



# Characterization of a Caney Shale Core from the Actively Producing Caney Play in the Ardmore Basin, Oklahoma

*Shale Resource Plays of Oklahoma,  
Oklahoma Geological Survey  
(Virtual) Workshop  
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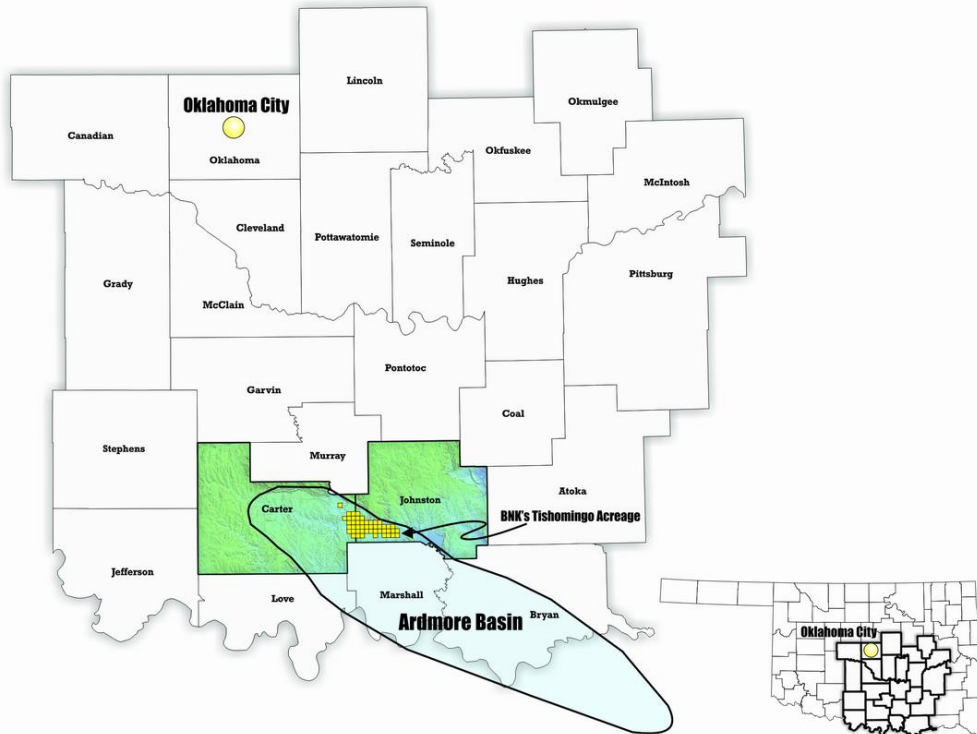
# INTRODUCTION

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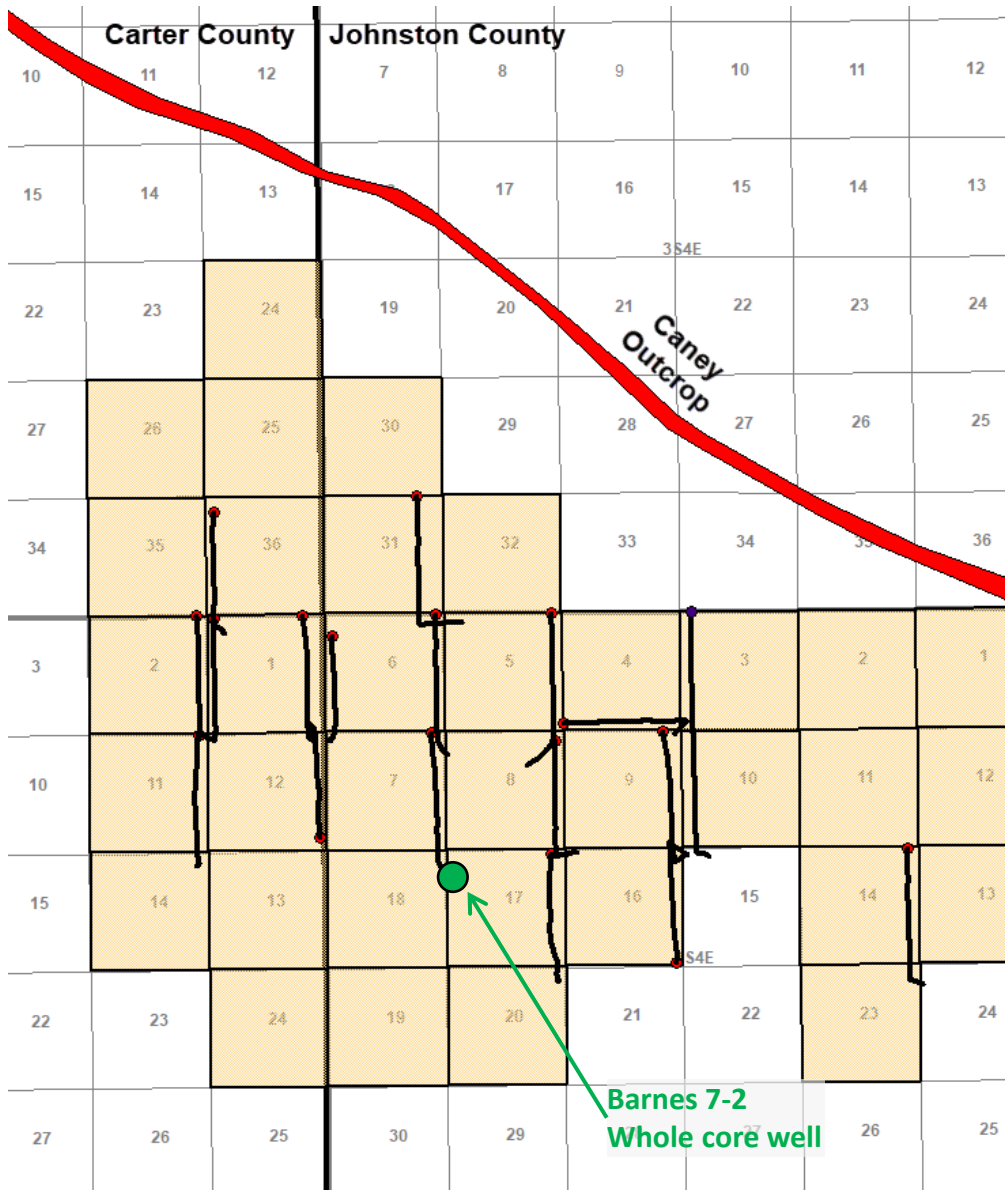
- A near complete core through the Caney Shale and into the Sycamore is characterized using outcrop, log analysis, core descriptions, and several rock properties analyses
- Six lithofacies are described across the entire core interval and correlated to local sequence stratigraphy
- Results indicate that the Caney Shale is self-sourcing hydrocarbons and contains the fractured enhanced, tight reservoir attributes necessary for a successful source rock reservoir play
- The core analysis and BNK's Caney Shale production should dispel the previous industry belief that the Caney Shale was too clay-rich to be successful

# BNK's TISHOMINGO FIELD

- The Tishomingo Field is in the Ardmore Basin of Oklahoma, 13 miles east of Interstate 35
- BNK sold the Woodford field but retained rights to the overlying Caney and Upper Sycamore
- In 2012, BNK Petroleum drilled and completed its first horizontal Caney Shale in the Ardmore Basin
- Since 2012, BNK has produced over 2.5MM barrels of oil equivalent fluids (80% oil) from 17 lateral wells, with proved reserves of 33.4 Million BOE from 18 wells



