Hydrocarbon Charge Considerations in Liquid-Rich Unconventional Petroleum Systems*

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General Comments

A liquid-rich unconventional play targets a reservoir which requires significant stimulation to provide economic liquid production rates. Considerations include:

- Source is the same as reservoir or there is an external charge (and migration).
- Reservoir is "shale" (fine-grained) or low-permeability (tight) sedimentary rock.
- Fluid type ranges from: black oil, volatile oil, condensate, to wet gas.

Technical distinctions between gas and liquid systems include:

- Size matters (e.g., methane (CH_4--3.75 Å) is much smaller than octane (C_8H_{18}--height 4.85 Å, length 13.17 Å)).
- Molecular interactions: gas (Van der Waals) versus liquid (viscous) forces.

Parameters critical for economically successful LRU play
Charge System

- Total organic carbon: how much organic carbon?
- Organic matter type: type of organic matter.
- Rock maturity: maximum temperature.
- Migration: expulsion versus retained hydrocarbons.

Production

- Storage: where is hydrocarbon stored?
- Flow: rock permeability, porosity, and pore pressure.

- Fluid properties: original/changes with production.
- Completions: rock properties critical to fracability.

Economics

- Drilling cost: location and depth.
- OOIP: how much oil is in-place.
- EUR: how much can be produced and at what rate?

Selected References

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Defining Liquid-Rich Unconventional Play

"fine-grained rock acting as both hydrocarbon source and reservoir, or a low- permeability reservoir with interbedded or juxtaposed organic-rich shale with liquid hydrocarbon potential"

Broader Definition: ***Reservoir which requires significant stimulation to provide economic liquid production rates*.**

Considerations

- ***Source:*** **same as reservoir or external charge (migrated).**
- ***Reservoir*: *"Shale"* (fine-grained) versus *low-permeability (tight) sand*.**
- ***Fluid type*: black oil vs volatile oil vs condensate vs wet gas.**

System Type	Characteristics	Secondary migration	Poro-Perm Components	Examples
1 – 'Conventional' Tight *Reservoir ≠ Source*	Tight SS, siltstone, carbonate interbedded w/ lean, immature source rock; Black oil to dry gas	Significant	Inter-granular/ Inter-xline	*Spraberry* *Lewis Shale* *Mancos* *Mesa Verde*
2 - Hybrid/Interbedded *Reservoir ≠ Source*	Tight SS, siltstone, carbonate interbedded w/ rich, mature source rock; Light oil to dry gas	Moderate		*Bakken* *Bone Springs* *2nd White Specs*
3 - Porous Mudstone *Reservoir = Source*	Source rocks with significant inter/intra-grain porosity at oil to gas/condensate level of maturity; includes organic-hosted porosity	Minimal	Intra-granular	*Eagle Ford* *Haynesville* *Barnett* *Woodford*
4 - Fractured Mudstone *Reservoir ± = Source*	Mature source rocks with significant fracture porosity; Heavy oil to dry gas	Minimal	Fracture	*Monterey* *Woodford* *Austin Chalk* *Barnett*

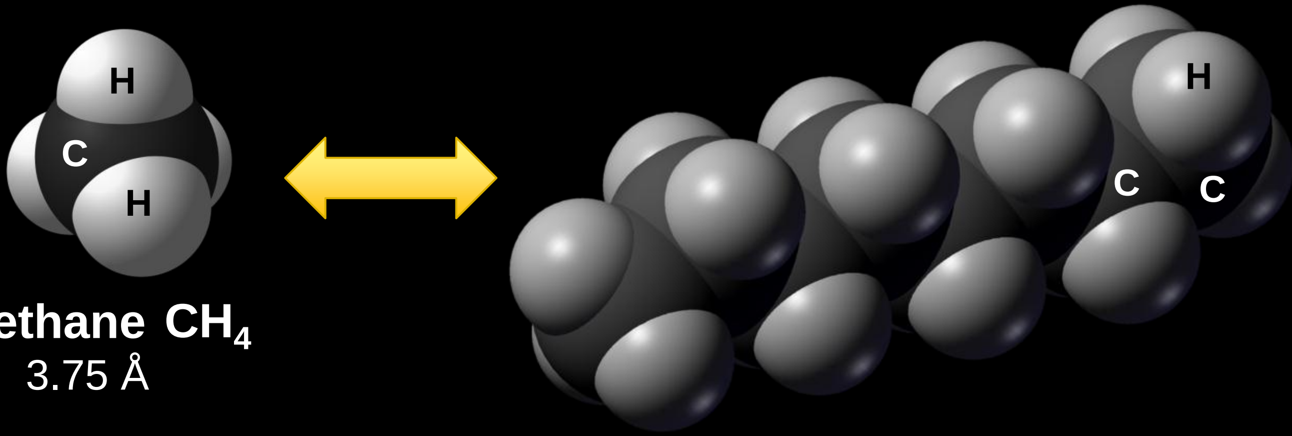
From Bohacs et al. (2013)

