Relationship Between Pore Geometry and Pore-Throat Geometry as a Means to Predict Reservoir Performance in Secondary Recovery Programs for Carbonate Reservoirs*

By

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Abstract

The purpose of this study was to develop a method by which a detailed porosity classification system could be used to understand the relationship between pore/pore-throat geometry, genetic porosity type, and facies. This study also investigated the relationships between pore/pore-throat geometry, petrophysical parameters, and reservoir performance characteristics. The focus was on the Jurassic Smackover reservoir rocks of Grayson field, Arkansas. This three part study developed an adapted genetic carbonate pore type classification system and used petrographic image analysis and mercury-injection capillary pressure tests to calculate pore/pore-throat sizes. These were compared to facies, pore type, and each other showing that pore-throat size is controlled by pore type and that pore size is controlled primarily by facies. Pore size range can be estimated from pore type and median pore-throat aperture. Capillary pressure data was used to understand the behavior of the dependent rock properties. It was determined that size-reduced samples tend to show similar dependent rock property behavior, but size-enhanced samples show dispersion. Capillary pressure data was used to understand fluid flow behavior of pore types and facies. Oncolitic grainstone samples show unpredictable fluid flow behavior compared to oolitic grainstone samples, yet oncolitic grainstone samples will move a higher percentage of fluid. Size-enhanced samples showed heterogeneous fluid flow behavior while the size-reduced samples could be grouped by the number of modes of pore-throat sizes. Finally, this study used petrographic image analysis to determine if 2-D porosity values could be compared to porosity values from 3-D porosity techniques. The heterogeneous pore network found in the Grayson reservoir rocks prevents the use of petrographic image analysis as a porosity calculation technique.

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Petrophysical Analysis- ConocoPhillips

M.S. Geology TAMU 2007

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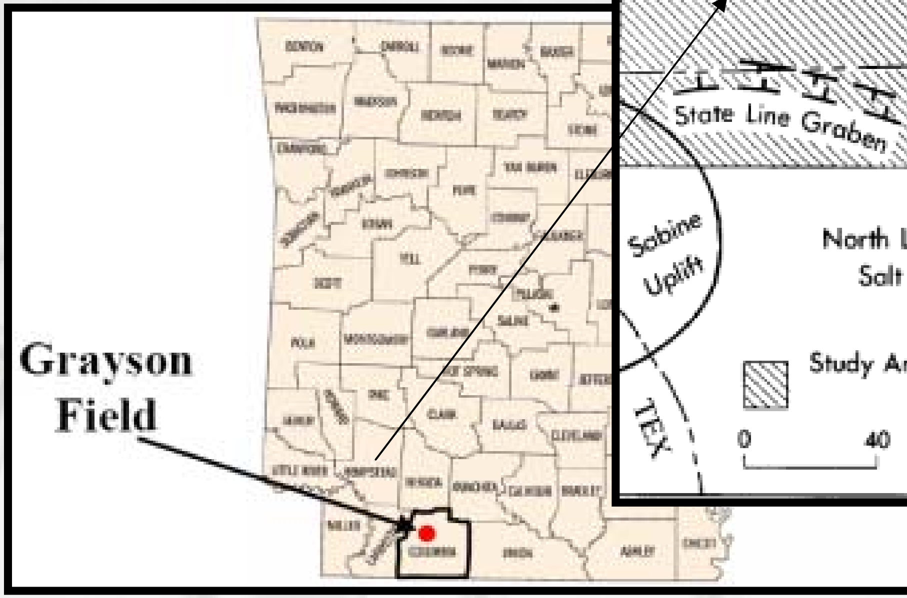
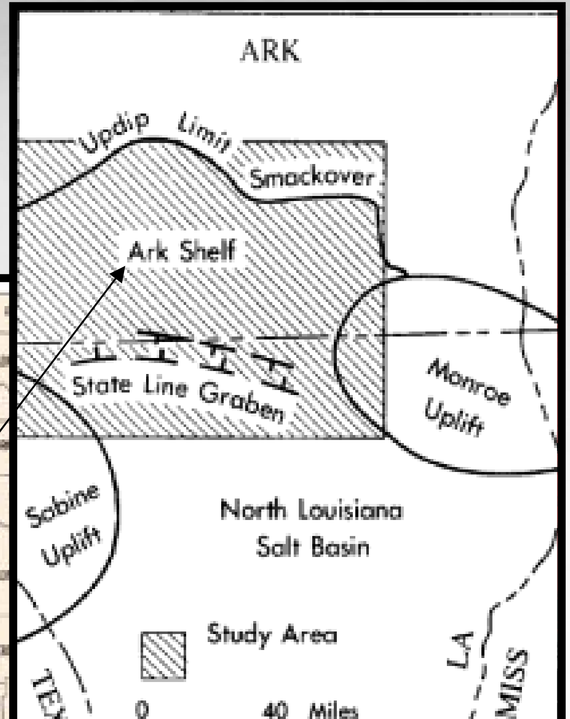
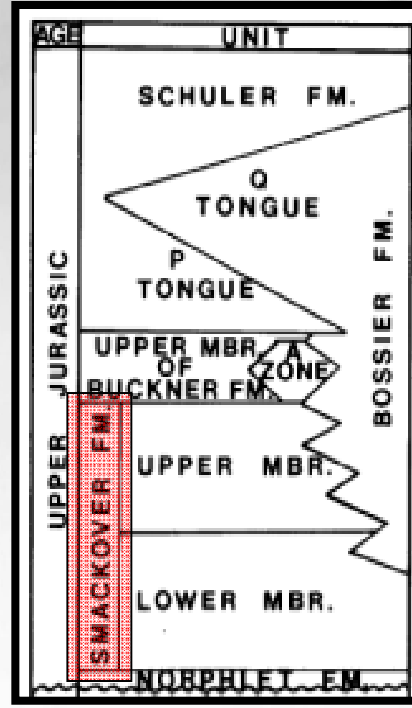
Outline

