

Rock Volatiles Analyses of Woodford Shale Cuttings and Cores from the Anadarko and Arkoma Basins

Supplied Through Advanced Hydrocarbon Stratigraphy (AHS)

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October 25, 2020

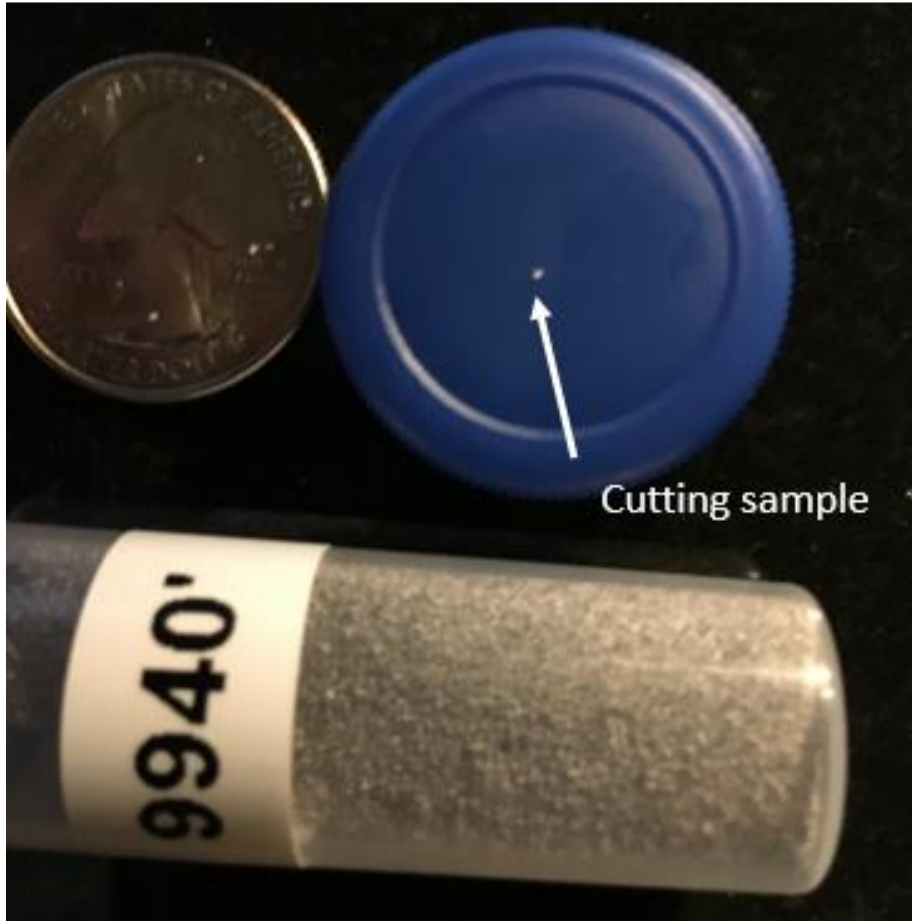
Title: Rock Volatiles Analyses of Woodford Shale Cuttings and Cores from the Anadarko and Arkoma Basins.

Emphasis: Reservoir Quality and Oil Versus Water Wetness, Especially the Role of Faults:
A Rock Volatiles (VAS) Study of Woodford Shale Cuttings.

Volatiles Analysis Services (VAS)

- Unique patented technology invented by AHS
- Available only from AHS through Baker Hughes
- Present day oil, gas, formation water, reservoir quality, etc.
- Evaluates new and old wells and DUCs
- Works even if logs are challenged: HPHT, Low Vis Pays, Tight Rocks, Fresh Water, Coiled Tubing, etc. No added rig time.

What Can Cuttings Tell Us?

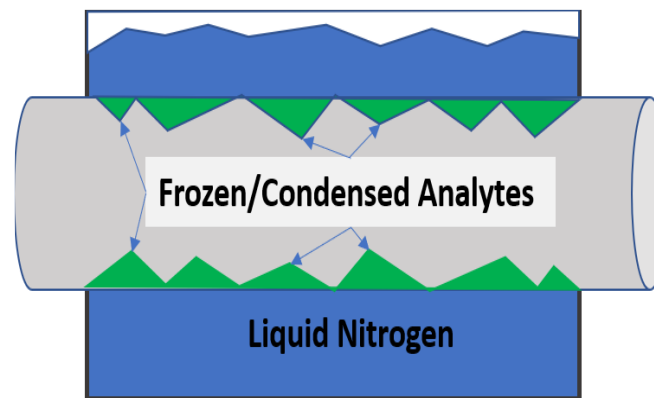
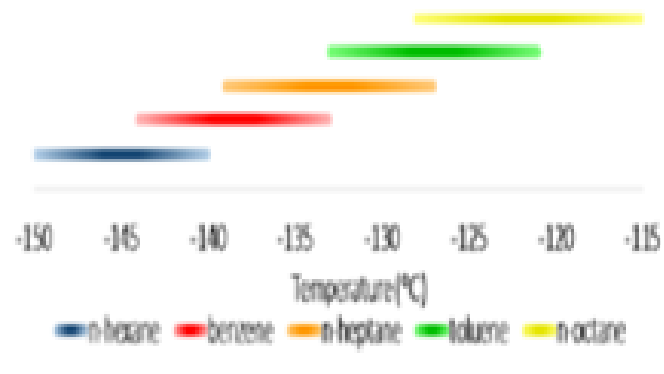
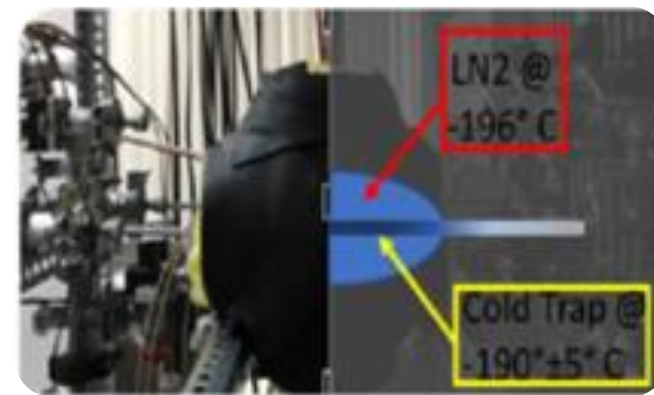


Volatiles Analysis Service (VAS) - Samples

- Sealed at Well or Lab Loaded
- WBM, OBM, Air Drilled
- PDC or Rock Bit cuttings,
- SWCs, Core, Mud.
- New or Old
- Even 70+ years old cuttings.

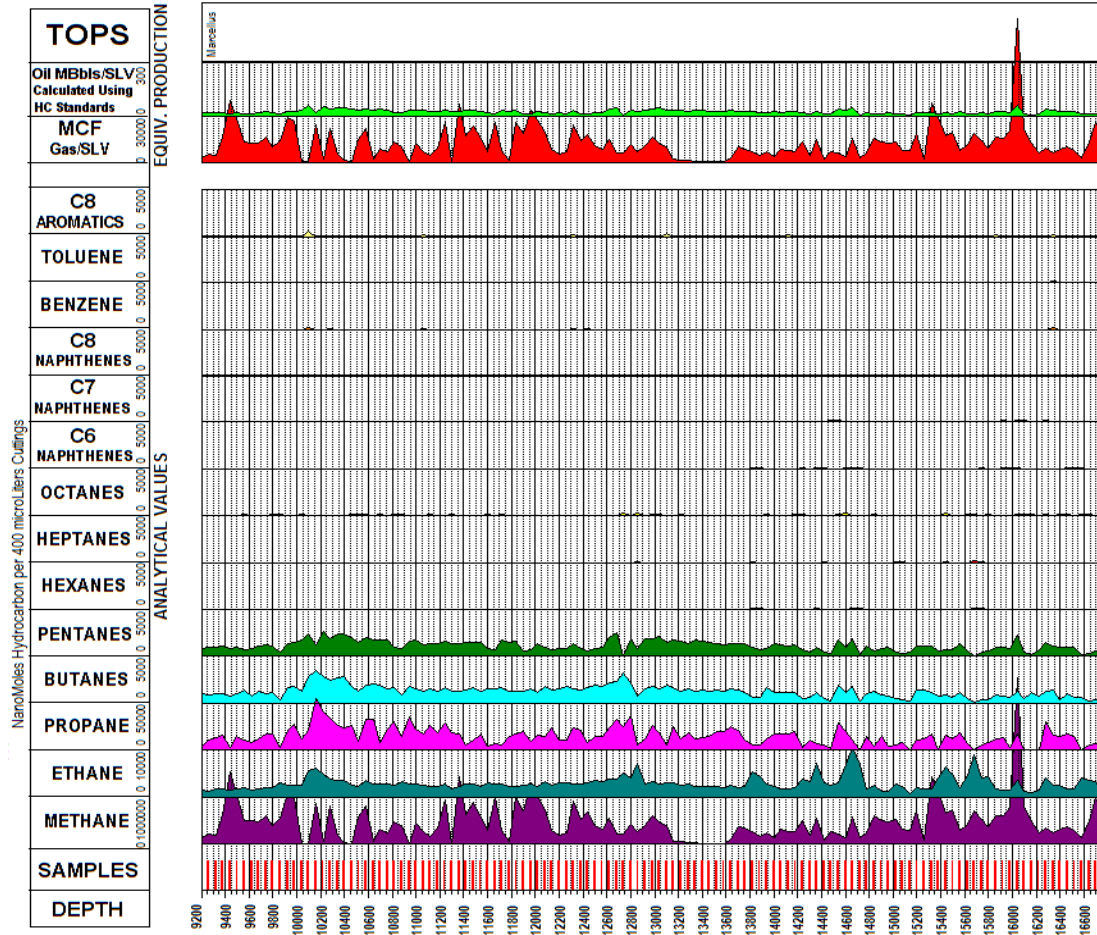


VAS: Novel Gentle Extraction & Cryo-Trap Mass Spec. Analysis



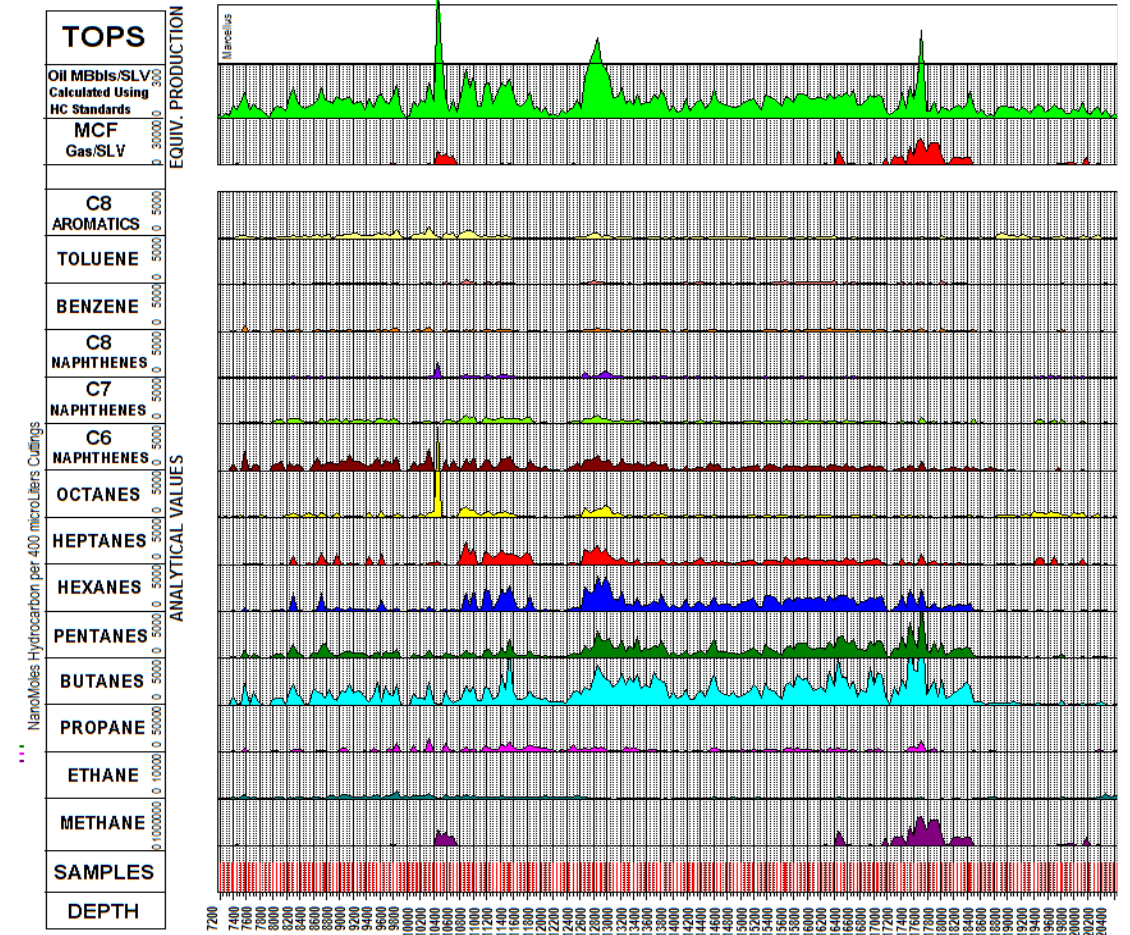
VAS Hydrocarbon Logs

Dry Gas PA Well



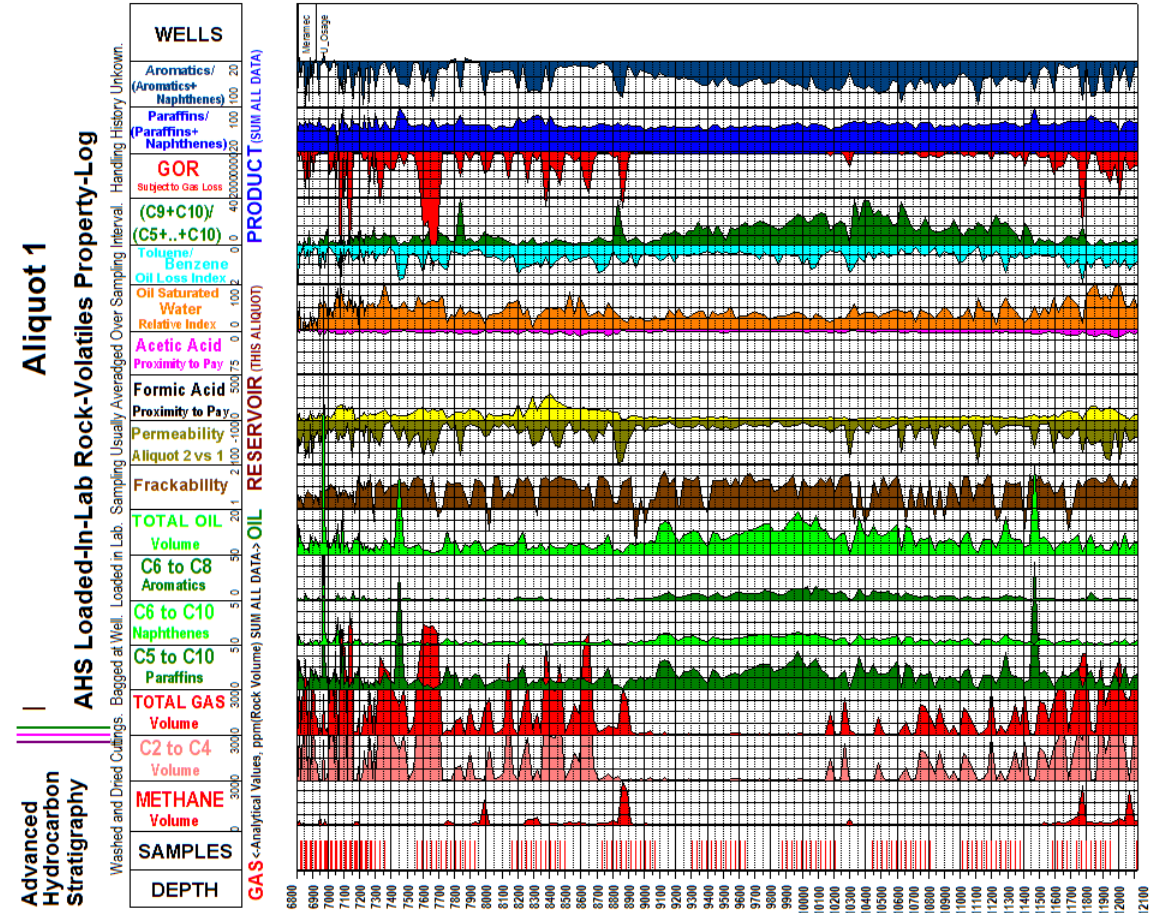
2 mile Marcellus lateral, 20 millibar extraction

Wet Gas WV Well



2 mile Marcellus lateral, 20 millibar extraction

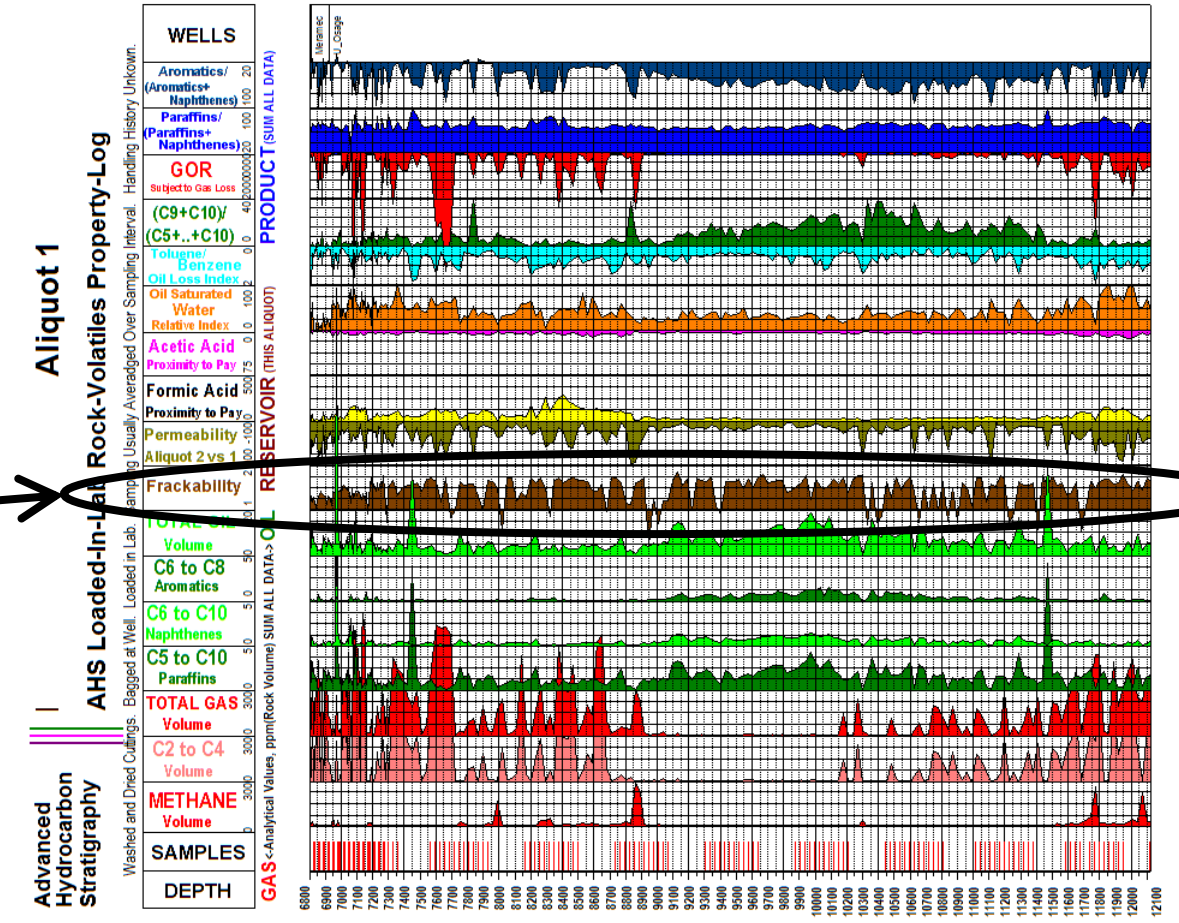
VAS Property Log



1 mile lateral, 20 millibar extraction

VAS Property Log

Mechanical Strength



1 mile lateral, 20 millibar extraction

VAS Analyses of Each Sample

2 Extractions: 20 and 2 millibars

Lab Loaded: Crush at Extraction Start

Sealed at Well: Extract Without Crush

Title: Rock Volatiles Analyses of Woodford Shale Cuttings and Cores from the Anadarko and Arkoma Basins.

Emphasis: Reservoir Quality and Oil Versus Water Wetness, Especially the Role of Faults:
A Rock Volatiles (VAS) Study of Woodford Shale Cuttings.