End Members

- ***Eagle Ford* (porous mudstone):**
  - ☞ **source = reservoir/no migration.**
- ***Bakken* (hybrid/interbedded):**
  - ☞ **source ≠ reservoir/migration.**

Technical Distinctions between Gas and Liquid Systems

Size matters (at least in gas versus liquids)



Methane CH_4
3.75 Å

Octane
C_8H_{18}
length 13.17 Å
height 4.85 Å

Why is this so important ?

☞ size of molecule relative to pore throat size is critical; differences between gas and liquid impacts production capabilities.

Molecular Interactions: Gas versus Liquid Forces

***gases* – molecular interactions (Van der Waals) versus *liquids* – viscous.**

✋ Gas shale learning's are of limited use in liquid-rich unconventional system.

Parameters critical for economically successful LRU play

Why is not every good source rock a good unconventional play?

	Parameter
SIZE	Scope
	Thickness
	Depth
RICH NESS	Shows
	OOIP
SOURCE	Level of Maturity
	TOC
HC	Oil Quality
FLOW	Permeabilty
	Porosity
	Pressure
Landing Zone	Thickness
	Definition
COMPLETION	Mineralogy
	Young's Modulus
	Poisson's Ratio
	Stress
	Seals

Charge System

- **Total Organic Carbon**: how much organic carbon.
- **Organic matter type**: type of organic matter.
- **Rock maturity**: maximum temperature.
- **Migration**: expulsion versus retained hydrocarbons.

Production

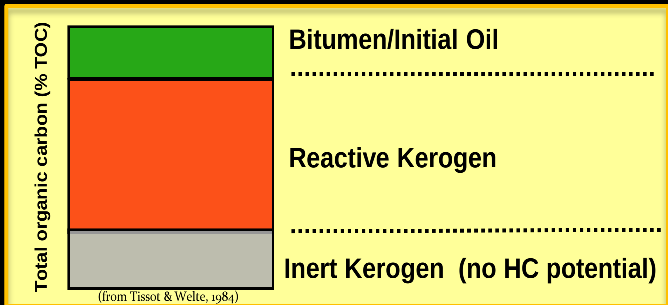
- **Storage**: where is hydrocarbon stored.
- **Flow**: rock permeability, porosity, and pore pressure.
- **Fluid properties**: original/changes with production.
- **Completions**: rock properties critical to fracability.

Economics

- **Drilling cost**: location and depth.
- **OOIP**: how much oil is in place.
- **EUR**: how much can you produce and at what rate.

Hydrocarbon Charge System

Whole rock analysis to evaluate both organic and inorganic components relative to petroleum generation, retention, and porosity development.



