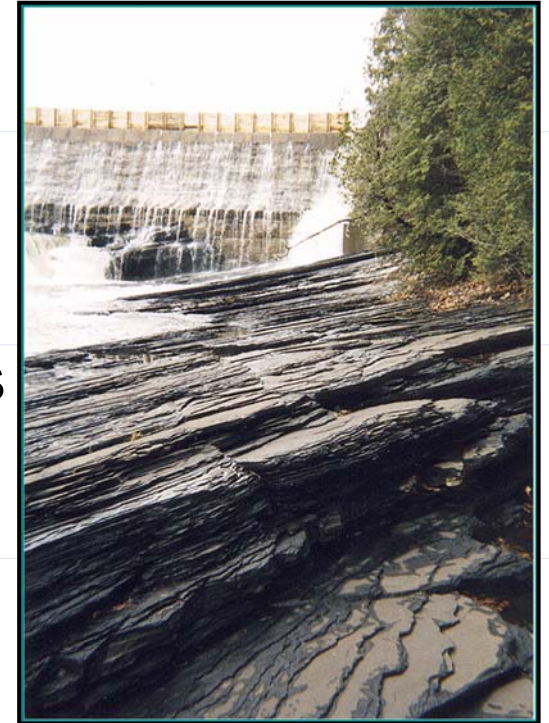


Wireline Evaluation Techniques of Shale Gas Reservoirs

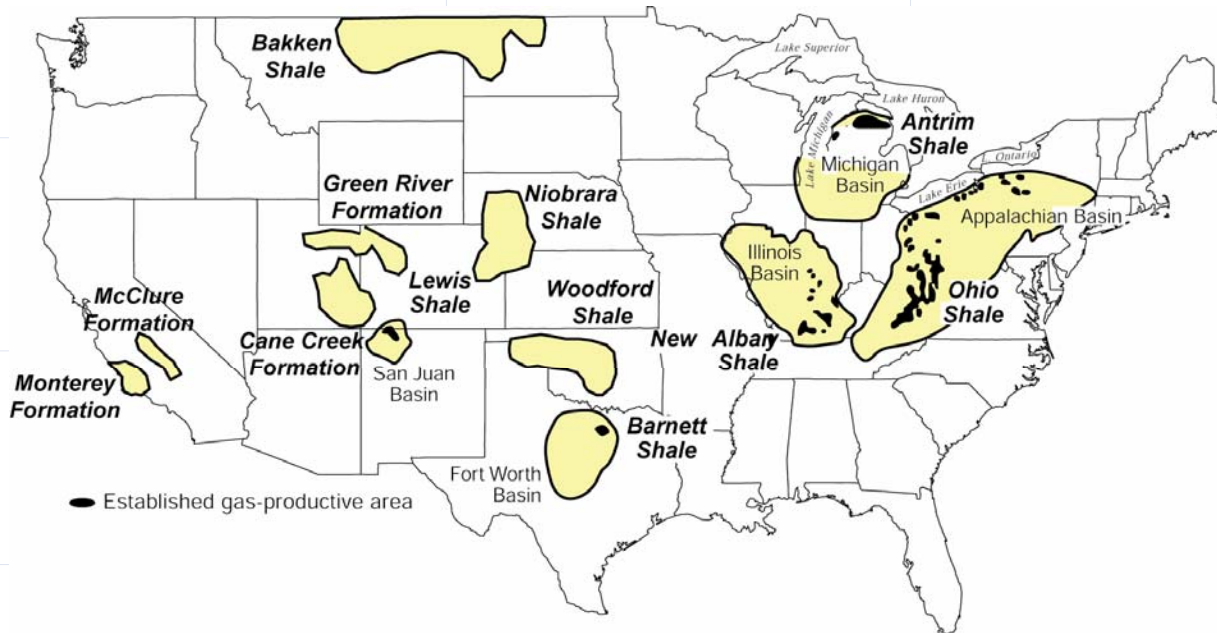
Keith Bartenhagen
Schlumberger
Oklahoma City

Gas Shales

- What are they?
 - Organic-rich shales
 - Source rocks
 - Adsorbed and free gas
 - Very low permeability
- Common traits of gas shale reservoirs
 - Abundant gas (40 to 120 BCF/section)
 - Low recovery efficiency (8 to 12%)
 - Large developments (economies of scale)
 - Fracture stimulation
 - Long well life