Fault
Associated
HC Liquids

Sealed @ Well
Cuttings

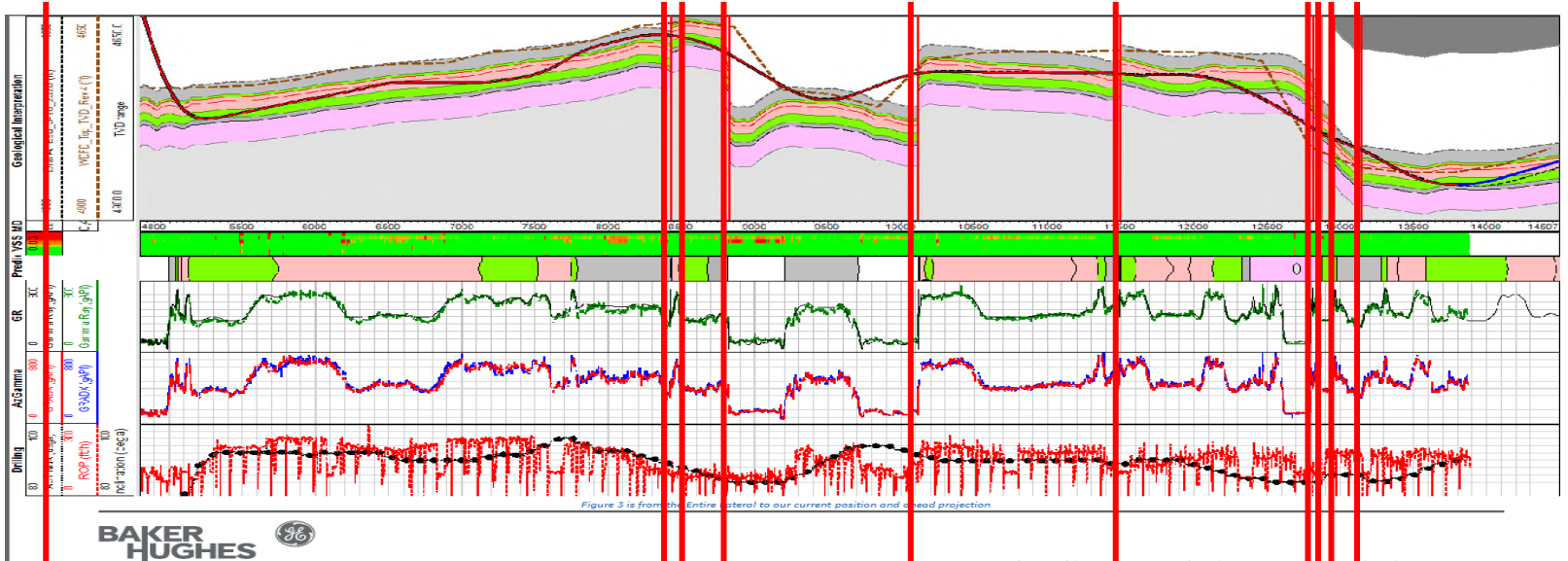
Woodford
Lateral

Arkoma Basin

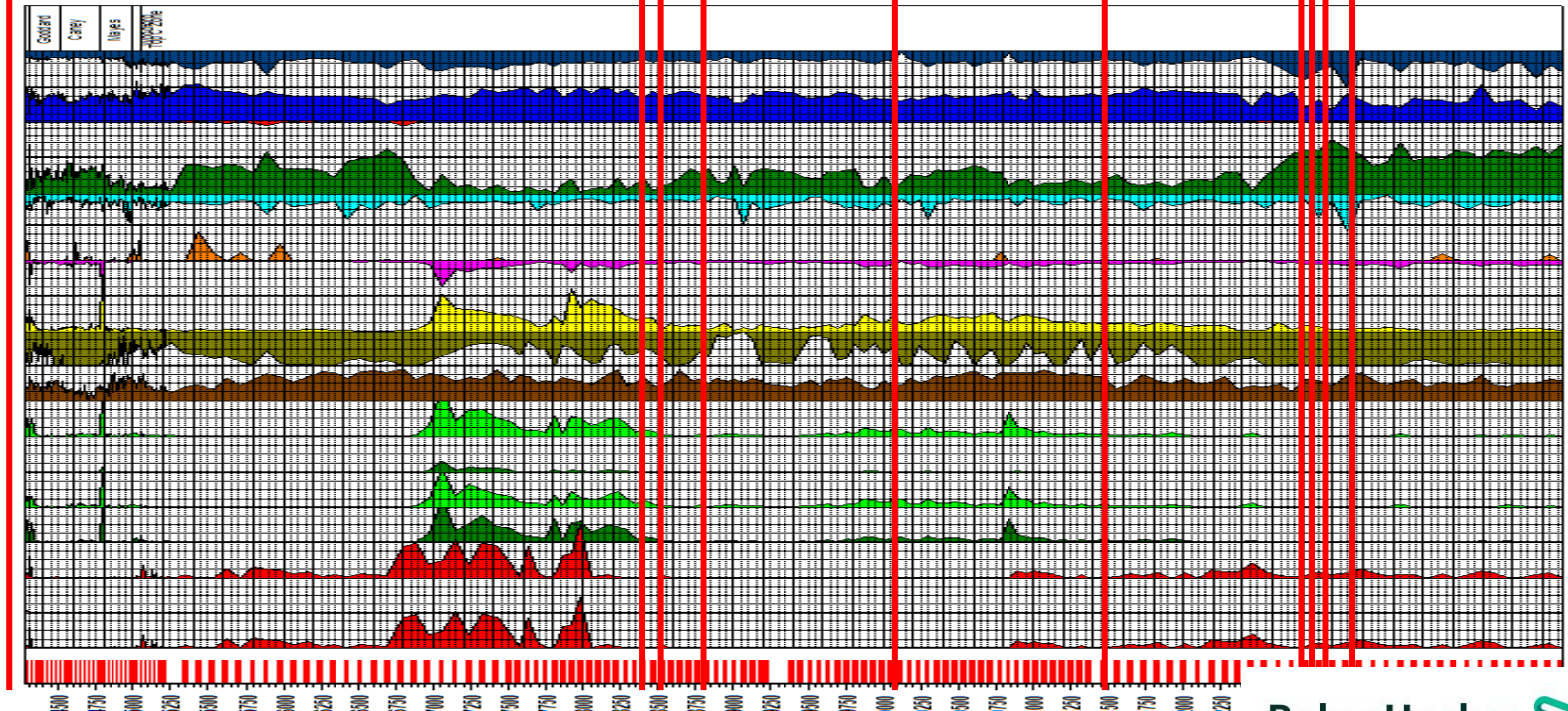
TOPS	
Aromatics/ (Aromatics+ Naphthenes)	0
Paraffins/ (Paraffins+ Naphthenes)	6000
GOR Subject to Gas Loss	0
(C9+C10)/ (C5+...C10)	0
Toluene/ Benzene	0
Total Water Relative Index	0
Acetic Acid Proximity to Pay	25000
Formic Acid Proximity to Pay	25000
Permeability Allquot 2 vs 1	20000
Frackability	20000
TOTAL OIL Volume	25000
C6 to C8 Aromatics	5000
C6 to C10 Naphthenes	5000
C5 to C10 Paraffins	5000
TOTAL GAS Volume	100000
C2 to C4 Volume	100000
METHANE Volume	100000
SAMPLES	
DEPTH	

PRODUCT (SUM ALL DATA)

GAS (Analytical Values, ppm/Block Volume) SUM ALL DATA > OIL RESERVOIR (THIS ALLOUT)



BAKER HUGHES



Fault
 Associated
 HC Liquids

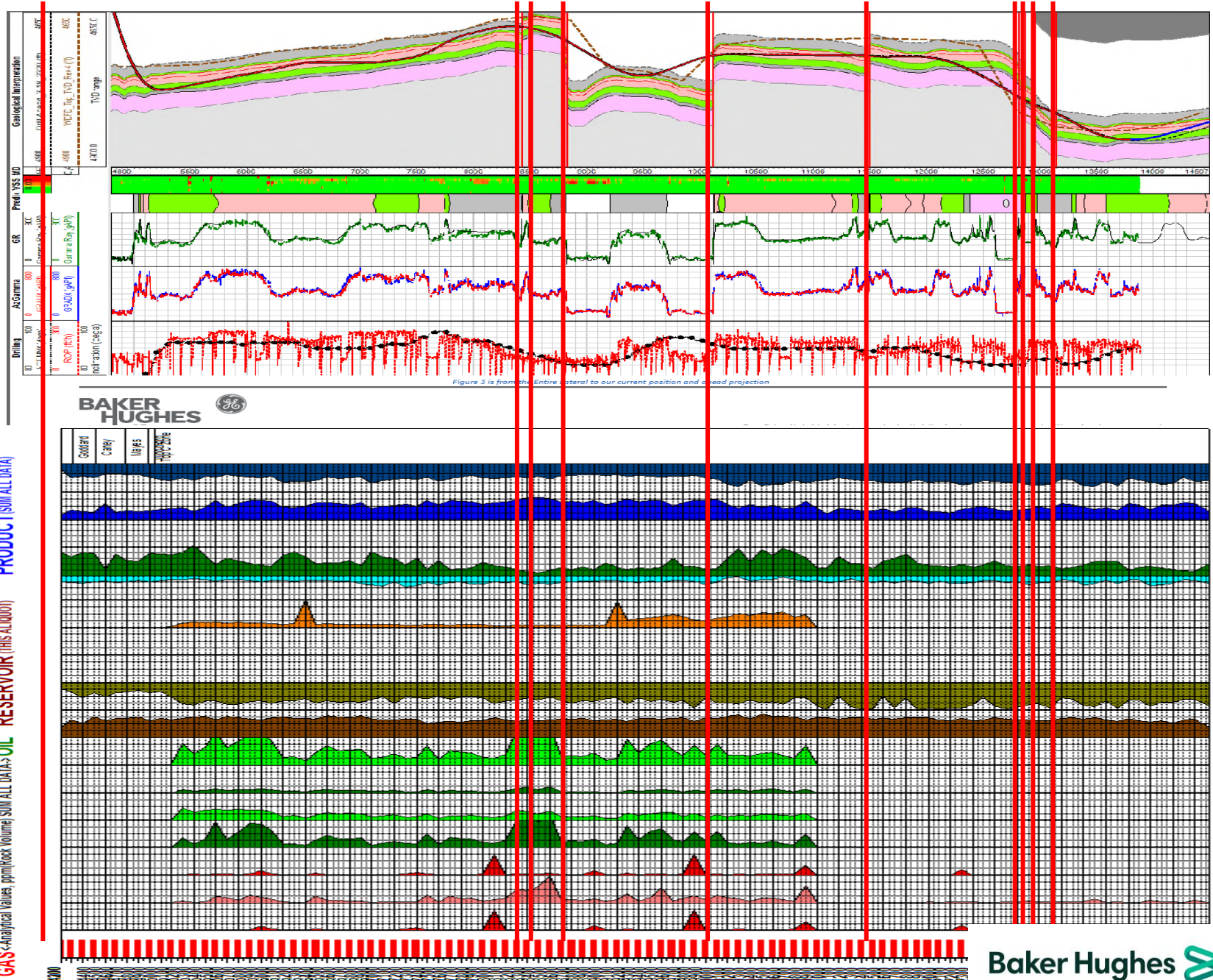
 Lab Loaded
 Cuttings

 Woodford
 Lateral

 Arkoma Basin

TOPS	
Aromatics/ (Aromatics+ Naphthenes)	0 100 100
Paraffins/ (Paraffins+ Naphthenes)	0 100 100
GOR Subject to Gas Loss (C9+C10)/ (C5+...+C10)	0 500000000 0
Toluene/ Benzene	0 10 10
Total Water Relative Index	0 100 100
Acetic Acid Proximity to Pay	0 2500000 0
Formic Acid Proximity to Pay	0 2500000 0
Permeability Alliquot 2 vs 1	0 2000 2000
Frackability	0 25000 25000
TOTAL OIL Volume	0 7500 7500
C6 to C8 Aromatics	0 7500 7500
C6 to C10 Naphthenes	0 7500 7500
C5 to C10 Paraffins	0 7500 7500
TOTAL GAS Volume	0 100000 100000
C2 to C4 Volume	0 5000 5000
METHANE Volume	0 100000 100000
SAMPLES	
DEPTH	

PRODUCT (SUM ALL DATA) RESERVOIR (THIS ALIQUOT) OIL (SUM ALL DATA) GAS (Analytical Values, ppm/Block Volume)

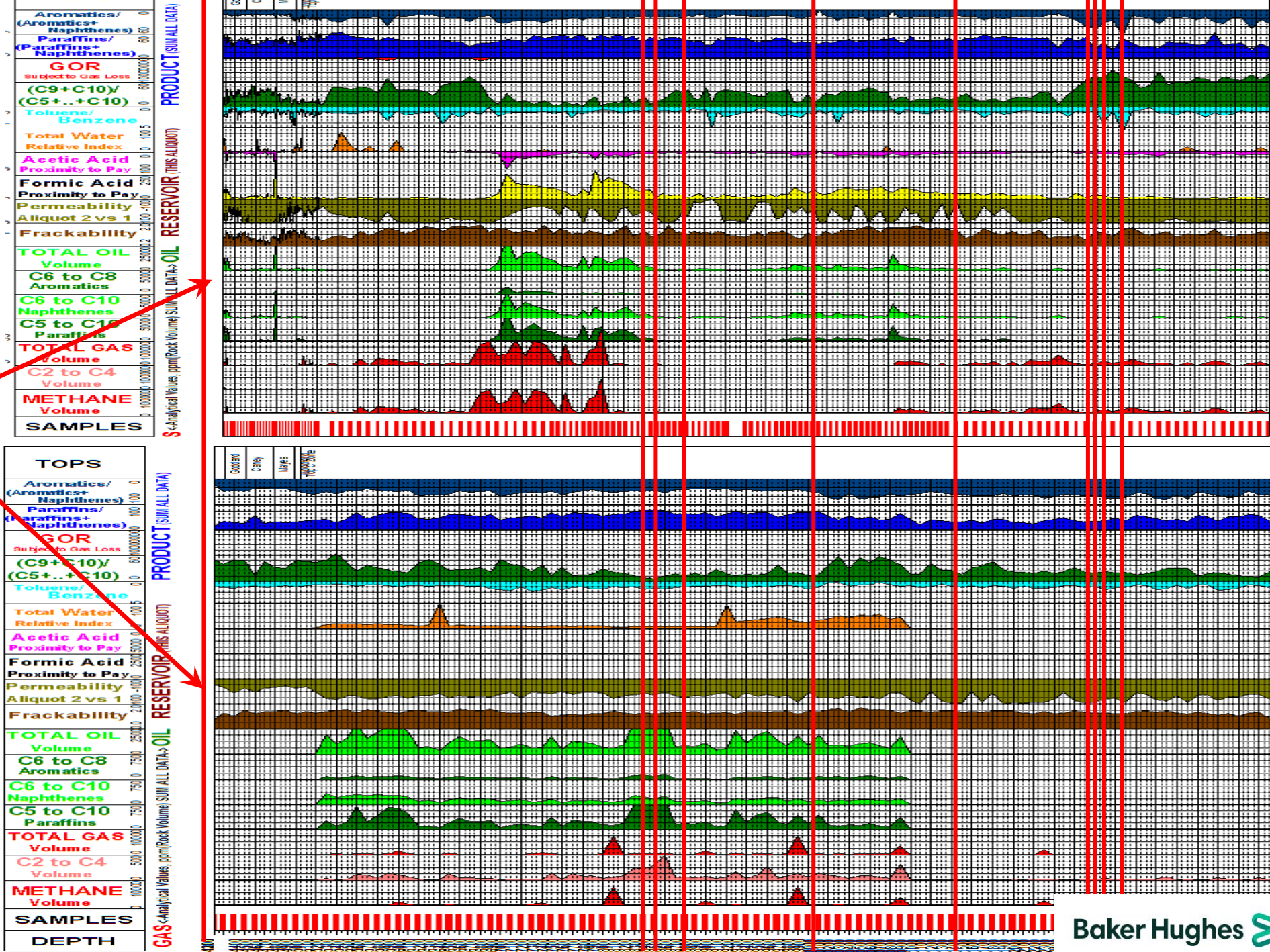


Fault
Associated
HC Liquids

Sealed @ Well
Vs. Lab Loaded
Cuttings

Woodford
Lateral

Arkoma Basin



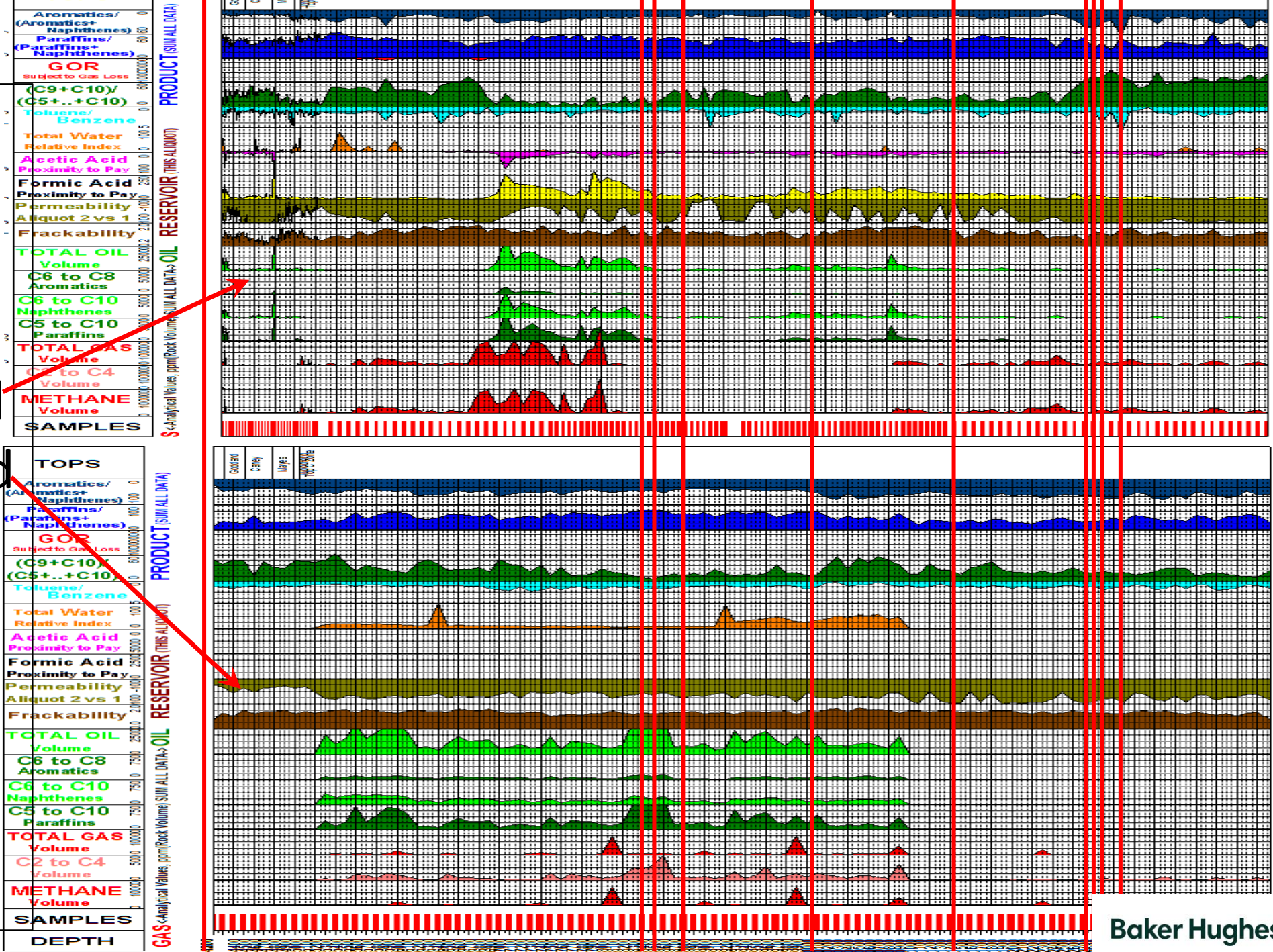
Today's Mission:
Understanding Differences Between
Sealed at Well versus Lab Loaded
Cuttings Volatiles, Especially for
Oil versus Water Wetting Reservoirs

Fault
Associated
HC Liquids

Sealed @ Well
Vs. Lab Loaded
Cuttings

Woodford
Lateral

Arkoma Basin



Lab Loaded Cuttings Volatiles

Without Sealed at Well Cuttings Volatiles

What Can We Learn?