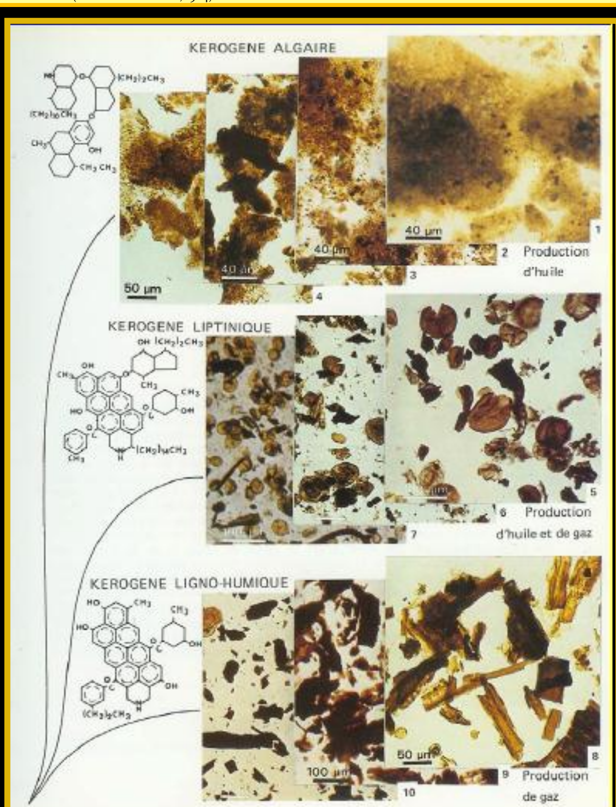


Image courtesy of Héctor Villar

Total Organic Carbon (TOC):

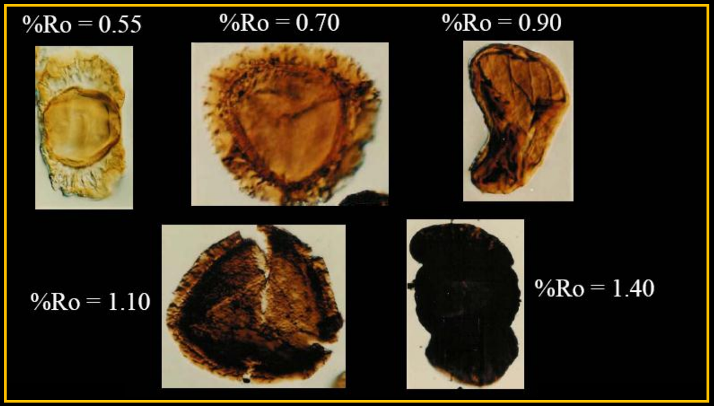
- Total organic carbon measurements? (Leco versus calculated SRA)
- What is minimum TOC required?
- Maturity impact on TOC value?
- Impact generated hydrocarbon on TOC?
- Impact mud additives on TOC?

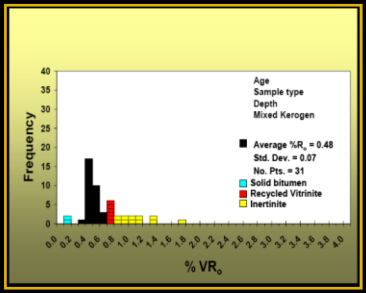
Organic Matter Type (OMT):

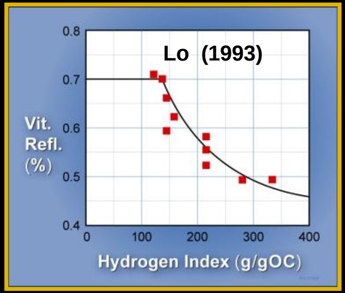
- Organic matter type determination? (pyrolysis, visual kerogen analysis, …..).
- Generation kinetics?
- Hydrocarbon product (oil versus gas)?
- Hydrocarbon composition?
- Impact on organic porosity.

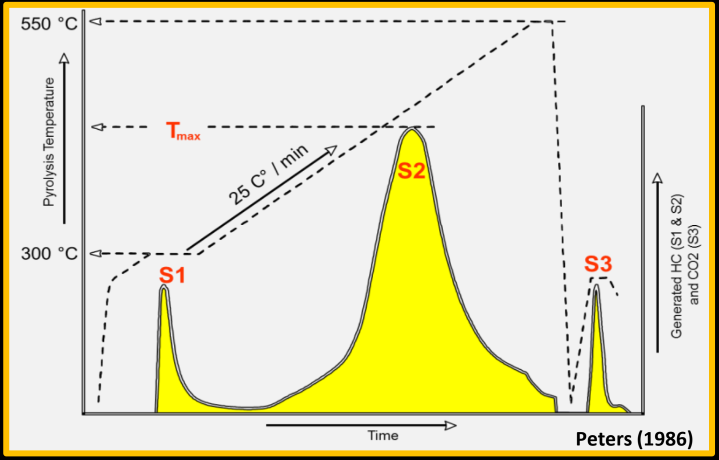
TOC and OMT critical measurements to understand liquid-rich unconventional system.

Hydrocarbon Charge System, cont.









