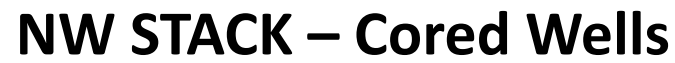


# Rock Volatiles Stratigraphy of Meramec, Upper Osage, and Lower Osage carbonates in Fairway Resource's NW STACK wells: logging horizontal STACK wells from PDC cuttings' volatile chemistry

Michael Smith\* (Advanced Hydrocarbon Stratigraphy), Geoff Ice (Fairway Resources), Greg Anderson (Fairway Resources), Sarah Rittenhouse (Advanced Hydrocarbon Stratigraphy), David Eby (Eby Petrography & Consulting, Inc.)



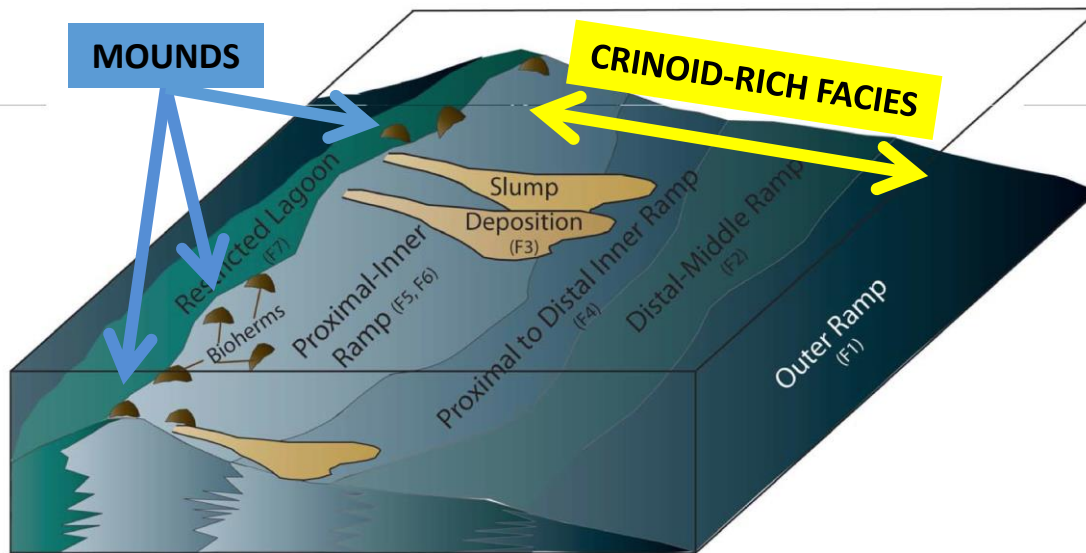
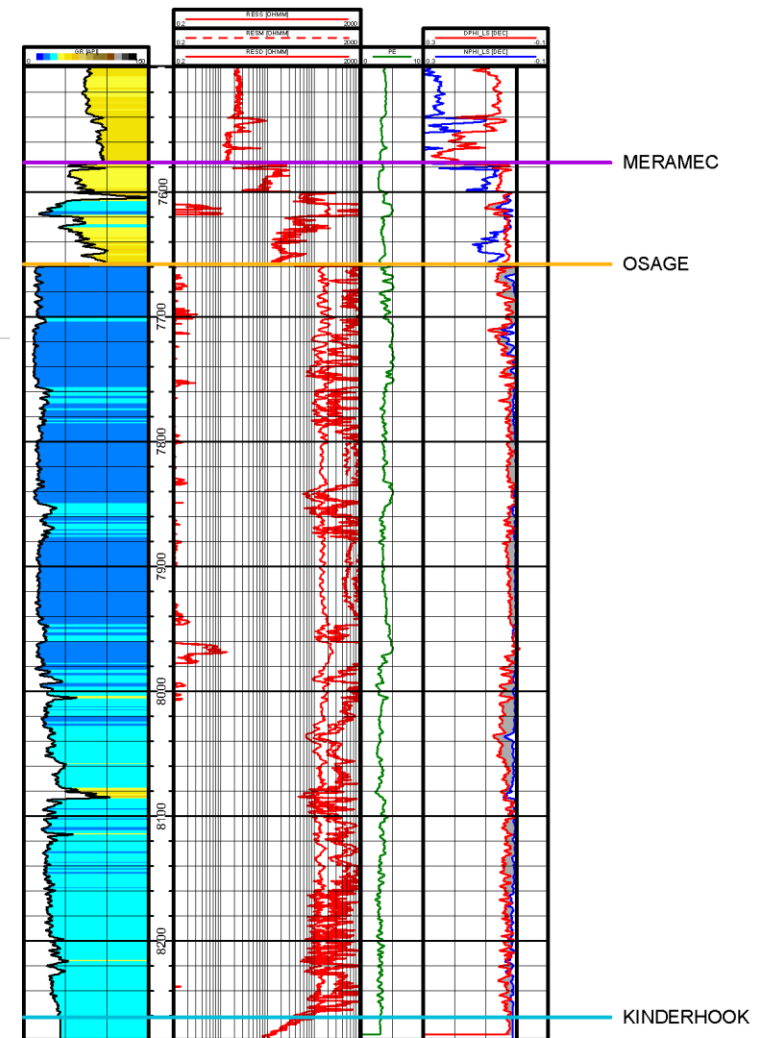


Figure 5. Block diagram showing generalized relationship of depositional environments and proposed lateral relationships assuming a carbonate ramp system with sub-basin topography.

(modified from Vanden Berg & Grammer, 2016, AAPG Mem. 112)





# THREE LIMESTONE RESERVOIR TYPES

---



## I. Mound (Bioherm) Facies (Diverse Skeletal Grainstone)

- Large, open pores (and some bitumen)
- Best Oil Production

## II. Clean Crinoidal Grainstone Facies

- Dissolution & mostly microporosity
- Background (fair to good) Oil Production

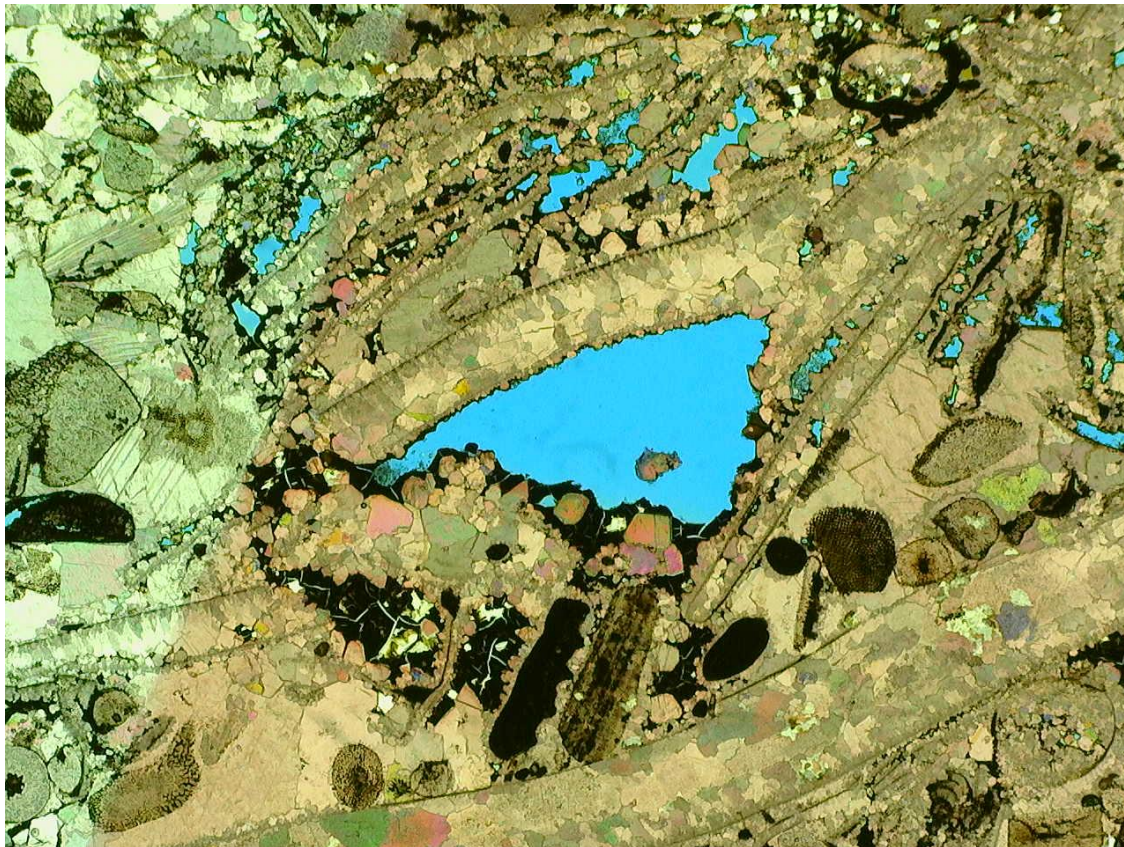
## III. Mixed Crinoid/Siliceous or Silty Facies

- Mostly nanoporosity (& high Gas/Oil ratios)
- Fair to Poor Oil Production w/ high gas content