1) Reservoir Quality

2) Mechanical Strength

3) Effects of Faults on Both

4) Oil vs Water Wettness with New Tech

(not developed yet for these data)

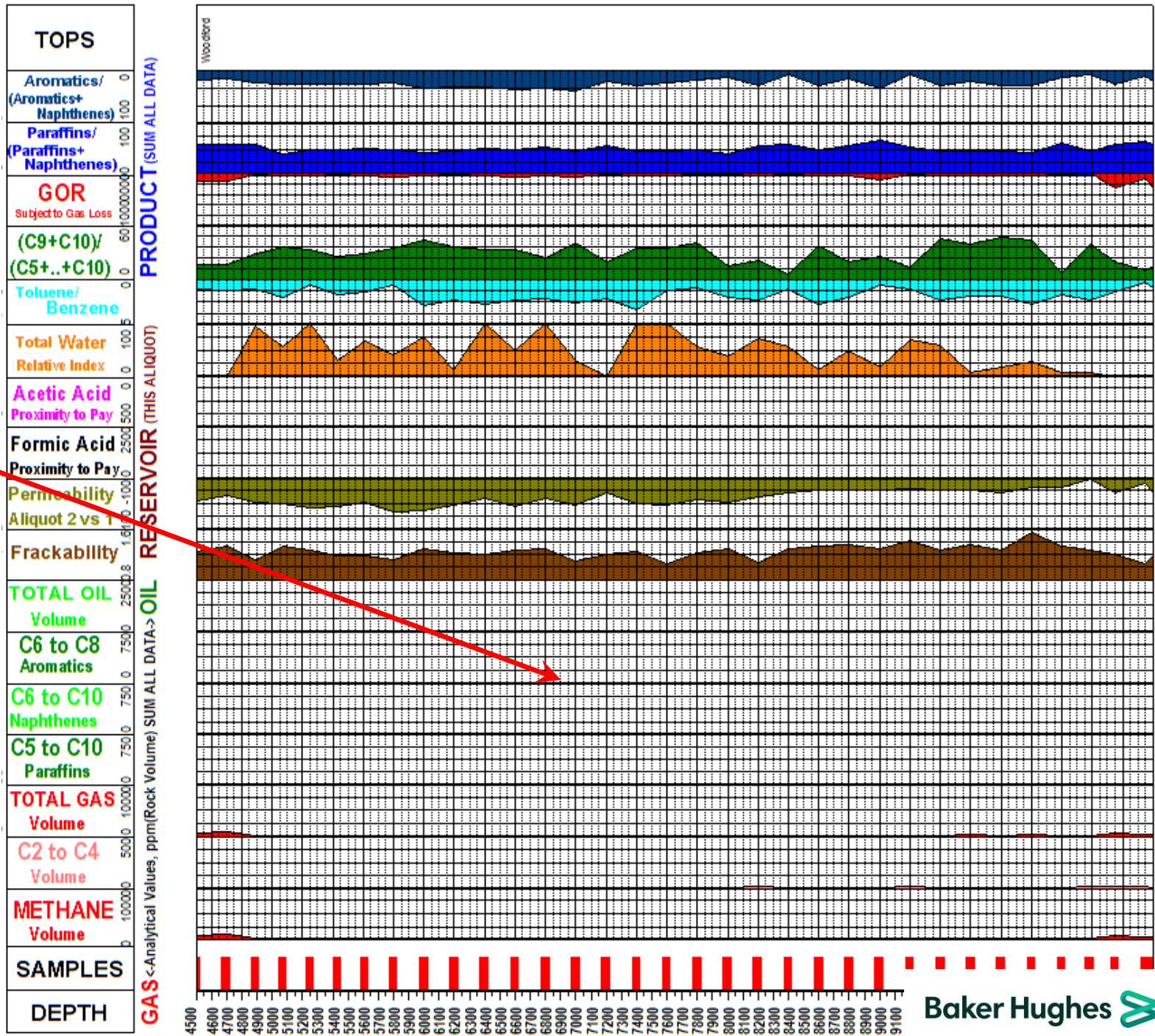
Client's Best Well

Lab Loaded Cuttings

Less Cuttings Oil = Good Reservoirs

Woodford 2 Mile Lateral

Arkoma Basin



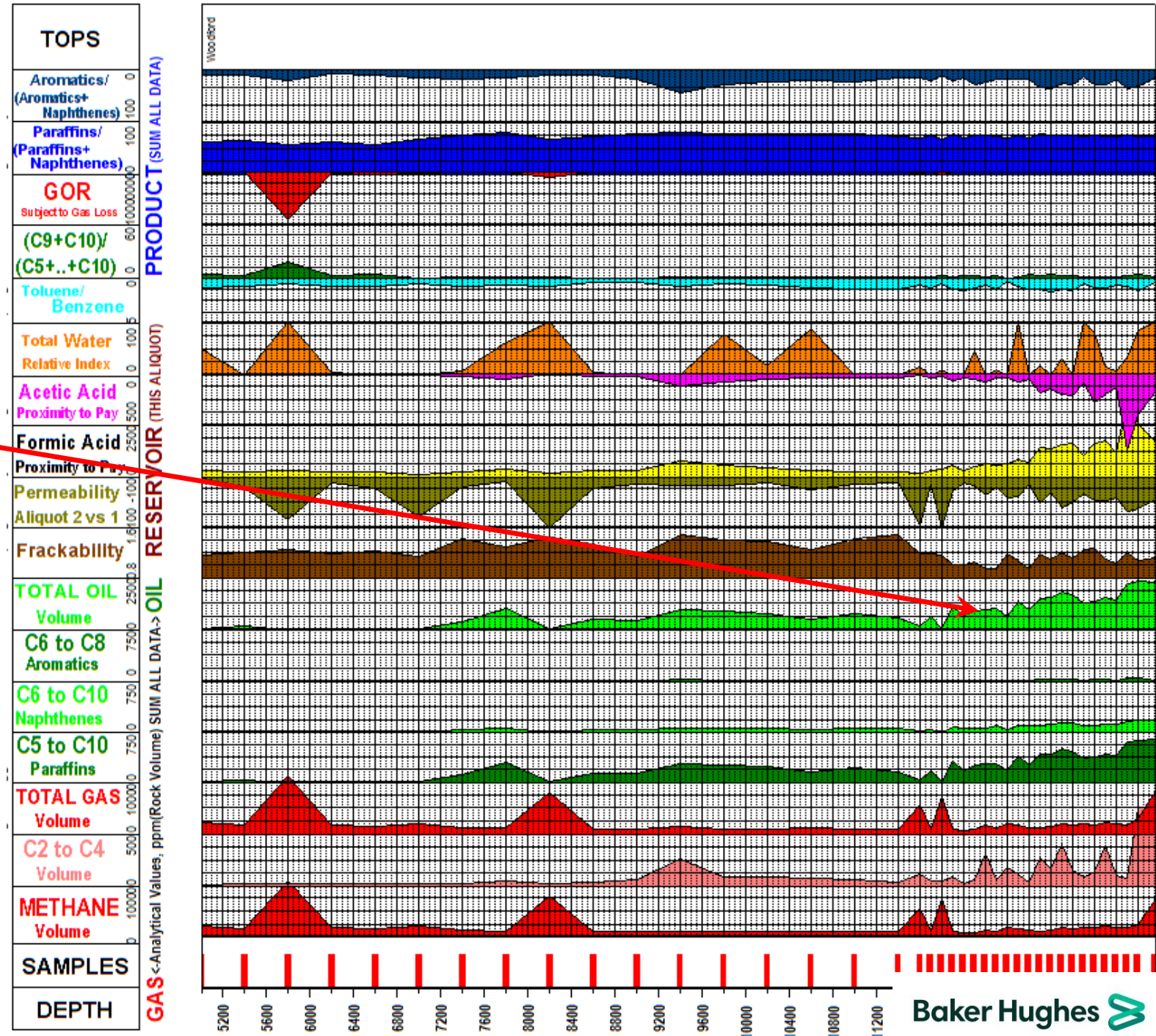
Poor Performing Well

Lab Loaded Cuttings

More Cuttings Oil = Tight Reservoirs

Woodford 2 Mile Lateral

Arkoma Basin



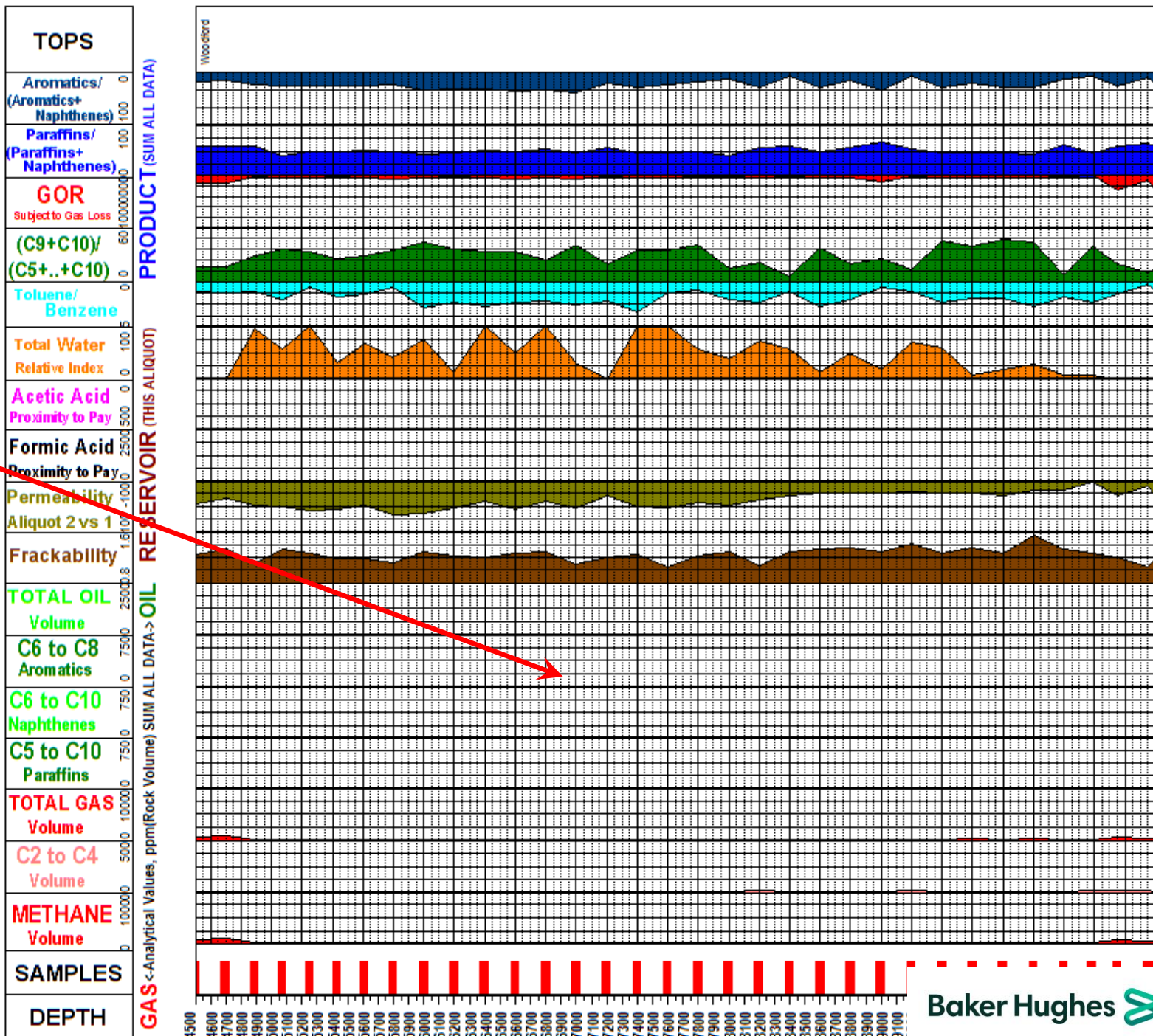
Client's Best Well

Lab Loaded Cuttings

Less Cuttings Oil = Good Reservoirs

Woodford 2 Mile Lateral

Arkoma Basin



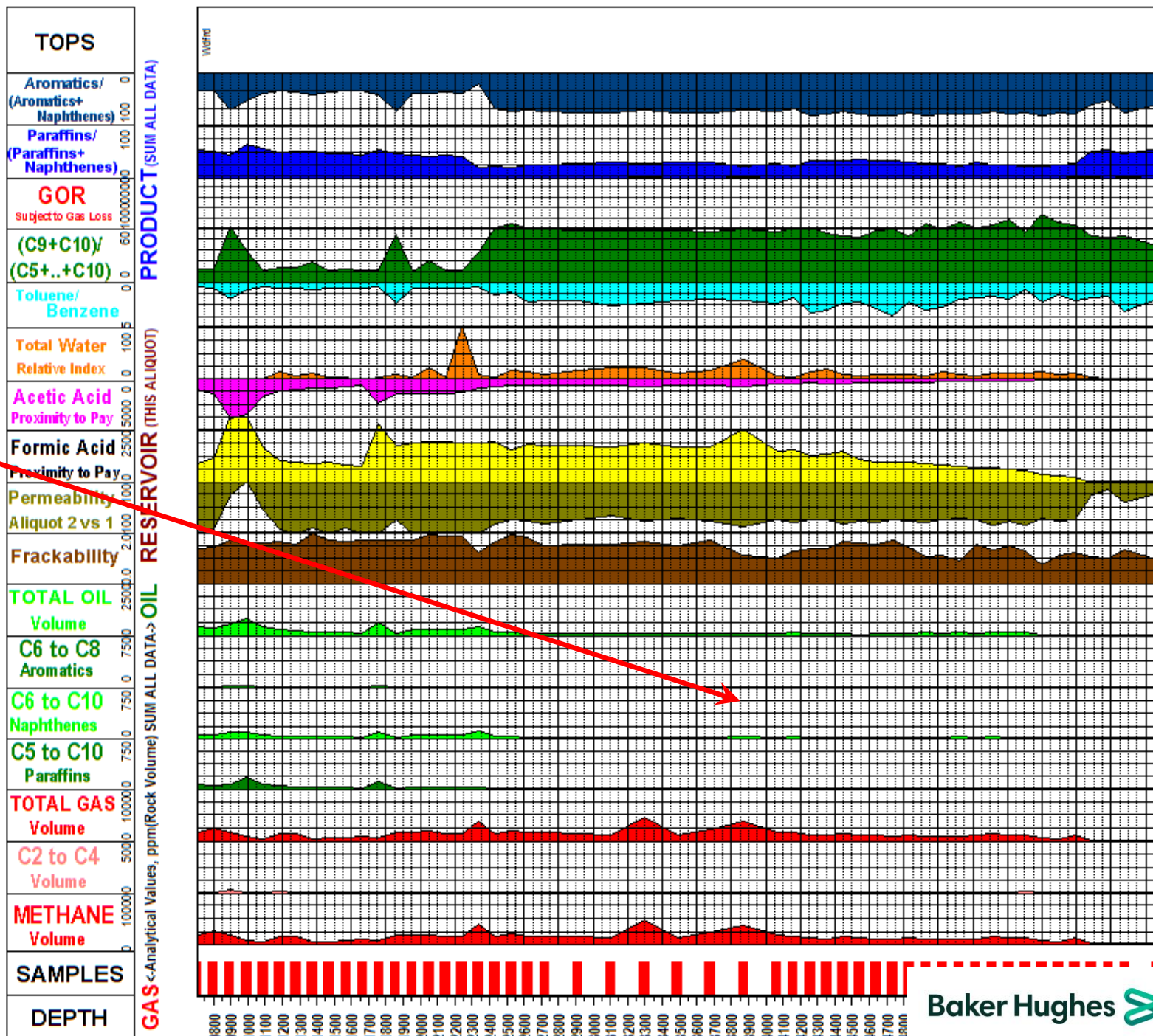
Good Producing Well

Lab Loaded Cuttings

Less Cuttings Oil = Good Reservoirs

Woodford 2 Mile Lateral

Arkoma Basin



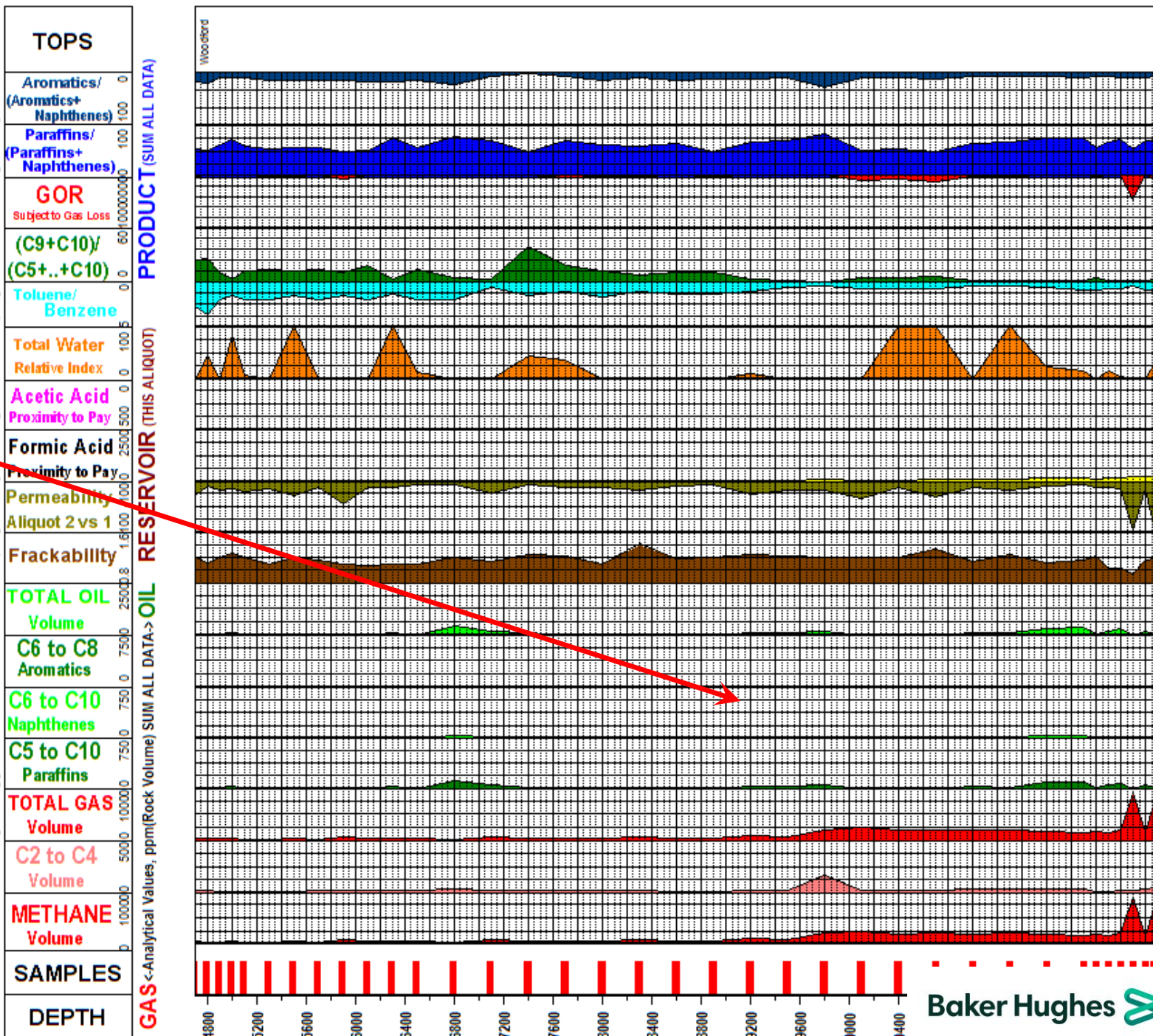
Good Producing Well

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Woodford 2 Mile Lateral

Arkoma Basin



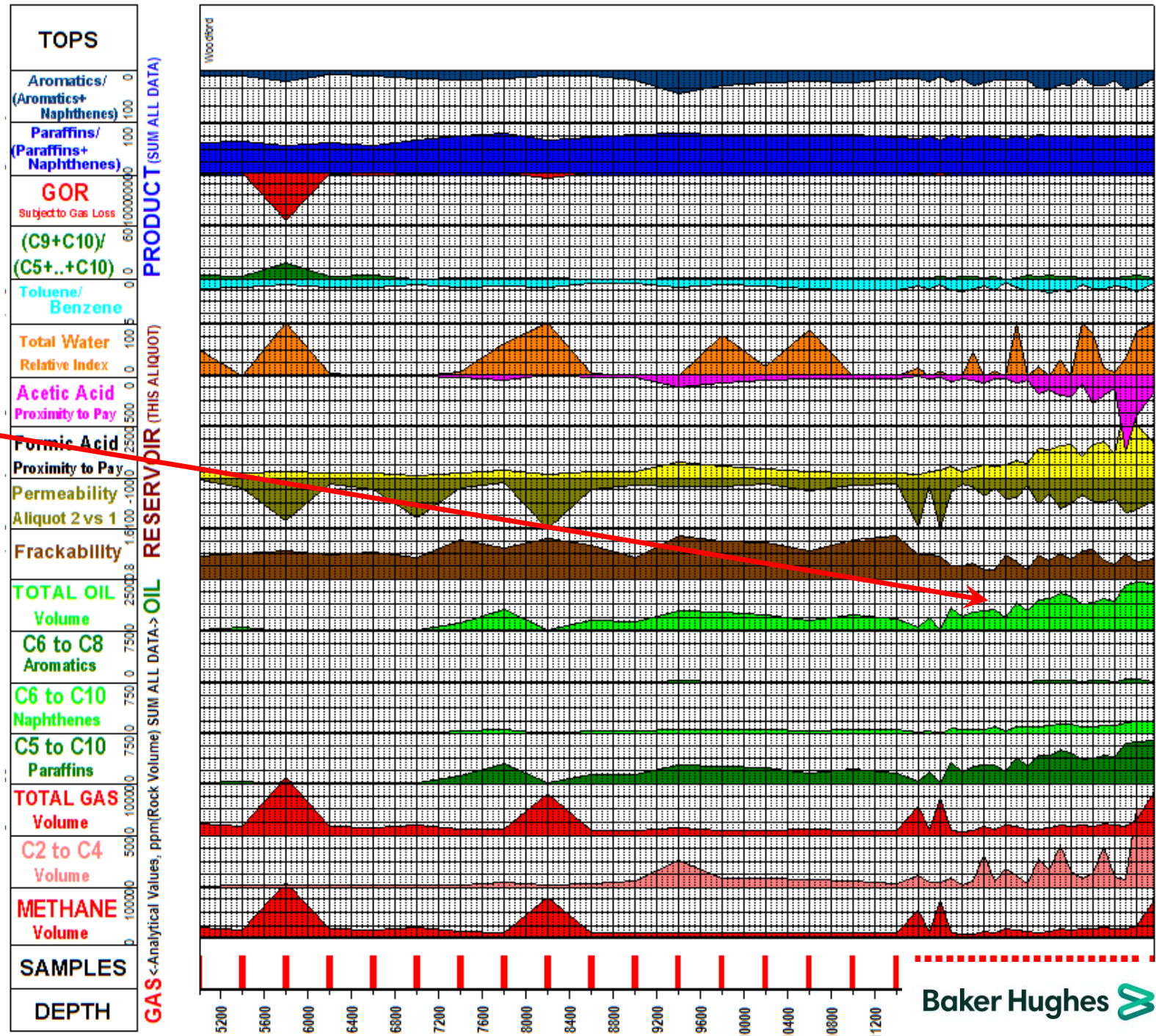
Poor Performing Well

Lab Loaded Cuttings

More Cuttings Oil = Tight Reservoirs

Woodford 2 Mile Lateral

Arkoma Basin



Poor Performing Well

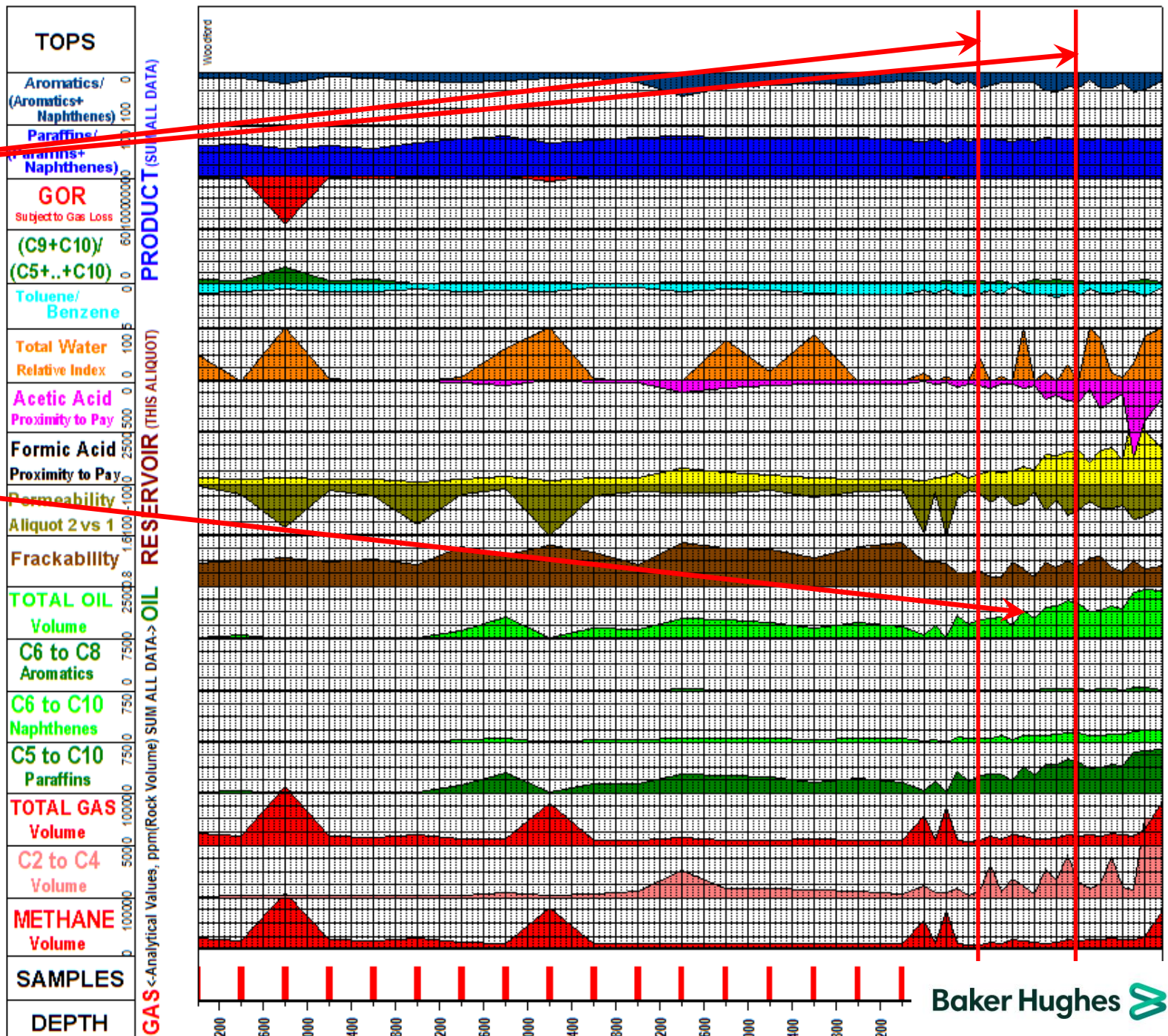
Major Faults

Lab Loaded Cuttings

More Cuttings Oil = Tight Reservoirs

Woodford 2 Mile Lateral

Arkoma Basin



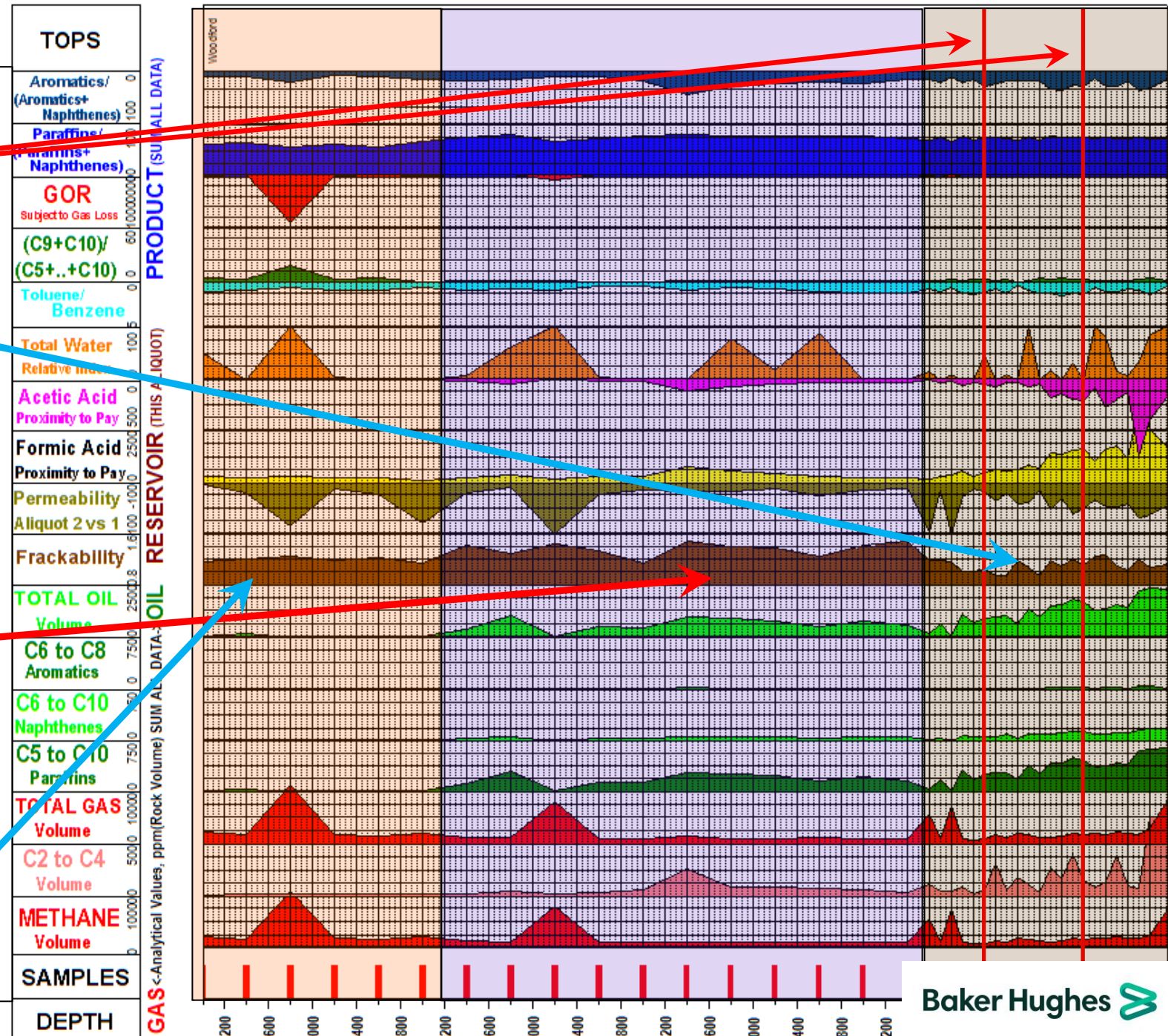
Poor Performing Well

Major Faults

Tight Reservoir with Fault
Microfabric Destruction.
Low Mechanical Strength

Tight Reservoir with Fault
Fluid Cementation.
High Mechanical Strength

Normal Woodford M.S.



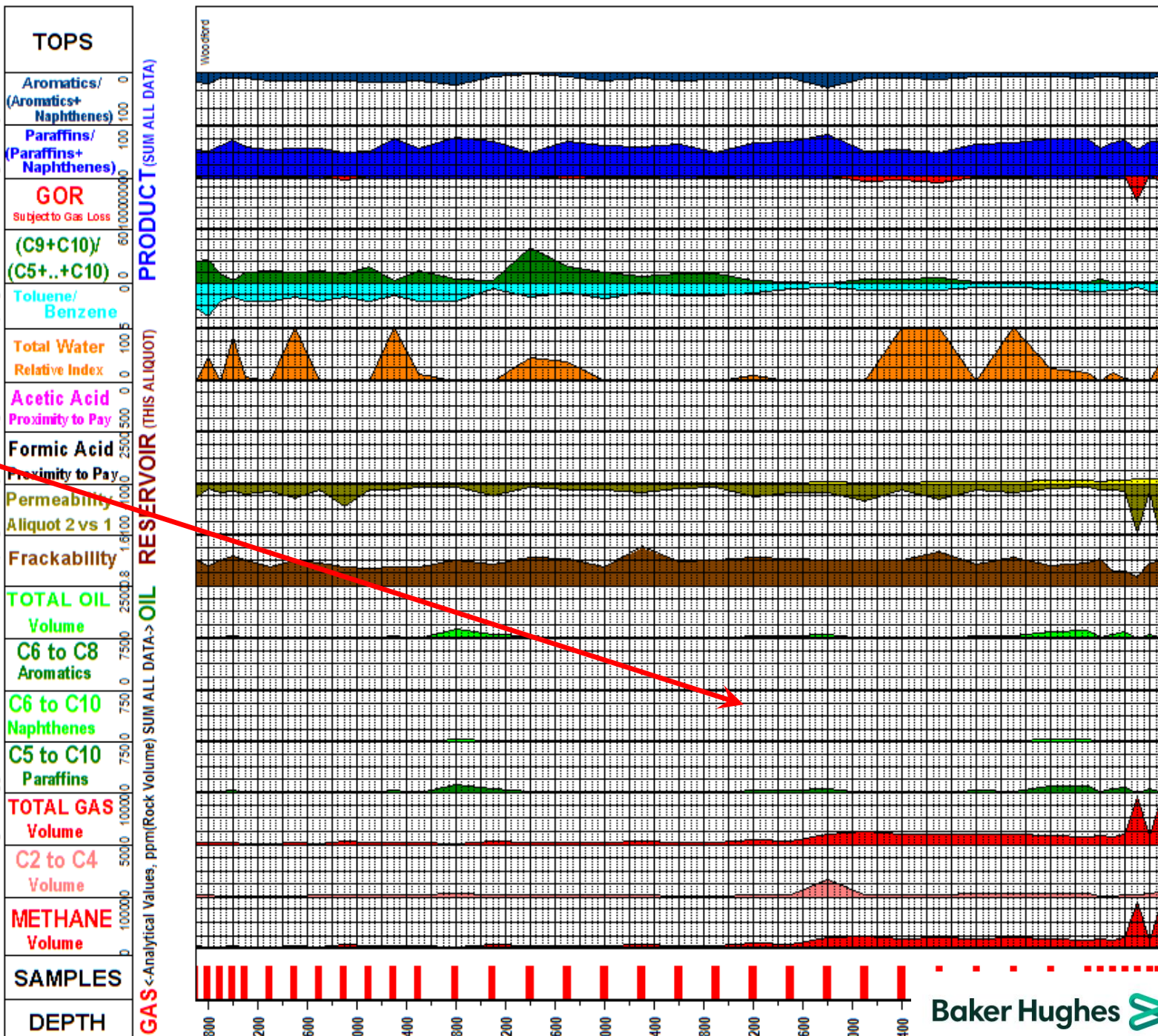