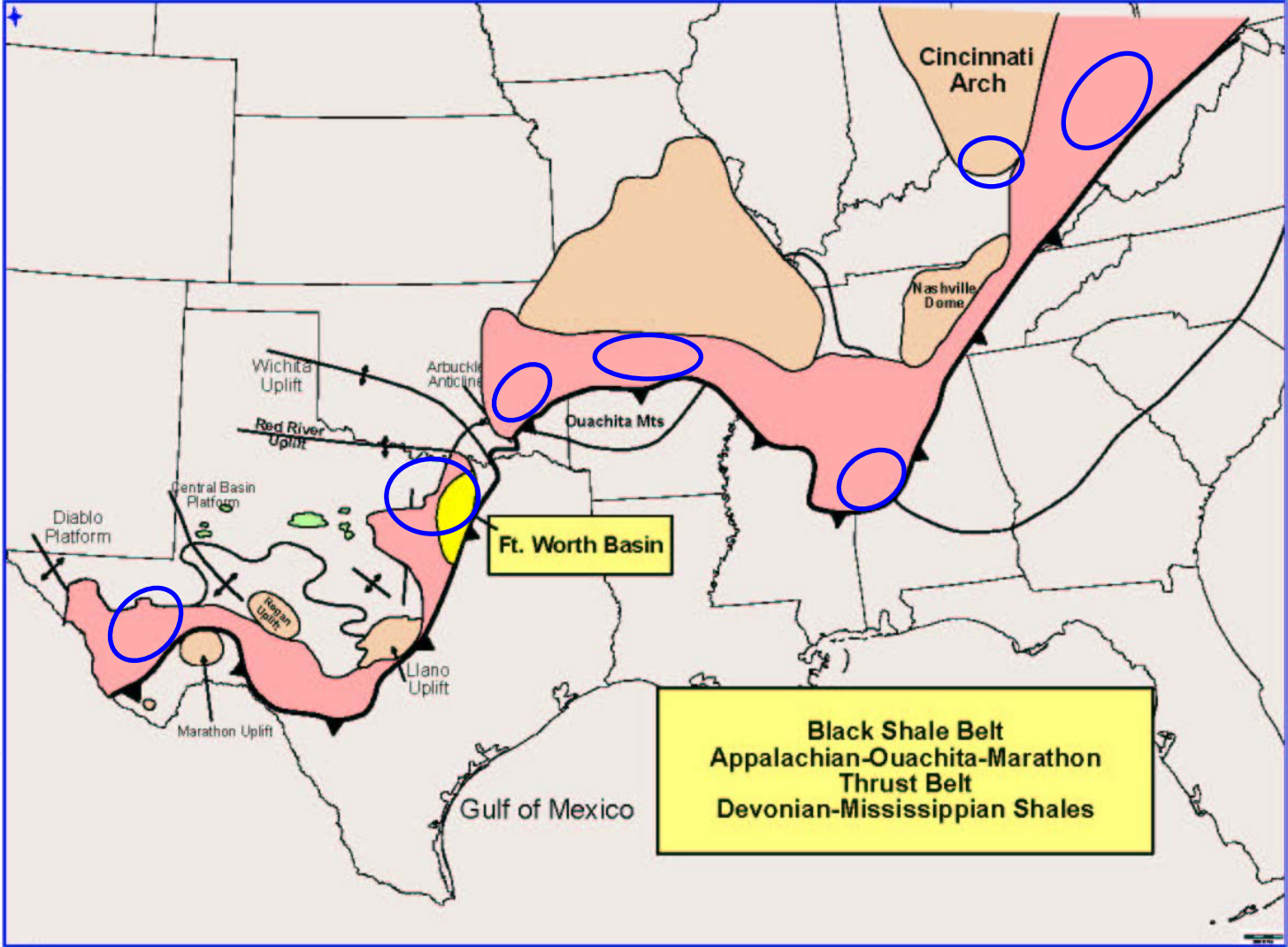
Gas Shales of the United States



- Resource: 500 - 780 TCF
- Regionally extensive
- 28,000 wells drilled
- Occur within major petroleum basins
- Next “big” onshore play

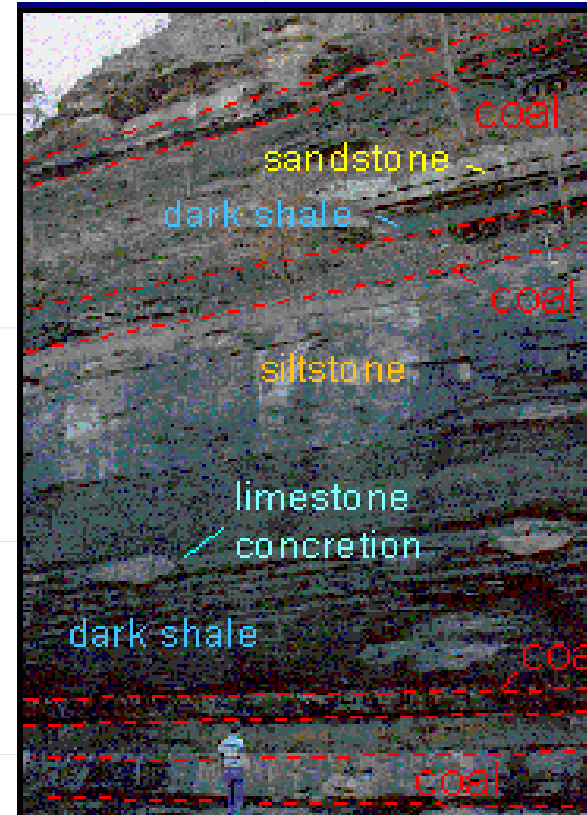
Hill and Nelson (2000)