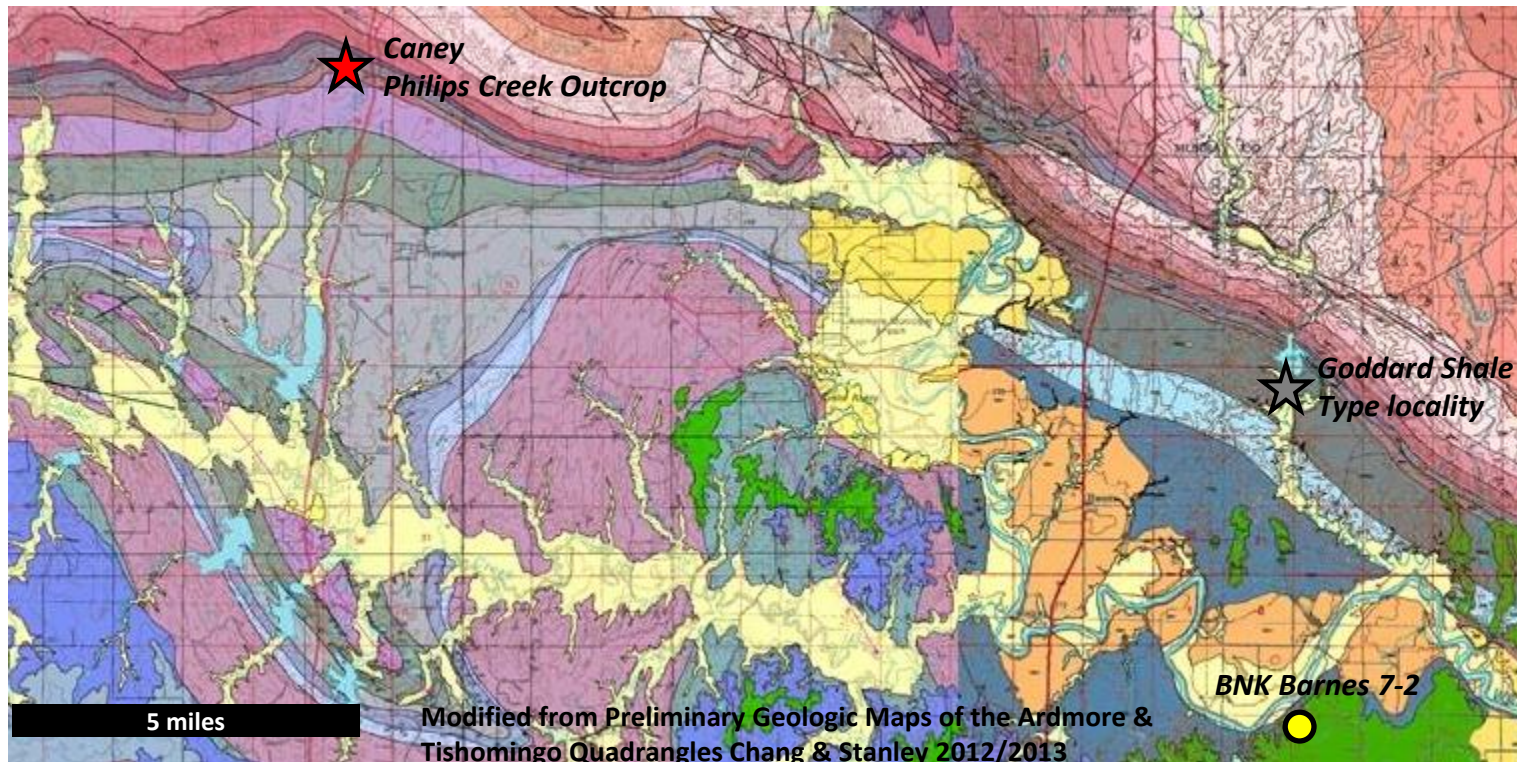
# LOCATION OF BNK'S WHOLE CORE



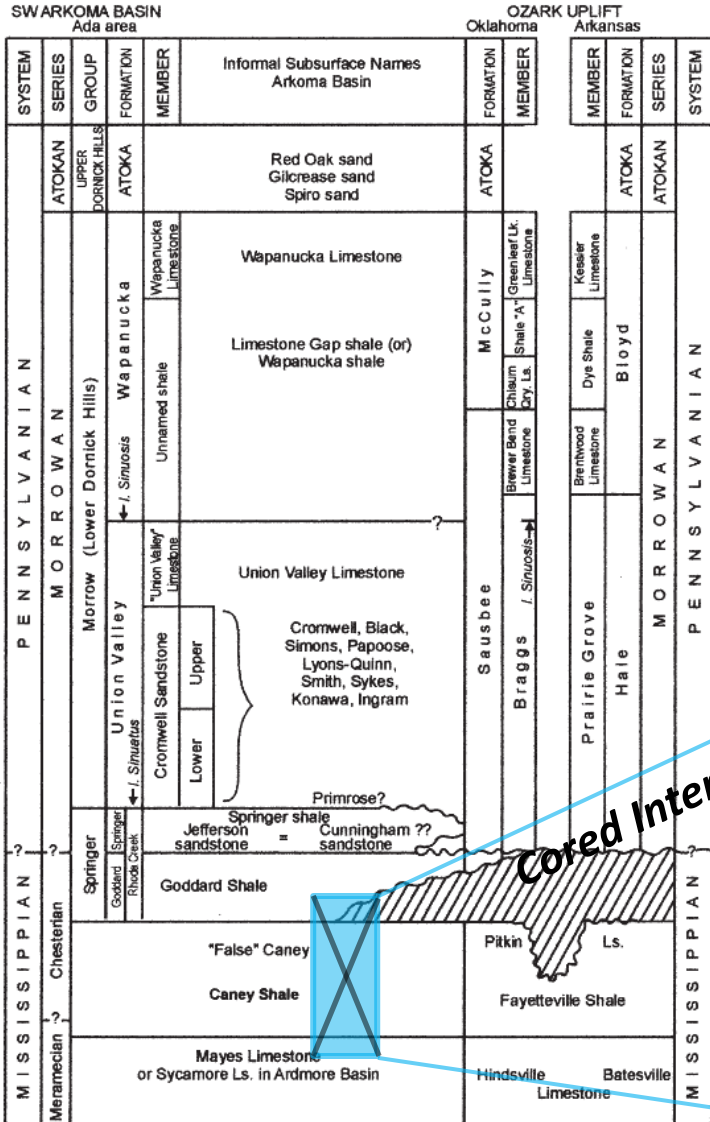
- In Fall of 2013, BNK recovered nearly 100% of 423 feet of 3" diameter whole core from the Barnes 7-2 pilot well from a base depth of approximately 10,660ft core depth
- The core spans the interval from the base of the Goddard Shale (Springer Group) across the entire Caney Formation and into the uppermost Sycamore Formation
- The core was analyzed using Schlumberger – TerraTek's tight rock analysis services in Salt Lake City, Utah
- Detailed core description by Dr. Matthew Watkinson and Robert Randell of EPI Group (formerly PDF Ltd, UK)

# LOCAL GEOLOGY

- The Arbuckle Anticline is north of BNK's acreage with the Woodford and Caney outcropping along the flanks
- The Caney shale erodes easily and is not visible along much of the surface interface
- The Philips Creek, Interstate-35 Caney outcrop location is ~16 miles NW of the Barnes 7-2 well
- The Caney is at surface 4 miles updip, NE of the Barnes 7-2 and the type location for the Goddard Shale is approx. 5 miles north (Miser et al. 1954)
- Across BNK's acreage the Caney is on a monocline dipping to the southwest at an average of 12°
- Barnes 7-2H has produced >350,000 barrels of equivalent oil (87% oil, 44 API gravity) with a 1<sup>st</sup> 90 day GOR of 904

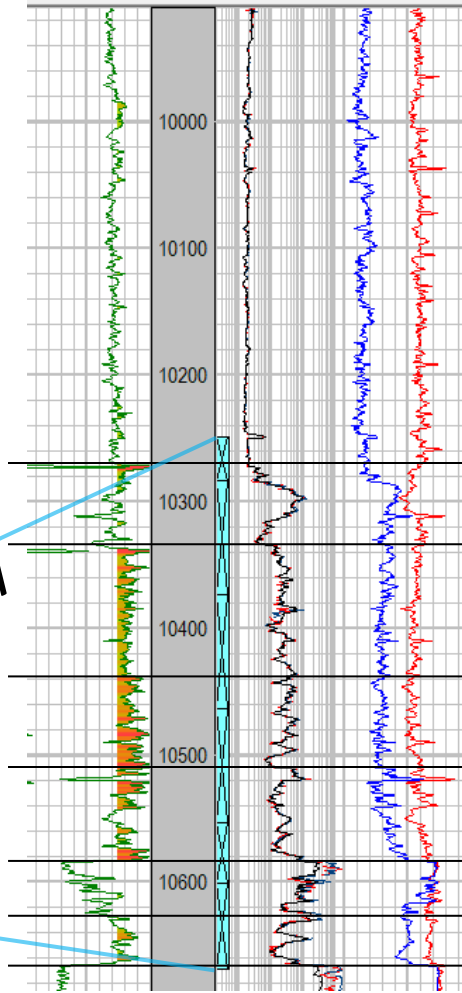


# BNK INTERNAL STRATIGRAPHY



Barnes 7-2

Correlation	Depth	Resistivity	Porosity
GR	MD	Res Shallow	PHIN(NPHI)
0 gAPI 2000		0.2 OHMM 2000	0.45 CFCF -0.15
GR>150AP		Res Med	RHOB
		0.2 OHMM 2000	1.95 G/C3 2.95
		Res Deep	
		0.2 OHMM 2000	

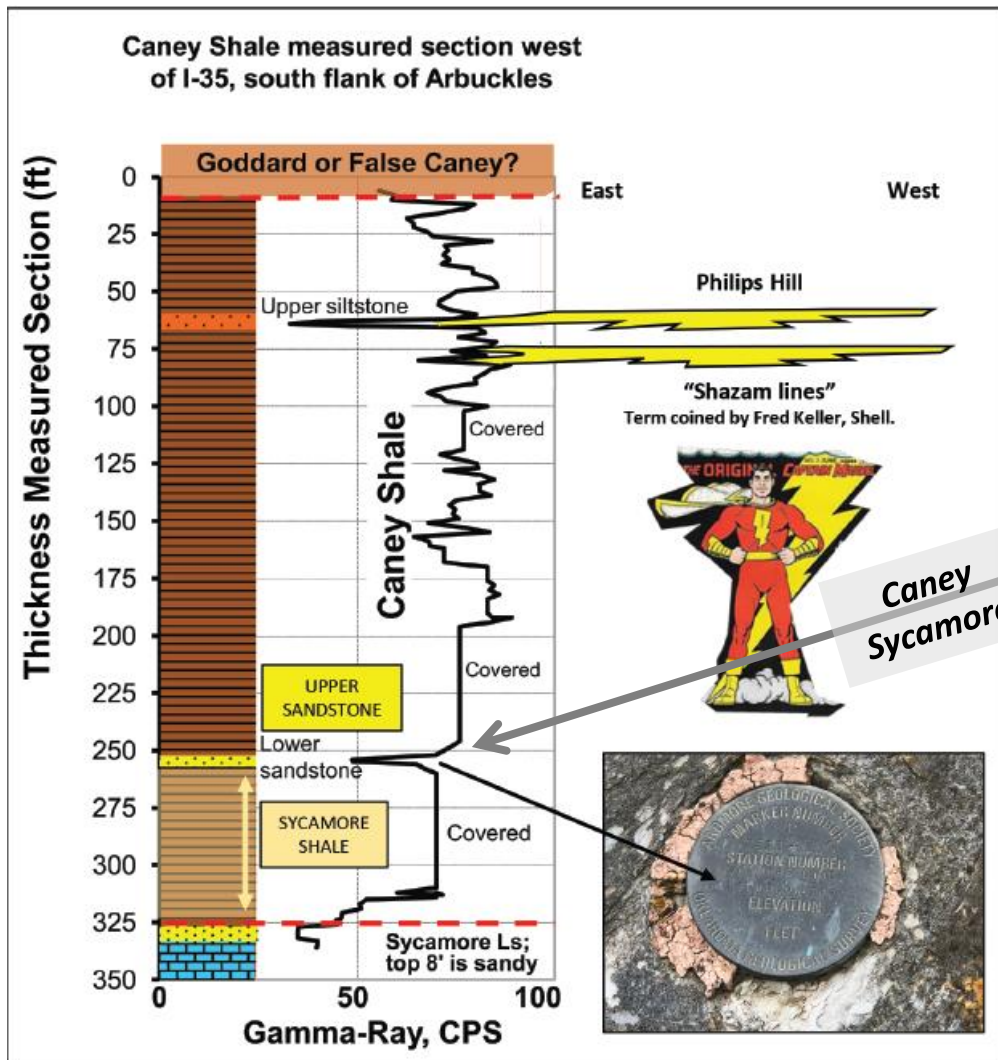


- Introduced for consistency of naming used in BNK's press releases
- Not intended to contribute to the already confusing history of the Caney stratigraphic nomenclature
- "False" Caney adopted from Andrews 2003 & 2007
- Unconformity at base of the Springer or Goddard Shale on the basis of "False" Caney thickness changes in Tishomingo Field

**Cored Interval**

(Modified from Andrews, 2003)