## I. Mound (Bioherm) Facies (Diverse Skeletal Grainstone)

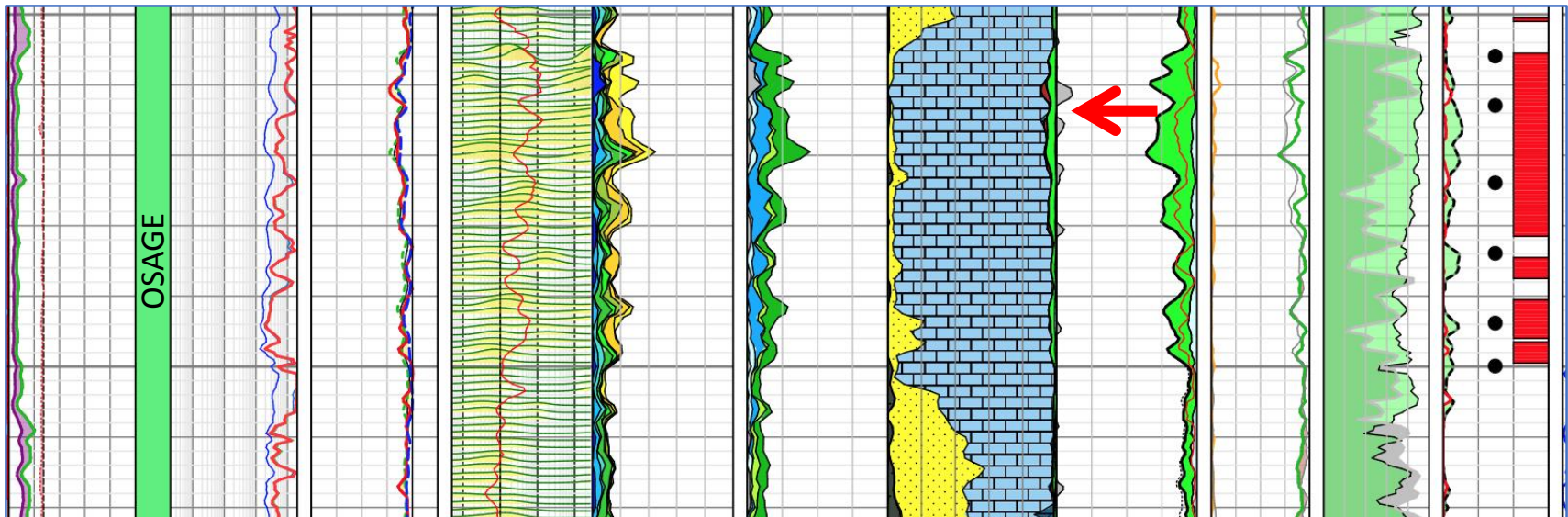
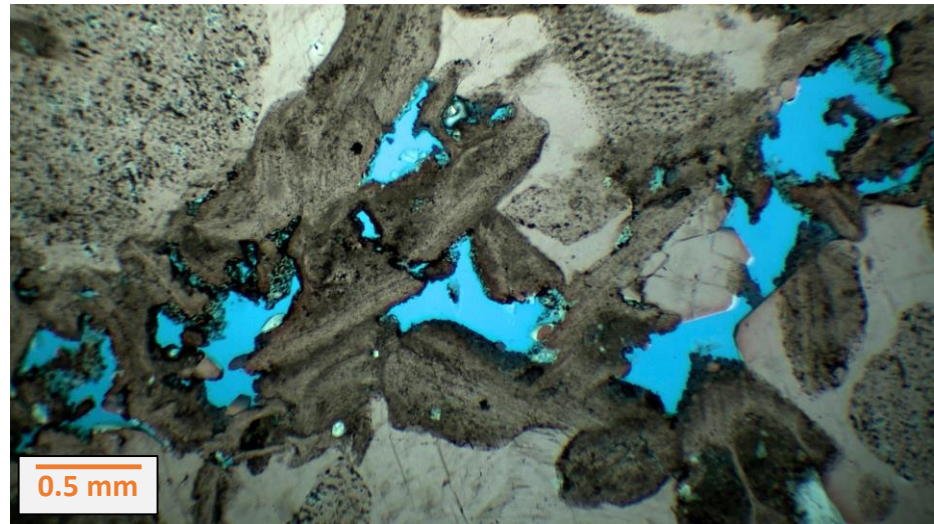
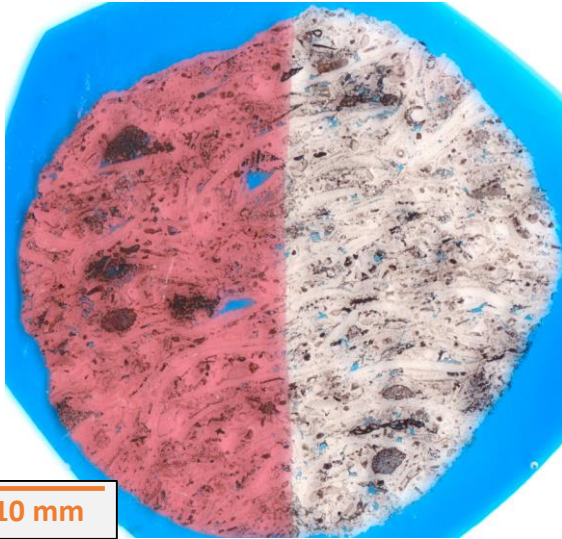
- Large, open pores (and some bitumen)
- **Best Oil Production**



Pl. Light

0.5 mm



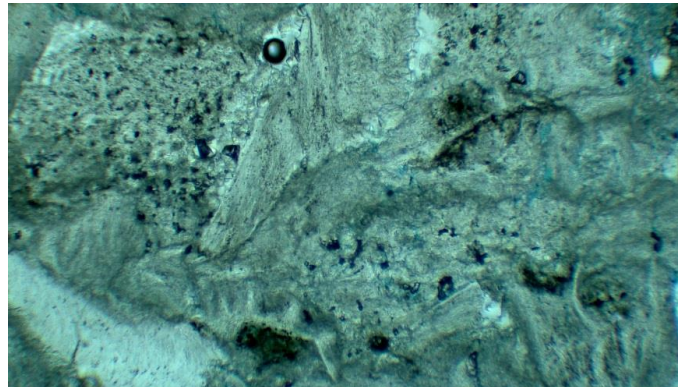




## II. Clean Crinoidal Grainstone Facies

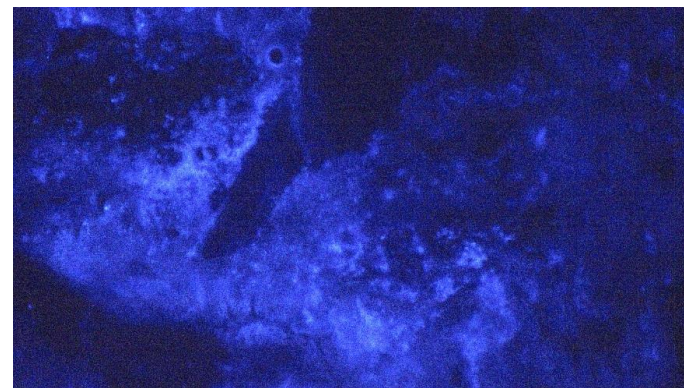
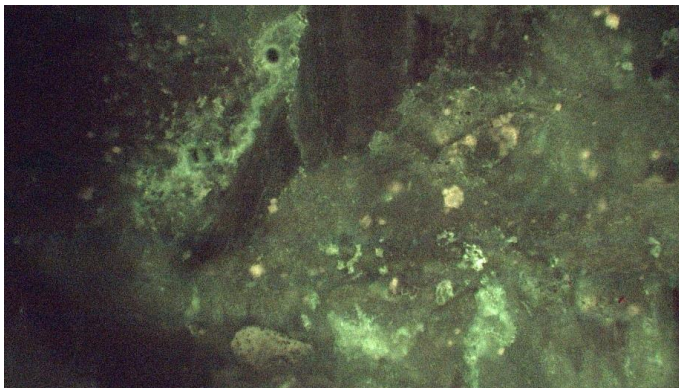
- Dissolution & mostly microporosity
- Background (fair to good) Oil Production

Pl. Light



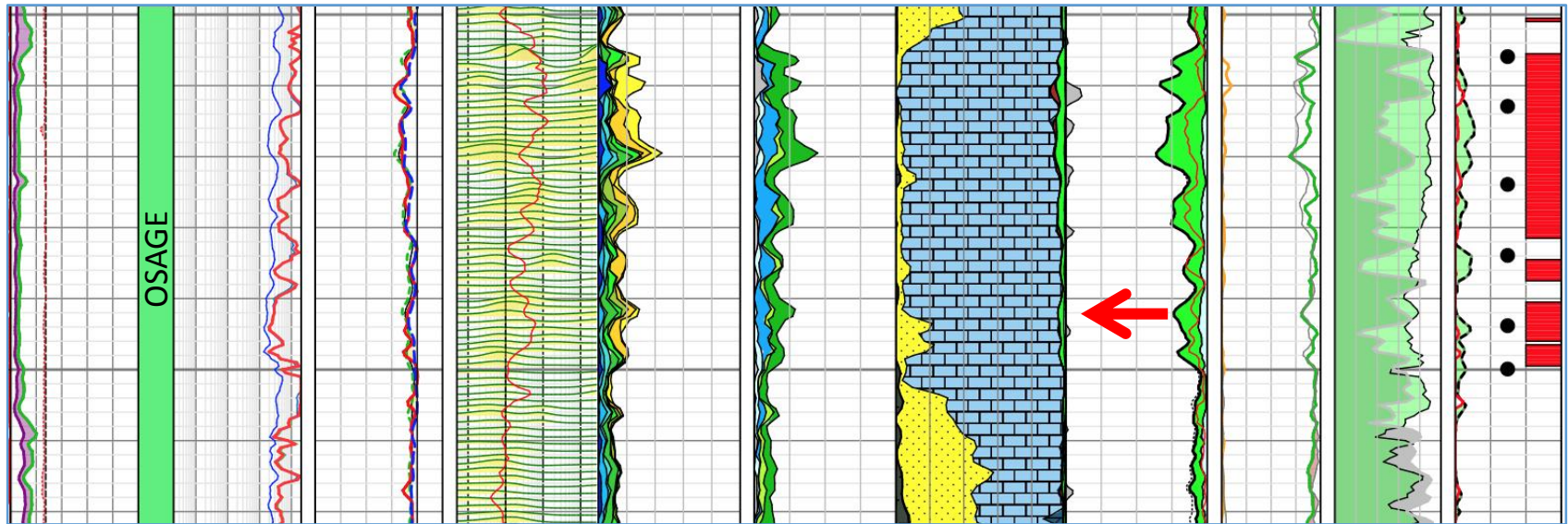
1.0 mm

EF  
(Blue Light)