Good Producing Well

Lab Loaded Cuttings

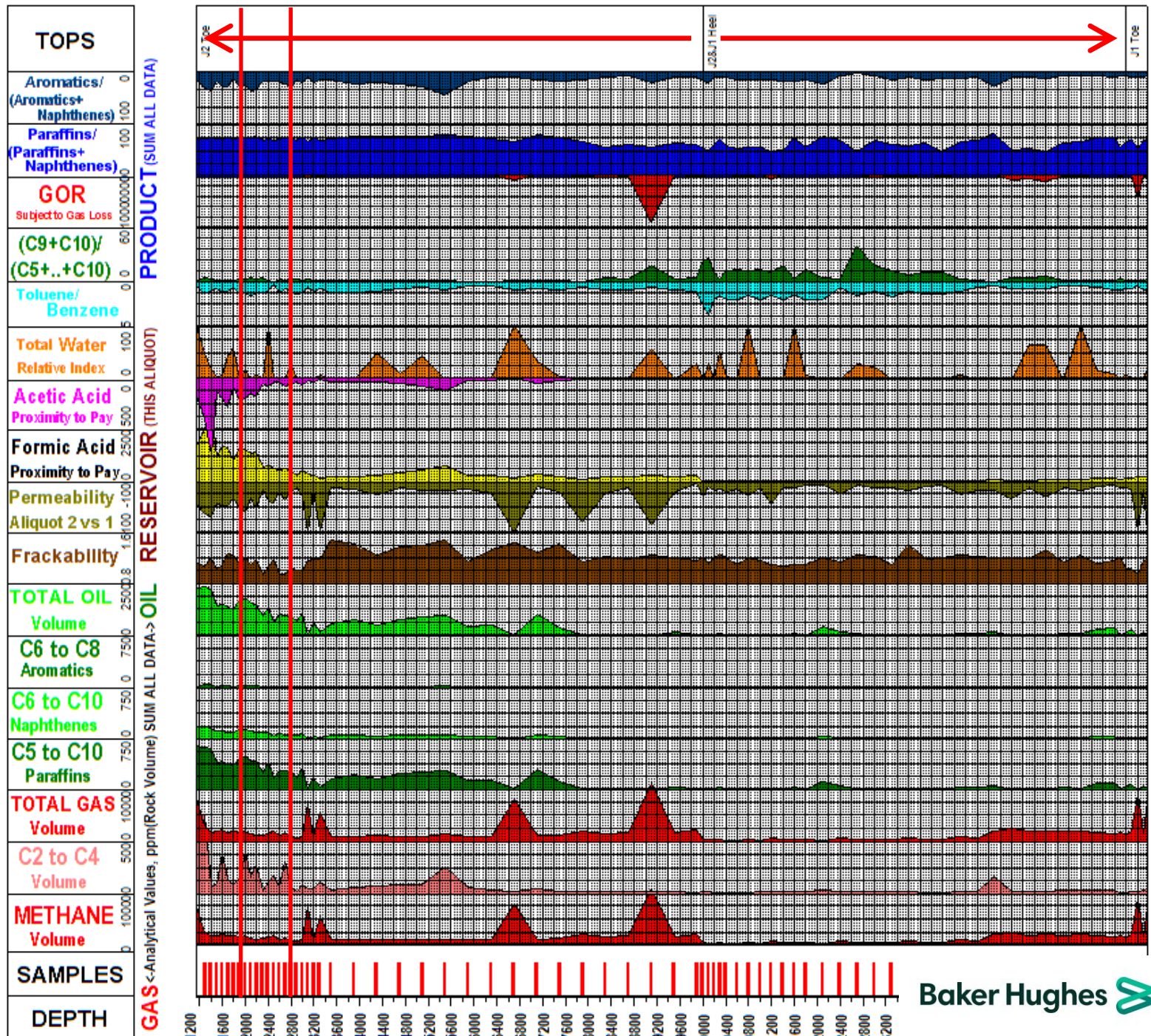
Less Cuttings Oil = Good Reservoirs

Woodford 2 Mile Lateral

Arkoma Basin



Poor Performing Well
 And
 Good Performing Well
 Drilled From Same Pad
 Plotted Together Like a
 Four Mile Lateral

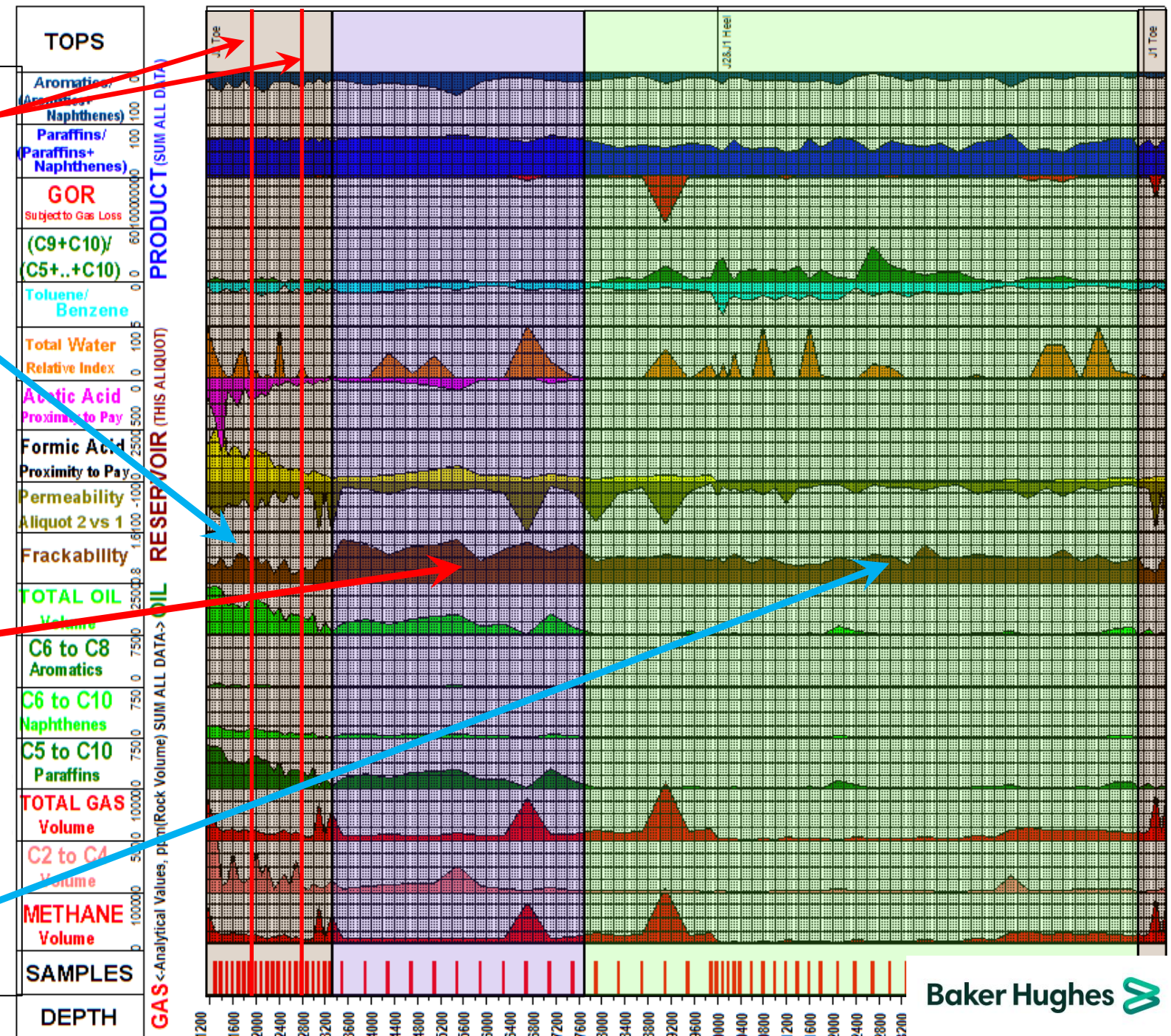


Poor Well w/ Major Faults
And Good Well

Tight Reservoir with Fault
Microfabric Destruction.
Low Mechanical Strength

Tight Reservoir with Fault
Fluid Cementation.
High Mechanical Strength

Normal Woodford M.S.



Lab Loaded Cuttings Volatiles

Without Sealed at Well Cuttings Volatiles

What Can We Learn?

1) Reservoir Quality

2) Mechanical Strength

3) Effects of Faults on Both

4) Oil vs Water Wettness with New Tech
(not developed yet for these data)

Lab Loaded Cuttings Volatiles
Without Sealed at Well Cuttings Volatiles
What Did We Learn?

Simpler, i.e. unFaulted, is Better.
Woodford near Faults Tends to have
Poorer Reservoir Quality from
Mechanical Disruption and Cementation

Today's Mission:
Understanding Differences Between
Sealed at Well versus Lab Loaded
Cuttings Volatiles, Especially for
Oil versus Water Wetting Reservoirs

VAS Analyses of Each Sample

2 Extractions: 20 and 2 millibars

Lab Loaded: Crush at Extraction Start

Sealed at Well: Extract Without Crush

Fault
Associated
HC Liquids

Sealed @ Well
Vs. Lab Loaded
Cuttings

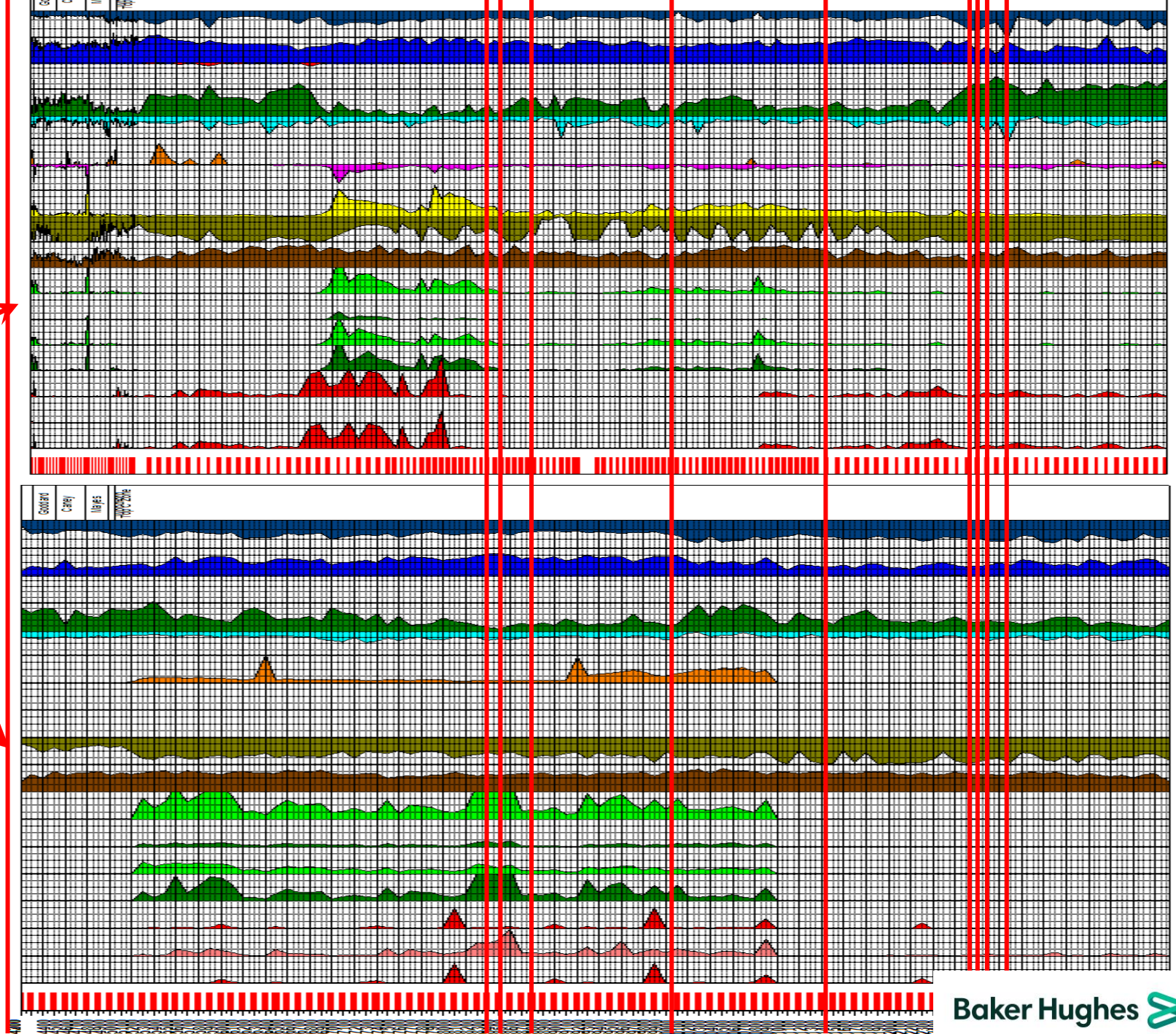
Woodford
Lateral

Arkoma Basin



PRODUCT (SUM ALL DATA)
RESERVOIR (THIS ALIQUOT)
OIL RESERVOIR (SUM ALL DATA) → OIL
GAS (Analytical Values, ppm/Reck Volume) SUM ALL DATA → GAS