Conclusion



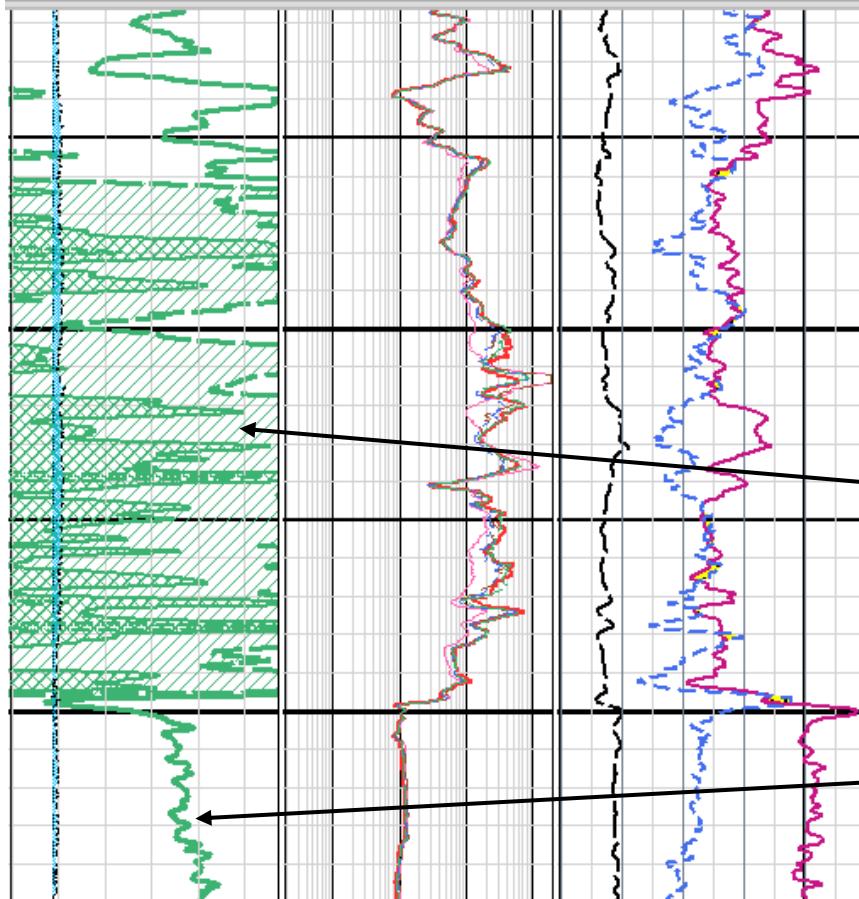
Shale Gas Evaluation Needs

- Delineation of shale gas beds
- Quantify gas
 - Adsorbed
 - Free
- Producibility
 - Matrix permeability
 - Amount and type of fractures
 - System permeability
 - Pressure
- Production prediction



Gas Shale Log

GR (800 - 1000)	AHT90 0.2 (ohm.m) 2000	Pe 0 () 20
Caliper 6 (in) 16	AHT10 0.2 (ohm.m) 2000	
Bit Size 6.3 (in) 16.3	AHT20 0.2 (ohm.m) 2000	X-Over
Washout	AHT30 0.2 (ohm.m) 2000	Density Phi (Ls) 0.4 (ft3/ft3) -0.1
Mudcake	AHT60 0.2 (ohm.m) 2000	Neutron Phi 0.4 (ft3/ft3) -0.1

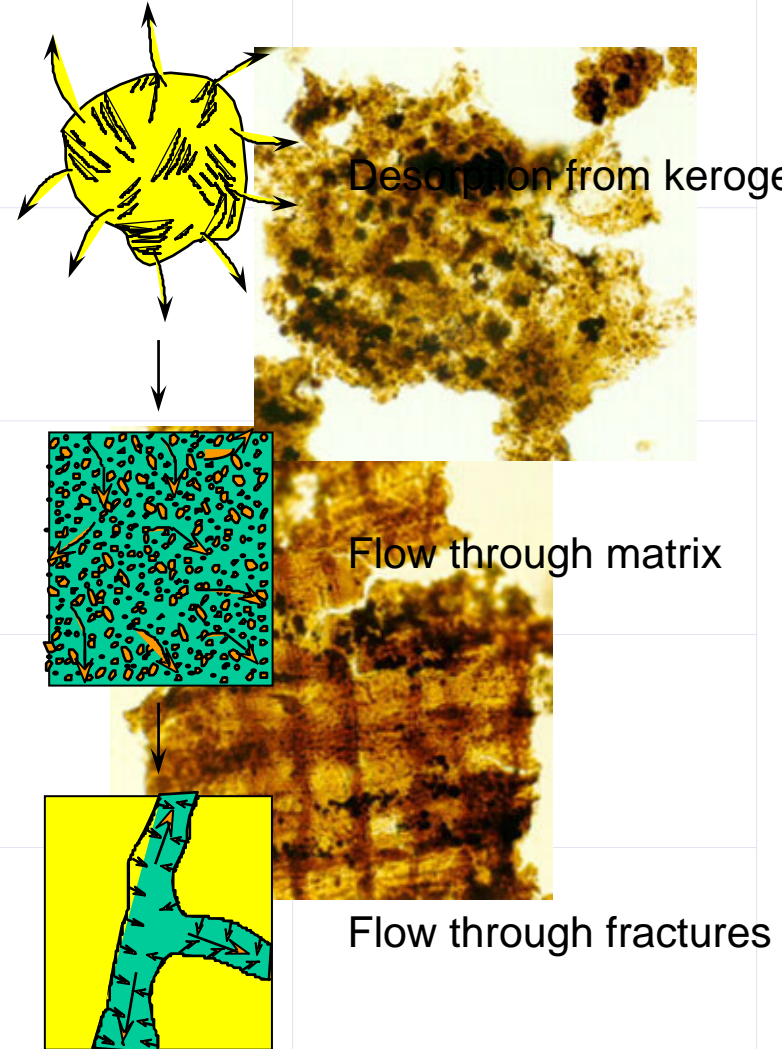


- High to very high gamma ray activity
- High resistivity
- High nuclear and sonic porosity
- Low P_e
Gas Shale