UV



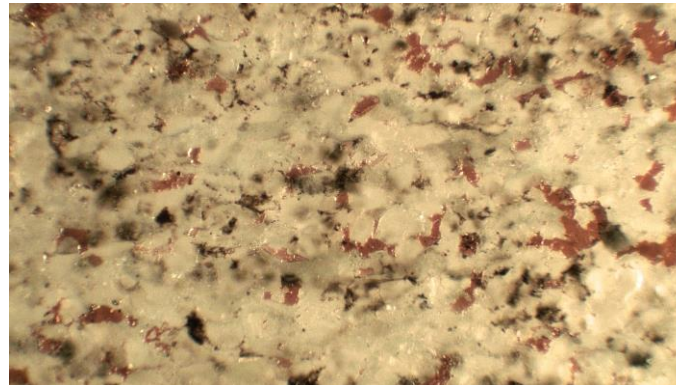






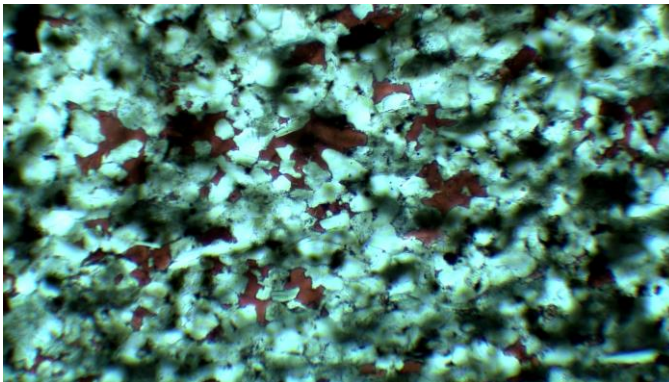
## III. Mixed Crinoid/Siliceous or Silty Facies

- Mostly nanoporosity (higher Gas/Oil ratios)
- Fair to poor oil production with higher gas content

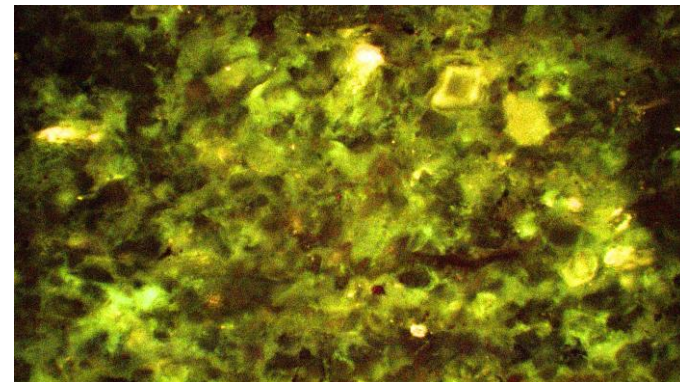


Pl. Light

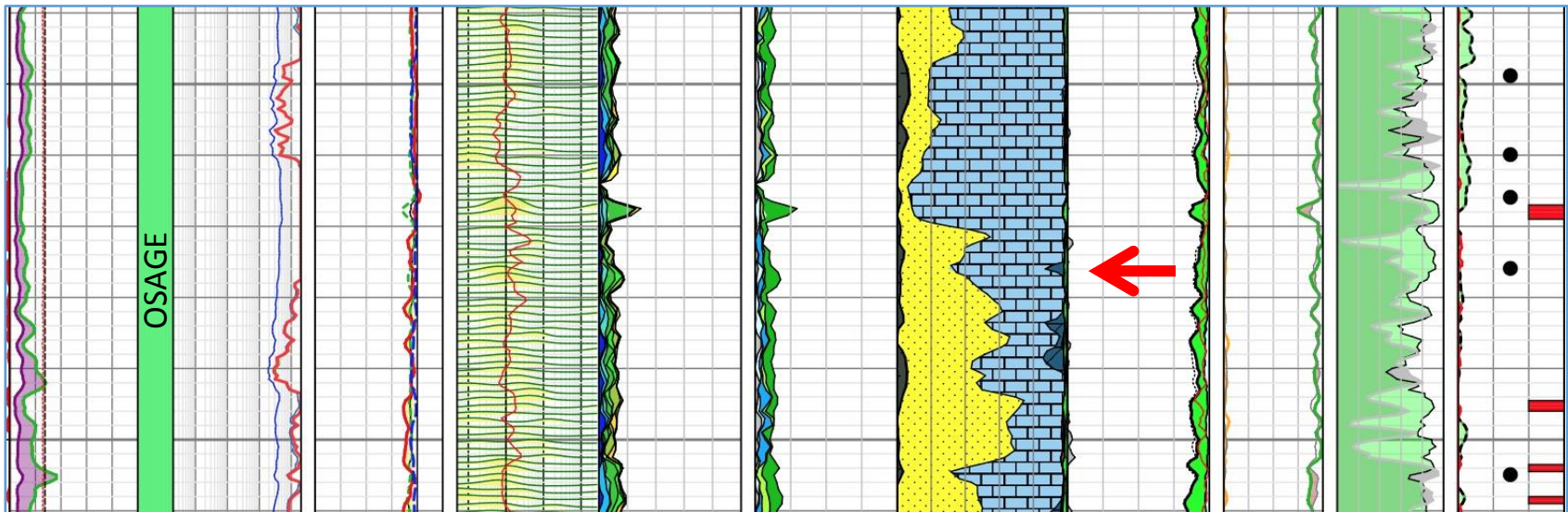
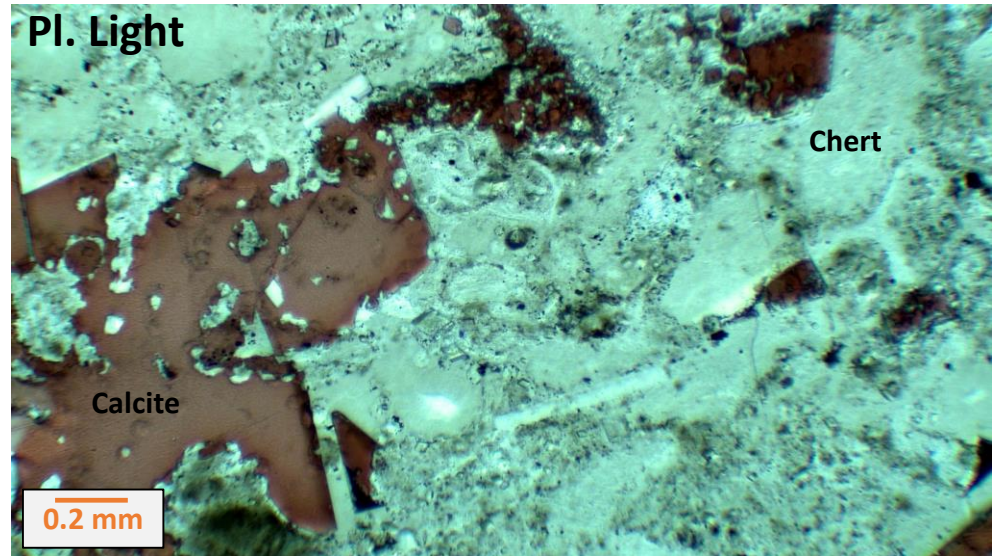
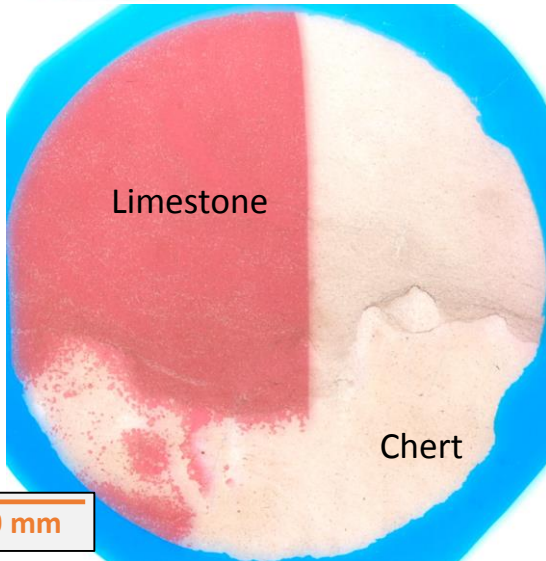
1.0 mm



XN Light



EF  
(Blue Light)





# Starting Material: PDC Cuttings

PDC Cuttings

Sub-Millimeter in size

Gently Caught

Washed and Dried then Loaded

Or

Sealed at Well Immediately after Gently Caught, and  
Washed. Usually sealed less than a minute after the  
cuttings are caught.

WBM or OBM

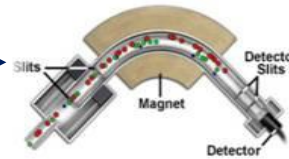
New Wells and Old Wells

Rock Bit Cuttings and Core Also.