# CANEY SHALE OUTCROP, ALONG I-35

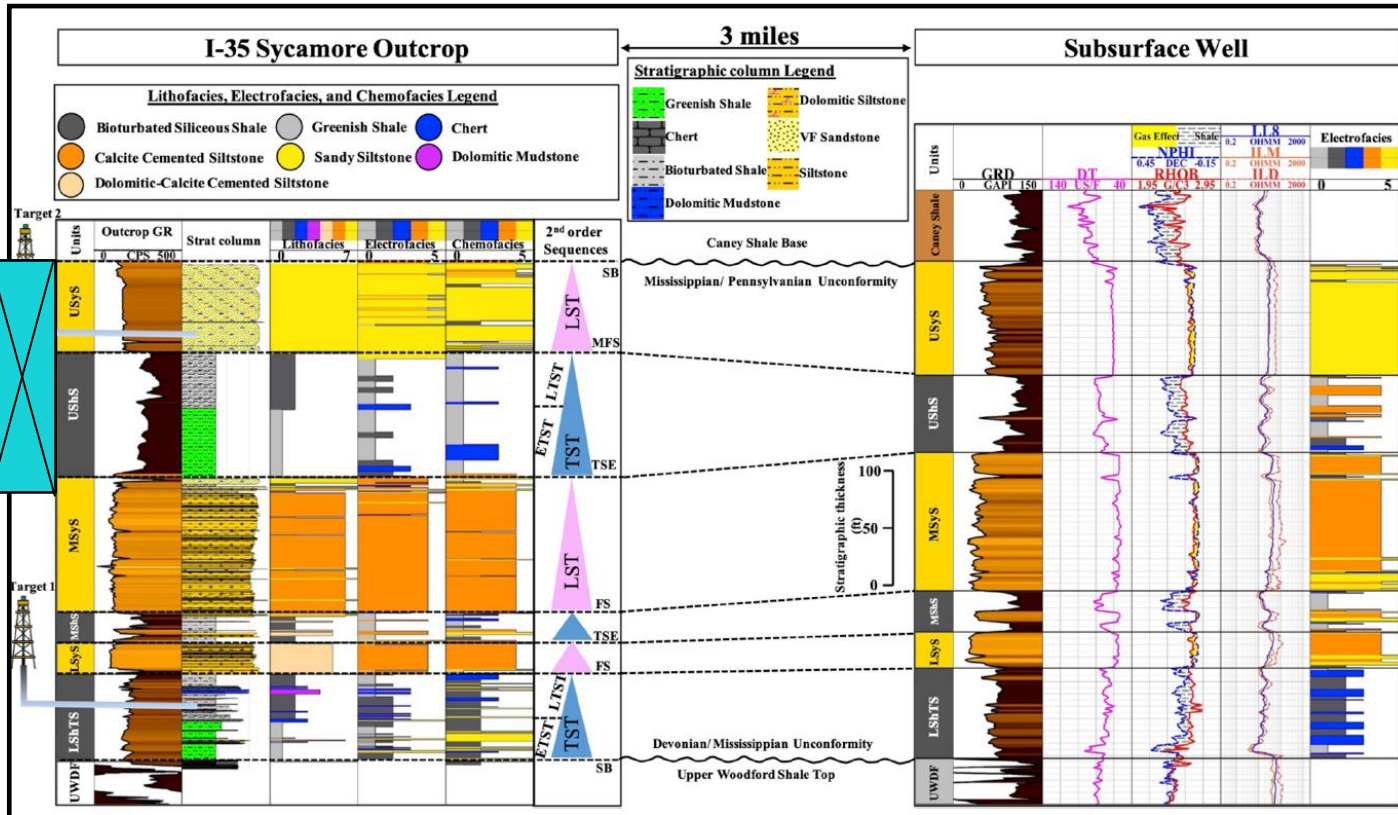


(Modified from Cullen 2019)  
(Original Andrews 2012)

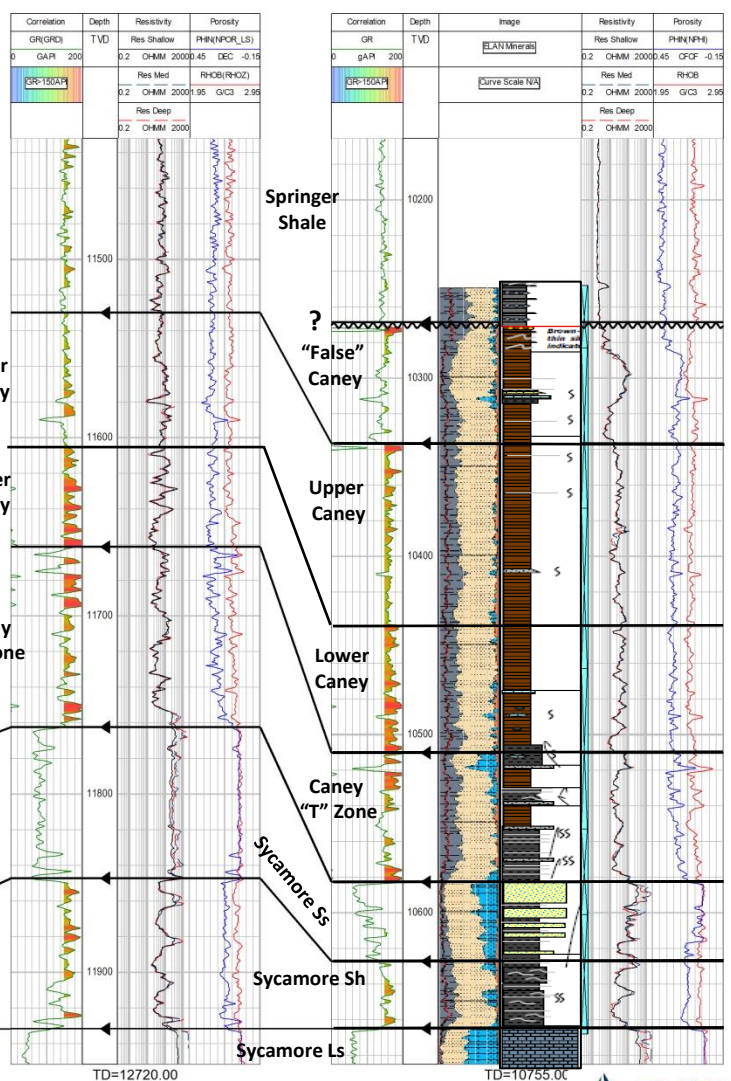
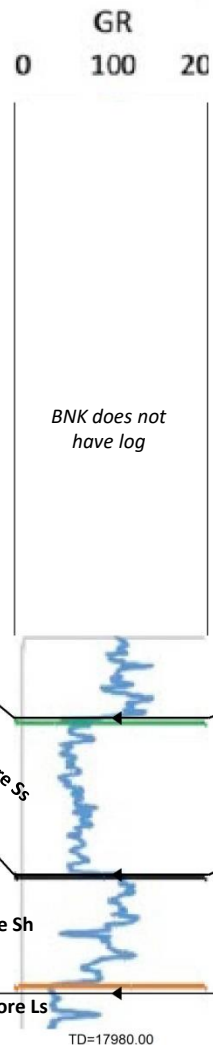
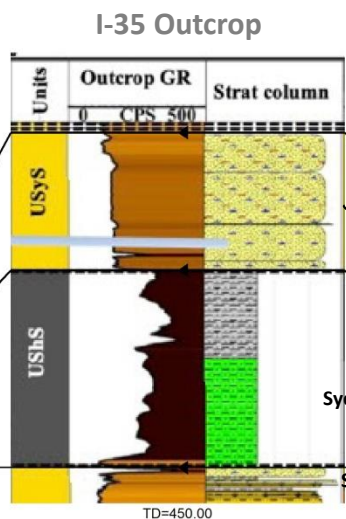
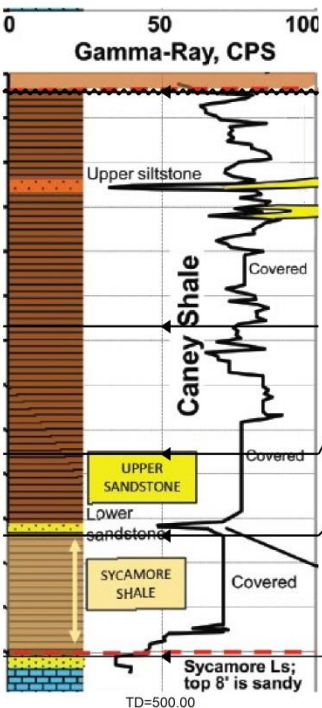
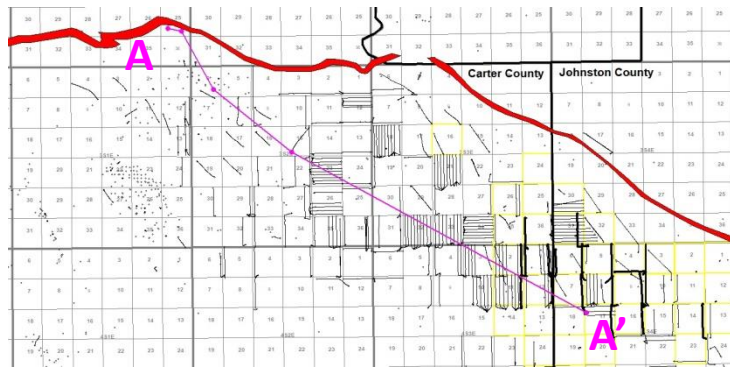
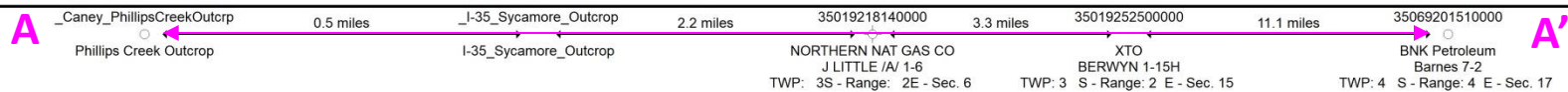
- Rick Andrews originally published the handheld gamma ray (GR) profile along the Caney Shale outcropping in Philips Creek near where Interstate-35 heads north into the Arbuckle Mountains (Andrews 2012)
- Andrew Cullen further supplemented this data by presenting a thin section description from a sandstone sample at this site apparently from the lower sandstone in Rick Andrews' GR profile (Cullen 2019)
- Andrew Cullen notes that he places "Andrews' lower Caney sandstone and basal shale at the top of the Sycamore"
  - This apparently keeps the "Upper Sandstone" (which remains mostly covered at this site) in the base of the Caney

# SYCAMORE OUTCROP, ALONG I-35

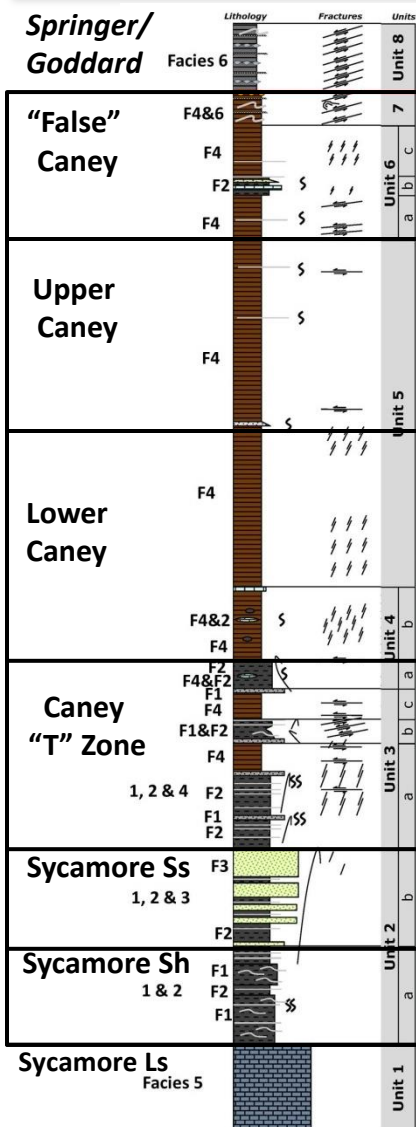
- In Feb. 2020, Benmadi Milad, et al. provided a detailed description of the much visited Sycamore outcrop along I-35 just north of the Caney Philips Creek outcrop (Milad, et al. 2020)
- BNK's Barnes 7-2 core covers the equivalent of their Sycamore sandstone (USyS), shale (UShS), and into the top of the dolomitic siltstone (MSyS)
- They provide a log correlation from outcrop to wells in the southeast, which we continue to the BNK Barnes 7-2 well on the next slide