Rock Maturity:

- Optimal maturity window hydrocarbon type?
- How to measure organic maturity?
  - ✓ Vitrinite reflectance.
  - ✓ Programmed pyrolysis Tmax.
- Potential issues:
  - ✓ vitrinite reflectance suppression.
  - ✓ reworked vitrinite reflectance.
  - ✓ absence vitrinite → age or deposition.
  - ✓ conversion Tmax to vitrinite reflectance.

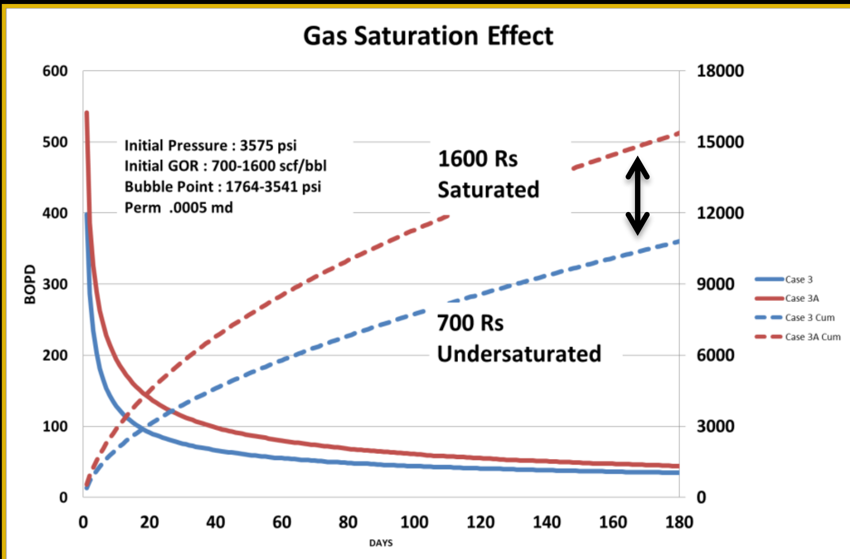
Migration/Explusion:

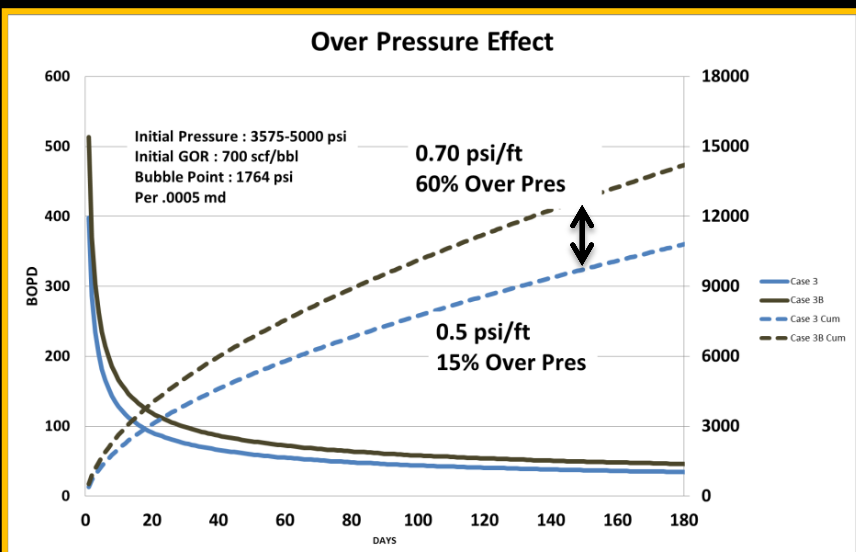
- How much hydrocarbon is retained?
- What is primary migration process?
- Role of generation micro-fracturing?
- Compound separation during migration?
- Production impact on retained hydrocarbons?

How does source/reservoir rock pore system impact the hydrocarbon charge?

Liquid-Rich Unconventional Development

What factors are critical in economic development of liquid-rich unconventional plays?





Images courtesy of Craig Rice

- ***Fluid Quality***: Type of fluid system and impact on production rates;
  - *Under-Saturated* (dead oil)
  - *Saturated*
  - *Liquids-Rich Gas* (volatile oil)

→ Fluid type driven by source rock organic matter type and level of maturity.