## LN2 Cryo Trap Separation

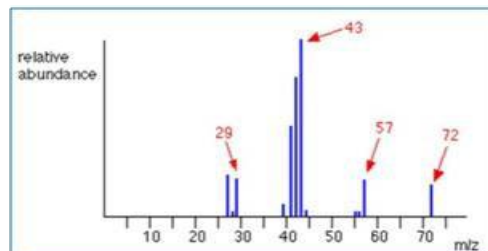


NanoMoles Hydrocarbon per 100 microliters cuttings. Lightly washed & rapidly stored at work-site. Outcrops are not not sequenced.

Depth (cm)

Methane  
Ethane  
Propane  
Butanes  
Pentanes  
Hexanes  
Heptanes  
Octanes  
Nonanes  
Decanes  
Undecanes  
Dodecane  
Tridecane  
Tetradecane  
Pentadecane

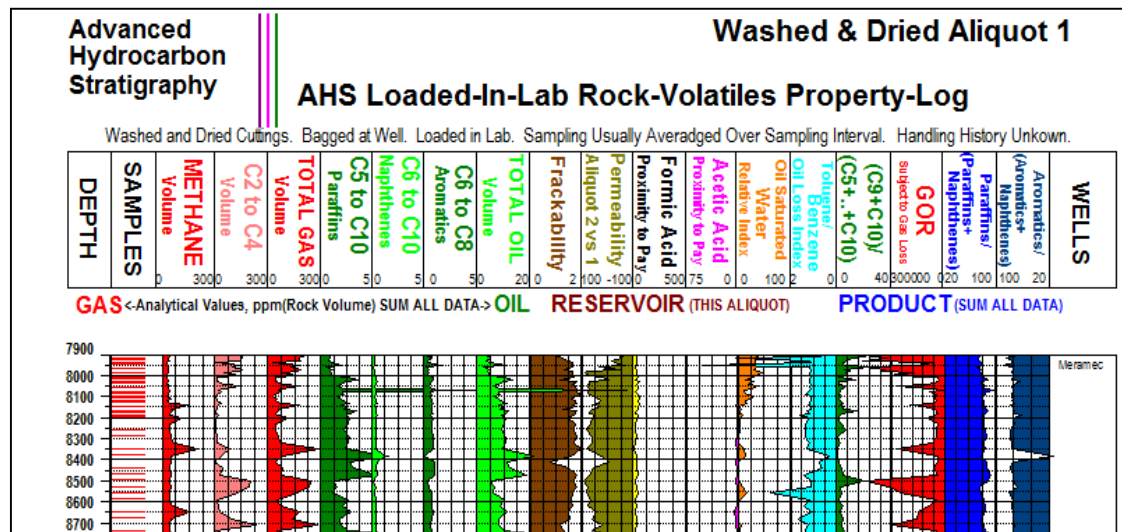
- ## MS Analysis



## The 4<sup>th</sup> Log

# AHS Products and Interpretation

ADVANCED  
HYDROCARBON  
STRATIGRAPHY



Category	Sample depth	C1-C10, Total Gas/Oil	Frac & Perm	Prospect Evaluation	HC Analysis	Well Tops
Interpretation		HC Detection, ID: faults, fractures, rock types, etc.	AHS exclusive analysis	Proximity to Pay, Organic Acids, Oil Migration	Pay Zone Mapping, product quality	From Client

# Fault May Feed Oil Into Reservoir

A  
H  
S

Tighter Rocks Maintain Oil and Gas from Cuttings through Drilling and Transport to the Surface

High Toluene/Benzene ratio at fault = Zone of Active Oil Migration

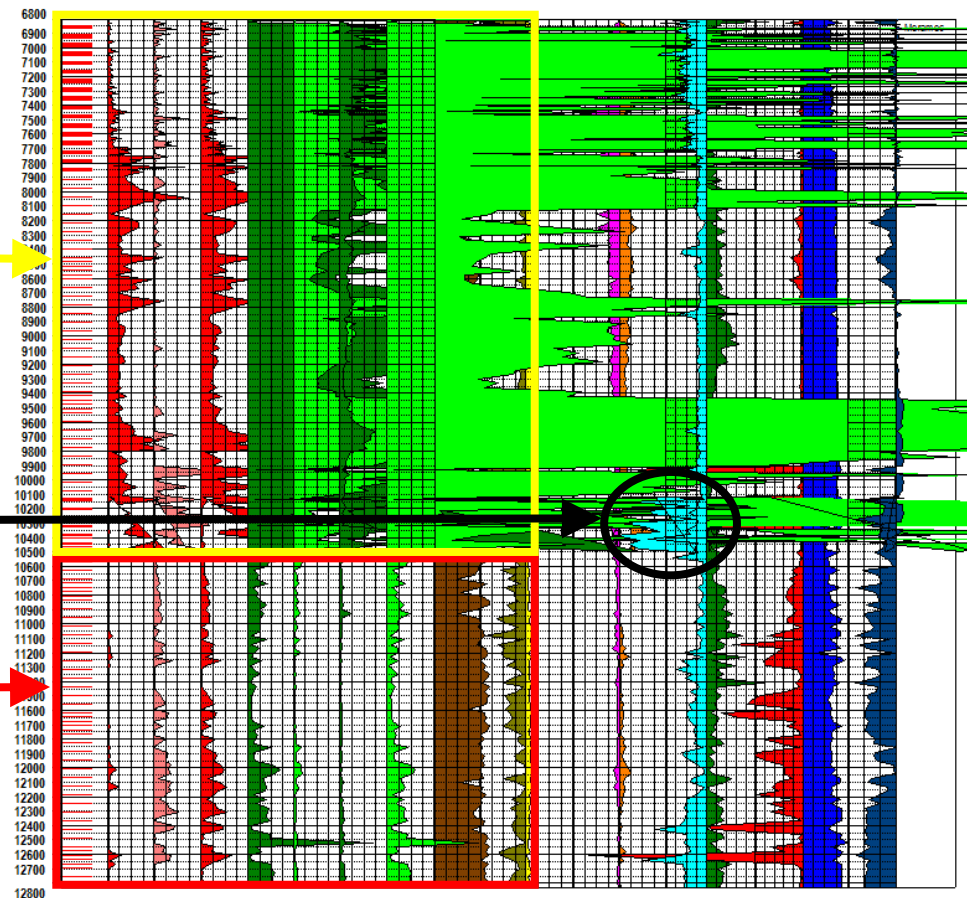
AHS Predicted Preferred Reservoir Zones

High Porosity High Permeability Rocks Can Lose Oil During Drilling, Transport, and Sample Prep

Washed and Dried Cuttings. Bagged at Well. Loaded in Lab. Sampling Usually Averaged Over Sampling Interval. Handling History Unknown.

DEPTH	SAMPLES	METHANE Volume	C2 to C4 Volume	TOTAL GAS Volume	Paraffins C5 to C10	Naphthenes C6 to C10	Aromatics C6 to C8	TOTAL OIL Volume	Frackability Aliquot 2 vs 1	Permeability	Formic Acid Proximity to Pay	Acetic Acid Proximity to Pay	Relative Index	Oil Saturated Water	Oil Loss Index	Toluene/Benzene	(C9+C10)/ (C5+. +C10)	(C9+C10)/ (C5+. +C10)	GOR Suspect on Loss	Paraffins/ Naphthenes	Aromatics/ (Aromatics+ Naphthenes)	TOPS
0		3000	3000	3000	50	50	50	200	2	100	500	75	0	0	100	0	0	40	800000	100	100	20

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





# Potential Rock Type 1 CO<sub>2</sub> Response

A  
H  
S

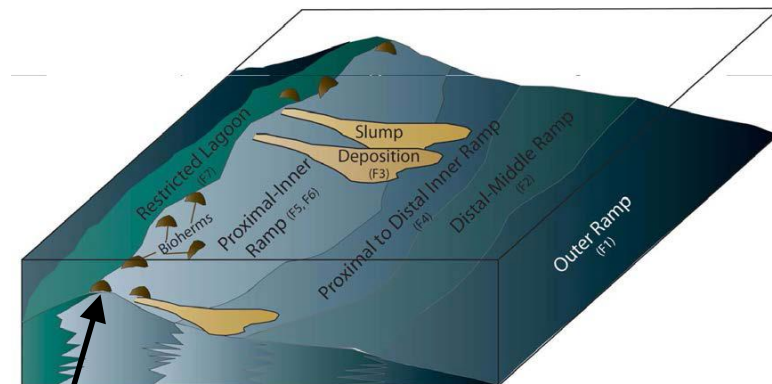
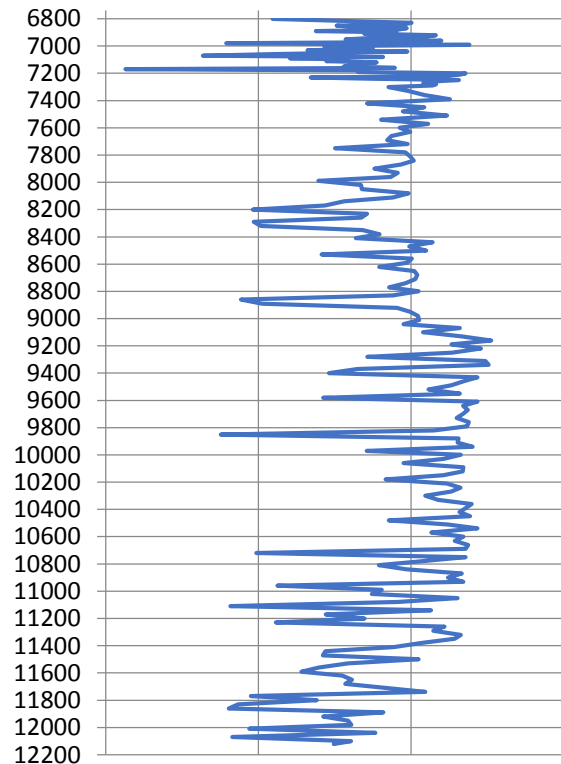