PRODUCT (SUM ALL DATA)
RESERVOIR (THIS ALIQUOT)
OIL RESERVOIR (SUM ALL DATA) → OIL
GAS (Analytical Values, ppm/Reck Volume) SUM ALL DATA → GAS



Water Wetting
Osage Lateral
NW Stack

Sealed at Well
Cuttings Log

Major Fault

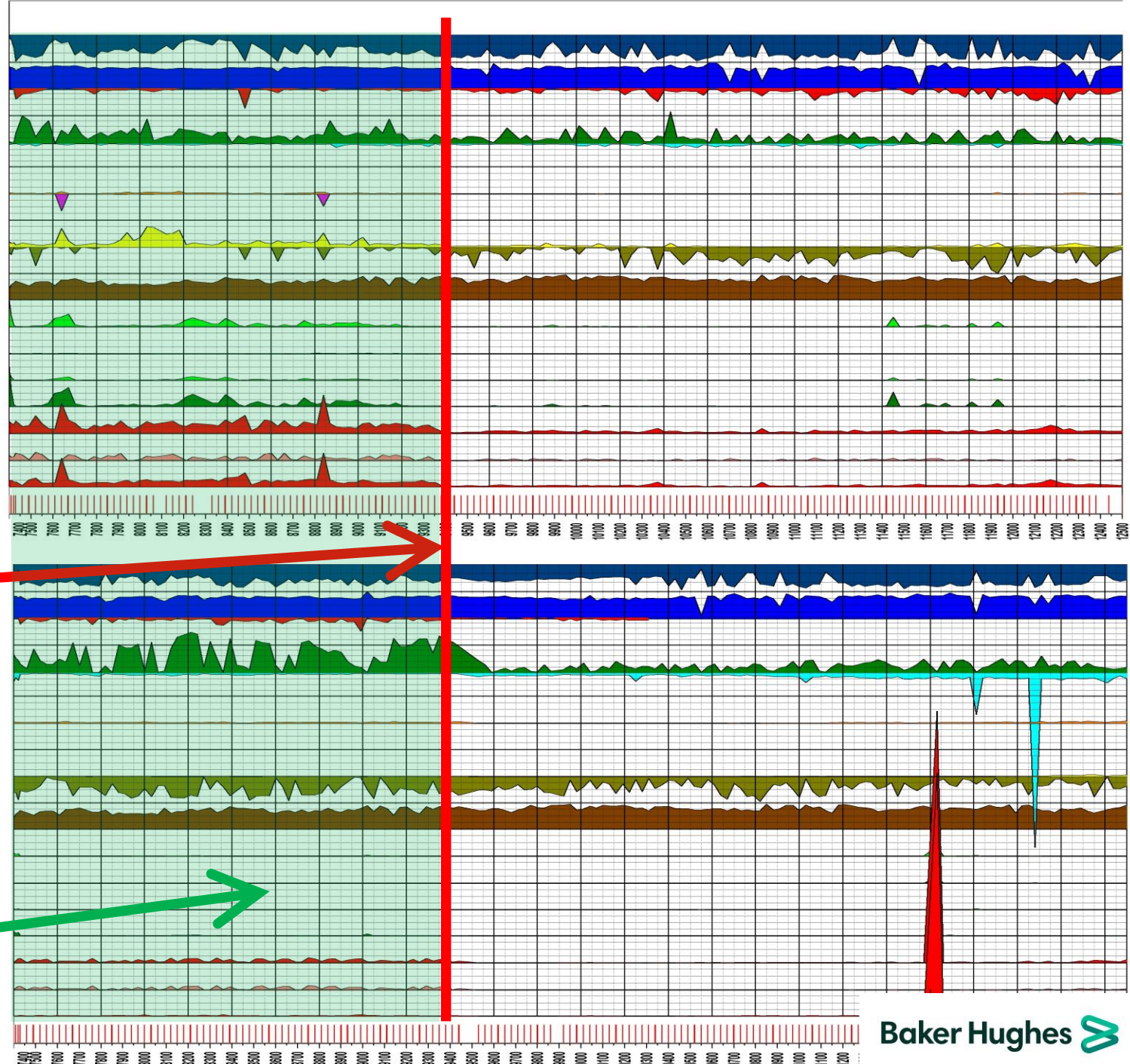
Lab Loaded
Cuttings Log

Pay Zone



TOPS	
Aromatics/ (Aromatic+ Naphthenes)	0 0 0 0
Paraffins/ (Paraffins+ Naphthenes)	0 0 0 0
GOR Subject to Gas Loss	0 0 0 0
(C9+C10)/ (C5+..+C10)	0 0 0 0
Toluene/ Benzene	0 0 0 0
Total Water Absolute	0 0 0 0
Acetic Acid Proximity to Pay	0 0 0 0
Formic Acid Proximity to Pay	0 0 0 0
Permeability Aliquot 2 vs 1	0 0 0 0
Mechanical Strength	0 0 0 0
TOTAL OIL Volume	0 0 0 0
C6 to C8 Aromatics	0 0 0 0
C6 to C10 Naphthenes	0 0 0 0
C5 to C10 Paraffins	0 0 0 0
TOTAL GAS Volume	0 0 0 0
C2 to C4 Volume	0 0 0 0
METHANE Volume	0 0 0 0
SAMPLES	
DEPTH	

TOPS	
Aromatics/ (Aromatic+ Naphthenes)	0 0 0 0
Paraffins/ (Paraffins+ Naphthenes)	0 0 0 0
GOR Subject to Gas Loss	0 0 0 0
(C9+C10)/ (C5+..+C10)	0 0 0 0
Toluene/ Benzene	0 0 0 0
Total Water Absolute	0 0 0 0
Acetic Acid Proximity to Pay	0 0 0 0
Formic Acid Proximity to Pay	0 0 0 0
Permeability Aliquot 2 vs 1	0 0 0 0
Mechanical Strength	0 0 0 0
TOTAL OIL Volume	0 0 0 0
C6 to C8 Aromatics	0 0 0 0
C6 to C10 Naphthenes	0 0 0 0
C5 to C10 Paraffins	0 0 0 0
TOTAL GAS Volume	0 0 0 0
C2 to C4 Volume	0 0 0 0
METHANE Volume	0 0 0 0
SAMPLES	
DEPTH	

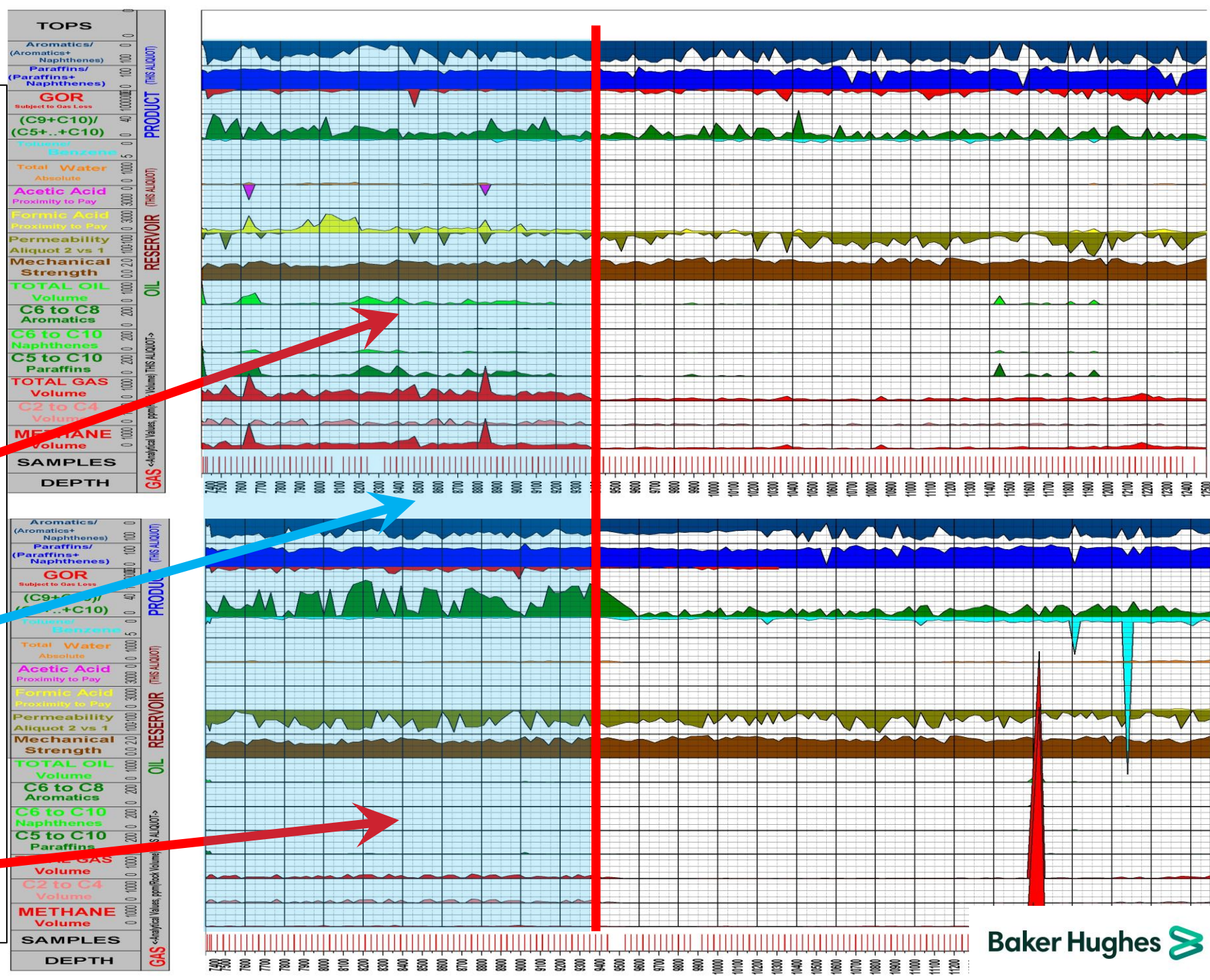


Water Wetting
Osage Lateral
NW Stack

Sealed at Well
Cuttings Oil: High

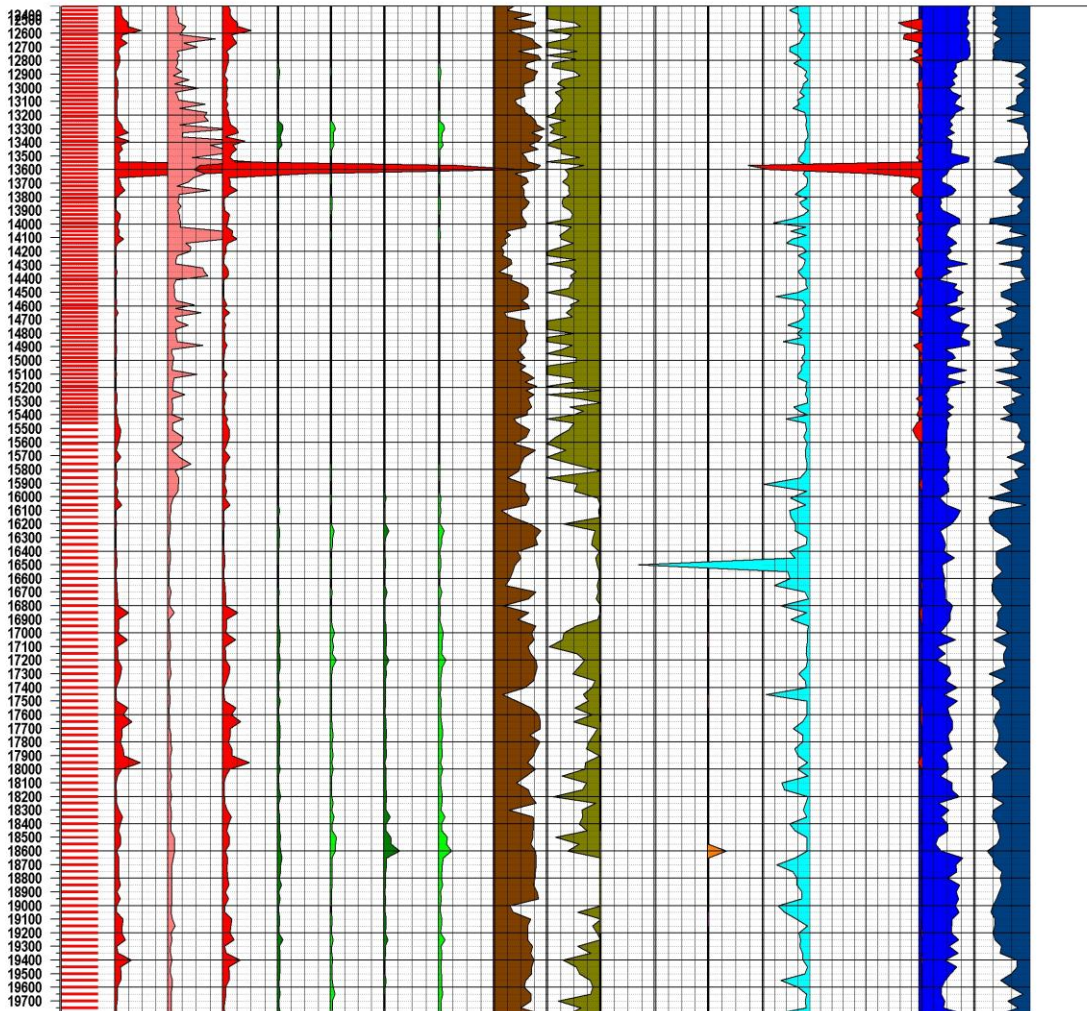
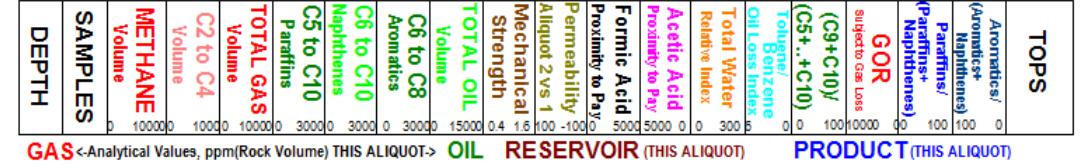
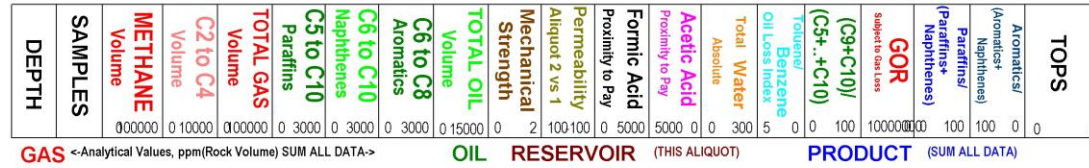
Water Wetting
Reservoir

Lab Loaded Cuttings
Oil: Low

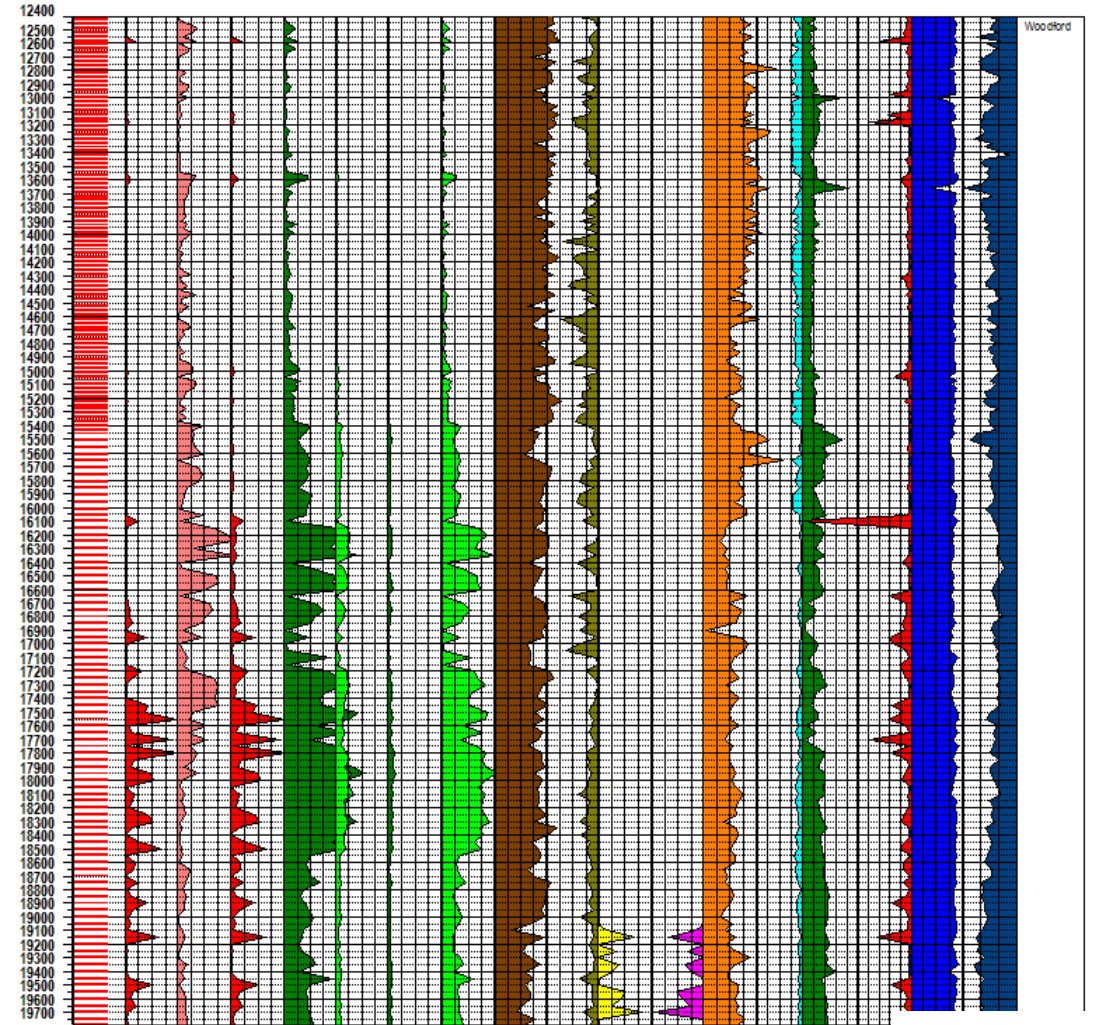


Oil in Cuttings From Water Wetting
Reservoirs Wants to Leave the
Cuttings.