"Typical" Shale

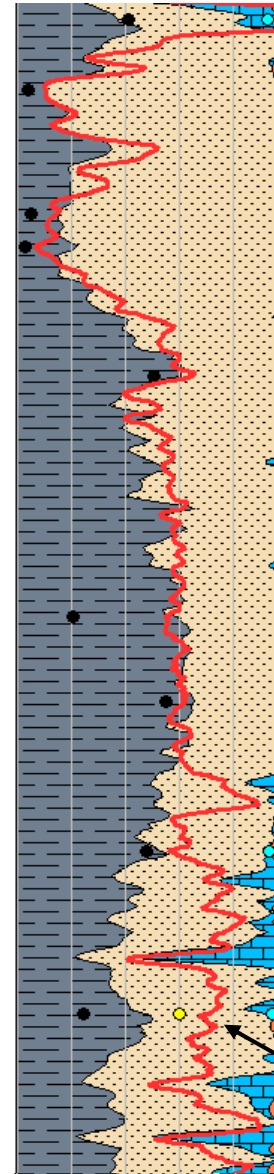
Solve for Adsorbed Gas

- Methane adsorbs to kerogen
 - Insoluble organic matter
 - Equivalent to TOC
- Kerogen petrophysical properties
 - Low density (1.1 g/cm^3)
 - Very high GR activity (500 to 4000 gAPI)
 - Low P_e (0.24)
 - High neutron porosity (60 pu)
- Methodology
 - Solve for kerogen via ELAN
 - Convert to TOC
 - Employ isotherm to convert to GIP
 - Conversion **requires** core analysis

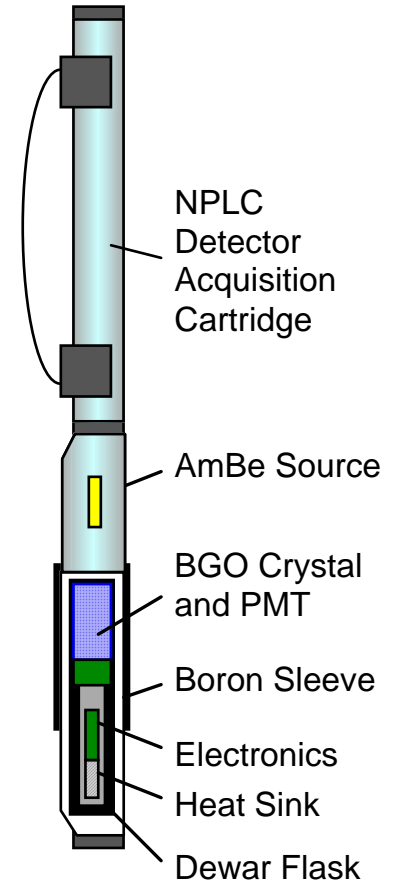


Clay Quantification

- Necessary for shale gas evaluation
 - Kerogen volume
 - S_w
- Geochemical log is key to evaluation
 - SpectroLith clay content independent of measurements affected by kerogen