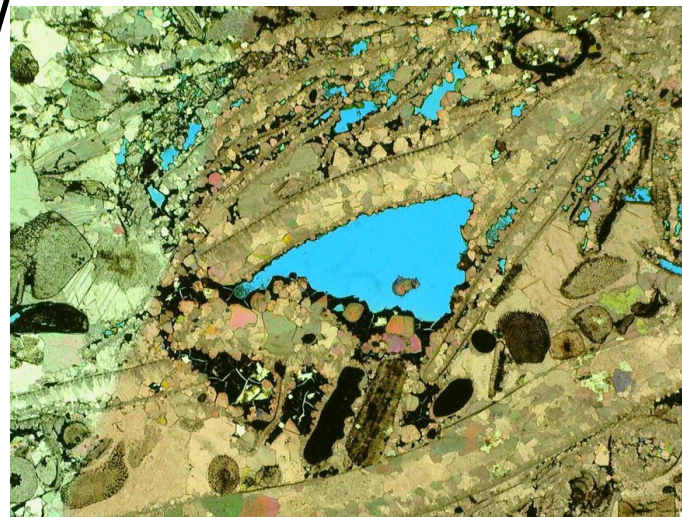
Figure 5. Block diagram showing generalized relationship of depositional environments and proposed lateral relationships assuming a carbonate ramp system with sub-basinal topography.

100000 1000000 10000000 100000000



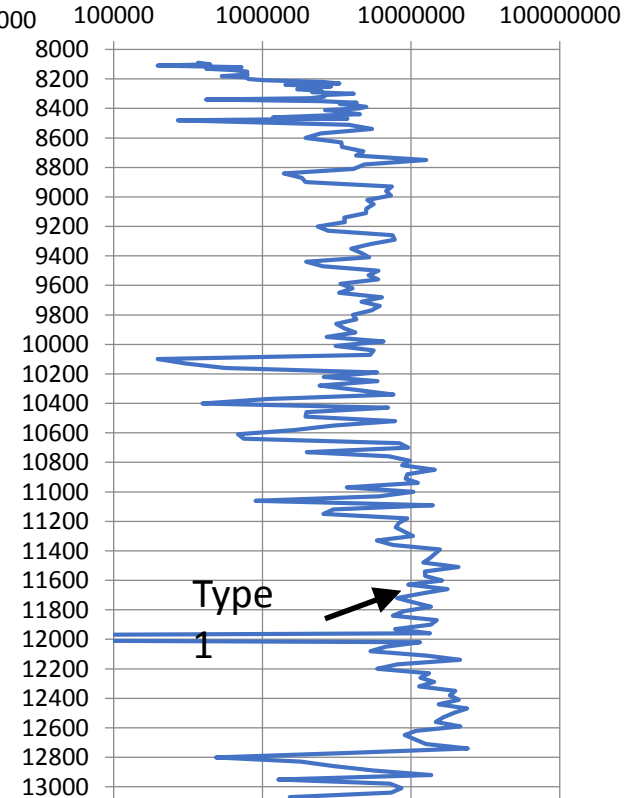
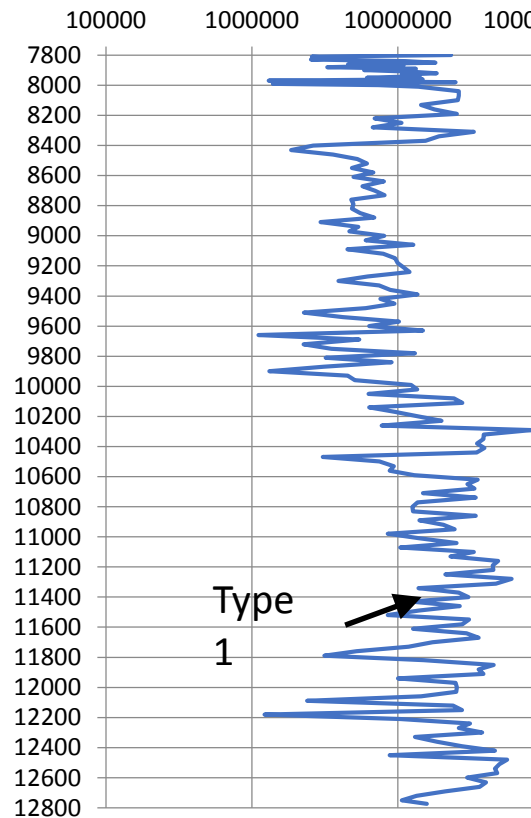
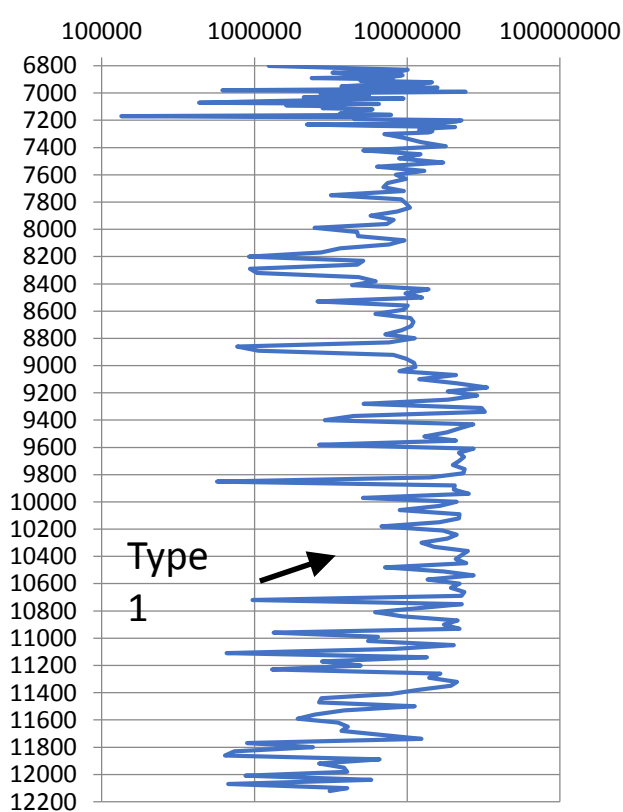
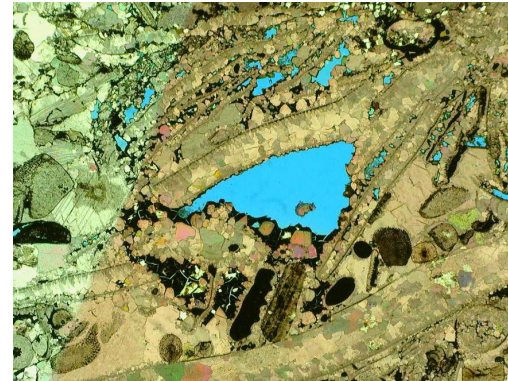
Potential  
ROCK Type 1  
CO<sub>2</sub>  
Response

Possibly  
Bioherms  
Largest Grains  
Largest Fluid Inclusions  
Highest CO<sub>2</sub> Release



# Potential Rock Type 1 CO<sub>2</sub> Response

A  
H  
S



# Potential Rock Type 2 CO<sub>2</sub> Response

A  
H  
S

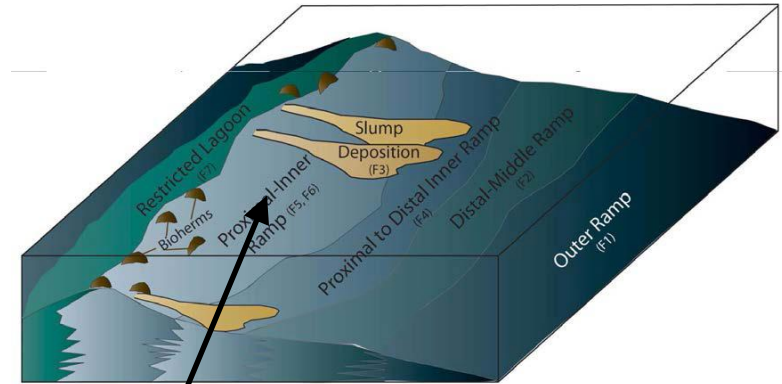
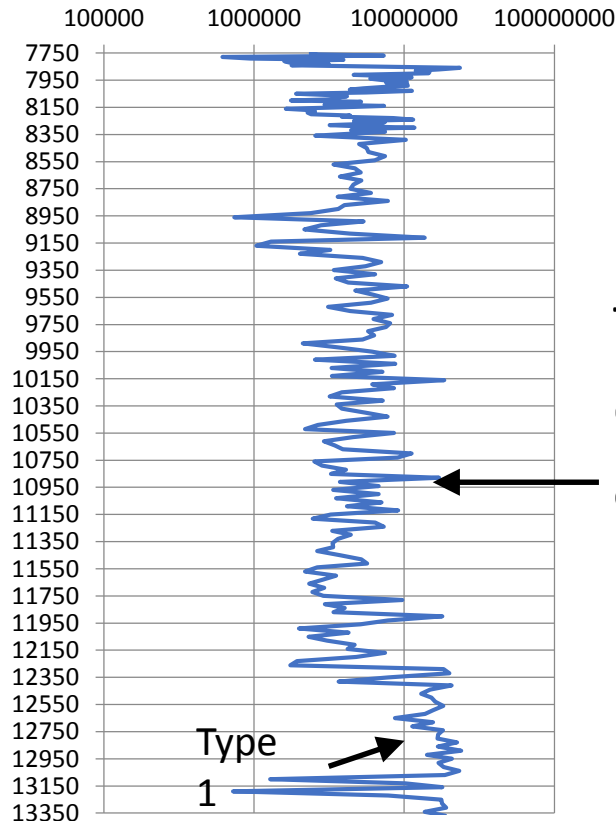
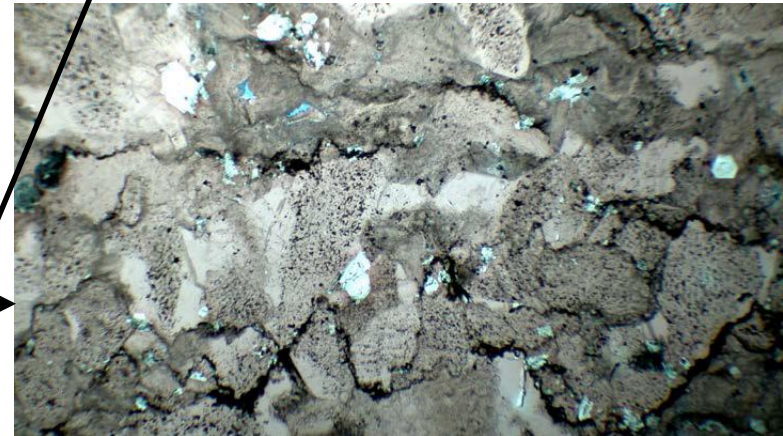