Oil Wetting Reservoirs' Cuttings Oil : Sealed at Well < Lab Loaded



Sealed at Well Cuttings

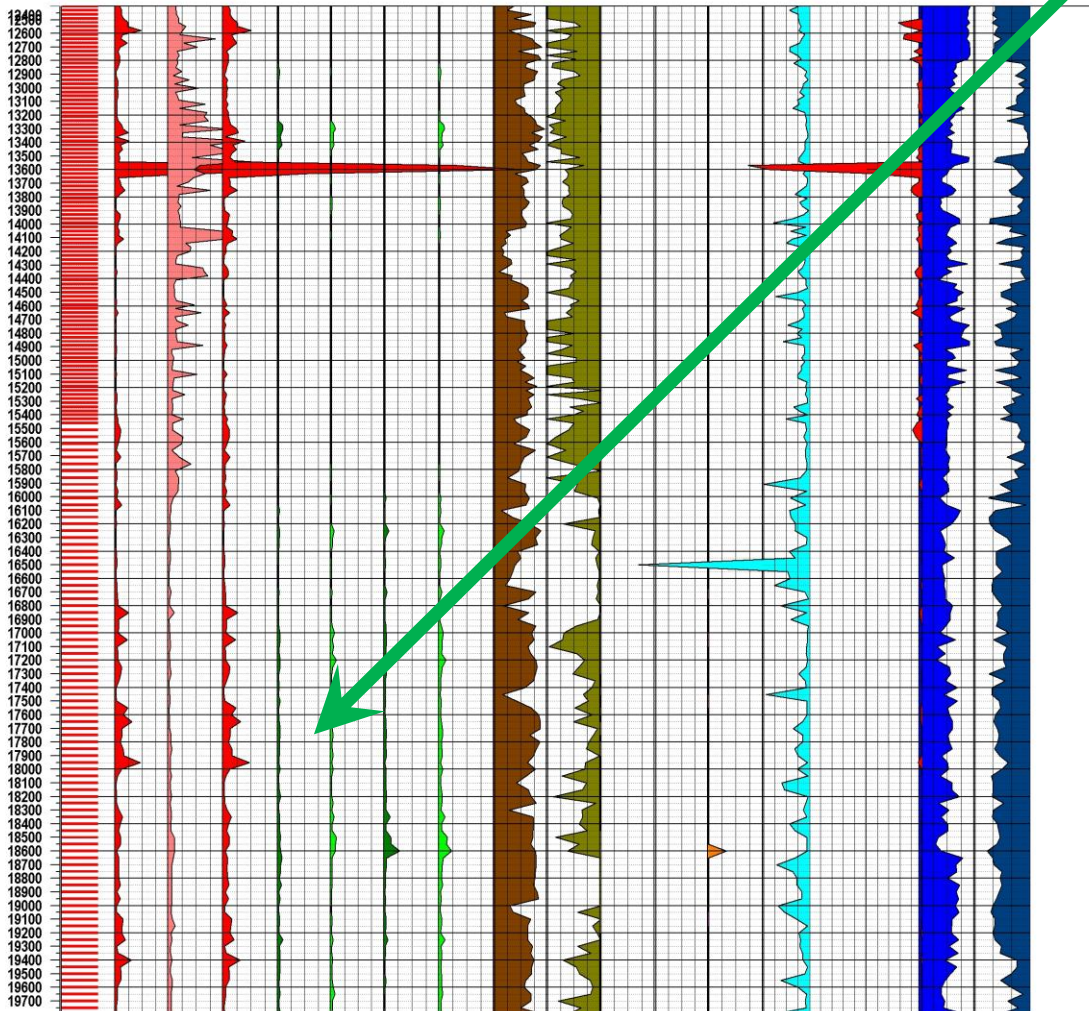


Lab Loaded Cuttings

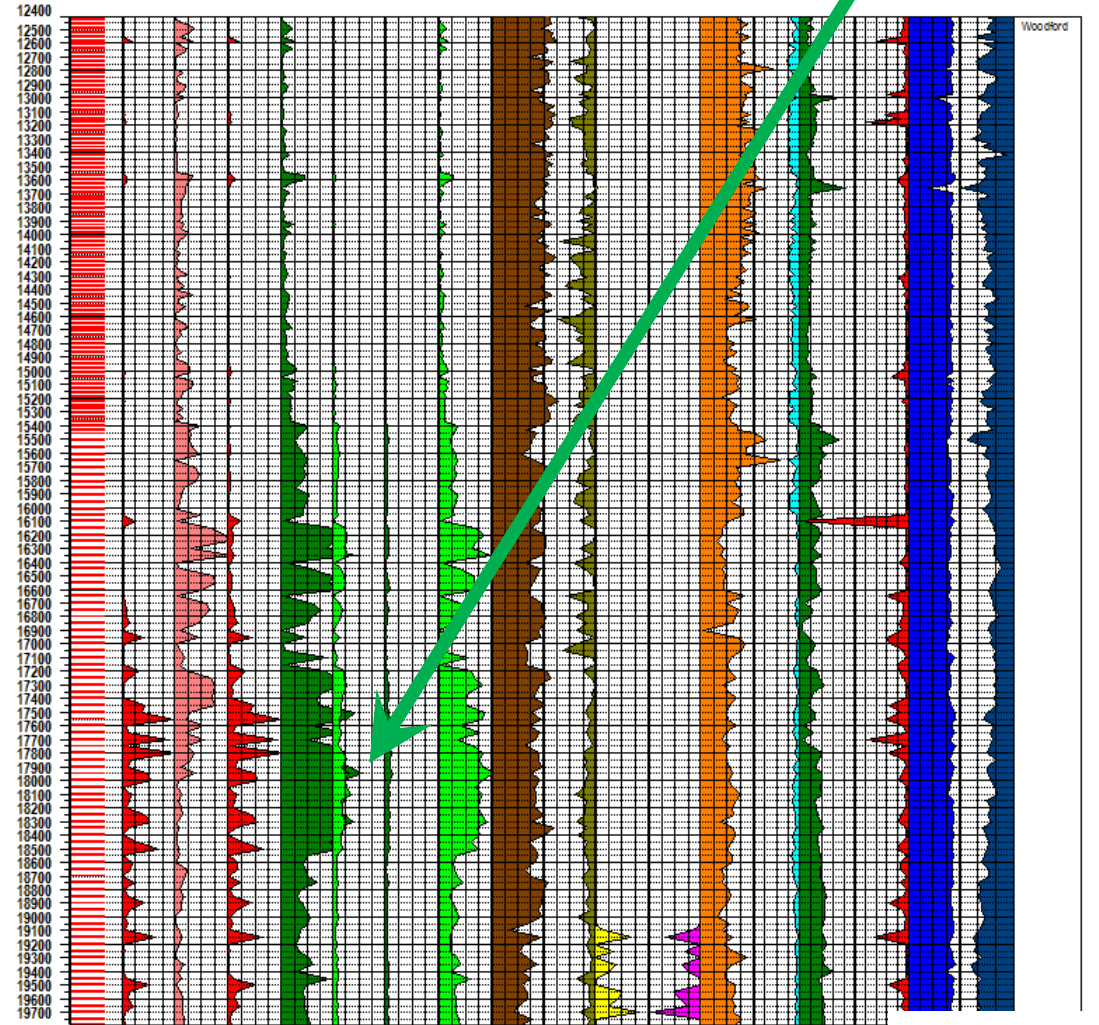
Oil Wetting Reservoirs' Cuttings Oil : Sealed at Well < Lab Loaded

TOPS		GAS		OIL		RESERVOIR		PRODUCT	
Aromatics+ (Naphthenes)	100	Analytical Values, ppm(Rock Volume) SUM ALL DATA->		THIS ALIQUOT		THIS ALIQUOT		SUM ALL DATA	
(Paraffins+ Naphthenes)	100	METHANE Volume	0.00000	TOTAL OIL Volume	0	Formic Acid Proximity to Pay	5000	GOR	100
(C9+C10) (C5+..+C10)	100	C2 to C4 Volume	0.10000	C6 to C8 Aromatics	0	Acetic Acid Proximity to Pay	5000	Subject to Gas Loss	100
Toluene/ Oil Loss Index	0	TOTAL GAS Volume	0.00000	C6 to C10 Naphthenes	0	Total Water Absolute	300	(C9+C10)/ (C5+..+C10)	100
Relative Index	300			C5 to C10 Paraffins	0	Oil Loss Index	5	Toluene/ Benzene	100
Formic Acid Proximity to Pay	5000							Oil Loss Index	0
Permeability Aliquot 2 vs 1	100								0
Mechanical Strength	2								0

TOPS		GAS		OIL		RESERVOIR		PRODUCT	
Aromatics+ (Naphthenes)	100	Analytical Values, ppm(Rock Volume) THIS ALIQUOT->		THIS ALIQUOT		THIS ALIQUOT		THIS ALIQUOT	
(Paraffins+ Naphthenes)	100	METHANE Volume	0.10000	TOTAL OIL Volume	0	Formic Acid Proximity to Pay	5000	GOR	100
(C9+C10) (C5+..+C10)	100	C2 to C4 Volume	1.00000	C6 to C8 Aromatics	0	Acetic Acid Proximity to Pay	5000	Subject to Gas Loss	100
Toluene/ Oil Loss Index	0	TOTAL GAS Volume	1.00000	C6 to C10 Naphthenes	0	Total Water Absolute	300	(C9+C10)/ (C5+..+C10)	100
Relative Index	300			C5 to C10 Paraffins	0	Oil Loss Index	5	Toluene/ Benzene	100
Formic Acid Proximity to Pay	5000							Oil Loss Index	0
Permeability Aliquot 2 vs 1	100								0
Mechanical Strength	0.4								0

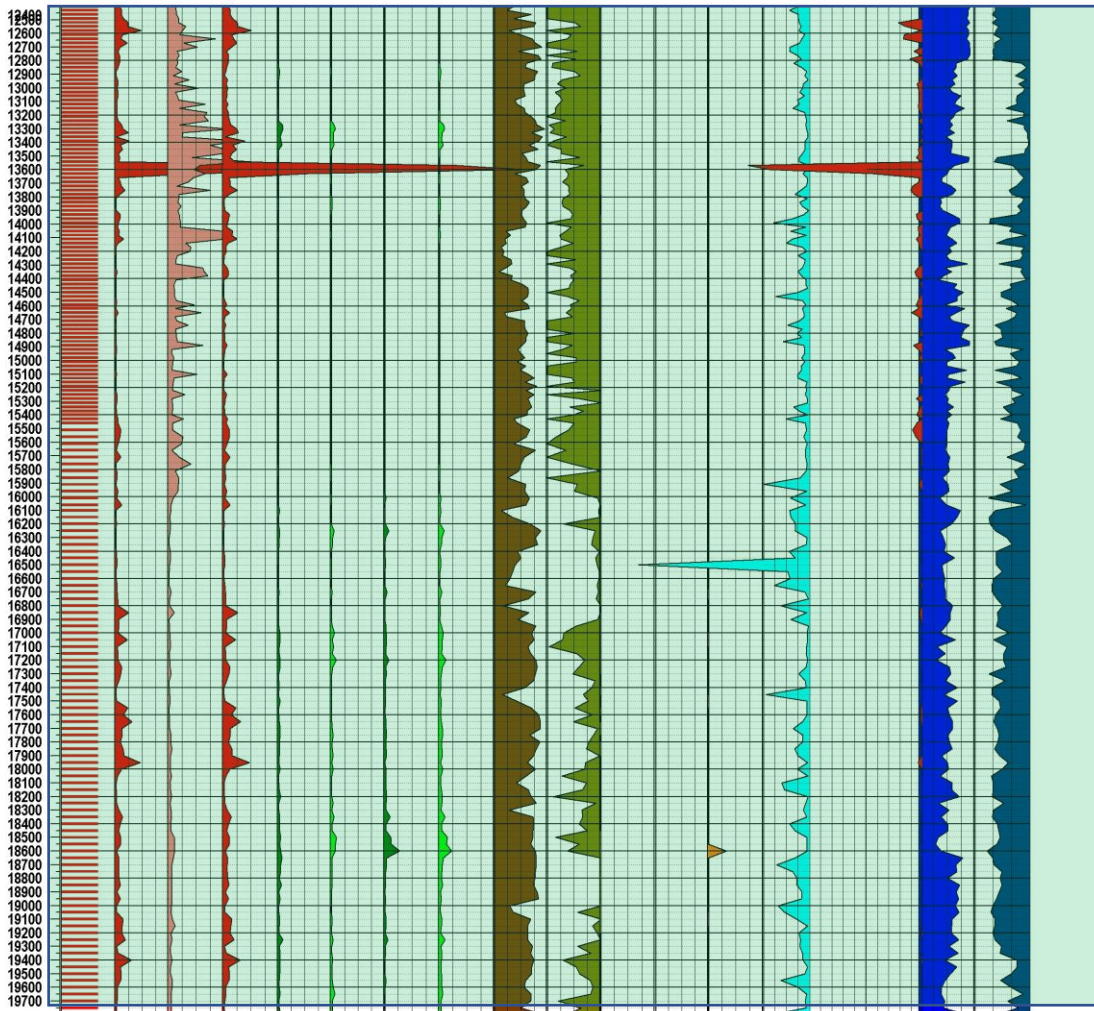
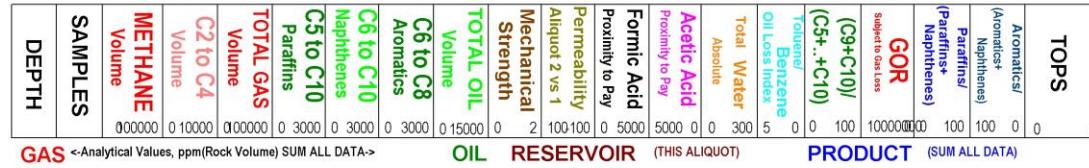


Sealed at Well Cuttings

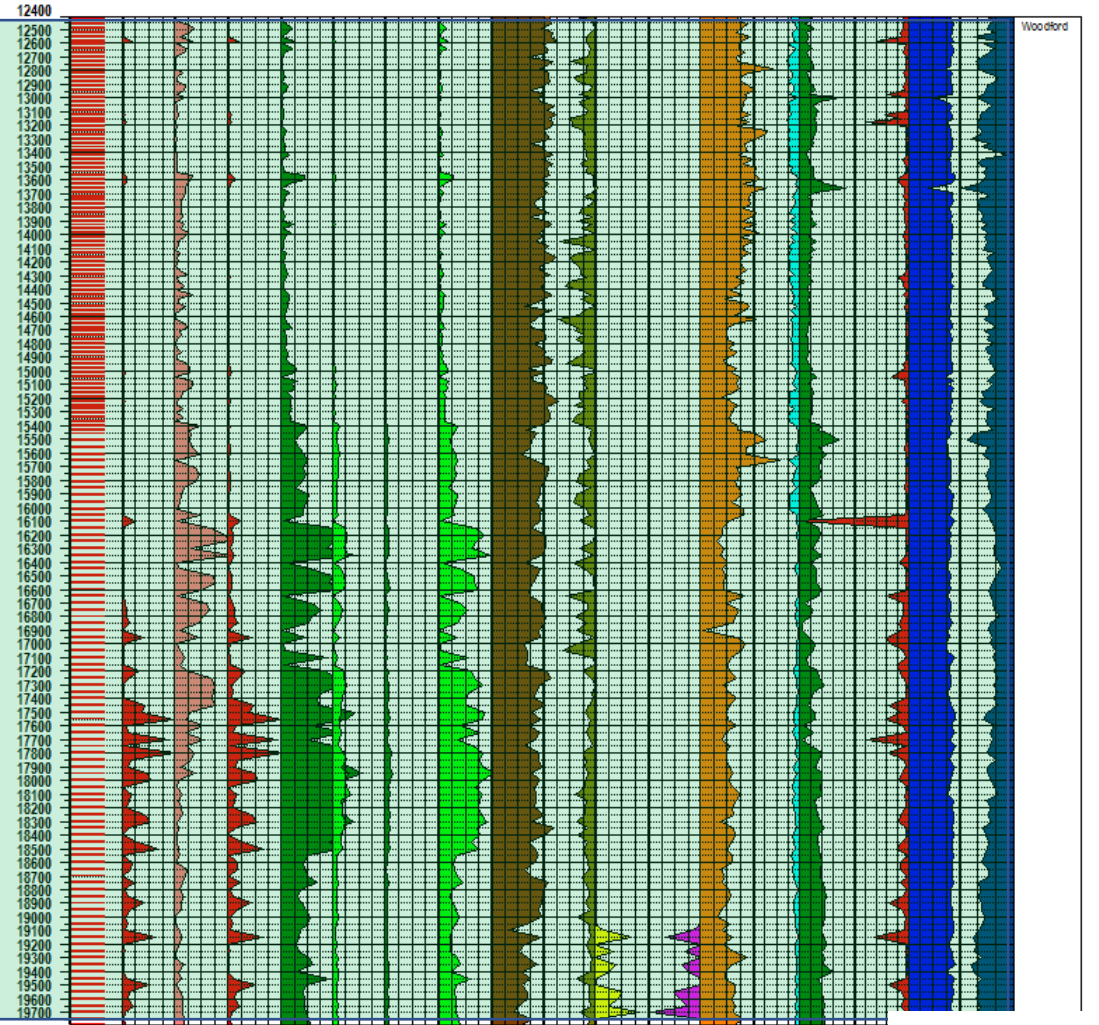


Lab Loaded Cuttings

Oil Wetting Reservoirs' Cuttings Oil : Sealed at Well < Lab Loaded



Sealed at Well Cuttings



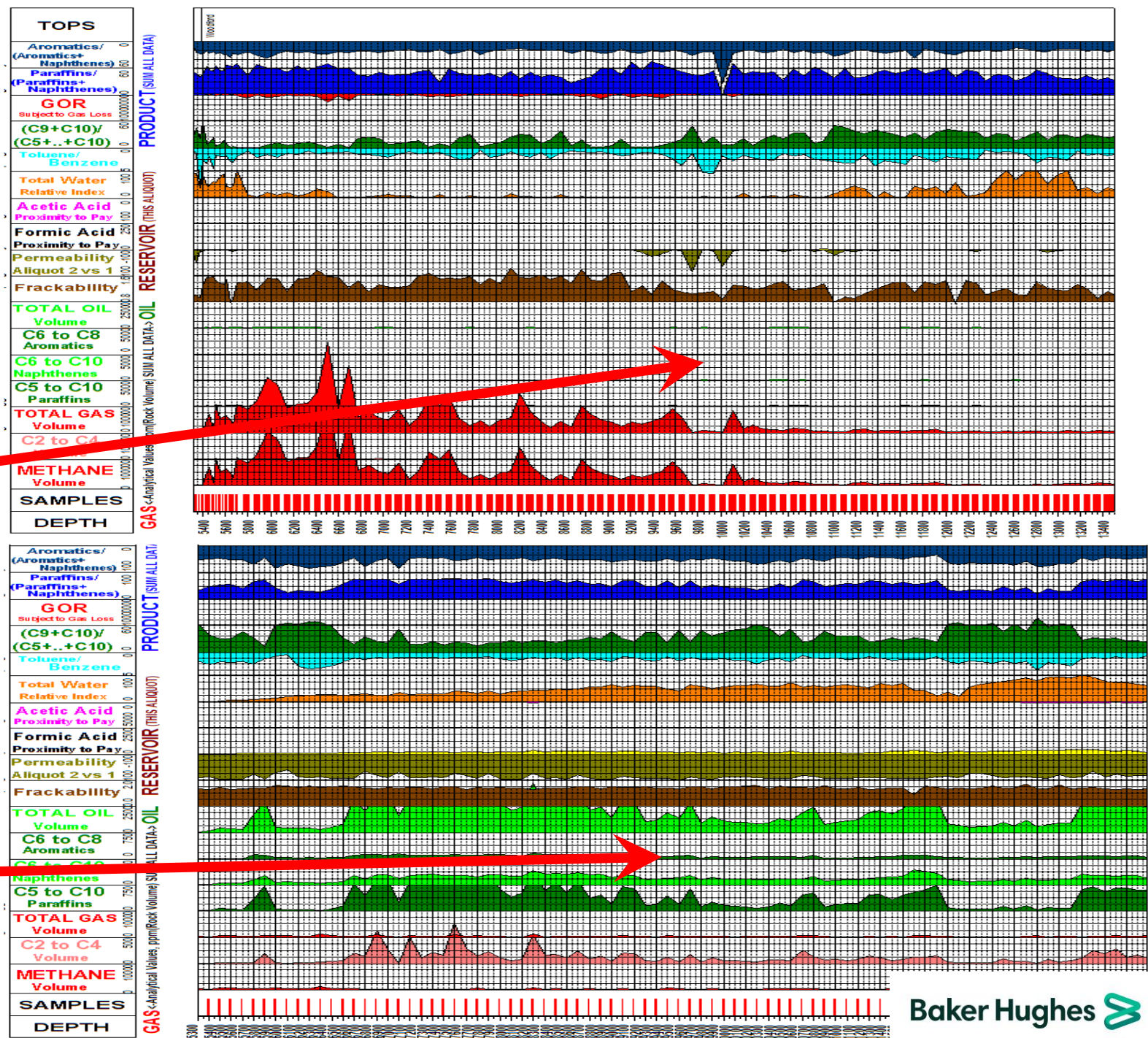
Lab Loaded Cuttings

Oil in Cuttings From Oil Wetting
Reservoirs Wants to Stay In the
Cuttings.