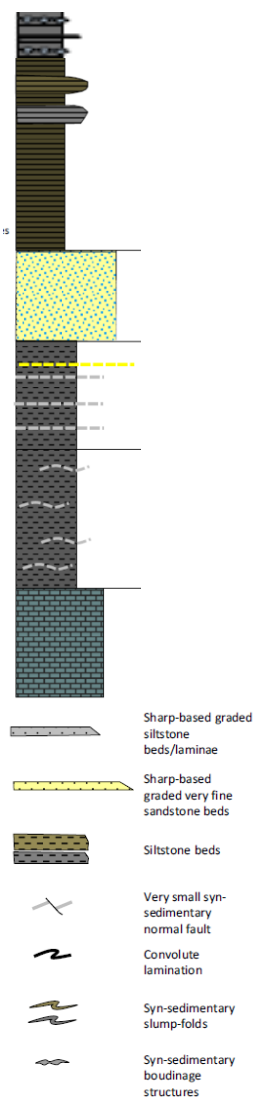
# CANEY OUTCROP TO BNK BARNES 7-2 WELL



# SIX DESCRIBED LITHOFACIES



## Stratigraphic Key



## Facies Descriptions

**Facies 6 - Silty Claystones & siltstones with slump features**  
 Heterolithic (laminated silty Claystones and siltstones) with syn-sedimentary slump structures. (*Base Springer & "False" Caney*)

**Facies 4 - Brown laminated silty Claystones**  
 Brownish grey-black silty laminated bituminous Claystone. Slightly micaceous. Laminated, fissile, brittle. Strong oil smell. (*"False" Caney, Upper Caney, Lower Caney, & Caney "T" Zone*)

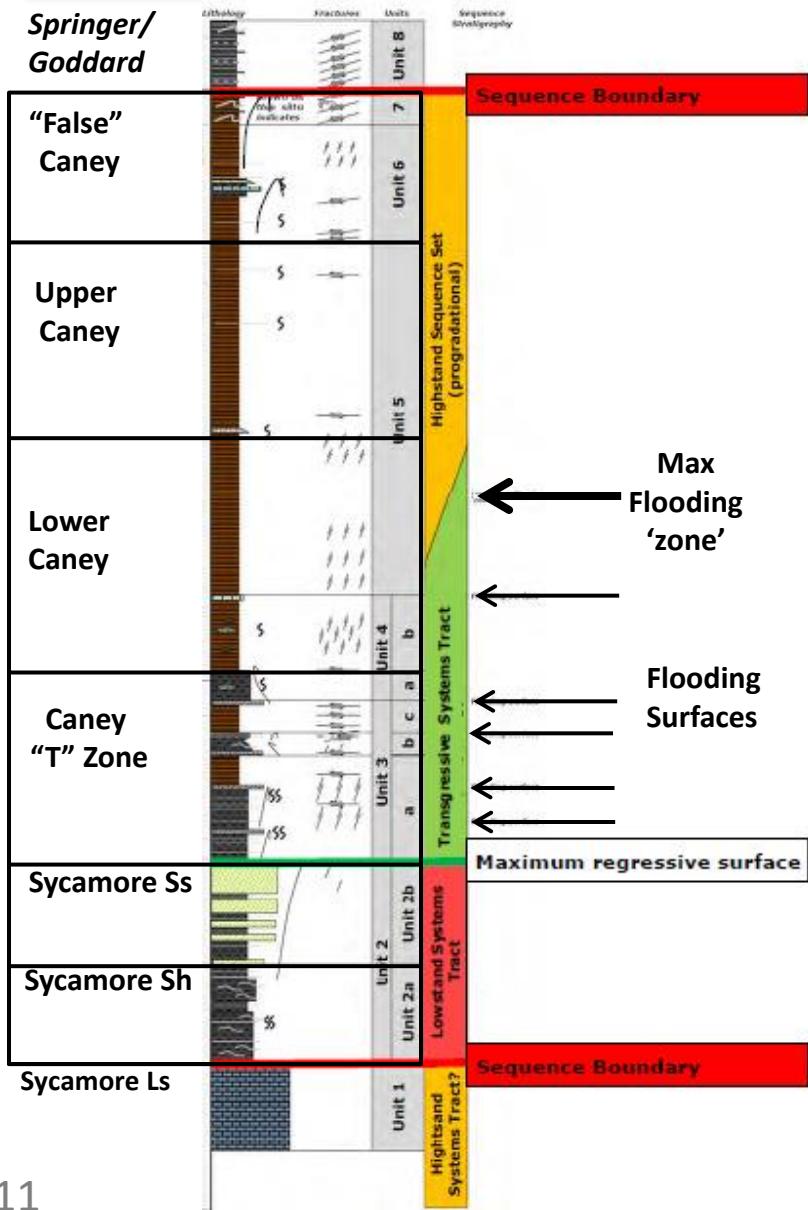
**Facies 2 - Grey laminated argillaceous siltstones**  
 Distinctive laminae of paler (dark grey), thicker argillaceous siltstones with thin (1/4 to 1/8th inch) darker, finer siltstones (*"False" Caney, Lower Caney, Caney "T" Zone, Sycamore Ss, & Sycamore Sh*)

**Facies 1 - Grey bioturbated argillaceous siltstones**  
 Non-calcareous greyish black to brownish grey black bituminous argillaceous siltstone, with some very-fine sand wisps, micaceous. Bioturbated (*Caney "T" Zone, Sycamore Ss, & Sycamore Sh*)

**Facies 3 - Very fine sandstones**  
 Calcite cemented massive very fine sandstones. (*Sycamore Ss*)

**Facies 5 - Bioclastic packstones**  
 Slightly argillaceous and silty bioclastic peloidal packstones (*Sycamore Ls*)

# SEQUENCE STRATIGRAPHY

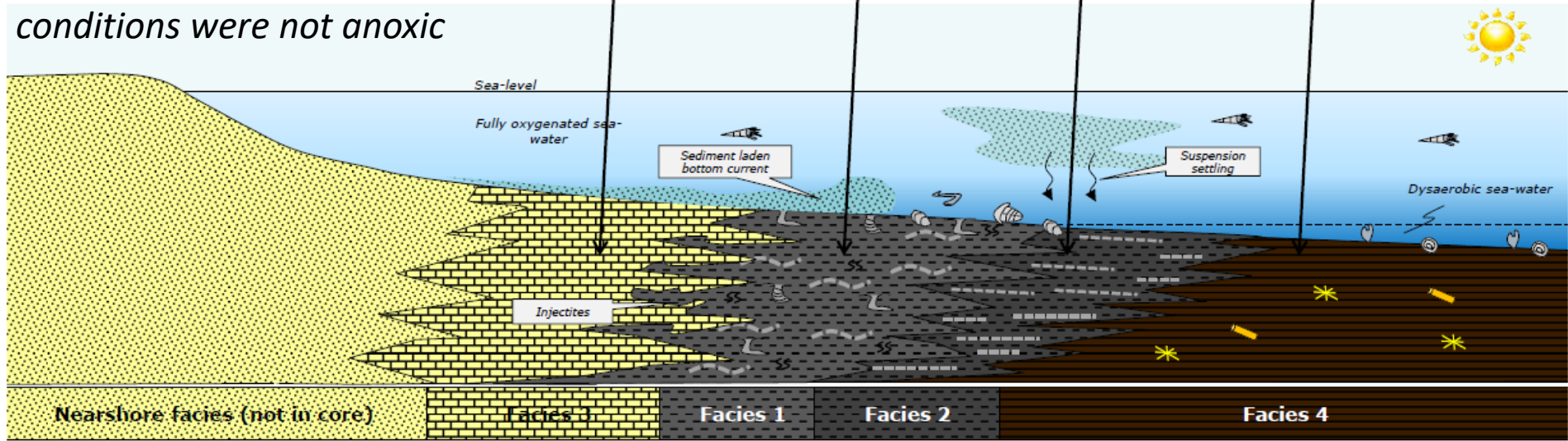
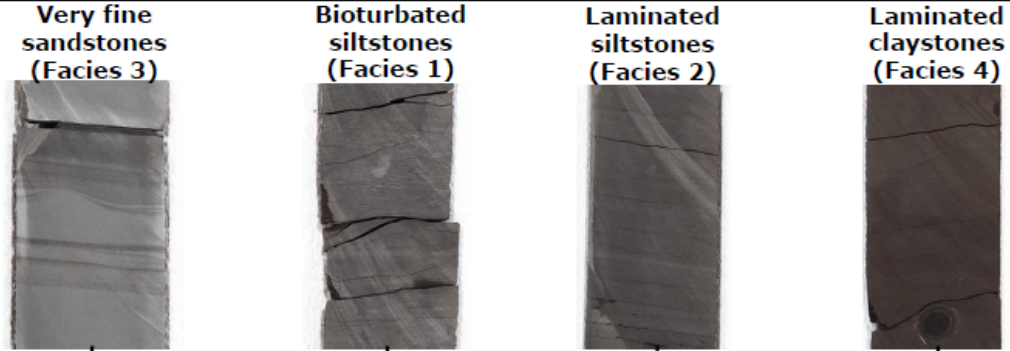


- **“False” Caney** has increasing amounts of siltstones and rare very fine sandstones indicating a highstand sequence tract with a sequence boundary marking the top of the interval at a highly cemented zone with abundant pyrite and phosphate cements indicating a possible unconformity
- **Upper & Lower Caney** does not have any well-defined maximum flooding surfaces at the top of the transgressive systems tract. A maximum flooding ‘zone’ is indicated with slightly coarser and bioturbated beds
- **Caney “T” Zone** consists of coarsening upward parasequences at the base and fining upward transgressive-regressive cycles in the upper portion
- **Sycamore Sh and Ss units** show a coarsening upward, the top of which may be the shallowest water depths interpreted from this core and representing a maximum regressive surface
- **Sycamore Ls basal carbonate** as possible highstand systems tract of an underlying carbonate ramp sequence. The top of the carbonate representing a sequence boundary.

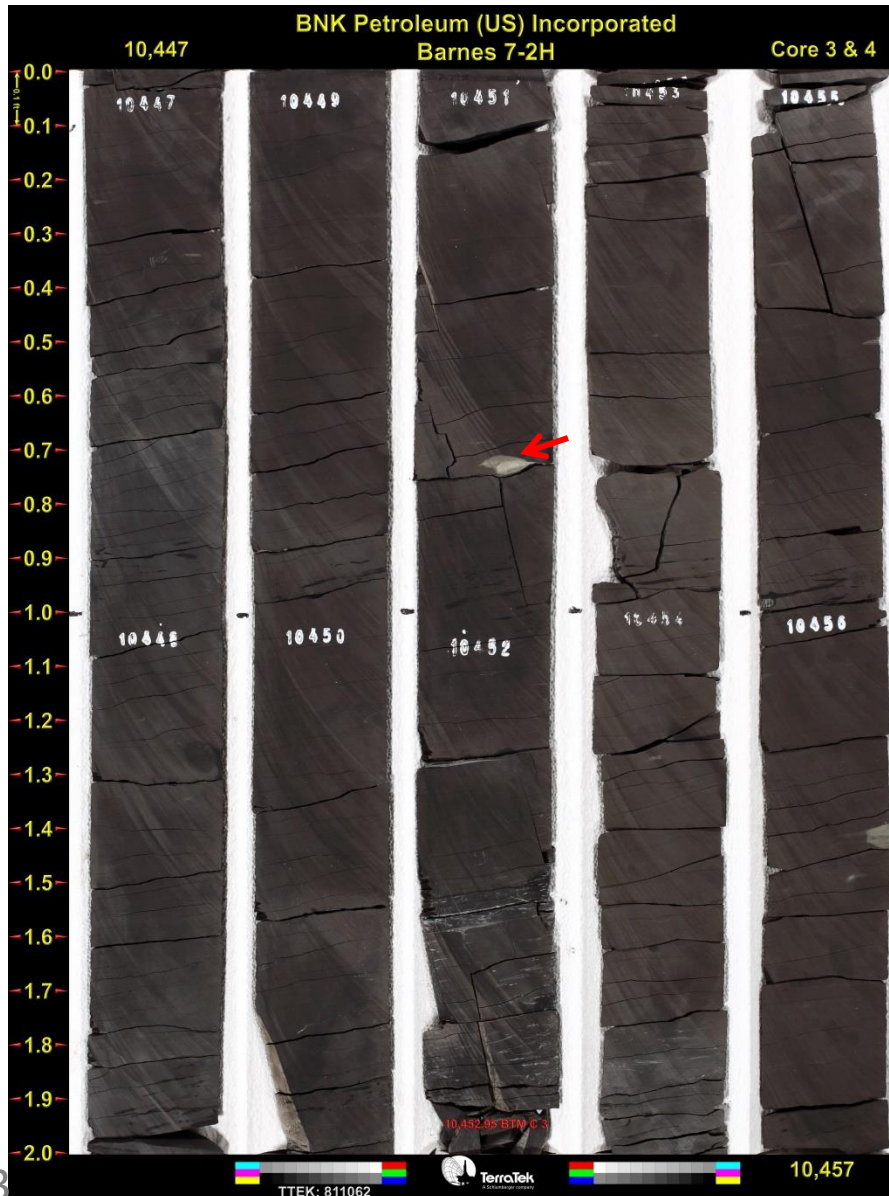
# DEPOSITIONAL MODEL FOR FACIES 1-4

Current BNK Target Zones

*Facies 2 & 4 deposited under low oxygen conditions under storm wave base, but abundant sponge spicules and rare inarticulate brachiopods suggest bottom conditions were not anoxic*



