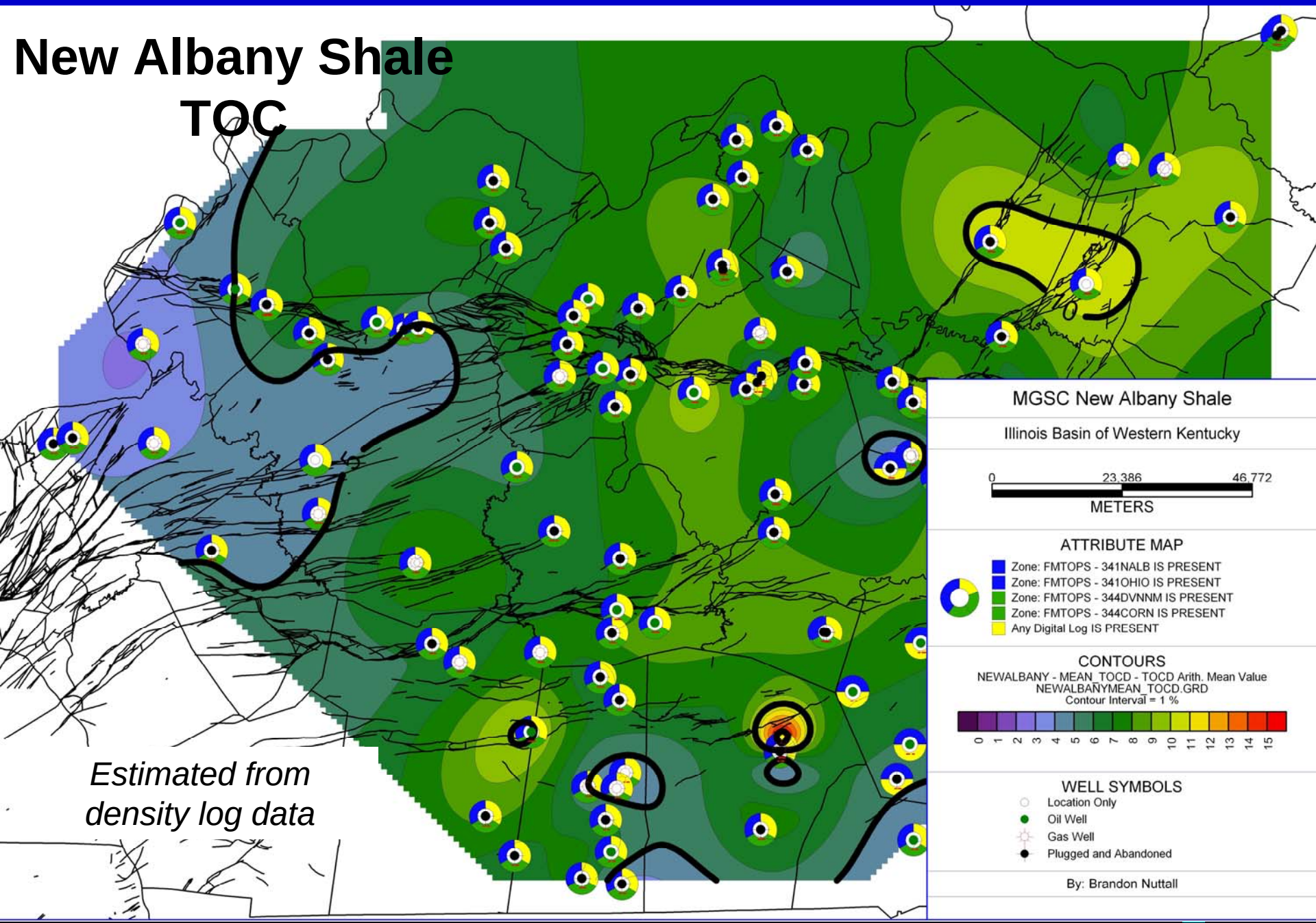
Calculate TOC from RhoB

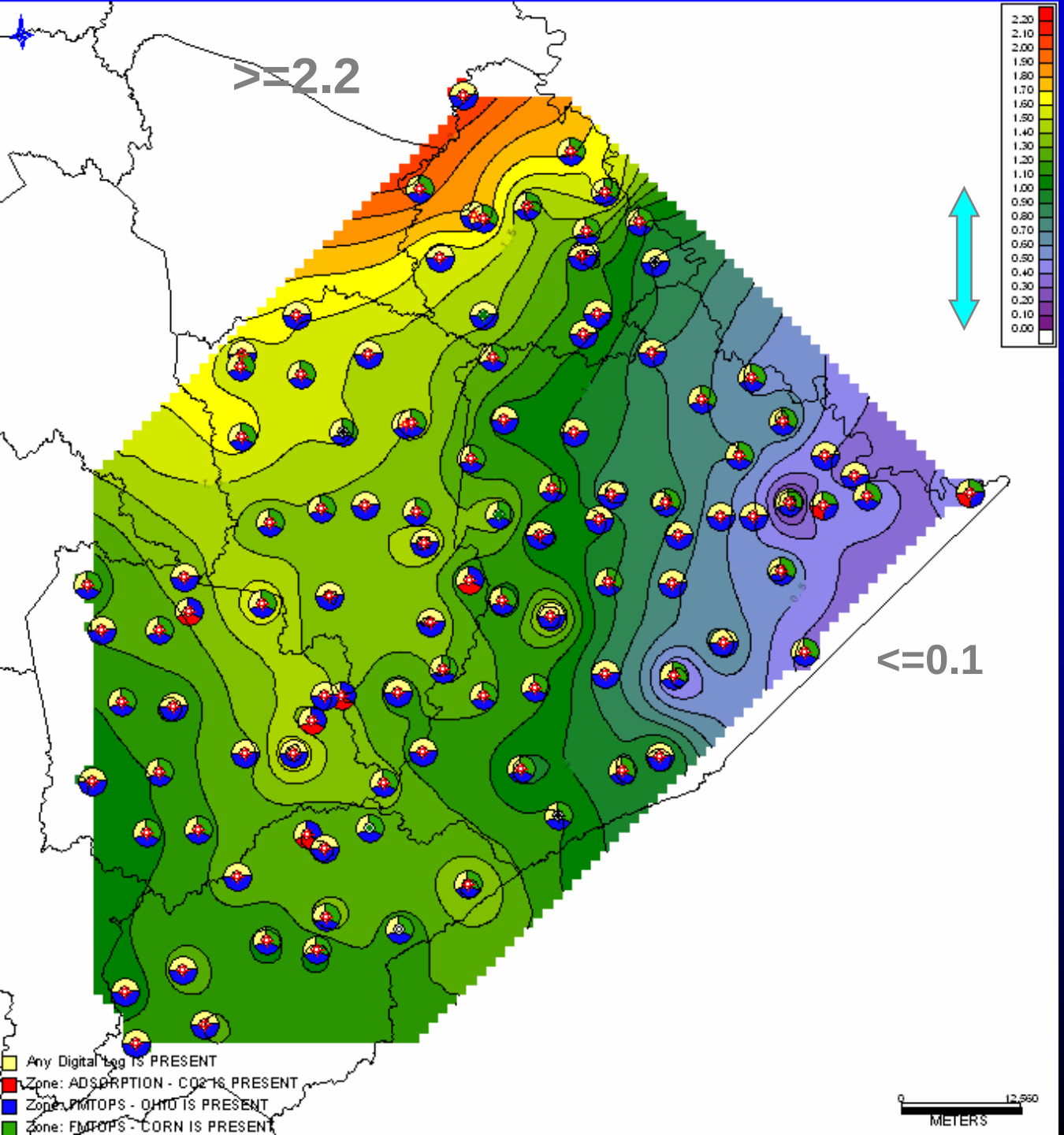
$$TOC = 55.822 * \left(\frac{\rho_B}{\rho} - 1 \right)$$

Schmoker, 1993, USGS Bull 1909

New Albany Shale TOC



Estimated from density log data



CO_2 Storage Capacity (million metric tonnes per km^2)

Total: 6.8 billion tonnes

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CO_2/Sand Frac Study

- Yost, Mazza, & Gehr, 1993, SPE 26925
- Fast flowback (2 to 3 days)
- Preliminary production
  - 56% > N_2 frac wells
  - 4.8 x shot wells
- Consistent with CO_2 adsorption