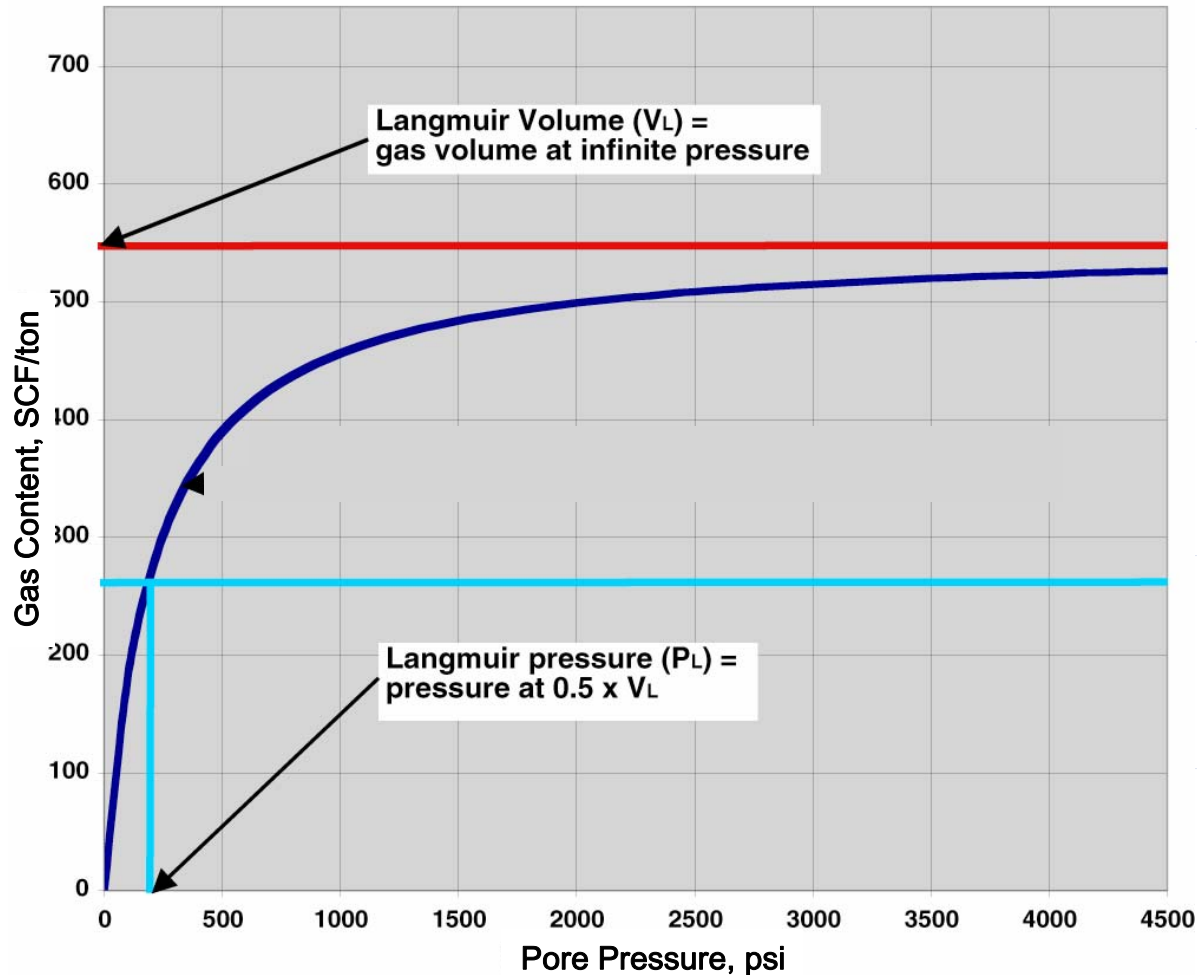


Gamma Ray



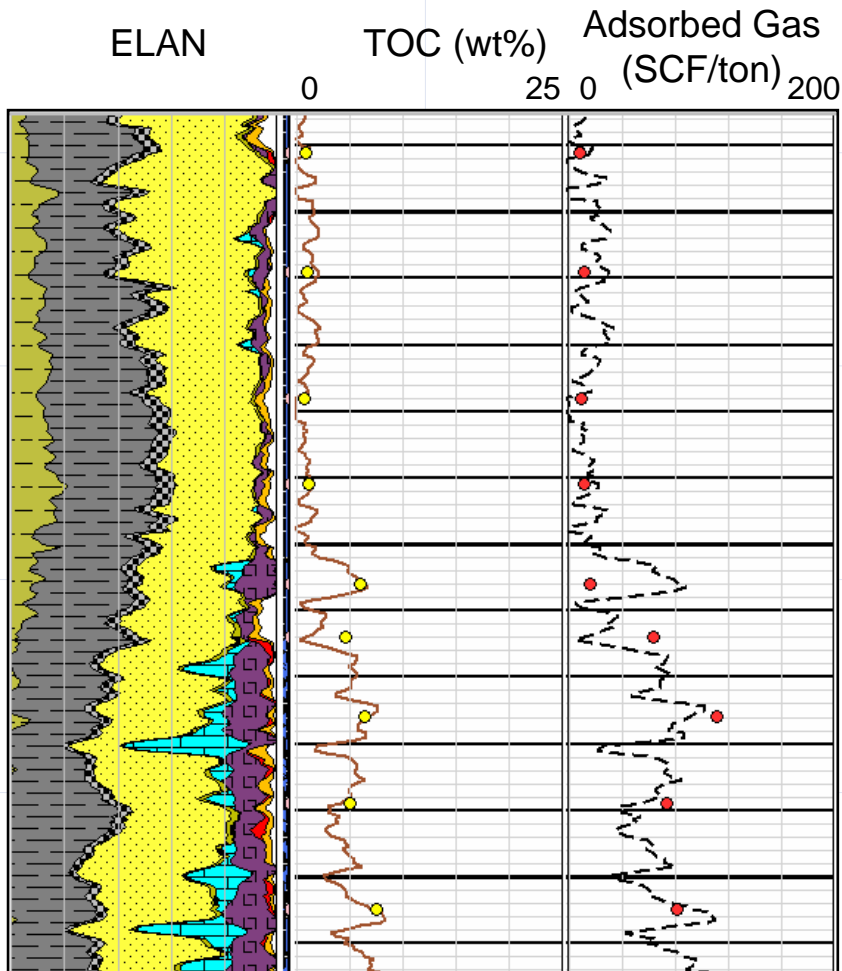
Shale Gas Adsorption / Desorption Isotherm