Figure 5. Block diagram showing generalized relationship of depositional environments and proposed lateral relationships assuming a carbonate ramp system with sub-basin topography.



Potential  
ROCK  
Type 2  
Crinoidal  
Grainstones  
Large Grains  
Large Fluid Inclusions  
2<sup>nd</sup> Highest CO<sub>2</sub> Release





# Potential Rock Types 1 and 2

A  
H  
S

Potential ROCK

Types 1 and 2 CO<sub>2</sub> Responses:

Bioherms and

Shelf Grainstones

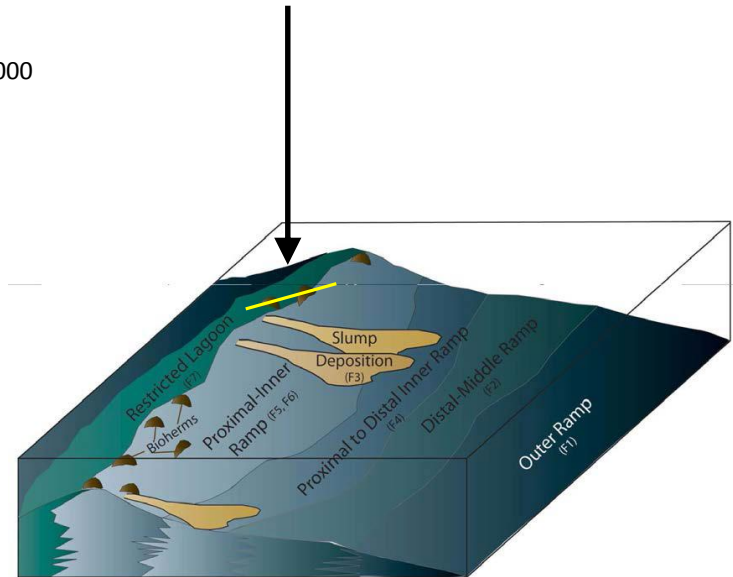
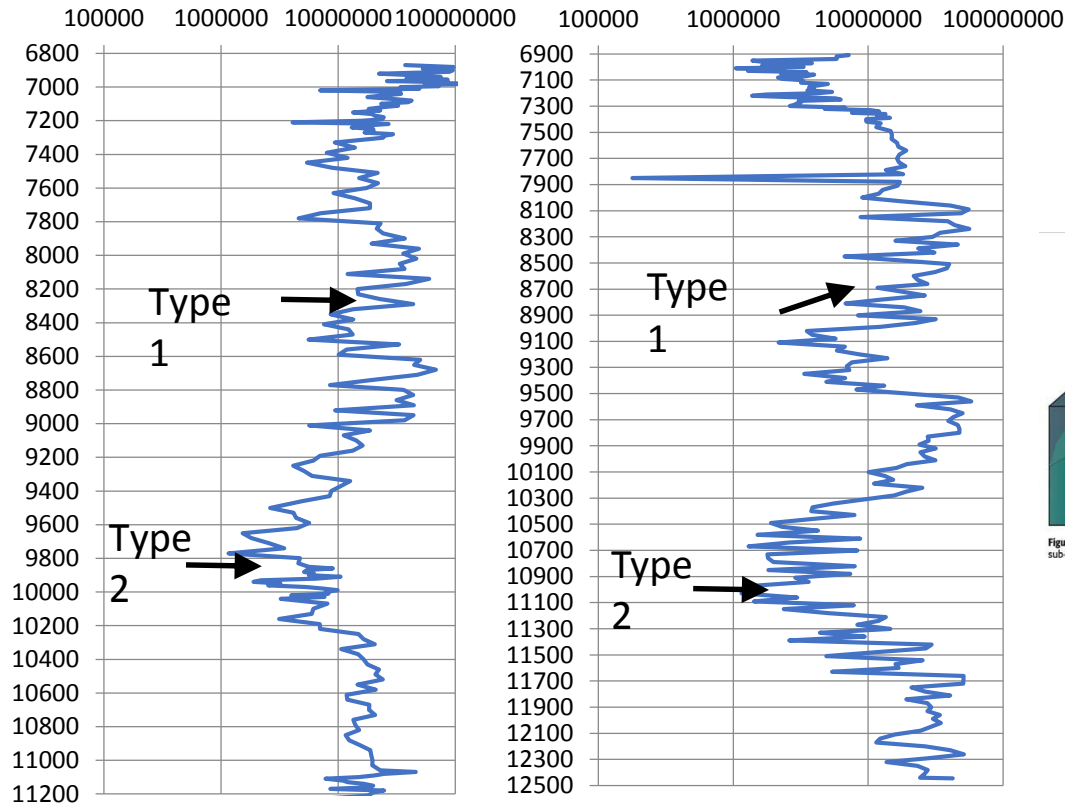


Figure 5. Block diagram showing generalized relationship of depositional environments and proposed lateral relationships assuming a carbonate ramp system with sub-basin topography.

# Reservoirs May Show Low Cuttings Oil Response

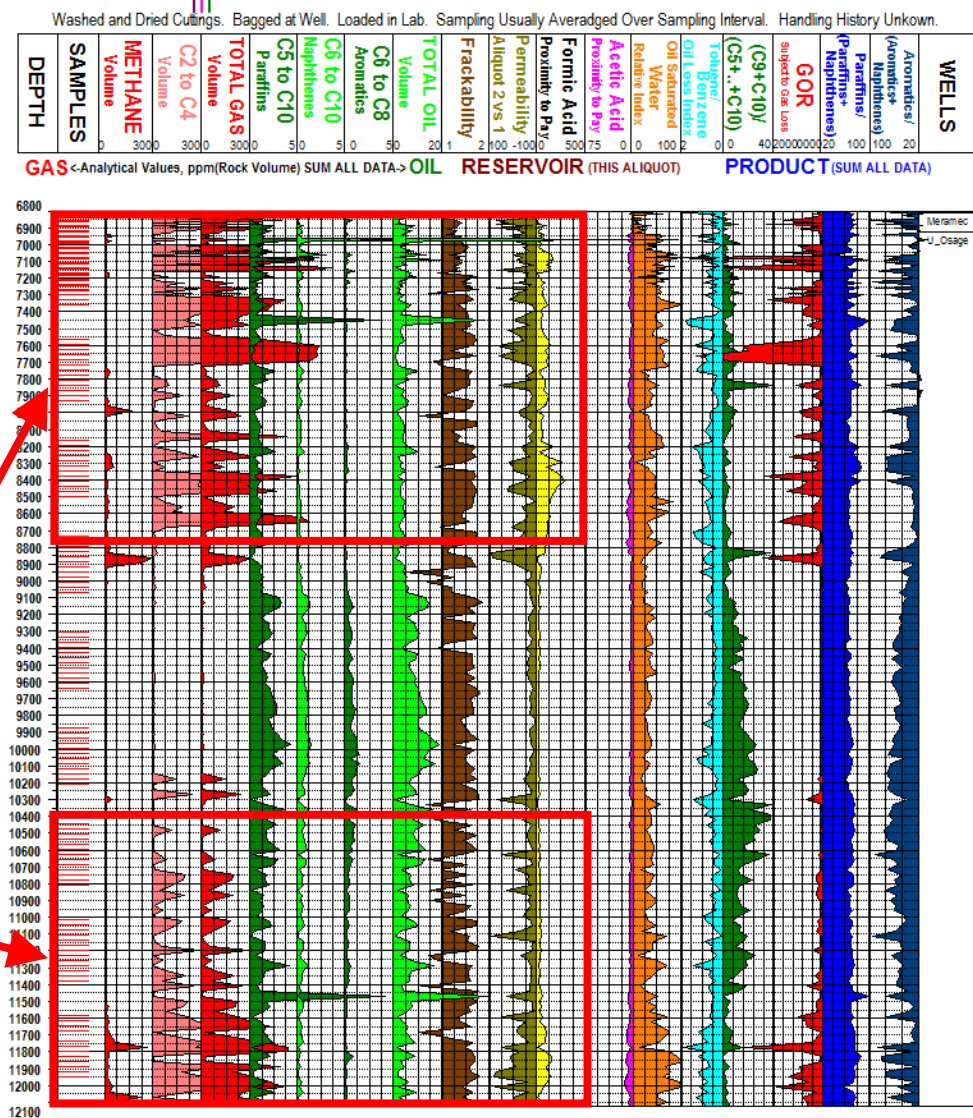
A  
H  
S

High Performing Well

Low Cuttings Oil Responses

High Porosity High Permeability Rocks Can Lose Oil During Drilling, Transport, and Sample Prep