HB-1 (2007) EGR in Shale

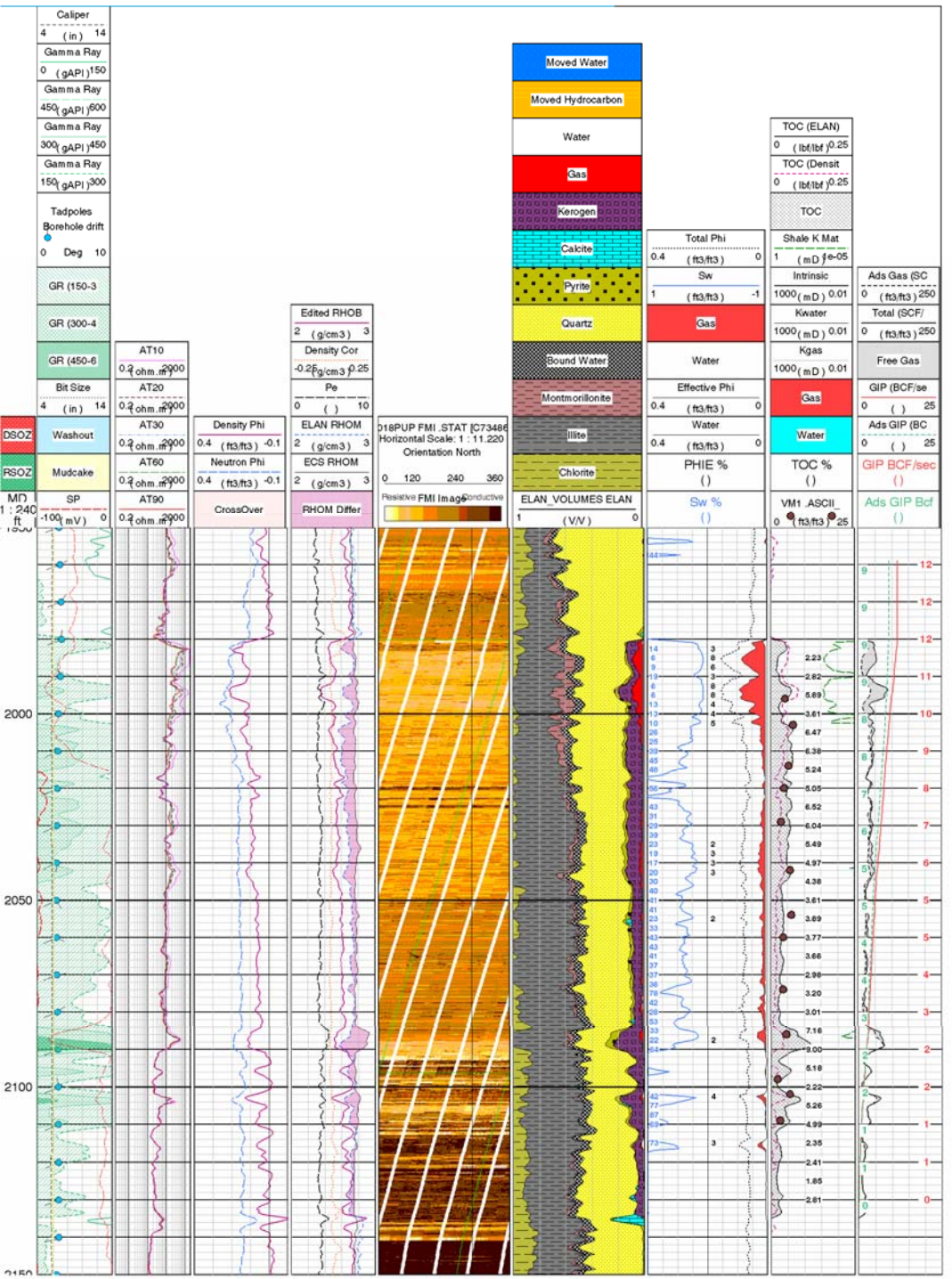
- Specifies: “At least one of the wells will test the Devonian shale for enhanced gas recovery and sequestration potential.”
- Encourages: the Survey to “…use these funds to match available federal and private funds to the extent possible.”