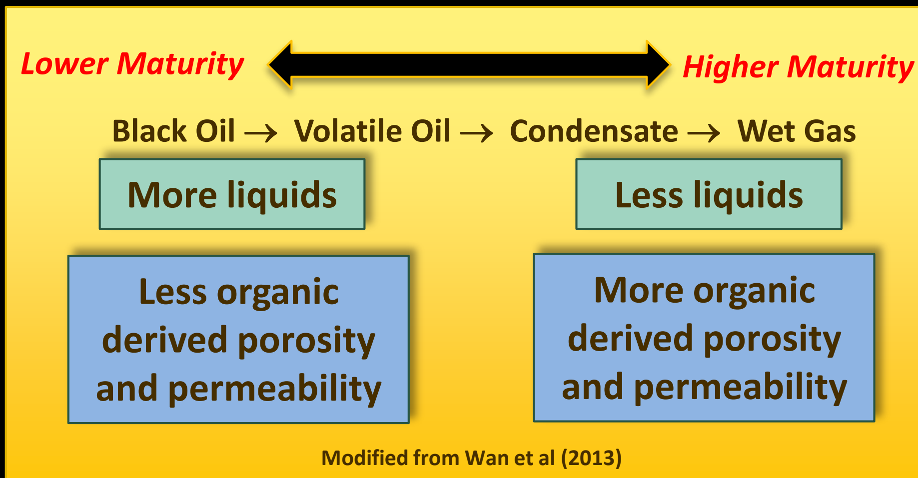
- ***Flow capacity***: Porosity, permeability, and pressure play major role in reservoir flow capacity.

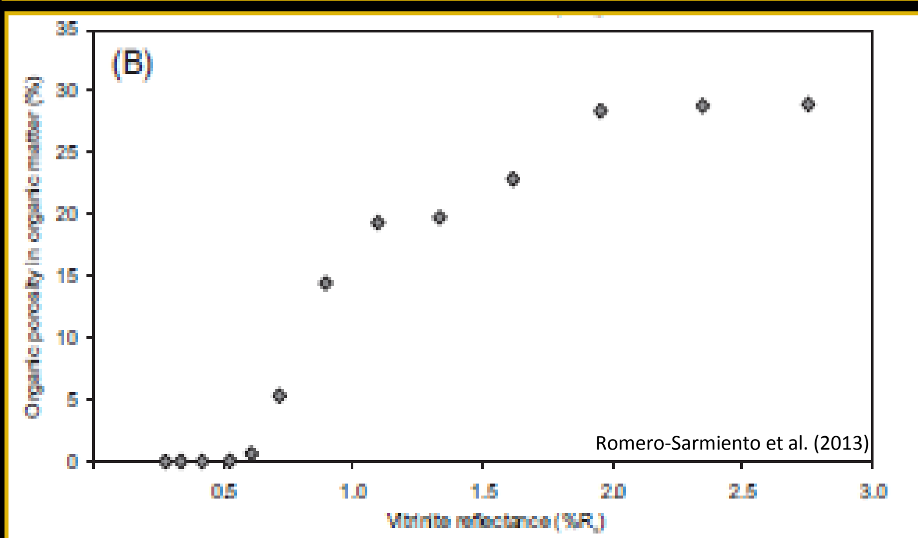
Depositional system, burial history, regional tectonics, and secondary changes all impact the three P's.

☛ Fluid quality and flow capacity have major impact to "swing the needle" on economics.

Organic P&P in Liquid-Rich Unconventionals

How important is organic porosity in liquid-rich unconventionals?





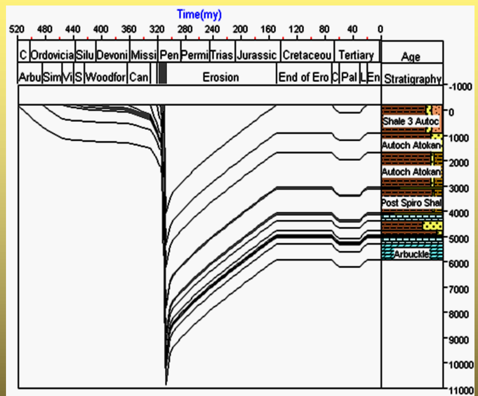
- Recent studies indicate organic porosity provides significant hydrocarbon storage potential in Liquid- Rich unconventional systems.
- Organic porosity impacted by thermal maturity and organic matter type.
- Additional work needed to better understand impact and build predictive model.
- Effective porosity requires connectivity within organic material as well as matrix (series or in parallel).