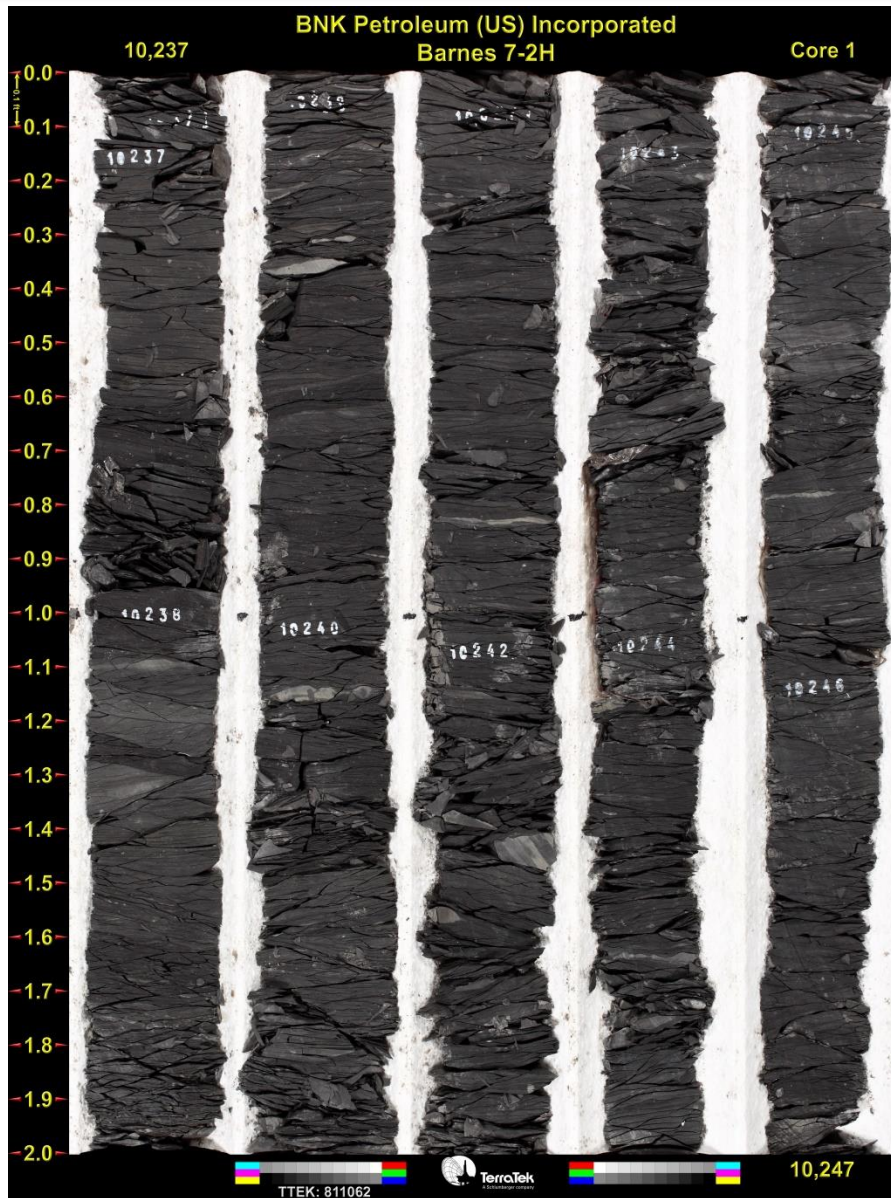
# FACIES 4 – LAMINATED SILTY CLAYSTONES



## Lower Caney target zone pictured

- Facies 4 occurs from “False” Caney into the Caney “T” Zone
- Brittle, faintly laminated brown greyish-black silty Claystones , strong oil odor
- Small concretions of pyrite (red arrow), calcite, and phosphate.
- Rare orbiculoid (inarticulate) brachiopods and abundant pyritized sponge spicules
- Suggests dysaerobic or low oxygen bottom conditions (rather than truly anoxic)
- Deposited as high organic carbon content muds and impregnated with self-sourced present-day oil
- Nearly stable lithology over 150ft, suggesting balanced rates of accommodation (relative sea-level rise) with rates of sediment supply

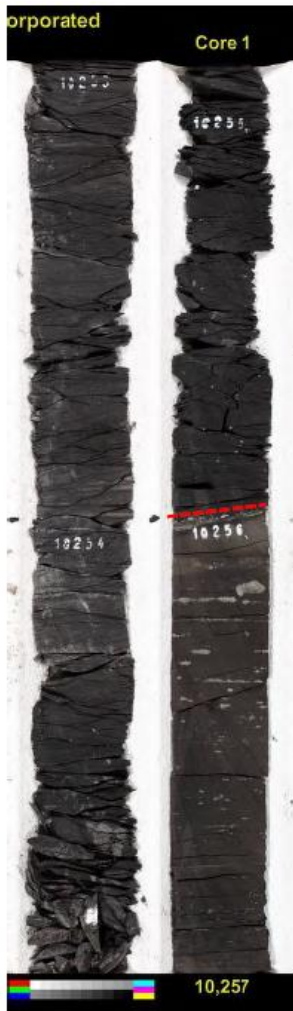
# FACIES 6 – SILTY CLAYSTONES & SILTSTONES WITH SLUMP FEATURES



## Base Springer Shale

- Syn-sedimentary shear zone
- Extremely fissile, and highly fractured (bed parallel shear) medium grey non-calcareous claystones
- Possibly representing the base of a slump of slide which detached above the highly cemented unconformity (next slide)
- Historically has caused drilling issues, but impact can be minimal with proper mud weight programs, hole cleaning procedures, and wellbore deviation

# LATE MISSISSIPPIAN UNCONFORMITY



## Base of Goddard Shale and top of “False” Caney

(Marked by red dashed line & white arrow)

- Above the possible unconformity is devoid of oil impregnation (unlike the majority of the core below this surface)
- Below the unconformity, in the “False” Caney, are hard densely cemented mudstones and irregular pyrite nodules
- Dense pyrite and phosphate or siderite cemented mudstones. Deeper XRD sample indicates high phosphate content from fluorapatite detections



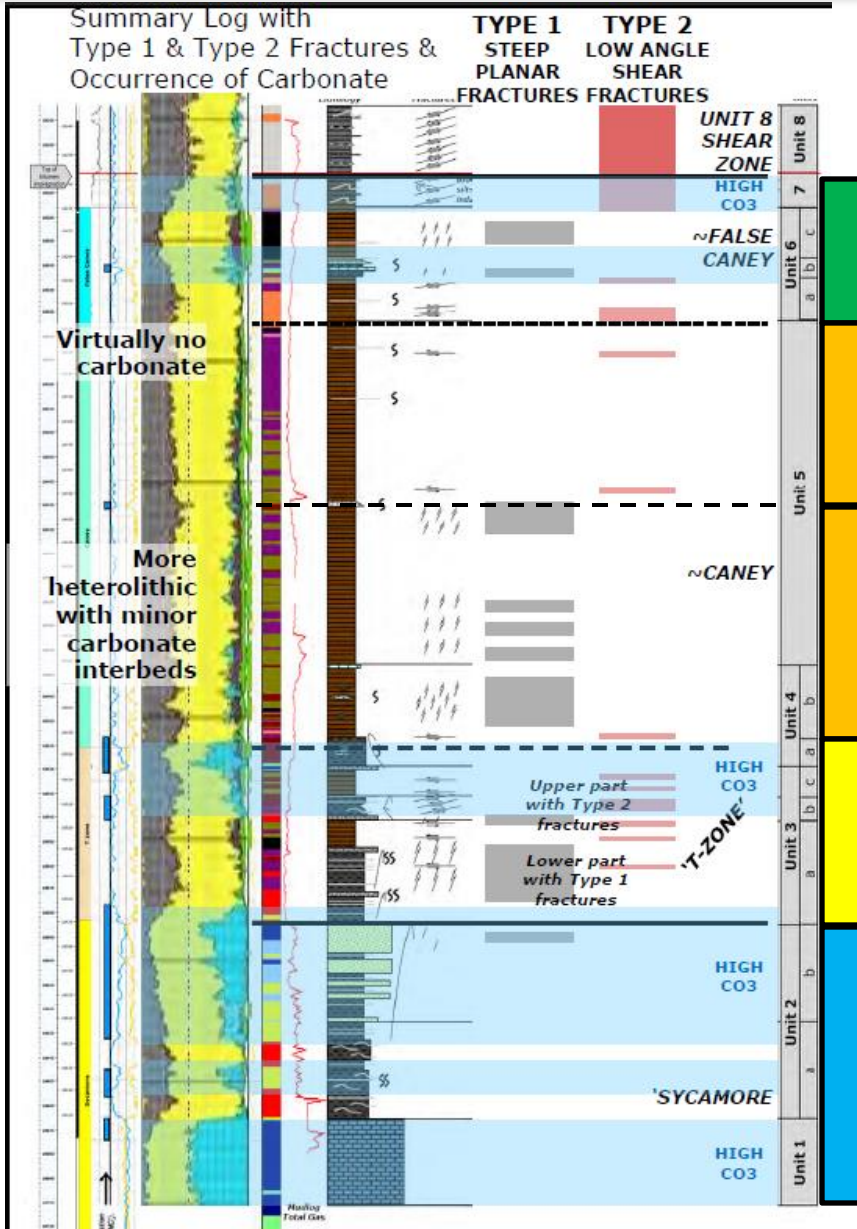
Core width is 3 inches.