Oil Wetting Woodford Lateral

Sealed at Well Cuttings
Oil: Low

Lab Loaded Cuttings Oil:
High



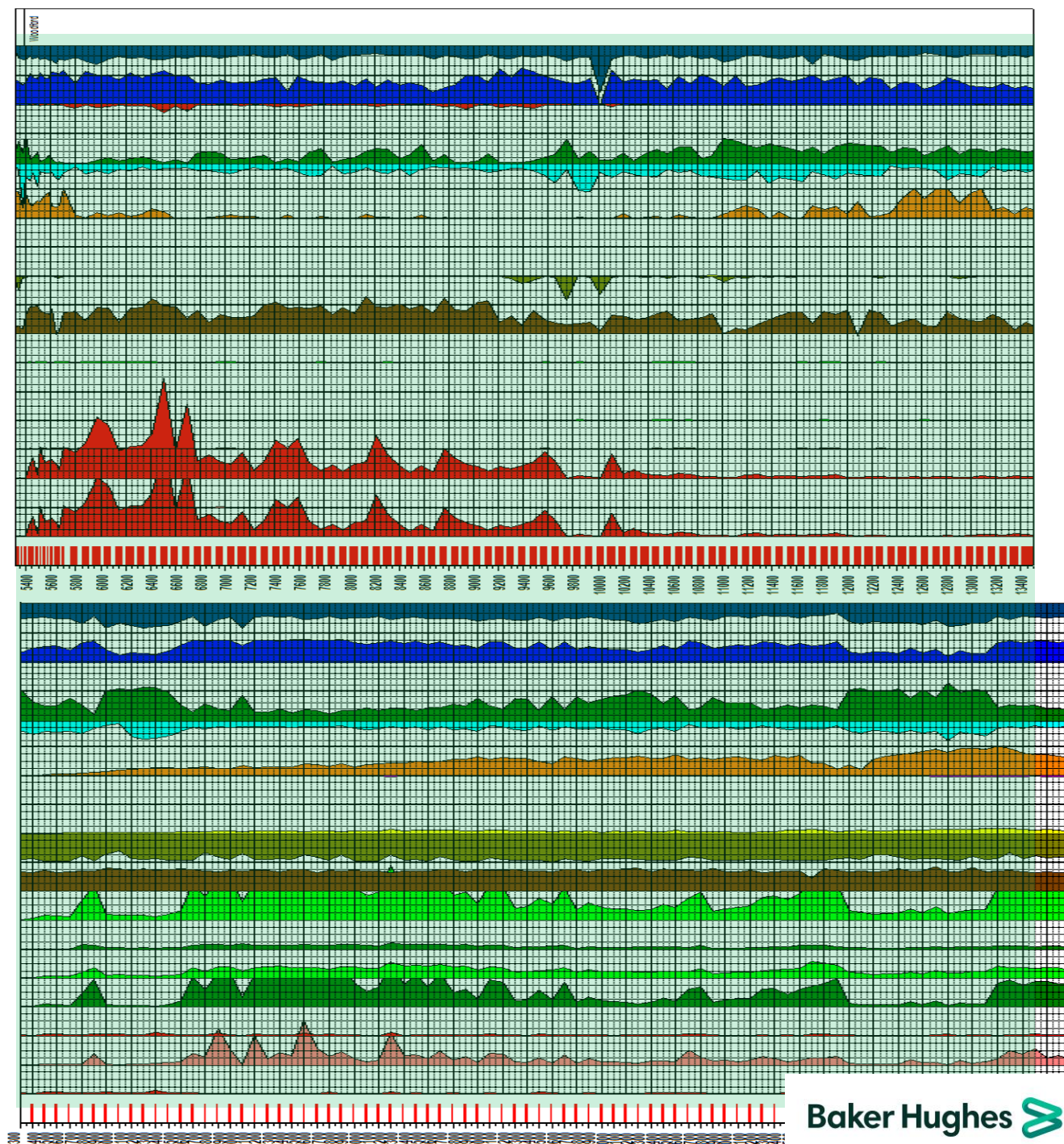
Oil Wetting Woodford Lateral

Sealed at Well Cuttings
Oil: Low

Lab Loaded Cuttings Oil:
High

TOPS	
Aromatics/ (Aromatics+ Naphthenes)	0
Paraffins/ (Paraffins+ Naphthenes)	0
GOR Subject to Gas Loss (C9+C10)/ (C5+...+C10)	0
Toluene/ Benzene	0
Total Water Relative Index	0
Acetic Acid Proximity to Pay	0
Formic Acid Proximity to Pay	0
Permeability Aliquot 2 vs 1	0
Frackability	0
TOTAL OIL Volume	0
C6 to C8 Aromatics	0
C6 to C10 Naphthenes	0
C5 to C10 Paraffins	0
TOTAL GAS Volume	0
C2 to C4 Volume	0
METHANE Volume	0
SAMPLES	
DEPTH	

GAS-Analytical Values, ppm/Root Volume SUM ALL DATA> OIL RESERVOIR (THIS ALIQUOT) PRODUCT (SUM ALL DATA)

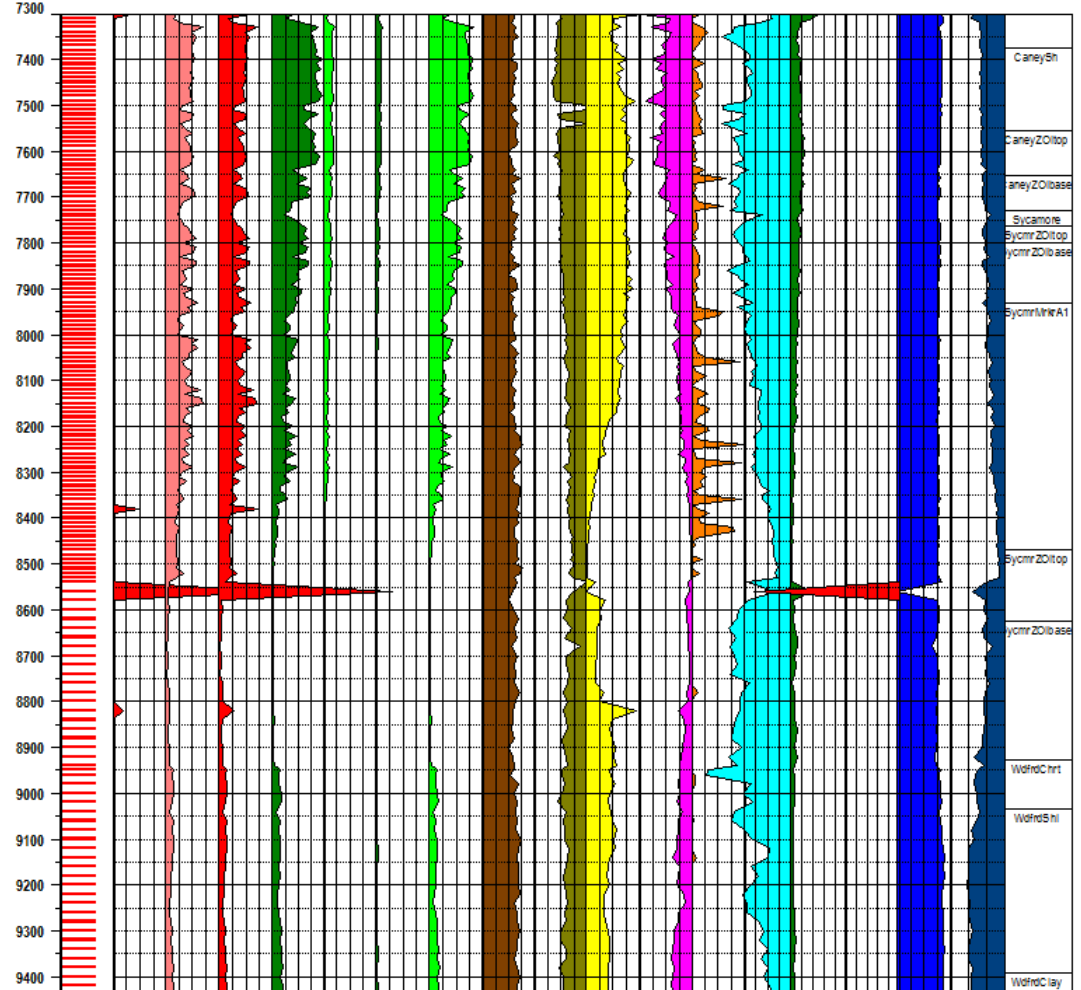
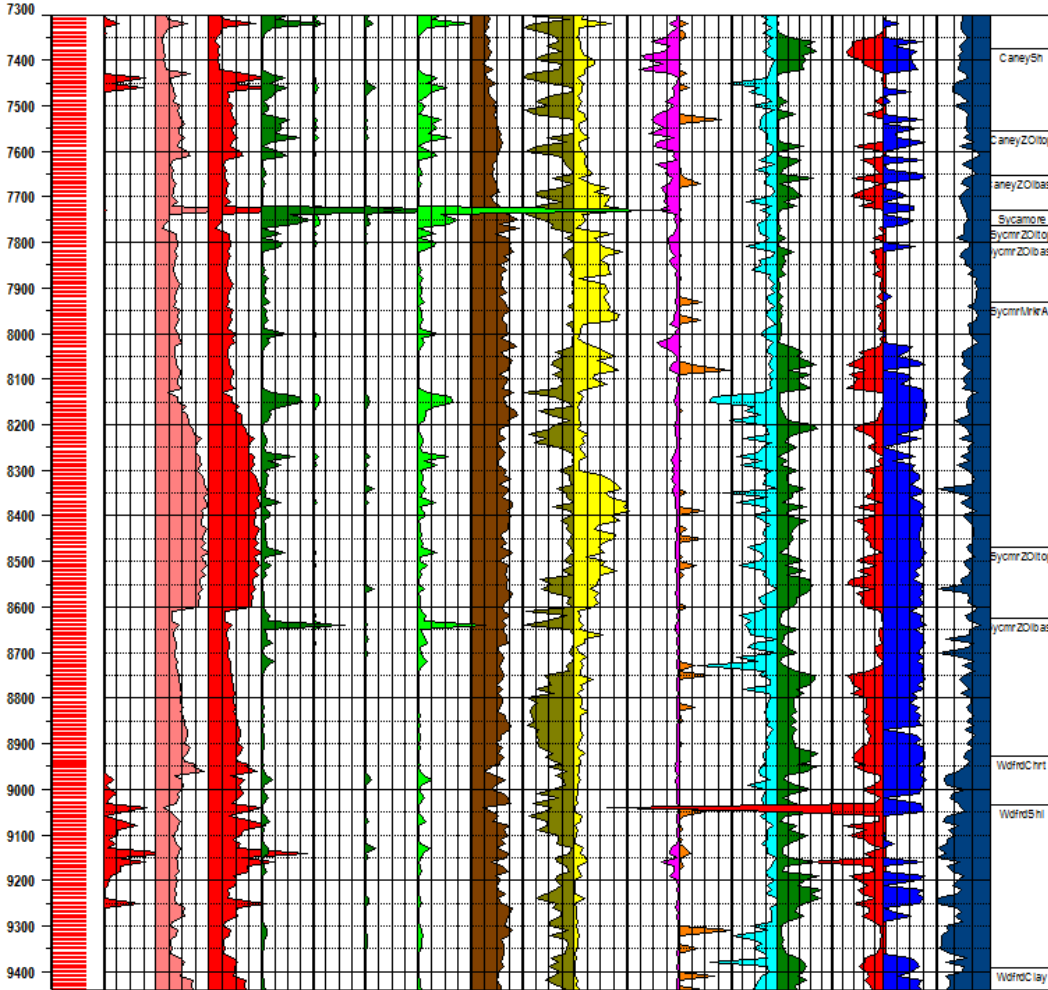


Oil in Cuttings From Oil Wetting
Reservoirs Wants to Stay In the
Cuttings.

Oil Wetting Reservoirs' Cuttings Oil : Sealed at Well < Lab Loaded

TOPS	PRODUCT (SUM ALL DATA)	OIL RESERVOIR (THIS ALIQUOT)	GAS <-Analytical Values, ppm(Rock Volume) SUM ALL DATA->
Aromatics/ (Aromatics+ Naphthenes)	0	100	0
Paraffins/ (Paraffins+ Naphthenes)	100	0	0
GOR subject to Gas Loss	0	0	0
(C9+C10)/ (C5+...+C10)	60	0	0
Toluene/ Benzene	0	0	0
Total Water Relative Index	0	100	0
Acetic Acid Proximity to Py	0	0	0
Formic Acid Proximity to Py	250	0	0
Permeability Aliquot 2 vs 1	0	0	0
Frackability	0	0	0
TOTAL OIL Volume	100000	0	0
C6 to C8 Aromatics	0	0	0
C6 to C10 Naphthenes	0	0	0
TOTAL GAS Volume	0	0	0
C2 to C4 Volume	0	0	0
METHANE Volume	0	0	0
SAMPLES	0	0	0
DEPTH	0	0	0

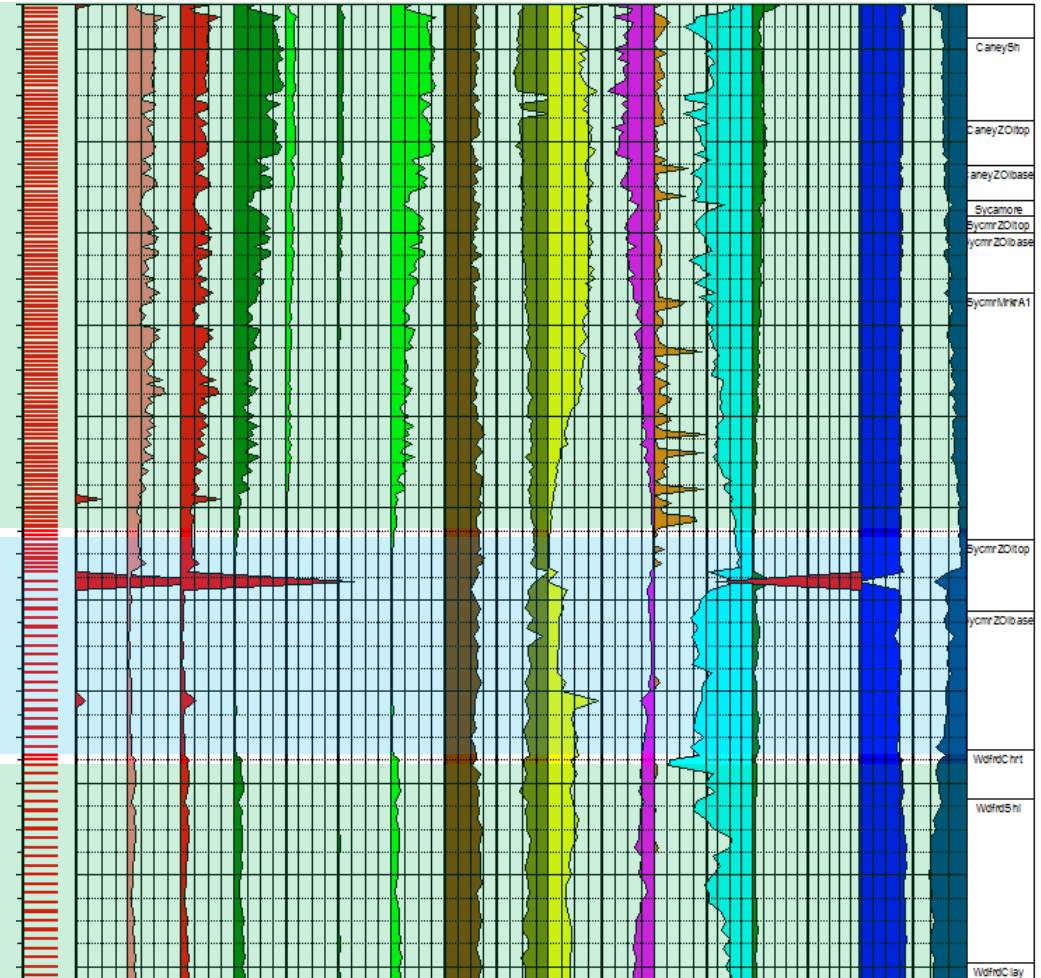
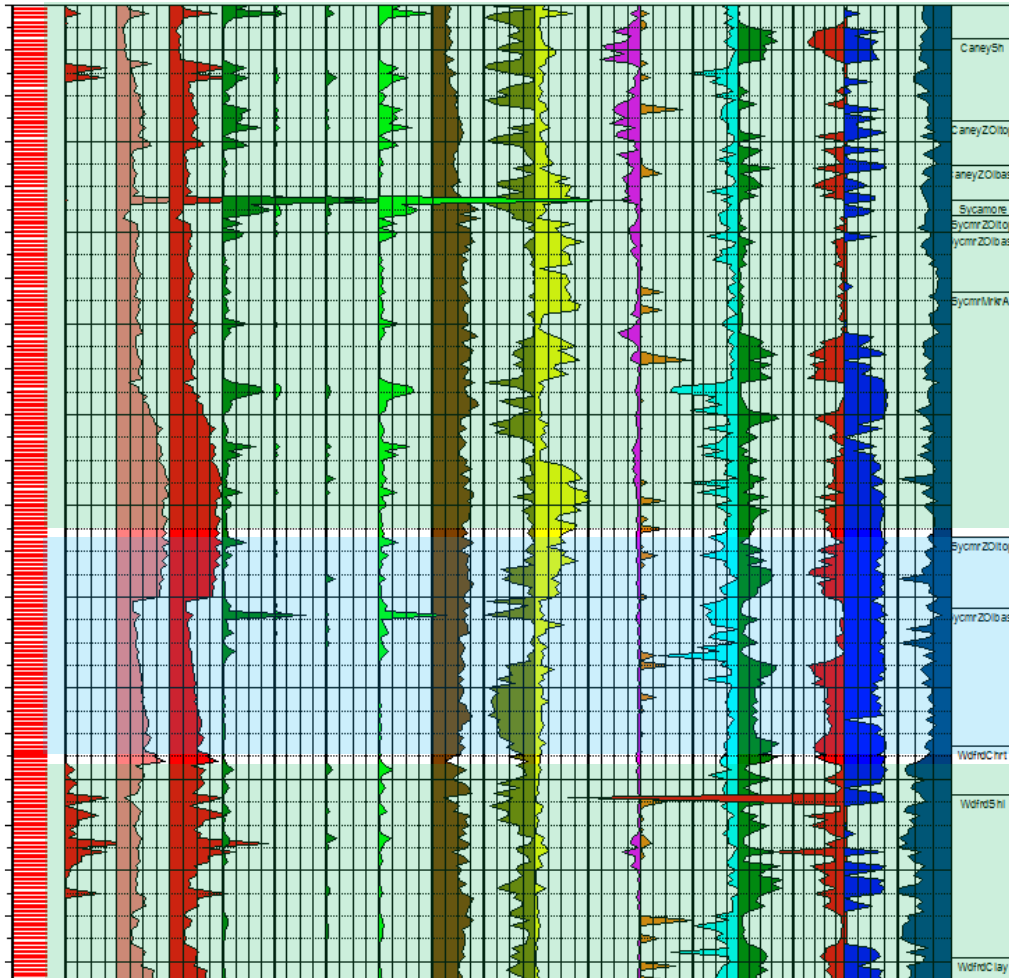
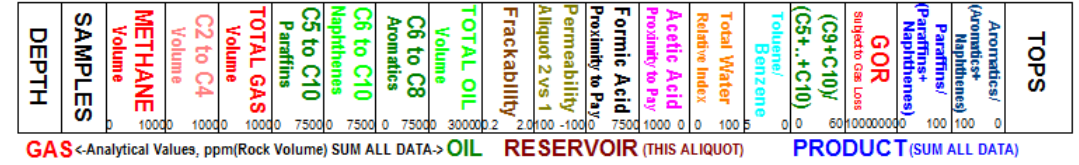
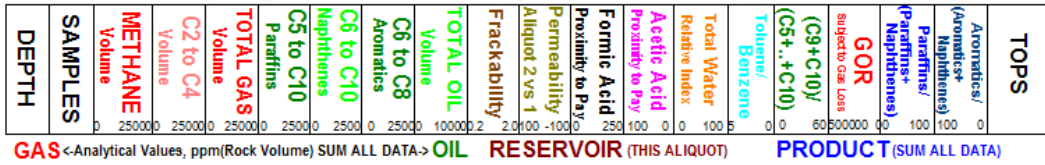
TOPS	PRODUCT (SUM ALL DATA)	OIL RESERVOIR (THIS ALIQUOT)	GAS <-Analytical Values, ppm(Rock Volume) SUM ALL DATA->
Aromatics/ (Aromatics+ Naphthenes)	0	100	0
Paraffins/ (Paraffins+ Naphthenes)	100	0	0
GOR subject to Gas Loss	0	0	0
(C9+C10)/ (C5+...+C10)	60	0	0
Toluene/ Benzene	0	0	0
Total Water Relative Index	0	100	0
Acetic Acid Proximity to Py	0	0	0
Formic Acid Proximity to Py	7500	0	0
Permeability Aliquot 2 vs 1	0	0	0
Frackability	0	0	0
TOTAL OIL Volume	300000	0	0
C6 to C8 Aromatics	0	0	0
C6 to C10 Naphthenes	0	0	0
C5 to C10 Paraffins	0	0	0
TOTAL GAS Volume	0	0	0
C2 to C4 Volume	0	0	0
METHANE Volume	0	0	0
SAMPLES	0	0	0
DEPTH	0	0	0



Sealed at Well Cuttings

Lab Loaded Cuttings

Oil Wetting Reservoirs' Cuttings Oil : Sealed at Well < Lab Loaded



Sealed at Well Cuttings

Lab Loaded Cuttings

Some Wells Drill Both Oil Wetting
and Water Wetting Reservoirs.

Fault
 Associated
 HC Liquids

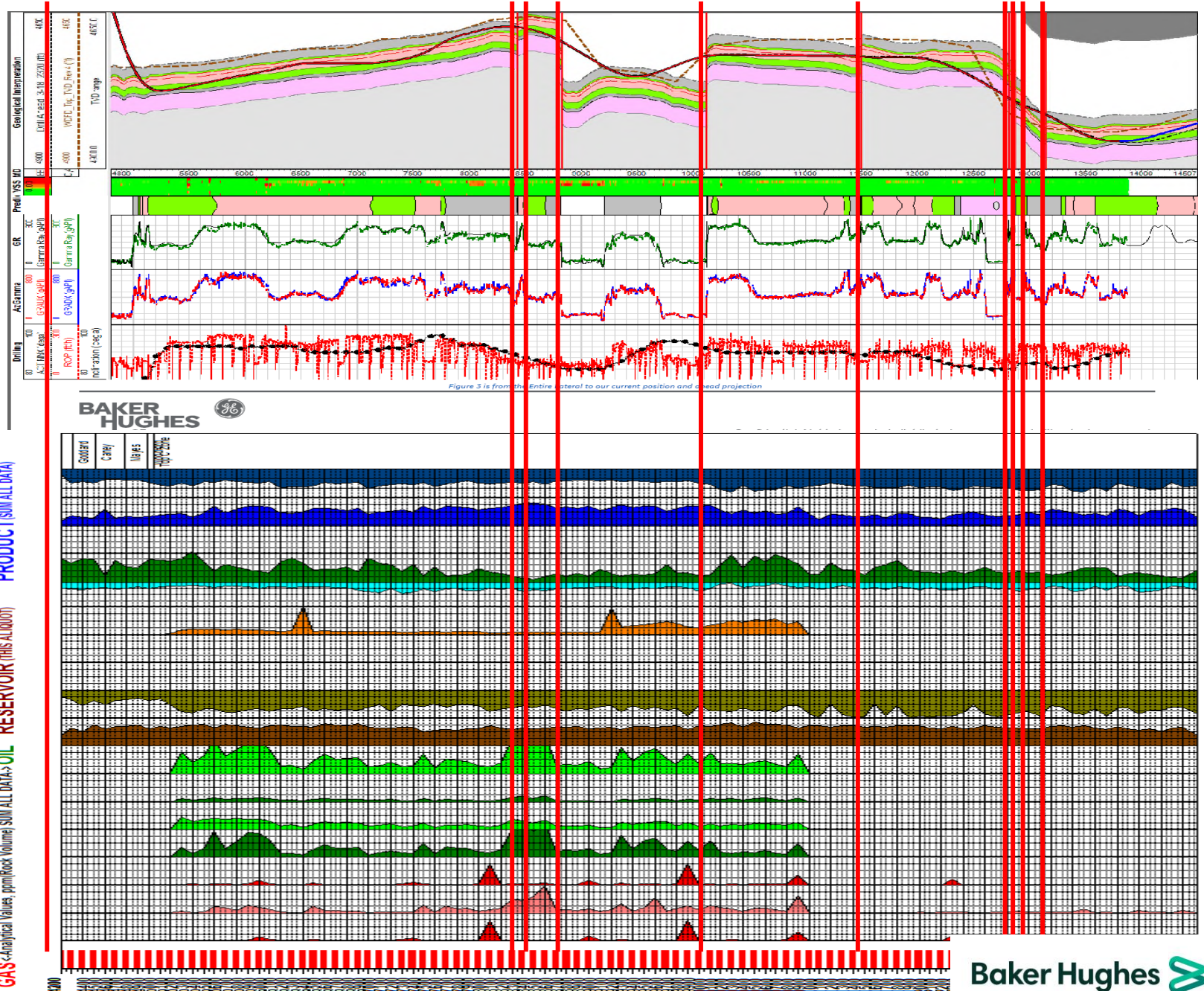
 Lab Loaded
 Cuttings

 Woodford
 Lateral

 Arkoma Basin

TOPS	
Aromatics/ (Aromatics+ Naphthenes)	0.0000000000 0.0000000000
Paraffins/ (Paraffins+ Naphthenes)	0.0000000000 0.0000000000
GOR Subject to Gas Loss	0.0000000000 0.0000000000
(C9+C10)/ (C5+...+C10)	0.0000000000 0.0000000000
Toluene/ Benzene	0.0000000000 0.0000000000
Total Water Relative Index	0.0000000000 0.0000000000
Acetic Acid Proximity to Pay	0.0000000000 0.0000000000
Formic Acid Proximity to Pay	0.0000000000 0.0000000000
Permeability Aliquot 2 vs 1	0.0000000000 0.0000000000
Frackability	0.0000000000 0.0000000000
TOTAL OIL Volume	0.0000000000 0.0000000000
C6 to C8 Aromatics	0.0000000000 0.0000000000
C6 to C10 Naphthenes	0.0000000000 0.0000000000
C5 to C10 Paraffins	0.0000000000 0.0000000000
TOTAL GAS Volume	0.0000000000 0.0000000000
C2 to C4 Volume	0.0000000000 0.0000000000
METHANE Volume	0.0000000000 0.0000000000
SAMPLES	
DEPTH	