Langmuir Equation



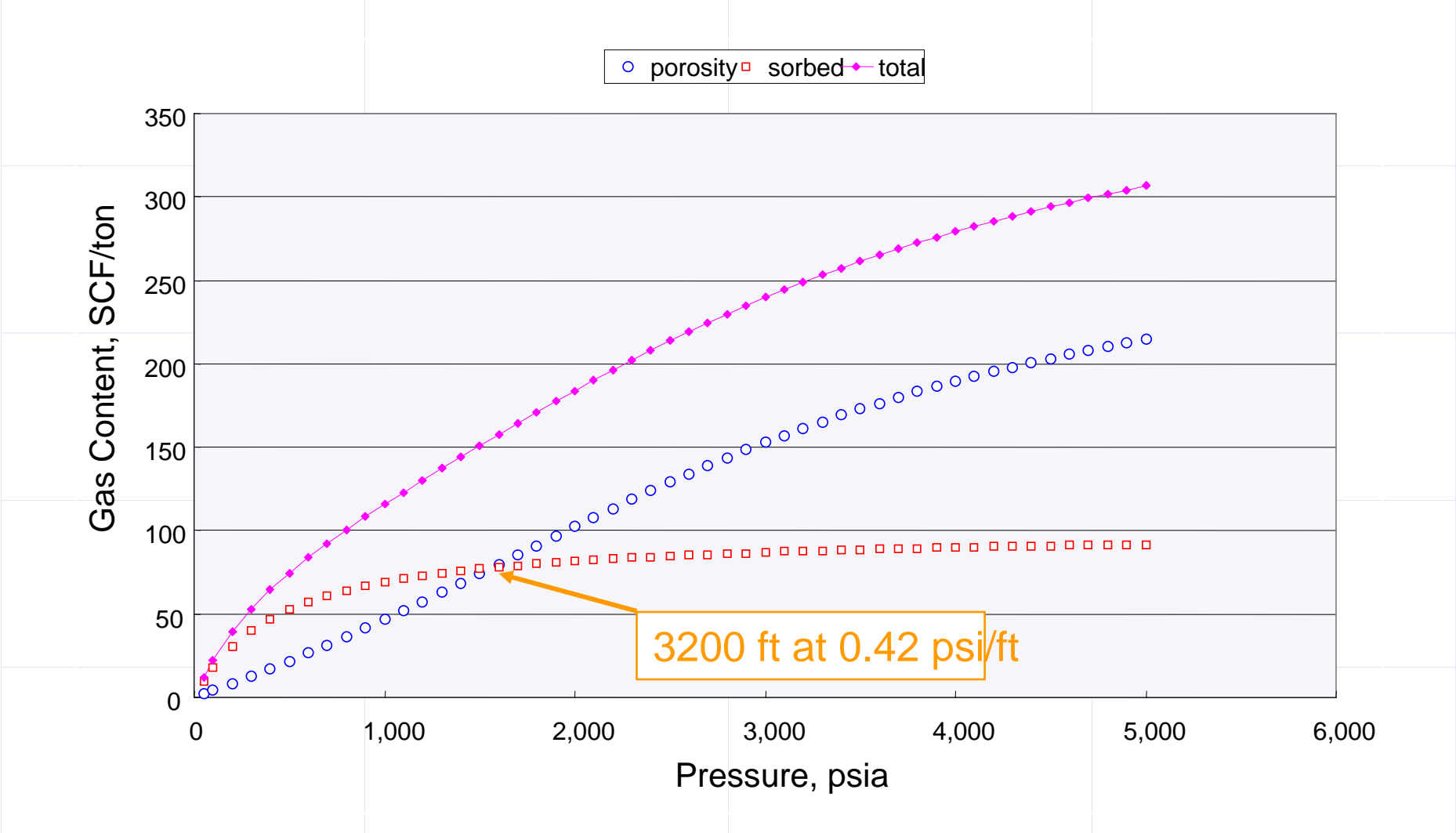
- “Gold Standard” for adsorption
- Outputs
 - V_L
 - P_L
 - TOC content
 - Temperature

Adsorbed Gas Log



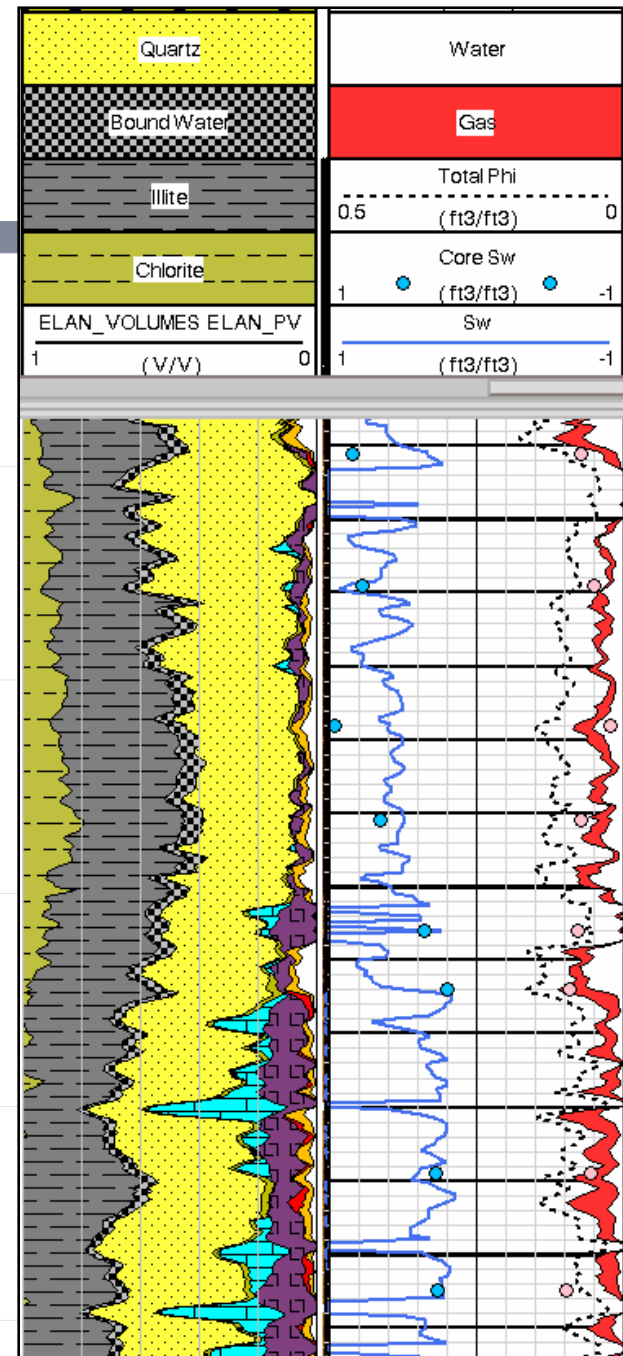
- Kerogen converted to TOC
 - Function of thermal maturity
- Isotherm used to calculate adsorbed gas
- Calculated in SCF/ton (industry standard)