## Close up detail of possible unconformity

- High degree of cementation indicating low sedimentation rates allowing sulfide-rich pore water to build-up and saturate
- White arrow at thin lag of small pebbles and granules of reworked pyrite and white phosphatic grains



# FRACTURE TYPES & PATTERNS



**Type 1** - Steep planar fractures (open or partial calcite & pyrite fill)

**Type 2** - Low-angle shear fractures with slicken fibers

*Type 3* – Pervasive, bedding parallel, induced fractures

**“False” Caney**

- Type 1, Steep planar fractures in silica rich Claystones

**Upper Caney**

- Type 1 fractures mostly absent

**Lower Caney**

- Type 1 fractures prevalent

**Caney “T” Zone**

- Type 2 fractures in upper part
- Type 1 fractures in lower part

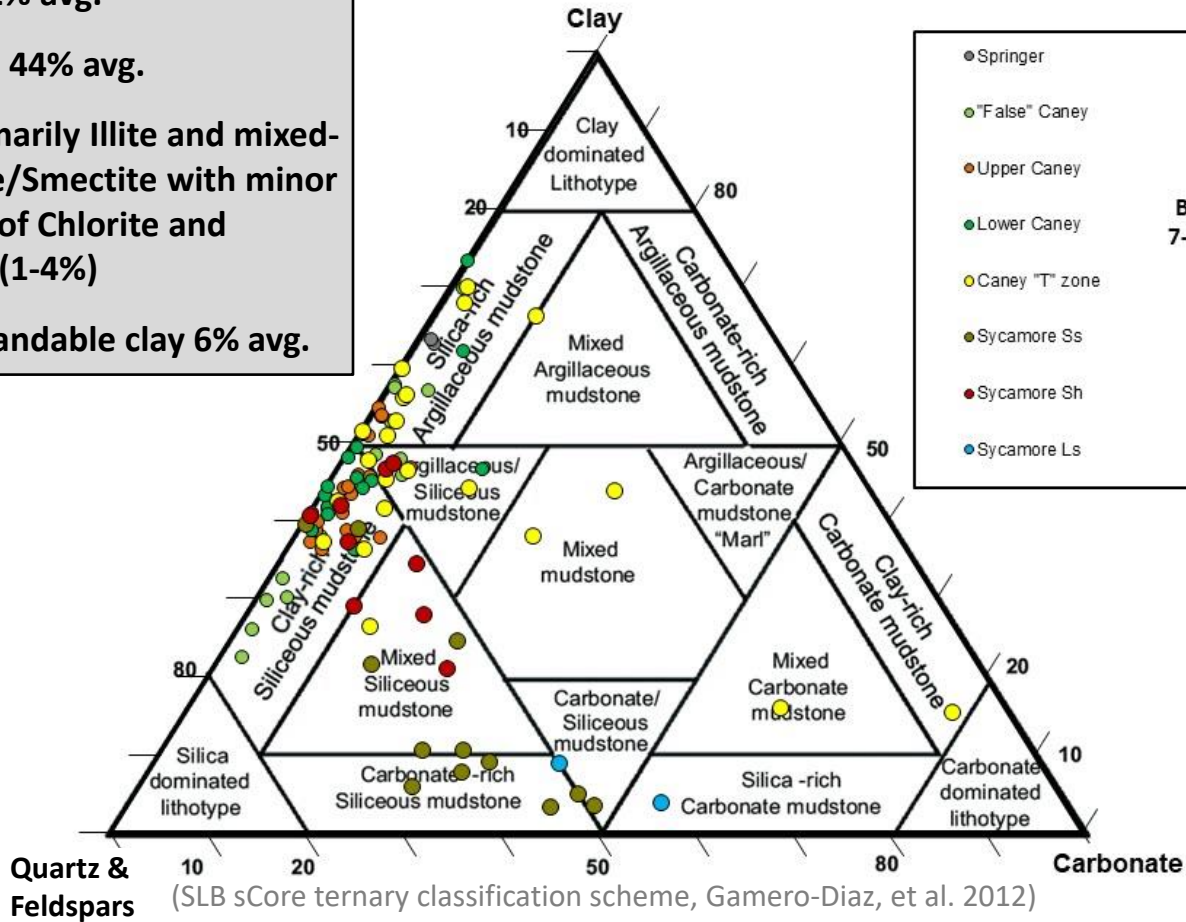
**Sycamore**

- Type 1 & 2 fractures mostly absent

# BNK BARNES 7-2, XRD (WT.%)

## Upper & Lower Caney

- Quartz 42% avg.
- Total Clay 44% avg.
- Clays primarily Illite and mixed-layer Illite/Smectite with minor amounts of Chlorite and Kaolinite (1-4%)
- Total Expandable clay 6% avg.

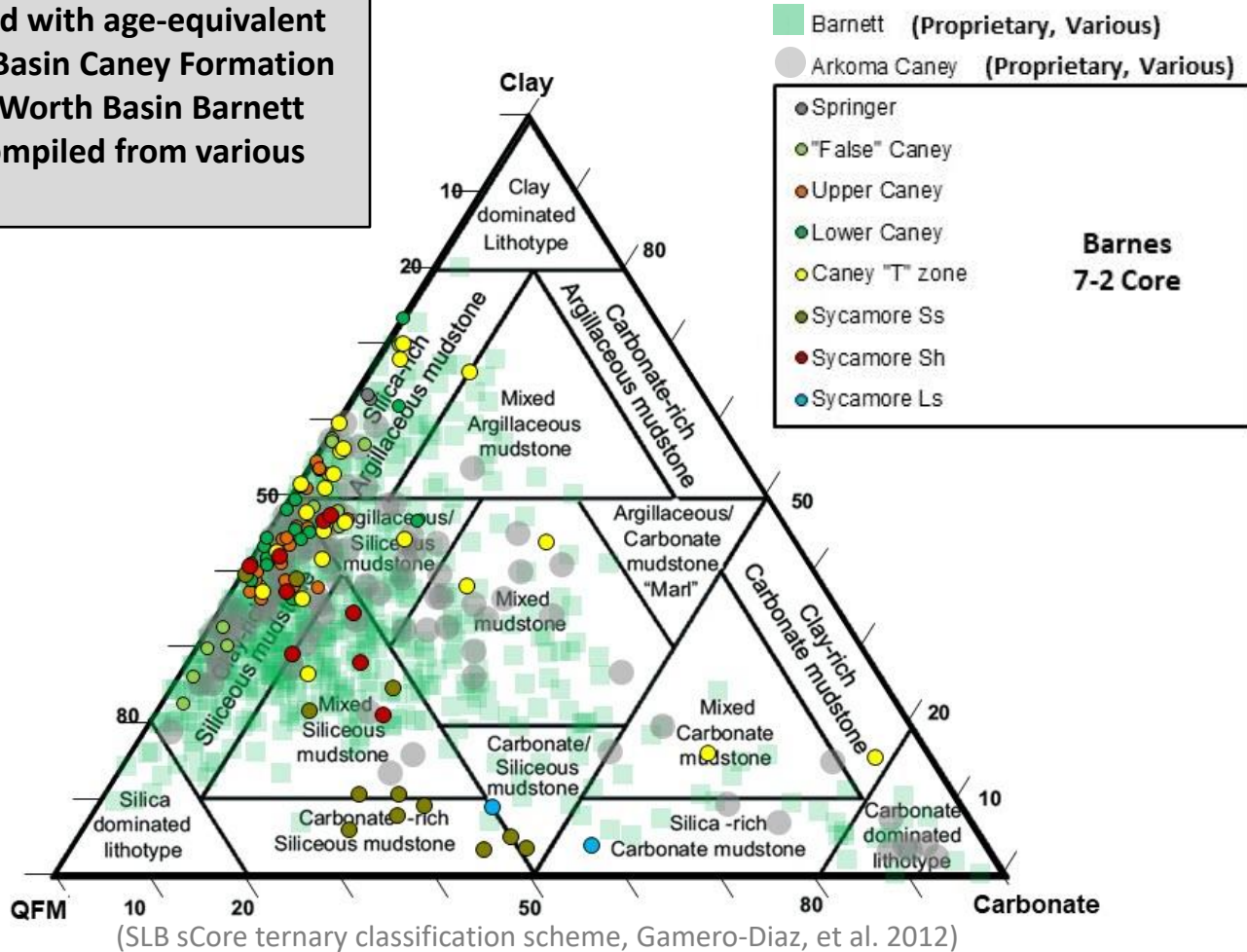


Barnes  
7-2 Core

- Clay content increases at the base of the Lower Caney and at the top Caney "T" Zone
- Carbonate content increases in certain facies within the Caney "T" Zone and Sycamore

# BNK BARNES 7-2 XRD & REGIONAL COMPARISONS

- Compared with age-equivalent Arkoma Basin Caney Formation and Fort Worth Basin Barnett Shale. Compiled from various sources



# MULTIVARIATE ANALYSIS OF BARNES 7-2 CORE XRD DATA

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- Multivariate Analysis of the XRD data matrix by Hierarchical Cluster Analysis. This technique is non-parametric (i.e. does not require the data to meet any prerequisite distribution), robust, and commonly utilized in geologic studies to define cryptic groupings. Data set was analyzed by Q-Mode Cluster Analysis
- 12 variables analyzed from the “False” Caney, Upper & Lower Caney, Caney “T” Zone, and Sycamore units (the 2 Springer Shale samples excluded)
  - Quartz, K-feldspar, Plagioclase, Calcite, Siderite, Ankerite/Fe-Dolomite, Dolomite, Pyrite, Fluorapatite, Barite, Magnetite, & Clay
- Identified 9 clusters, including one outlier
- Clusters are characterized by their dominant average mineral assemblages on the following slide

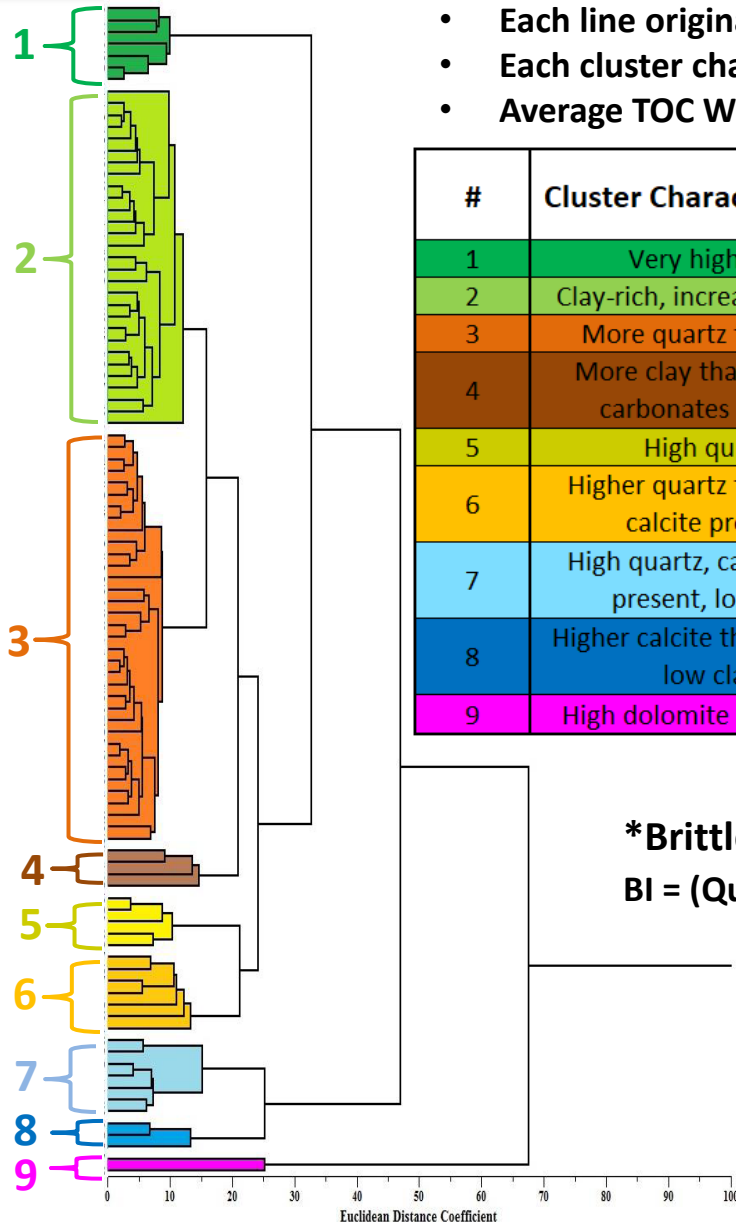
# BARNES 7-2 CORE; “FALSE” CANEY TO SYCAMORE LS (EXCLUDES SPRINGER SHALE) 99 SAMPLES, 12 XRD VARIABLES; Q-MODE CLUSTER ANALYSIS