Project Outline

- Advisory group (experimental protocol)
- Consortium (partnership)
- Site selection
- Data collection, analysis, modeling
  - Background MMV
- Injection
- Data analysis and reporting
  - Model refinement and confirmation
  - MMV

Indicators of Success

- Increase in gas production rate
- Mass balance indicates CO_2 adsorption
- After flowback and cleanup, pipeline quality gas



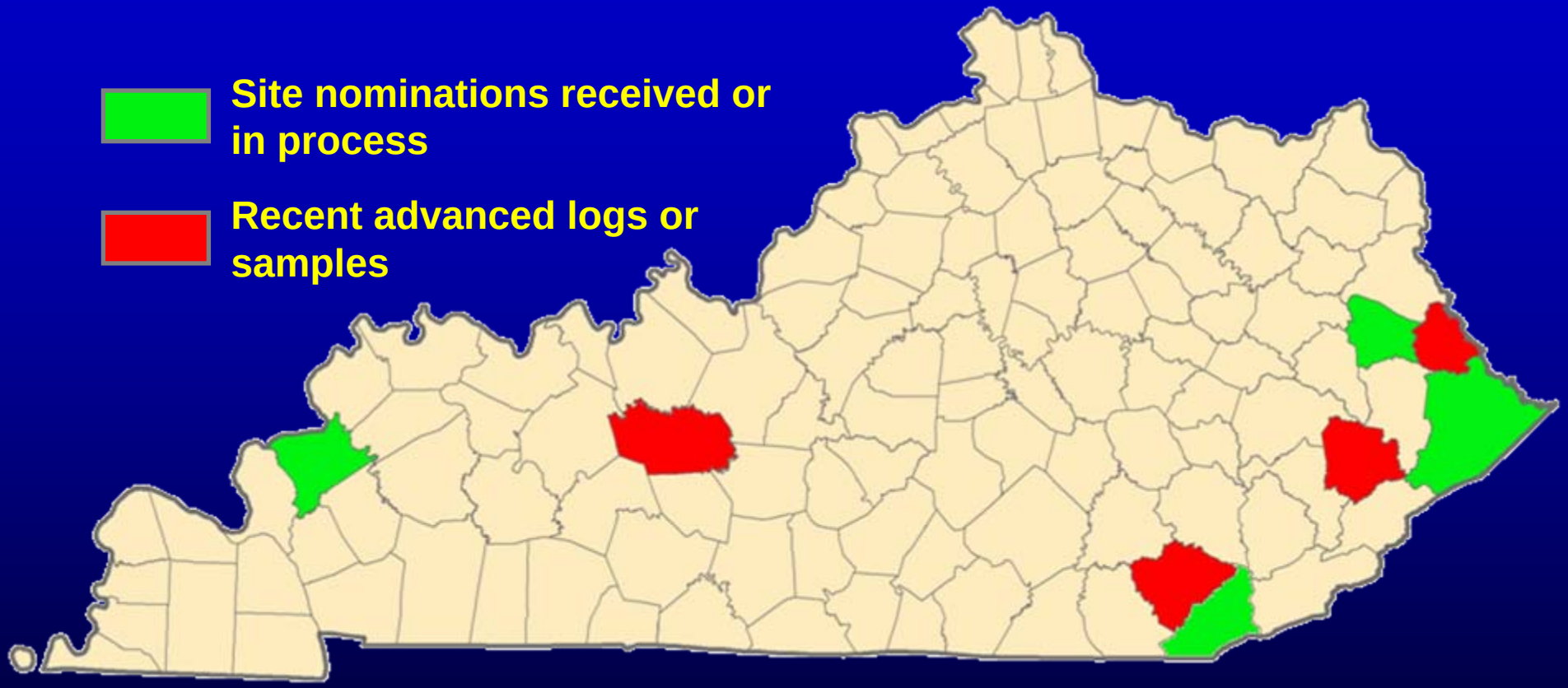
Limitations: Detailed data for modeling

- Shale analysis logs
- Petrographic analysis
- Mechanical data

Status

Site nominations received or in process

Recent advanced logs or samples



KGS Well Sample and Core Library is being searched for additional cores.

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