☛ How can we better understand if organic porosity is major contributor and if not, need to examine matrix for hydrocarbon storage.

Critical Factors for Evaluating Reservoir Fracability

How do we better understand rock fracability ?

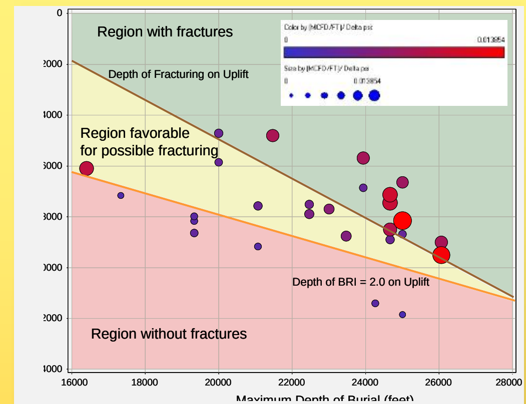
- ***Rock mineralogy***: **major impact on brittleness (ductile versus brittle).**
- ***Burial history***: **maximum depth, burial rate, and potential uplift.**
- ***Stress assessment***: **regional structural regime (amount and direction).**



- Burial and exhumation history timing
- Thermal gradient
- Gross geologic setting
- Geomechanics properties (if available)

Image courtesy of Steve Wilson

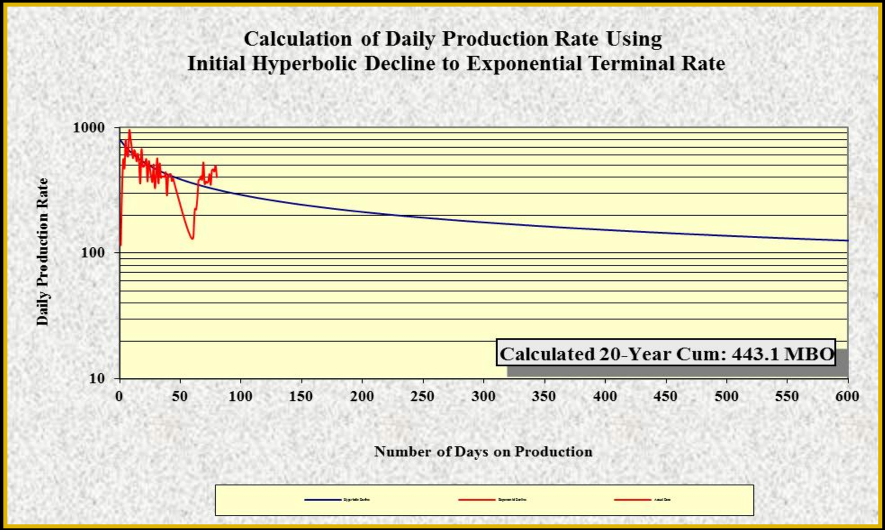
- Assessment of stresses ahead of drilling
- Identification of regions susceptible to fracturing
- Contributes to 'sweet spot' identification