- Each line originating on left side of tree is a sample depth
- Each cluster characterized by the average of the 12 XRD variables for its samples
- Average TOC Wt.% and Brittleness Index provided, but were not a variable

#	Cluster Characterization	4 Highest XRD Variables (Avg. Vol %)	Avg. Wt. % TOC	BI*
1	Very high clay	Clay 66; Quartz 23; Plagioclase 4; Pyrite 2	3.7	0.32
2	Clay-rich, increased quartz	Clay 49; Quartz 36; Plagioclase 5; Pyrite 3	4.7	0.49
3	More quartz than clay	Quartz 46; Clay 39; Plagioclase 5; Pyrite 3	3.8	0.59
4	More clay than quartz, carbonates present	Clay 41; Quartz 28; Calcite 8; Dolomite 6	4.2	0.57
5	High quartz	Quartz 60; Clay 27; Plagioclase 4; K-Feldspar 4	5.1	0.72
6	Higher quartz than clay, calcite present	Quartz 43; Clay 25; Calcite 8; Plagioclase 7	2.0	0.73
7	High quartz, carbonates present, low clay	Quartz 48; Calcite 19; Dolomite 11; Plagioclase 9	0.3	0.92
8	Higher calcite than quartz, low clay	Calcite 39; Quartz 37; Plagioclase 8; Clay 6	0.1	0.94
9	High dolomite & ankerite	Dolomite 51; Clay 15; Ankerite/Fe-Dolomite 12; Quartz 9	1.1	0.94

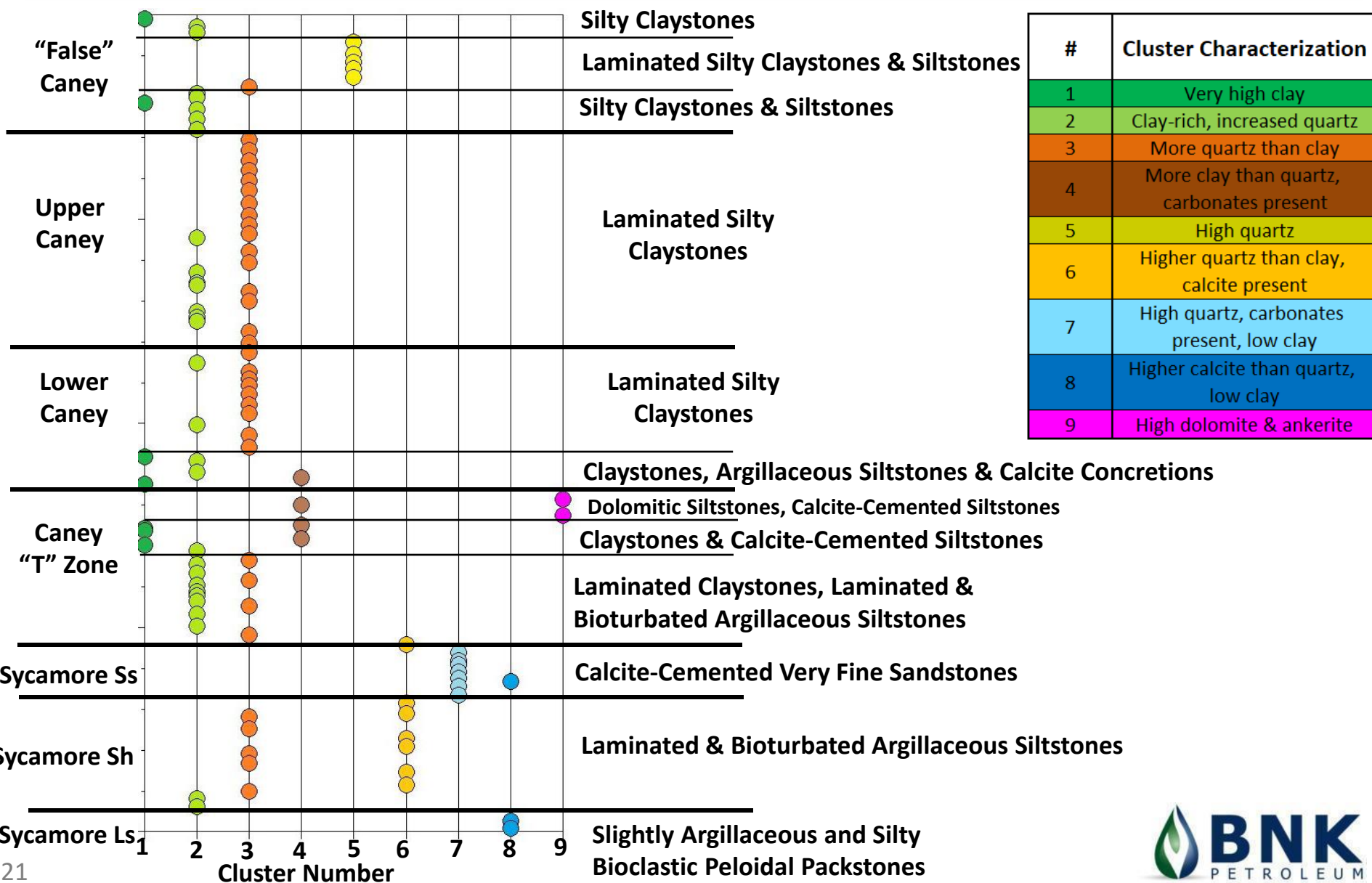
**\*Brittleness Index (Mineral Brittleness Equation)**

$$BI = \frac{Quartz + Feldspars + Carbonates}{Quartz + Feldspars + Carbonates + Clay}$$