Gas Content of Free and Adsorbed Gas

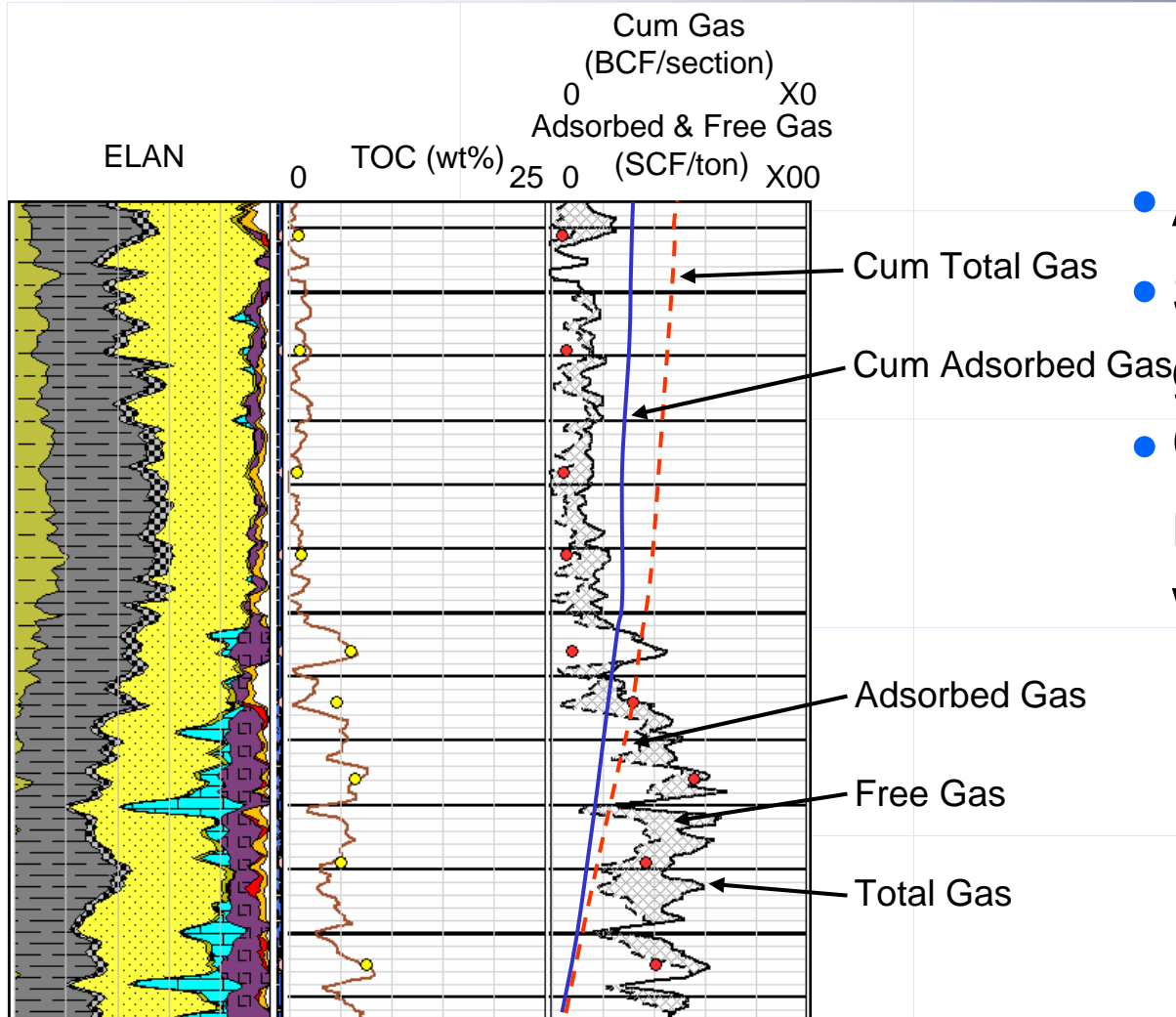


Free Gas Log

- Accurate measure of gas within shale microporosity
 - Effective Phi
 - S_w
- Requires knowledge of
 - Clay content
 - Matrix density
 - R_w , R_{bw}
(core S_w)
- ELAN evaluation
 - Best luck with Simandoux



Total Gas Log

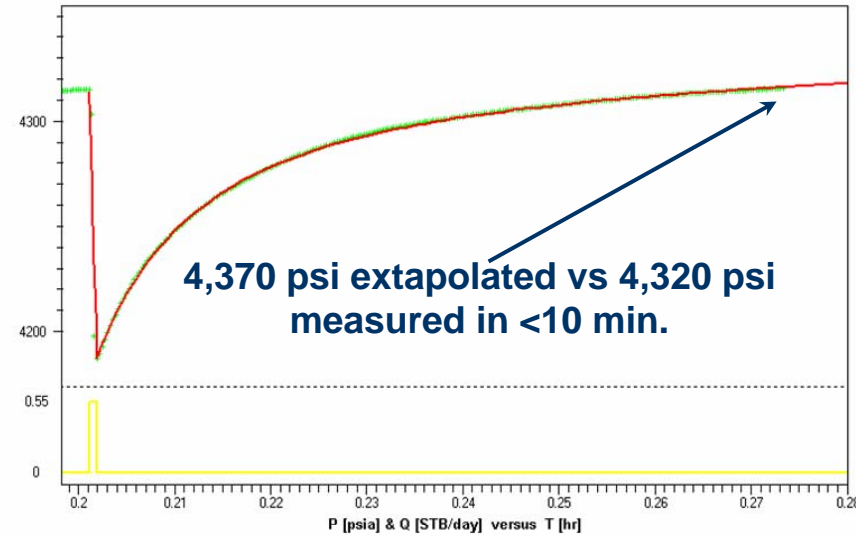
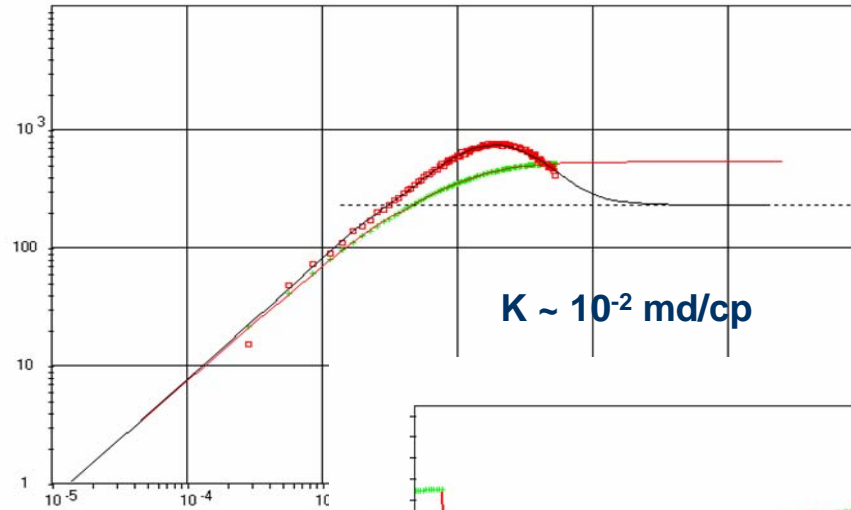