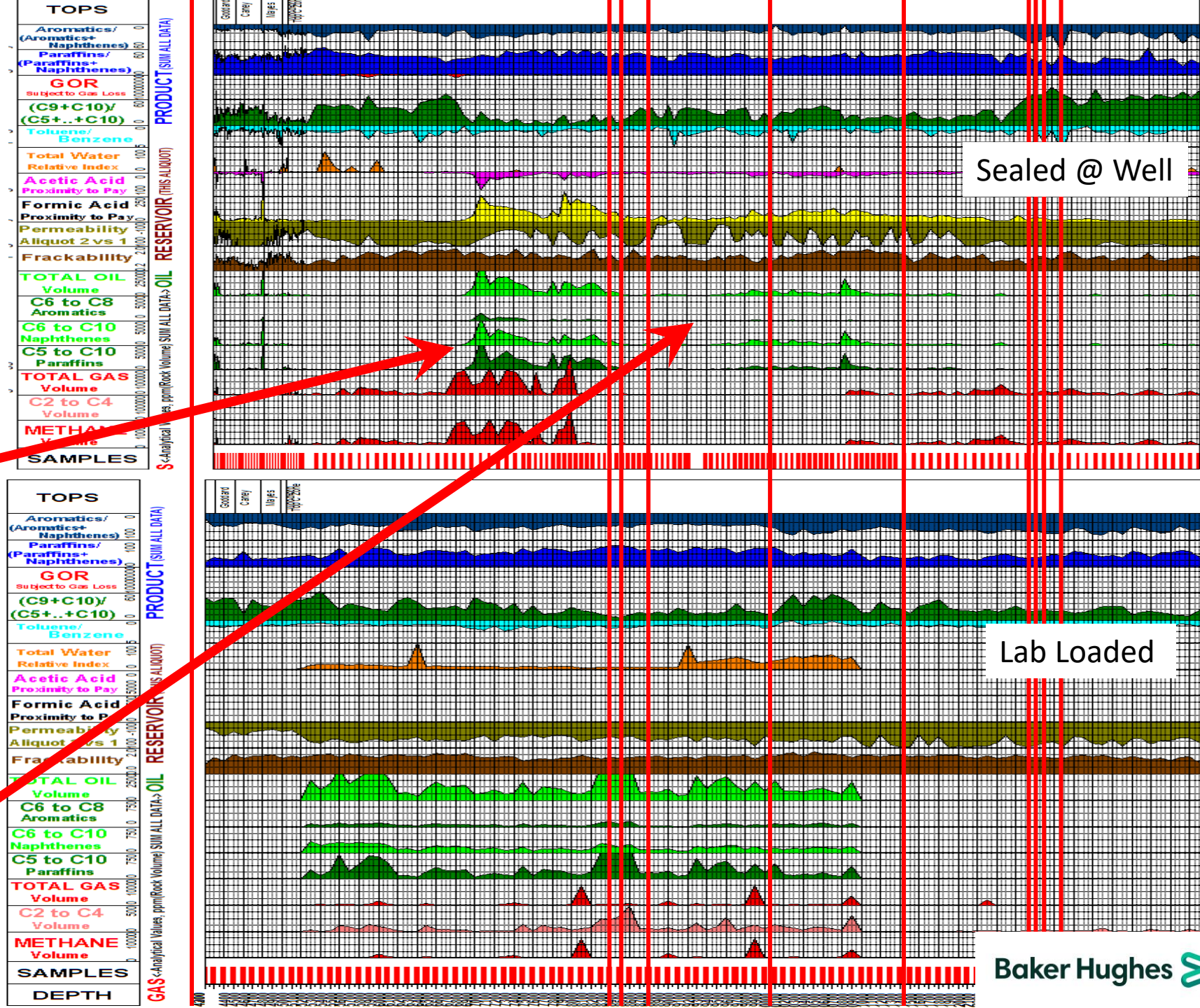
PRODUCT (SUM ALL DATA)
RESERVOIR (THIS ALIQUOT)
OIL (SUM ALL DATA)
GAS (Analytical Values ppm/Root Volume) (SUM ALL DATA)



Mixed Wetting
Woodford Lateral

Sealed at Well:
High Cuttings Oil =
Water Wetting.
Fault Related
Wetting Alteration

Sealed at Well:
Low Cuttings Oil =
Oil Wetting



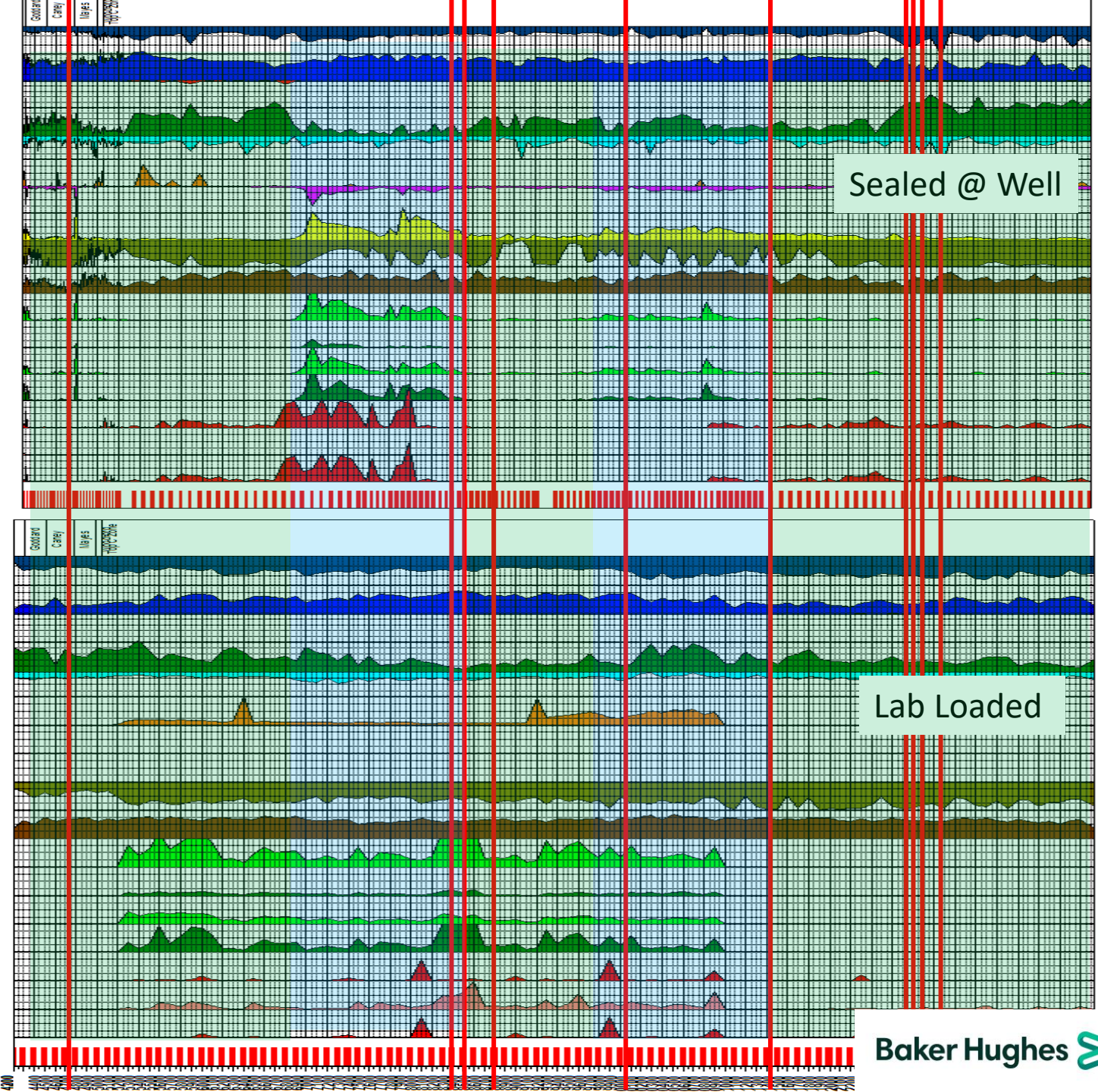
Mixed Wetting Woodford Lateral

Sealed at Well:
High Cuttings Oil =
Water Wetting.
Fault Related
Wetting Alteration

Sealed at Well:
Low Cuttings Oil =
Oil Wetting

TOPS	
Aromatics/ (Aromatics+ Naphthenes)	0
Paraffins/ (Paraffins+ Naphthenes)	60/60
GOR Subject to Gas Loss (C9+C10)/ (C5+...+C10)	0
Toluene/ Benzene	0
Total Water Relative Index	0
Acetic Acid Proximity to Pay	250
Formic Acid Proximity to Pay	100
Permeability Allquot 2 vs 1	2,000
Frackability	2
TOTAL OIL Volume	25000
C6 to C8 Aromatics	0
C6 to C10 Naphthenes	5000
C5 to C10 Paraffins	5000
TOTAL GAS Volume	100000
C2 to C4 Volume	100000
METHANE Volume	0
SAMPLES	

TOPS	
Aromatics/ (Aromatics+ Naphthenes)	0
Paraffins/ (Paraffins+ Naphthenes)	100/100
GOR Subject to Gas Loss (C9+C10)/ (C5+...+C10)	0
Toluene/ Benzene	0
Total Water Relative Index	0
Acetic Acid Proximity to Pay	250
Formic Acid Proximity to Pay	100
Permeability Allquot 2 vs 1	2,000
Frackability	2
TOTAL OIL Volume	25000
C6 to C8 Aromatics	0
C6 to C10 Naphthenes	750
C5 to C10 Paraffins	750
TOTAL GAS Volume	100000
C2 to C4 Volume	5000
METHANE Volume	0
SAMPLES	
DEPTH	



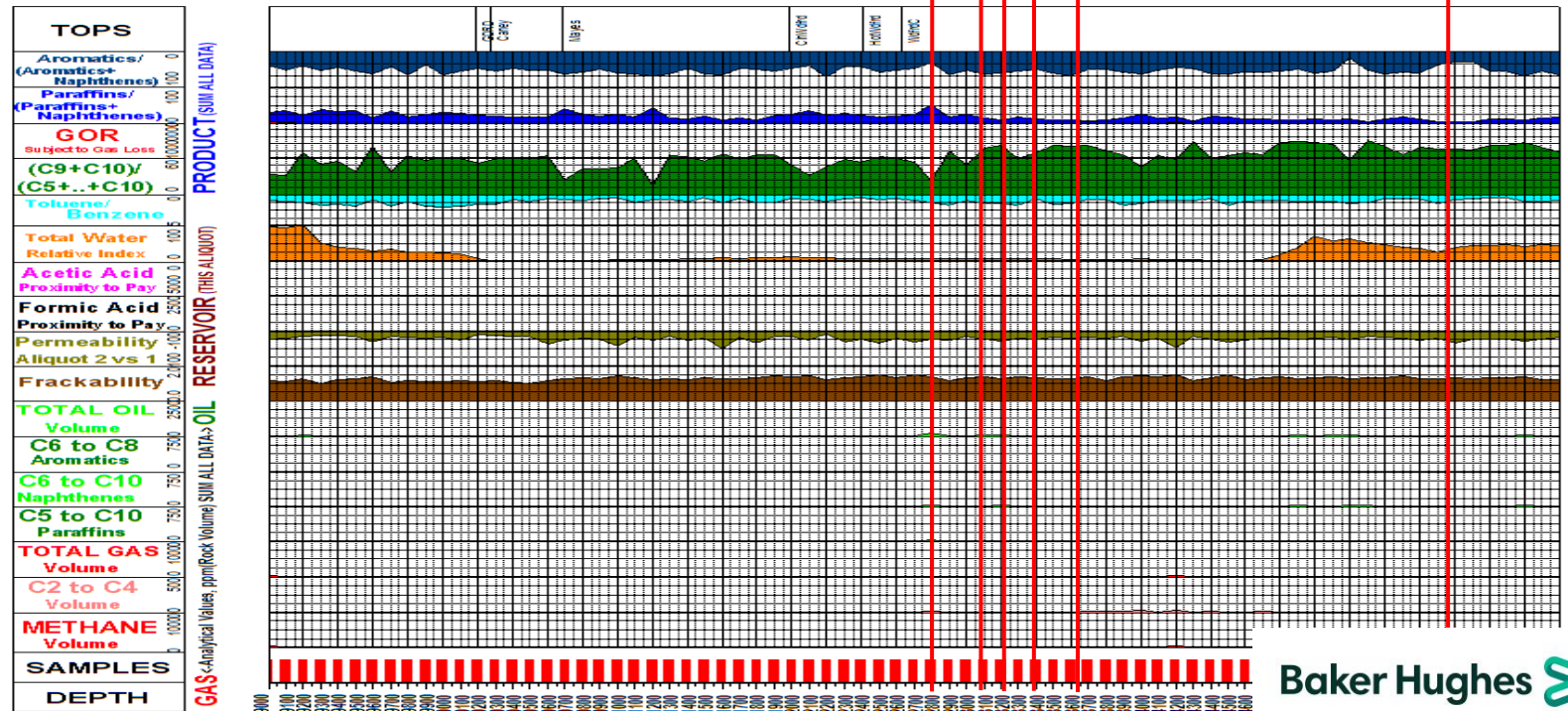
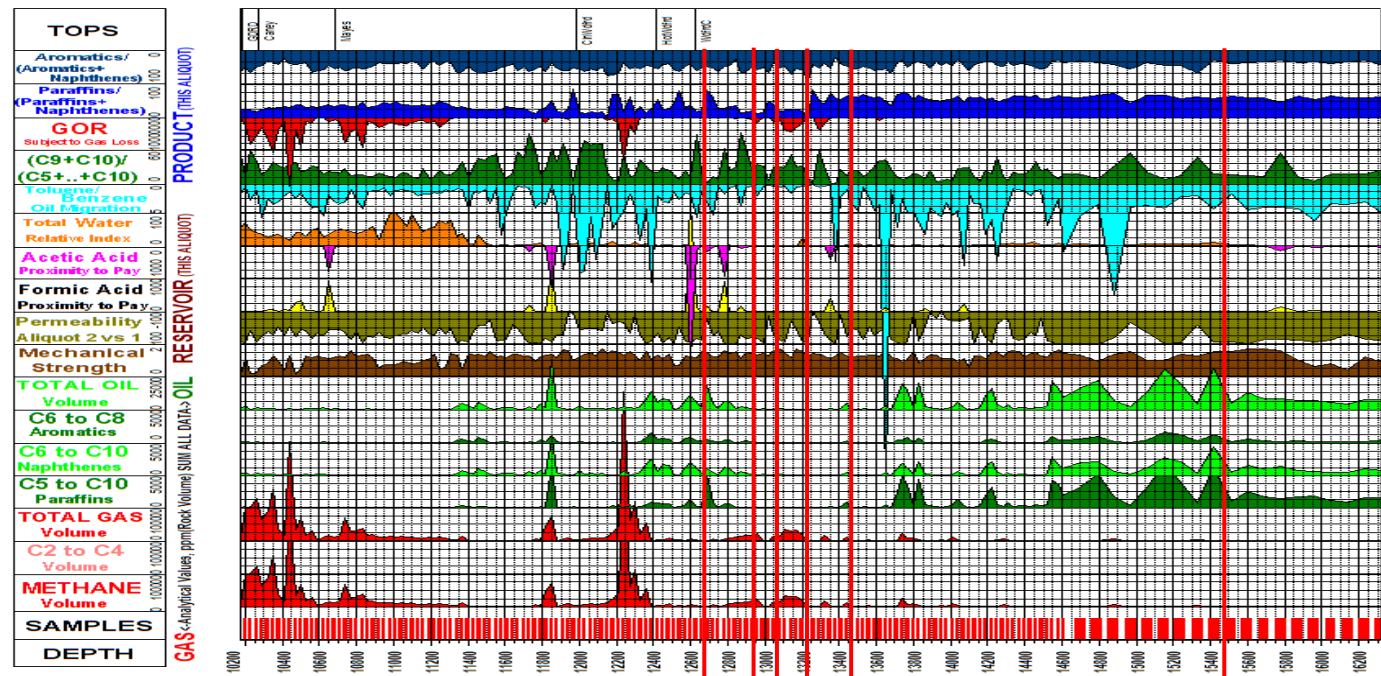
Sealed @ Well

Lab Loaded

Mixed Wetting
 Mayes-Woodford
 Lateral

Sealed at Well:
 High Cuttings Oil =
 Water Wetting.
 Fault Related
 Wetting Alteration

Sealed at Well:
 Low Cuttings Oil =
 Oil Wetting



Lab Loaded Cuttings Volatiles
Without Sealed at Well Cuttings Volatiles
What Did We Learn?

Simpler, unFaulted, is Better.
Woodford near Faults Tends to have
Poorer Reservoir Quality from
Mechanical Disruption and Cementation

Today's Mission:
Understanding Differences Between
Sealed at Well versus Lab Loaded
Cuttings Volatiles, Especially for
Oil versus Water Wetting Reservoirs

Lab Loaded Cuttings Volatiles Combined
With Sealed at Well Cuttings Volatiles.
What Did We Learn?

Simpler, un-Faulted, Woodford is Better.
Woodford Near Faults Tends to be Tight.
Woodford Near Faults is often Changed
from Oil Wetting to Water Wetting.

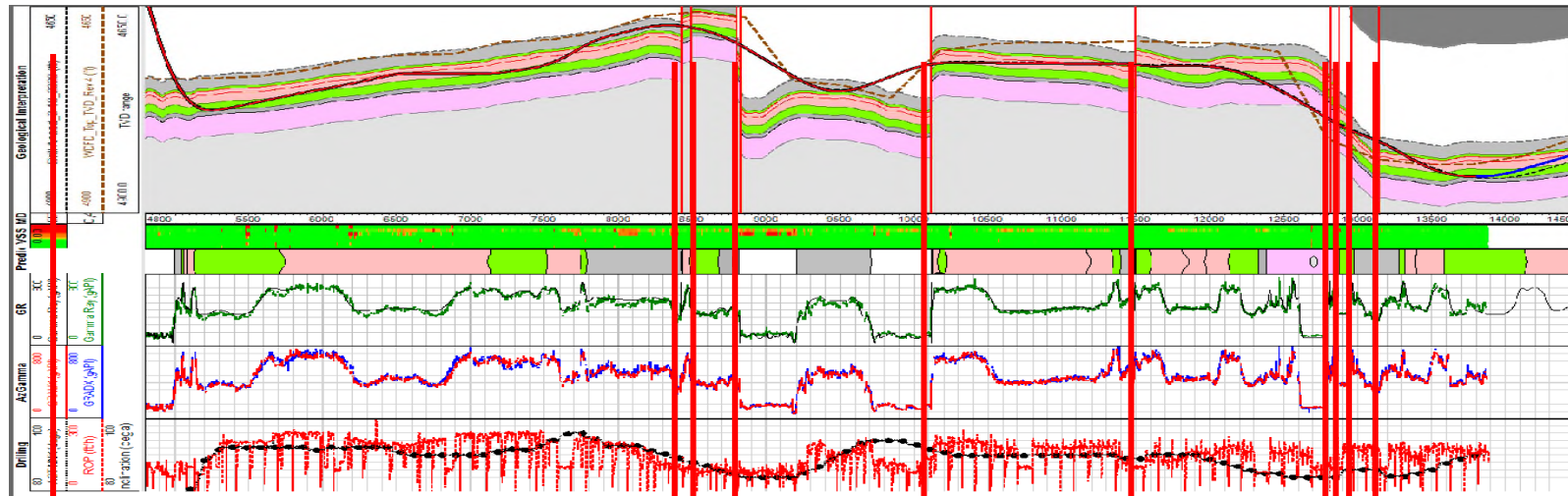


Figure 3 is from the Entire lateral to our current position and lead projection



Thank You!!!!

TOPS	DEPTH
Aromatics/ (Aromatics+ Naphthenes)	0
Paraffins/ (Paraffins+ Naphthenes)	6000
GOR Subject to Gas Loss	200000000
(C9+C10)/ (C5+...+C10)	0
Toluene/ Benzene	0
Total Water Relative Index	0
Acetic Acid Proximity to Pay	25000
Formic Acid Proximity to Pay	25000
Permeability Aliquot 2 vs 1	2000
Frackability	2000
TOTAL OIL Volume	25000
C6 to C8 Aromatics	5000
C6 to C10 Naphthenes	5000
C5 to C10 Paraffins	5000
TOTAL GAS Volume	100000
C2 to C4 Volume	100000
METHANE Volume	100000
SAMPLES	
DEPTH	

PRODUCT (SUM ALL DATA)

GAS (Analytical Values, ppm(Rock) Volume) SUM ALL DATA > OIL RESERVOIR (THIS ALMOST)