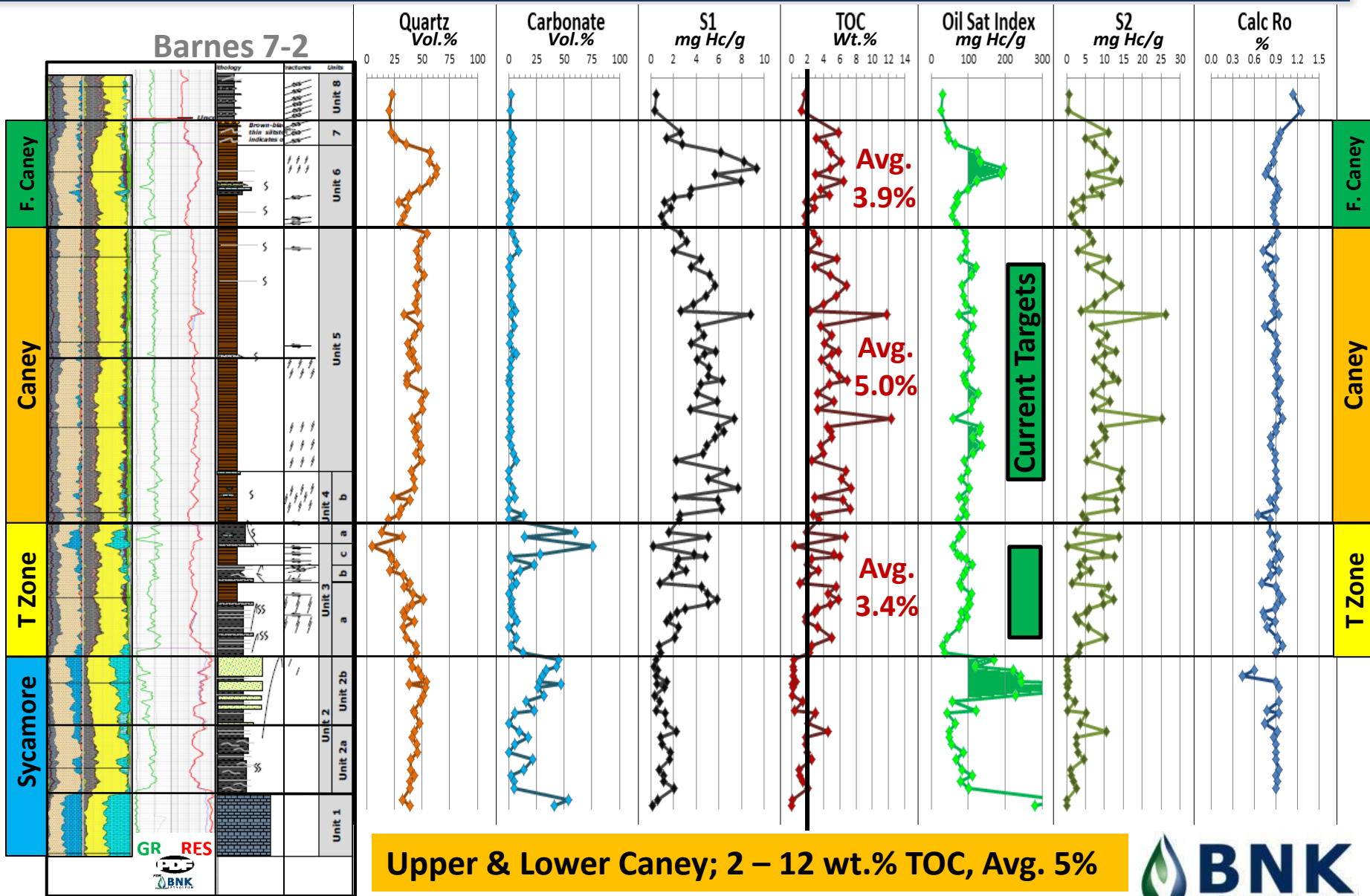


# BARNES 7-2 CANEY CORE

## RELATIVE SAMPLE DEPTH & DISTRIBUTION OF XRD CLUSTERS

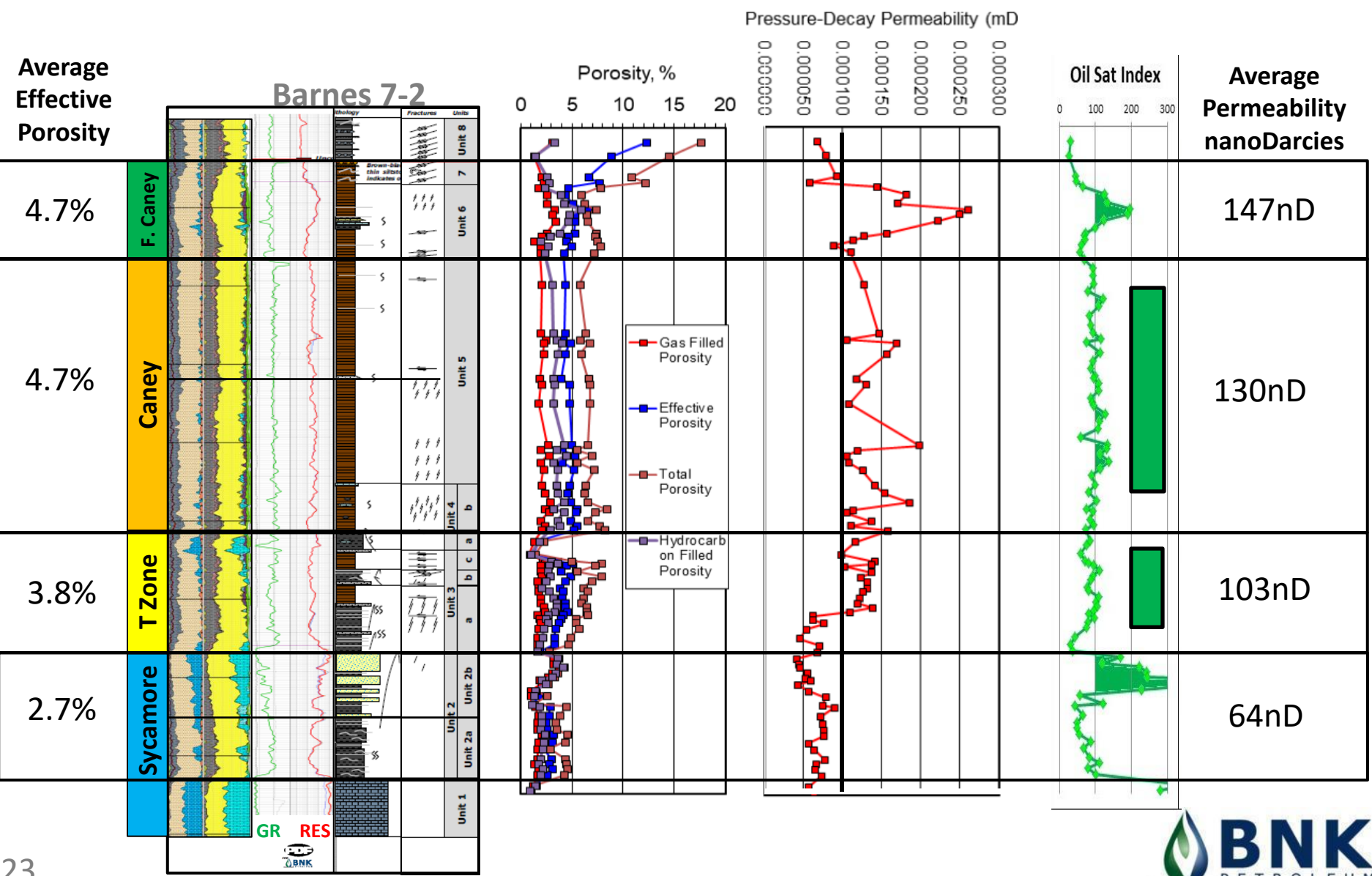


# TOC & Rock Eval PYROLYSIS



# POROSITY & PERMEABILITY

Current Targets



# VISUAL THERMAL MATURITY ANALYSIS

## 3 depths analyzed for vitrinite reflectance and whole rock maceral analysis (257ft Interval)

- Primarily Type II Marine Kerogen – Liptinite
- Vitrinite noted as “rare and small”
  - Vitrinite  $R_o$  0.98 – 1.01%
- Average Solid Bitumen  $R_o$  0.77 – 0.83%
  - Transformed Bitumen  $R_o$  by 3 published equations
  - VRE range of 0.88 – 1.14%
- Rock Eval calculated  $R_o$  from the TMax those 3 sample depths 0.83 – 0.99 %
- Using a peak oil window of 0.8 – 1.0% VRO, puts the samples in peak generation window and possibly slightly into volatile oil window

Barnes 7-2 Whole Rock Visual Maceral Estimates		
Volume %, Mineral Matter Free Basis		
Average 3 Samples		
Type II	Liptinite	85
Type III	Vitrinite	2
Type IV	Inertinite	3
Solid Bitumen		10
Total		100

Zone	Minimum $R_o$ (%)	Maximum $R_o$ (%)	Number of points	Standard deviation	Mean $R_o$ value of indigenous vitrinite %	Mean $R_o$ value of solid bitumen %
"False" Caney	0.82	1.15	36	0.08	0.98	0.77
Lower Caney	0.83	1.17	27	0.09	0.99	0.80
Caney "T" Zone	0.85	1.16	28	0.08	1.01	0.83

Zone	Mean $R_o$ value of solid bitumen %	VRE value (%) Jacob, 1989	VRE value (%) Schoenherr et al, 2007	VRE value (%) (Landis&Castano,1995)
"False" Caney	0.77	0.88	0.97	1.08
Lower Caney	0.80	0.89	1.00	1.11
Caney "T" Zone	0.83	0.91	1.02	1.14

### Vitrinite reflectance equivalent (VRE)

$$VRE (Jacob)=0.618*SB+0.4$$

$$VRE (Landis\&Castano,1995)=(SB+0.41)/1.09$$

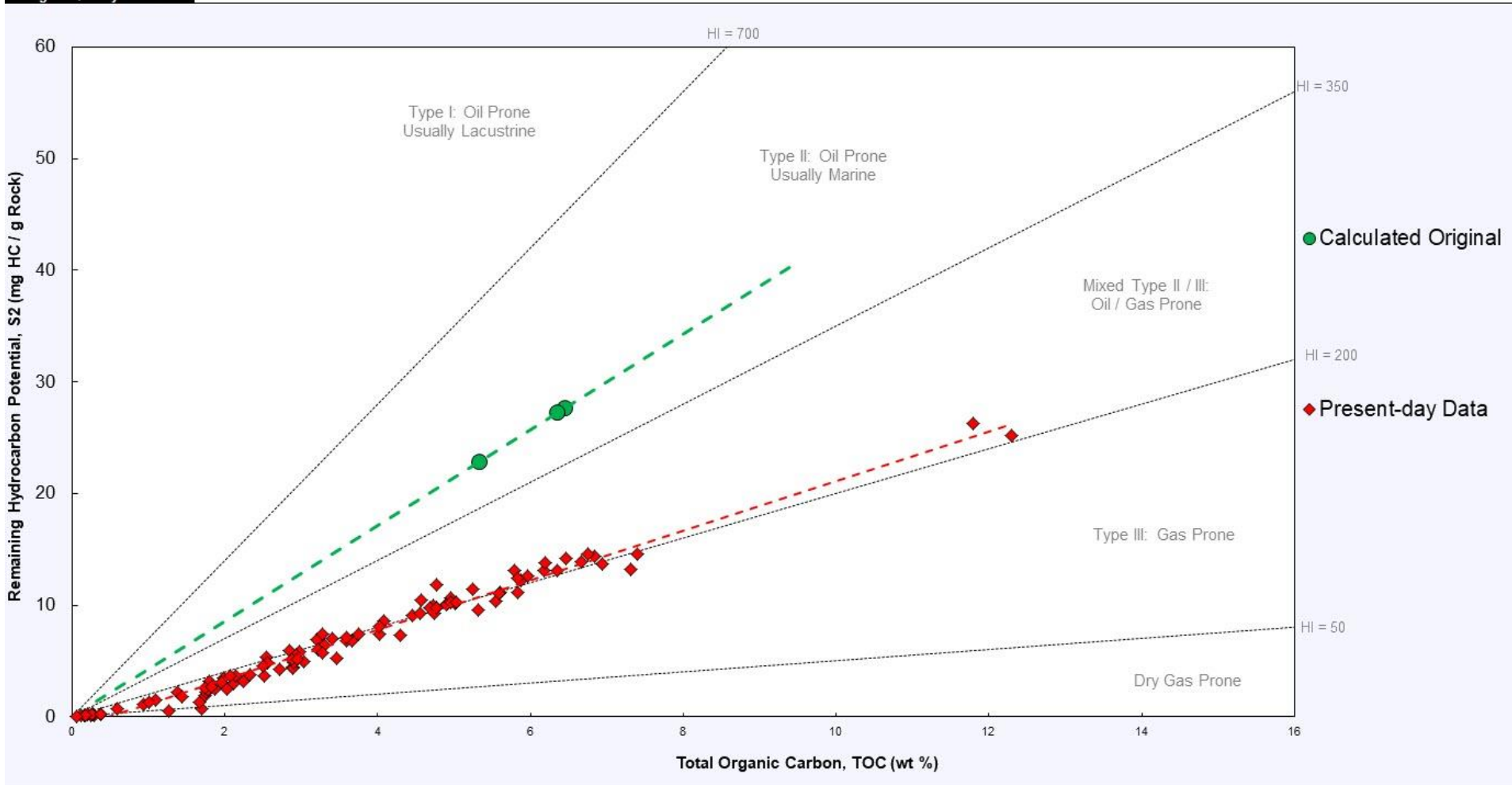
$$VRE (Schoenherr et al 2007) =(SB+0.2443)/1.0495$$

Zone	LECO TOC Wt. %	S1	S2	S3	Tmax	Report Calculated $R_o$
"False" Caney	6.2	8.2	13.1	0.4	446	0.87
Lower Caney	5.0	5.7	10.3	0.5	444	0.83
Caney "T" Zone	5.8	5.9	12.4	0.4	453	0.99

# ROCK EVAL PYROLYSIS - KEROGEN QUALITY PLOT

- The original TOC and original S2 (Jarvie 2011) are plotted for the 3 VRo samples along with the present-day TOC
- The transformed TOC data more closely match the visual maceral analysis results (Majority Type II – Liptinite)

Kerogen Quality Plot



# SUMMARY

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- As evidenced by the Barnes 7-2 core, the Caney Shale in BNK Petroleum's Tishomingo field shares many of the same characteristics as other successful "shale" plays
- It is a very organic-rich shale that is most certainly self-sourcing. Based on core analysis, BNK's target reservoir interval in the Upper/Lower Caney has the following characteristics;
  - **Laminated silty, claystone with steep planar fracture sets**
  - **Thickness**, 155ft
  - **TOC**, 2 – 12 wt.%, 5% avg.
  - **Maturation**, 0.99 VRo (0.88 – 1.14% VRE range) in the peak oil generation window
  - **Source Rock**, almost entirely Type II (Marine)
  - **Reservoir mineralogy**, Quartz 34-54%; 45% avg.; Clay 36-53%; 42% avg
  - **Effective Porosity**, 4 -5%; 5% avg.
  - **Permeability**, 105nD - 199 nD; 137nD avg.
- Similar reservoir targets are also present in the lower Caney "T" Zone where BNK drilled early wells that are still producing and also in the "False" Caney which has not yet been targeted
- Since 2012, BNK has produced over 2.5MM barrels of oil equivalent fluids (80% oil) from 17 lateral wells with low declines (avg. 1<sup>st</sup> year BOE decline of 47%). BNK has proved reserves of 33.4 Million BOE from 18 wells in the Caney Shale with much more room to step-out and expand the successfully producing Caney Shale footprint

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# ACKNOWLEDGMENTS

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