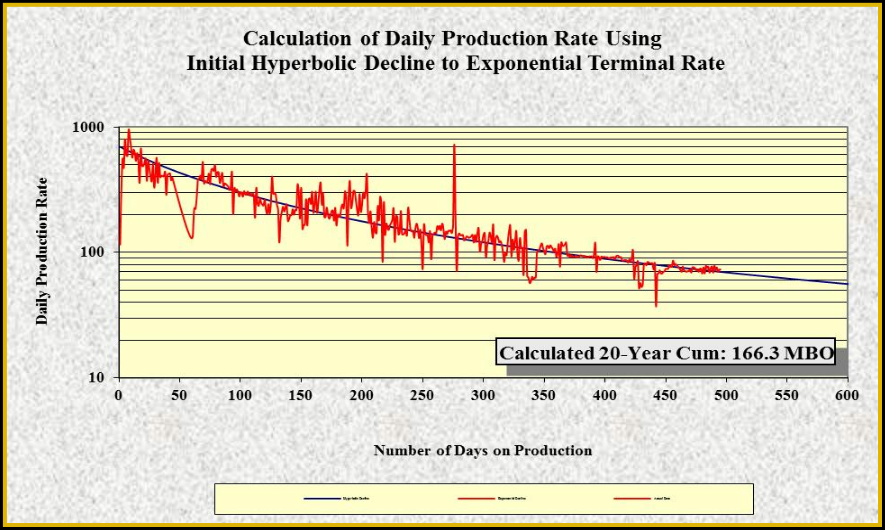


- Enhanced production occurs for optimal combinations of burial and exhumation
- Relatively simple screening tool for ranking access areas

Economically Successful Liquid-Rich Unconventional Play

How to evaluate production rates and ultimate recovery, Liquid-rich versus Gas unconventional systems ?





Images courtesy of Chuck Smith

Calculation of Daily Production and 20-year Cum

Initial hyperbolic decline using B factor = 2 to exponential terminal rate:

→ 443.1 MBO

Initial hyperbolic decline using B factor = 1 to exponential terminal rate:

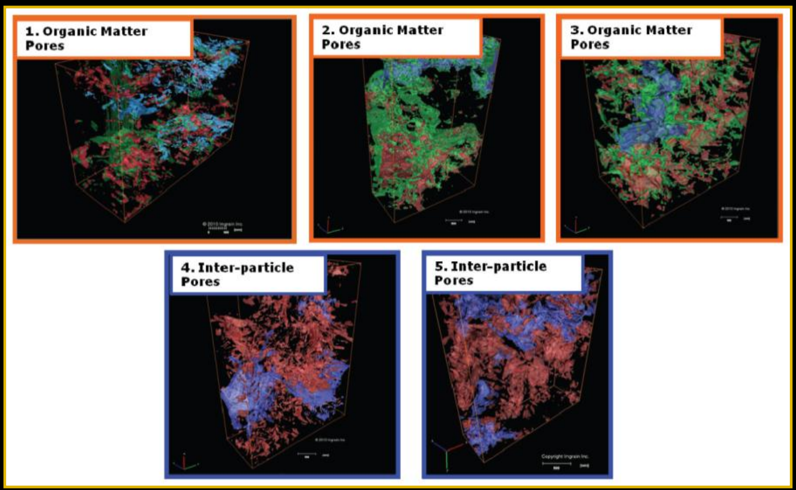
→ 166.3 MBO

- Initial decline fit misleading, resulting in incorrect Performance Prediction.

☛ Can decline curves be used to predict performance, if not how do we more accurately calculate?

Technology Developments
Understanding Liquid-Rich Unconventional Play

Significant advancements in imaging and analytical measurements are needed to better evaluate Liquid-Rich Unconventional Play.



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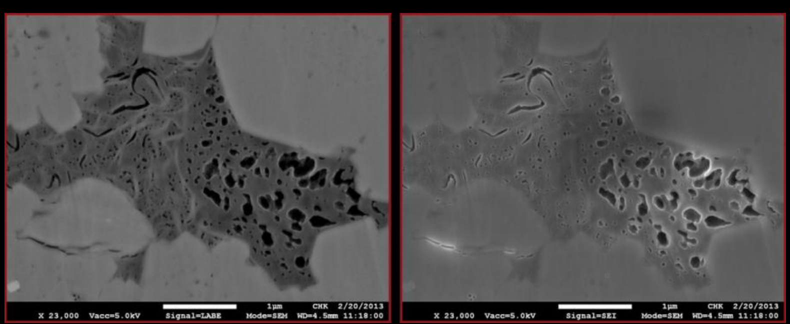


Leo Alcantar-Lopez and Steve J. Chipera (2013) Improving Our Understanding of Porosity in Source Rock Reservoirs through Advanced Imaging Techniques, URTeC 1619700

Imaging:

- Ability to image larger areas at higher resolution crucial to address upscaling.
- Automated software for stitching together high resolution images.
- Improvements in imaging processing?