AHS Predicted Preferred Reservoir Zones



# Reservoirs May Be Filled by Nearby Fault

A  
H  
S

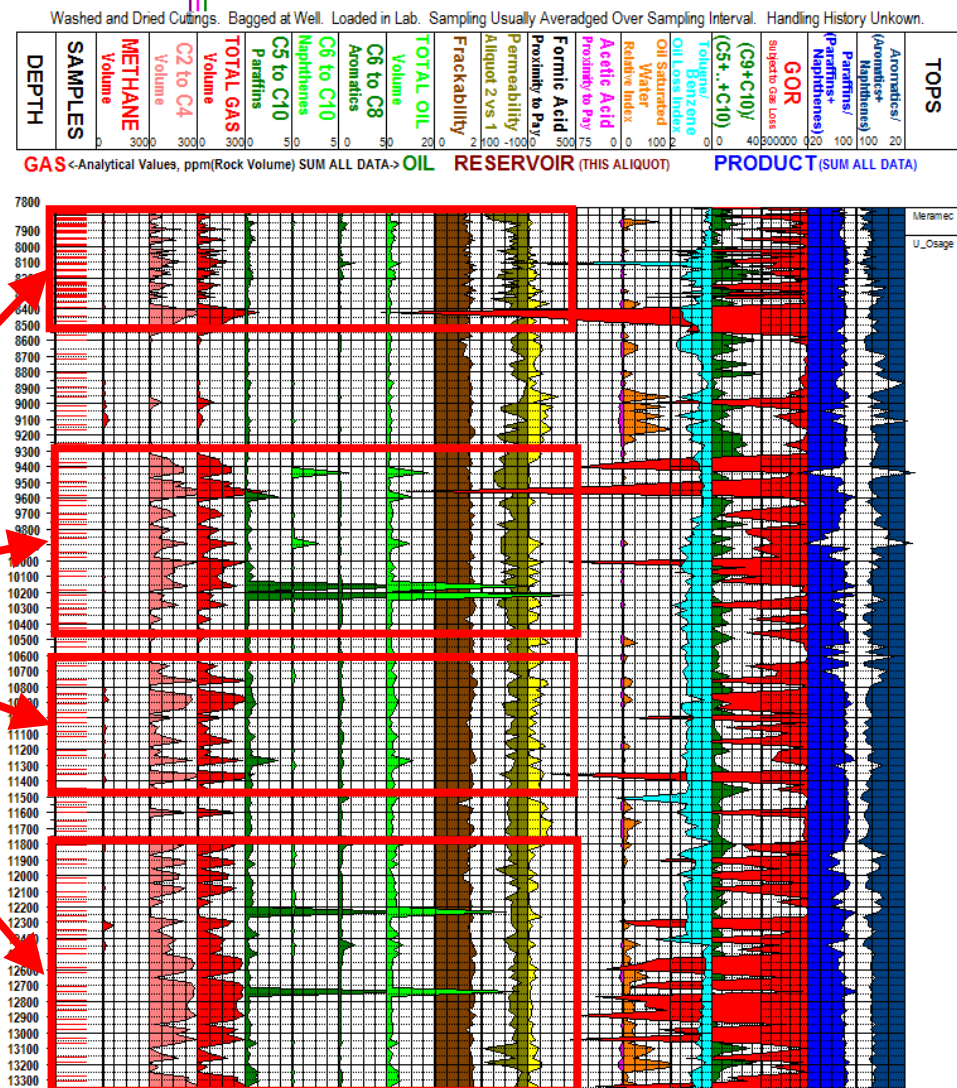
High Performing Well

Lateral Drilled Along N-S Fault

AHS Predicted  
Preferred Reservoir Zones

Nearby Parallel Fault  
May be Filling Reservoirs the  
Entire Length of Lateral

High Porosity High Permeability  
Rocks Can Lose Oil During Drilling,  
Transport, and Sample Prep





# Fault May Feed Oil Into Reservoir

A  
H  
S

Tighter Rocks Maintain Oil and Gas from Cuttings through Drilling and Transport to the Surface

High Toluene/Benzene ratio at fault = Zone of Active Oil Migration

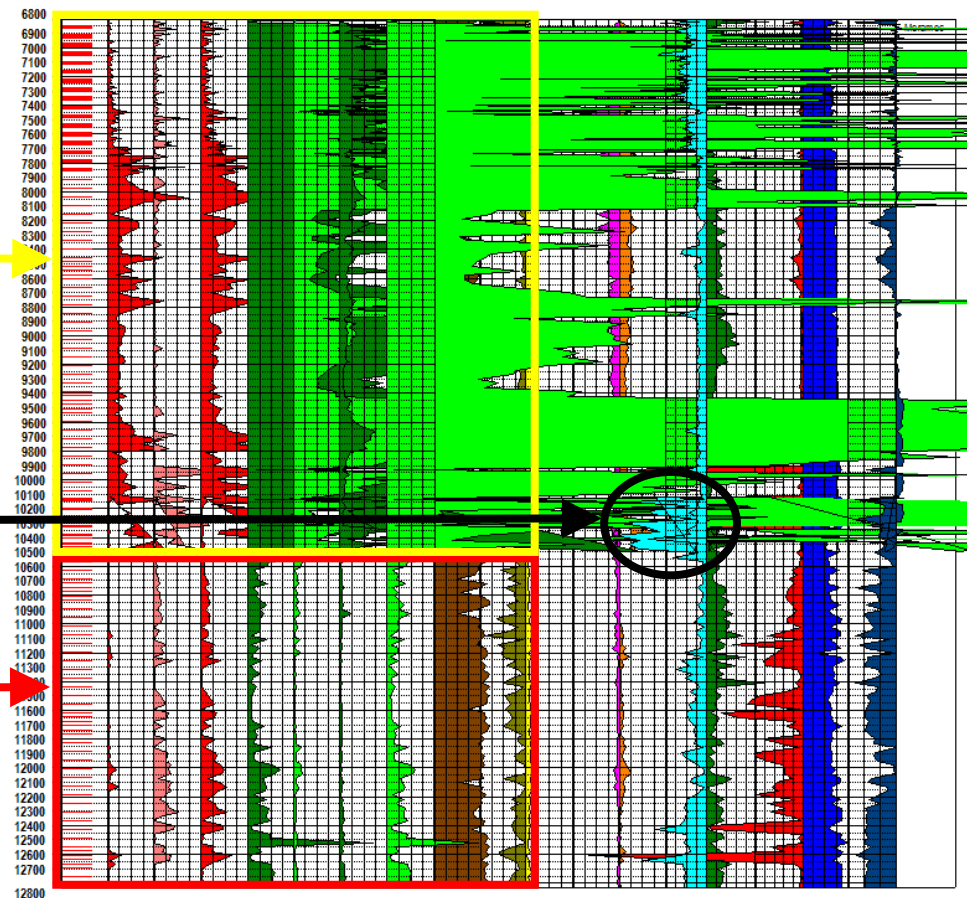
AHS Predicted Preferred Reservoir Zones

High Porosity High Permeability Rocks Can Lose Oil During Drilling, Transport, and Sample Prep

Washed and Dried Cuttings. Bagged at Well. Loaded in Lab. Sampling Usually Averaged Over Sampling Interval. Handling History Unknown.

DEPTH	SAMPLES	METHANE Volume	C2 to C4 Volume	TOTAL GAS Volume	Paraffins C5 to C10	Naphthenes C6 to C10	Aromatics C6 to C8	TOTAL OIL Volume	Frackability Aliquot 2 vs 1	Permeability	Formic Acid Proximity to Pay	Acetic Acid Proximity to Pay	Relative Index	Oil Saturated	Water	Oil Loss Index	Toluene/Benzene	(C9+C10)/(C5+.+C10)	(C9+C10)/C5+.+C10	GOR	Paraffins/Paraffins+Naphthenes	Aromatics/Aromatics+Naphthenes	TOPS
0	0	3000	3000	3000	50	50	50	200	2	100	500	75	0	0	0	0	0	40	800000	120	100	100	20

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



# Faults Might Feed Reservoirs and Create Porosity

A  
H  
S

Washed and Dried Cuttings, Bagged at Well, Loaded in Lab. Sampling Usually Averaged Over Sampling Interval. Handling History Unknown.