- All gas in SCF/ton
- Solves for cumulative gas
- Identify and quantify resource not visible with conventional logs

Pressure??

PressureXpress

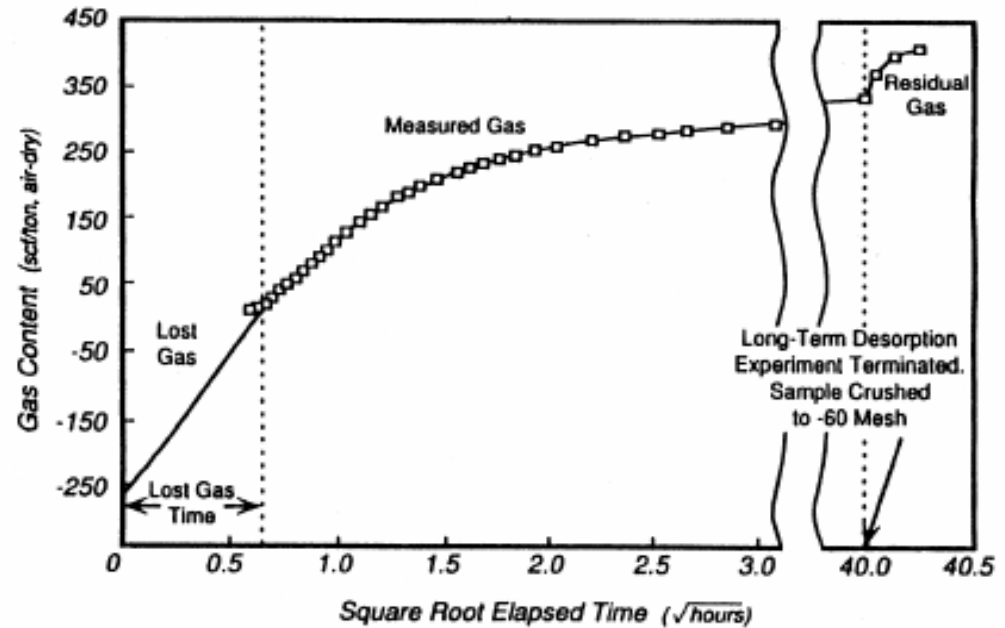
Determines
Reservoir Pressure
in very low mobility
shale gas
reservoirs



PressureXpress* r
reservoir with mobility as low as 10^{-2} md/cp

Recommended Coring Program

- **Capillary Suction Test**
 - Fluid sensitivities
- **P&P**
 - Tight-Rock Analysis (TRA)
 - Porosity, saturations, matrix perm
 - R_w , K_{int} , S_{oil}
- **TOC**
 - Maturation
- **XRD**
 - Mineralogy
 - Clays
- **Langmuir Isotherm**
 - Adsorbed gas content
 - V_l , P_l
- **Thermal Maturity**



Horizontal Trend

- **Common Trend in Unconventional Reservoirs**
- **Economics support method**
- **Makes evaluation difficult.**

Logging Program

- | | | | |
|--|--|--|--|
| <ul style="list-style-type: none">• PeX<ul style="list-style-type: none">• Porosity• Saturations | | | |
| <ul style="list-style-type: none">• ECS<ul style="list-style-type: none">• Clay content• Differentiate adsorbed and free gas | | | |
| <ul style="list-style-type: none">• DSI - MSIP<ul style="list-style-type: none">• Mechanical properties• Anisotropy | | | |
| <ul style="list-style-type: none">• FMI<ul style="list-style-type: none">• Natural fractures - Faults• Drilling-induced fractures | | | |
| <ul style="list-style-type: none">• XPT<ul style="list-style-type: none">• Formation Pressure• Estimation of Frac Gradients | | | |

Conclusions

- Shale gas log evaluation
 - Lithology / mineralogy
 - TOC
 - Porosity and matrix perm
 - GIP (adsorbed and free)
- Geochemical log critical to evaluation
 - Robust clay quantification independent of kerogen
 - Matrix density
 - Cased hole option
- Future needs
 - Robust identification of complex clay mineralogy
 - System permeability from open-hole measurements
 - Production prediction from logs

Thanks!