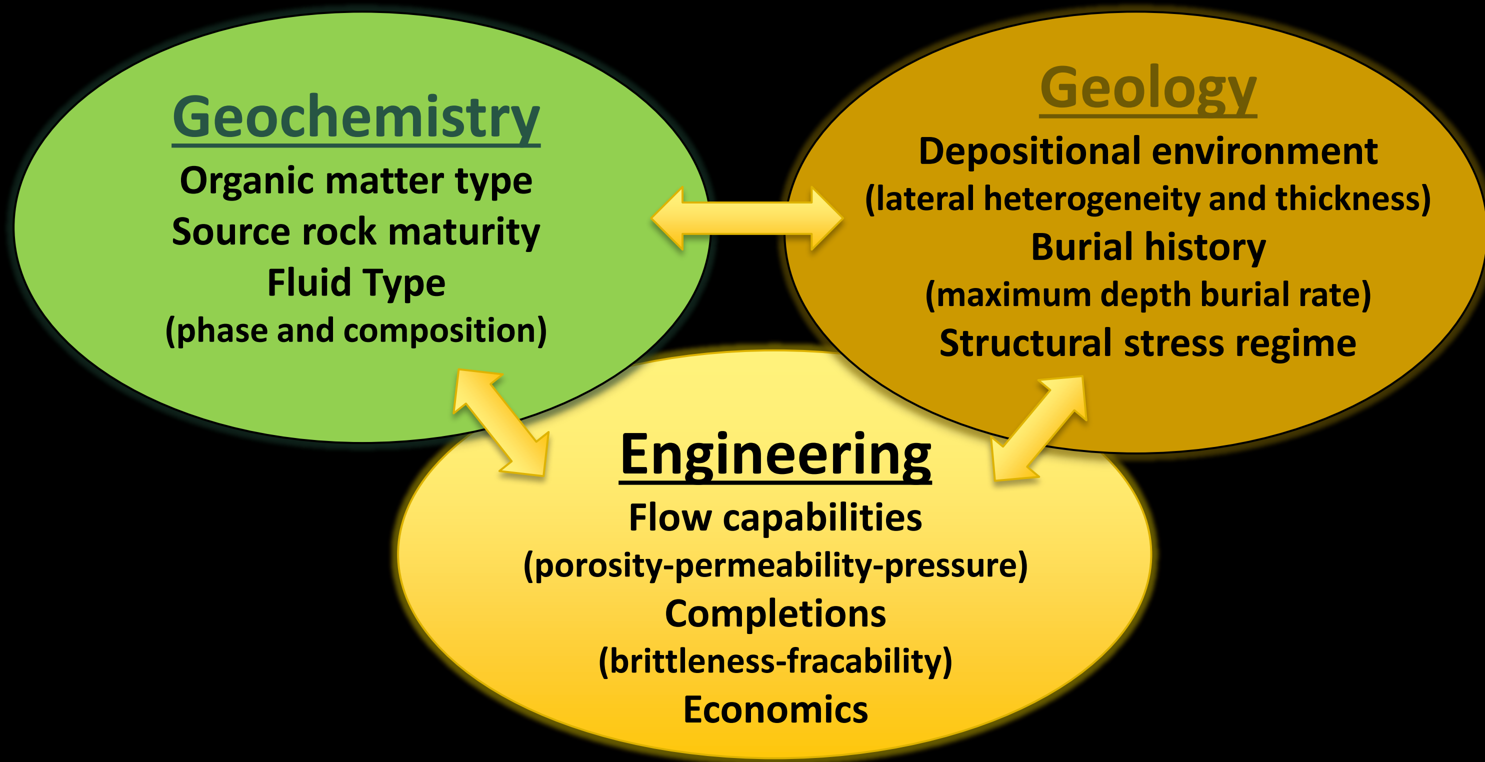
Source rock analysis:

- Look beyond conventional TOC, VKA, VR, SRA, and Rock-eval to characterize Liquid rich unconventional potential.
- Where are the new advancements ?

☛ **What new advancements and who is going to take the lead (academia, service companies, and/or industry)?**

Hydrocarbon Charge Considerations in Liquid-Rich Unconventional Petroleum Systems

Significant advancements in understanding the Liquid-Rich Unconventional Play yet we are still far from fully understanding how best to explore and develop.



Requires integration of geological, geochemical, and engineering experts to explore and produce an economic liquid-rich unconventional play.

Thank you

Michael Abrams, Joseph Curiale, Ross Clark, and Volker Dieckmann