DEPTH	SAMPLES	METHANE Volume	C2 to C4 Volume	TOTAL GAS Volume	Paraffins	Hydrocarbons C5 to C10	Aromatics C8 to C10	Volume	Frackability	Permeability Atmos 2 vs 1	Proximity to Py	Formic Acid	Acetic Acid	Relative Index	Oil Saturated	Oil Loss Index	Oil Loss Index	GOR (C3+C4+C5+C6+C7+C8+C9+C10) suggests oil loss	Paraffins/ Hydrocarbons	Aromatics/ Hydrocarbons	Wells

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

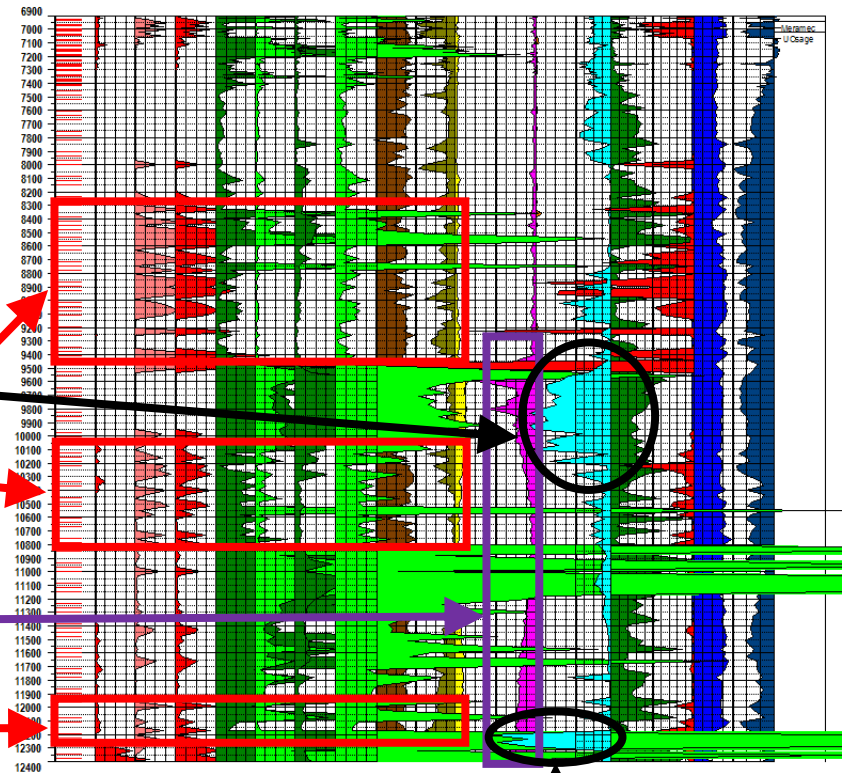
Lateral Drilled through a Fault

High Toluene/Benzene =  
Oil Migration along Fault

AHS Predicted Preferred Reservoir Zones  
Surrounding Fault

High Acetic Acid Toe Side of Fault

Small Fault Feeding Small Reservoir



# Faults Migrating Oil and Acetic Acid

A  
H  
S

## Lateral Drilled through 2 NE-SW Faults

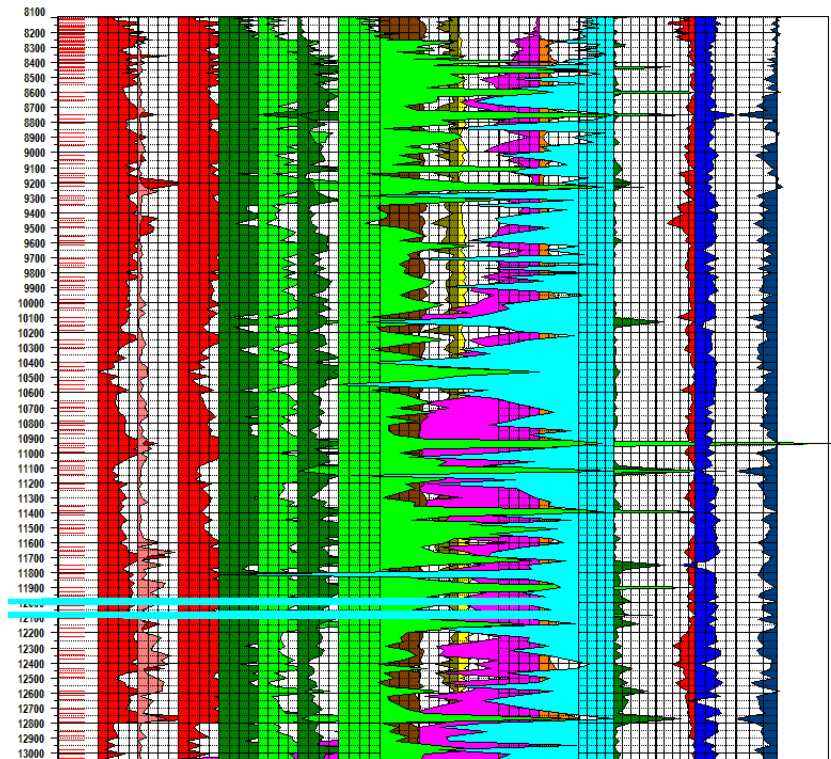
- Very High Acetic Acid and Toluene/Benzene
- Oil and Acid Rich Oil Field Brines Migrating on NE-SW Faults



Washed and Dried Cuttings. Bagged at Well. Loaded in Lab. Sampling Usually Averaged Over Sampling Interval. Handling History Unknown.

DEPTH	SAMPLES	METHANE Volume	C2 to C4 Volume	TOTAL GAS Volume	C5 to C10 Paraffins	Naphthenes	Aromatics	TOTAL OIL Volume	Frackability	Permeability Aliquot 2 vs 1	Formic Acid Proximate to Py	Acetic Acid Proximate to Py	Relative Index	Oil Solvent Index	Toluene Benzene (C9+C10) (C5+C10)	GOR Sample to Lab	Paraffins Naphthenes Aromatics	TOPS
0		3000	3000	3000	50	50	50	20.0	2	100	75	0	0	0	40	8000000	0	20

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





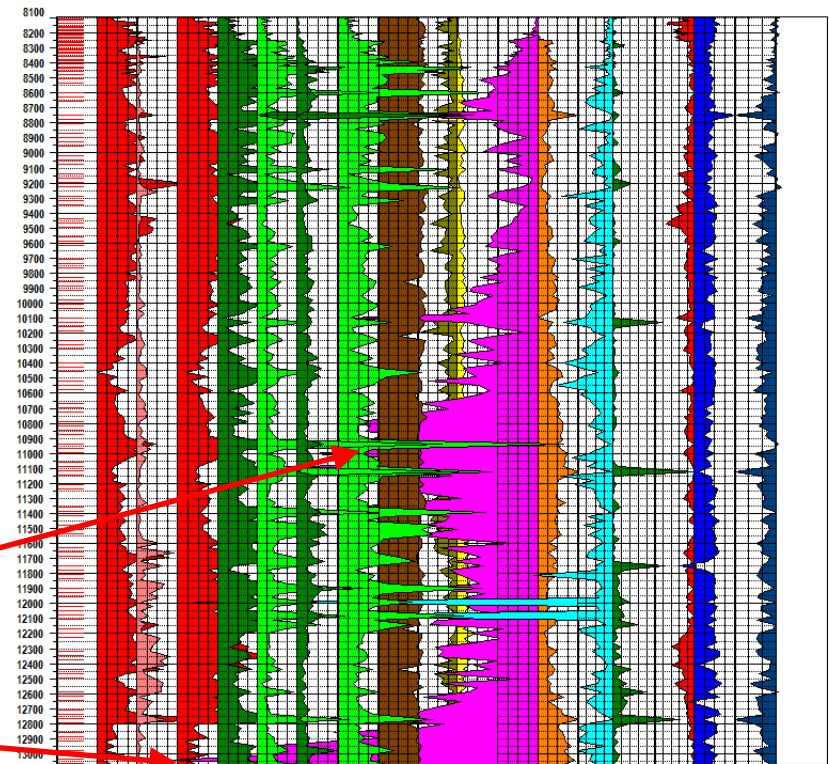
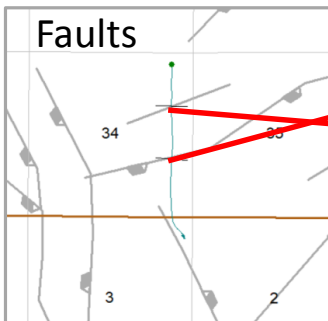
# Faults Migrating Oil and Acetic Acid

A  
H  
S

Washed and Dried Cuttings, Bagged at Well, Loaded in Lab, Sampling Usually Averaged Over Sampling Interval, Handling History Unknown.																						
DEPTH	SAMPLES	VOLUME	METHANE	C2 to C4	TOTAL GAS	Paraffins	Naphthenes	Aromatics	Volume	TOTAL OIL	Frackability	Permeability	Formic Acid	Acetic Acid	Relative Index	Oil Saturated	Longphene	(C9+C10)	GOR	Paraffins/ Naphthenes	Aromatics/ (Naphthenes)	TOPS
		0 3000	0 3000	0 3000	0 3000	0 100	0 100	0 100	0 100	0 300	0 2	0 1000	0 500	0 100	0 100	0 100	0 100	0 40	0 200	0 100	0 20	
GAS <Analytical Values, ppm(Rock Volume) SUM ALL DATA->												OIL RESERVOIR (THIS ALIQUOT)					PRODUCT (SUM ALL DATA)					

Lateral Drilled through 2 NE-SW Faults

- Very High Acetic Acid and Toluene/Benzene
- Oil and Acid Rich Oil Field Brines Migrating on NE-SW Faults
- High Response Scaling



# Conclusions

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- Fairway Resources is successful in producing liquids in the NW STACK by applying a variety of innovative technologies
  - Rock typing identifies potentially producible facies
- AHS RVStrat attempts to map reservoir quality, oil and gas migration and pay zones
  - Combined with rock type facies for more predictive mapping and results
- Faults can be chemically identified
  - Porosity creation may increase rock facies reserves
  - Oil migration pathways provide clarity for well placement and potentially producible zones