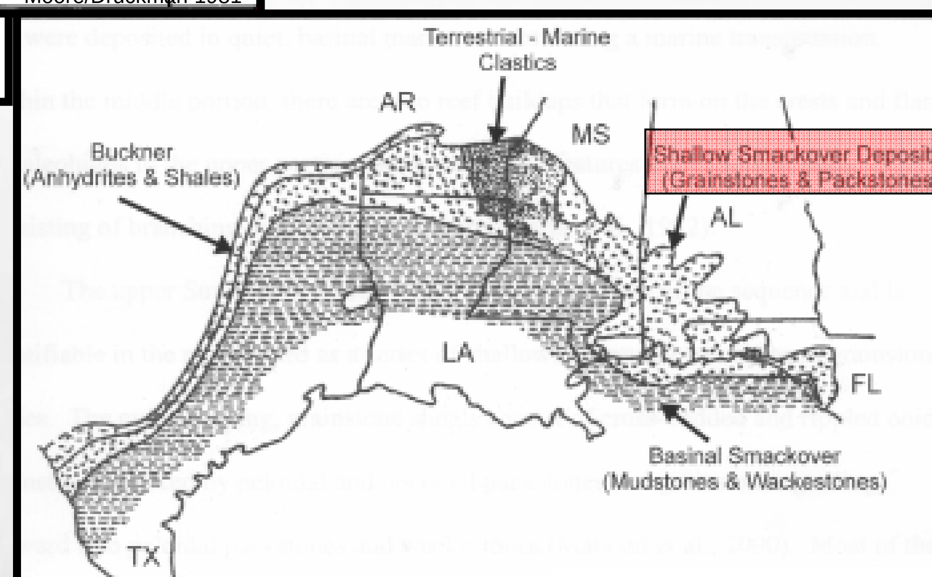
- Scope of Study
- Pore Type Classification
- Pore size, Pore-throat size, and Pore type Correlations and Petrophysical Attributes
- Pore-throat size, Pore type, and Flow
- Recommendations





Modified from Moore/Druckman 1981





Modified from Ahr, 1973

Study Scope

Objective

To improve the efficiency of secondary recovery by:

- developing a unique porosity classification system to understand the relationship between pore/pore-throat geometry, genetic porosity type, and facies
- investigating the relationships, between pore/pore-throat geometry and petrophysical parameters

And gain an overall better understanding of how the dependent rock properties can affect recovery

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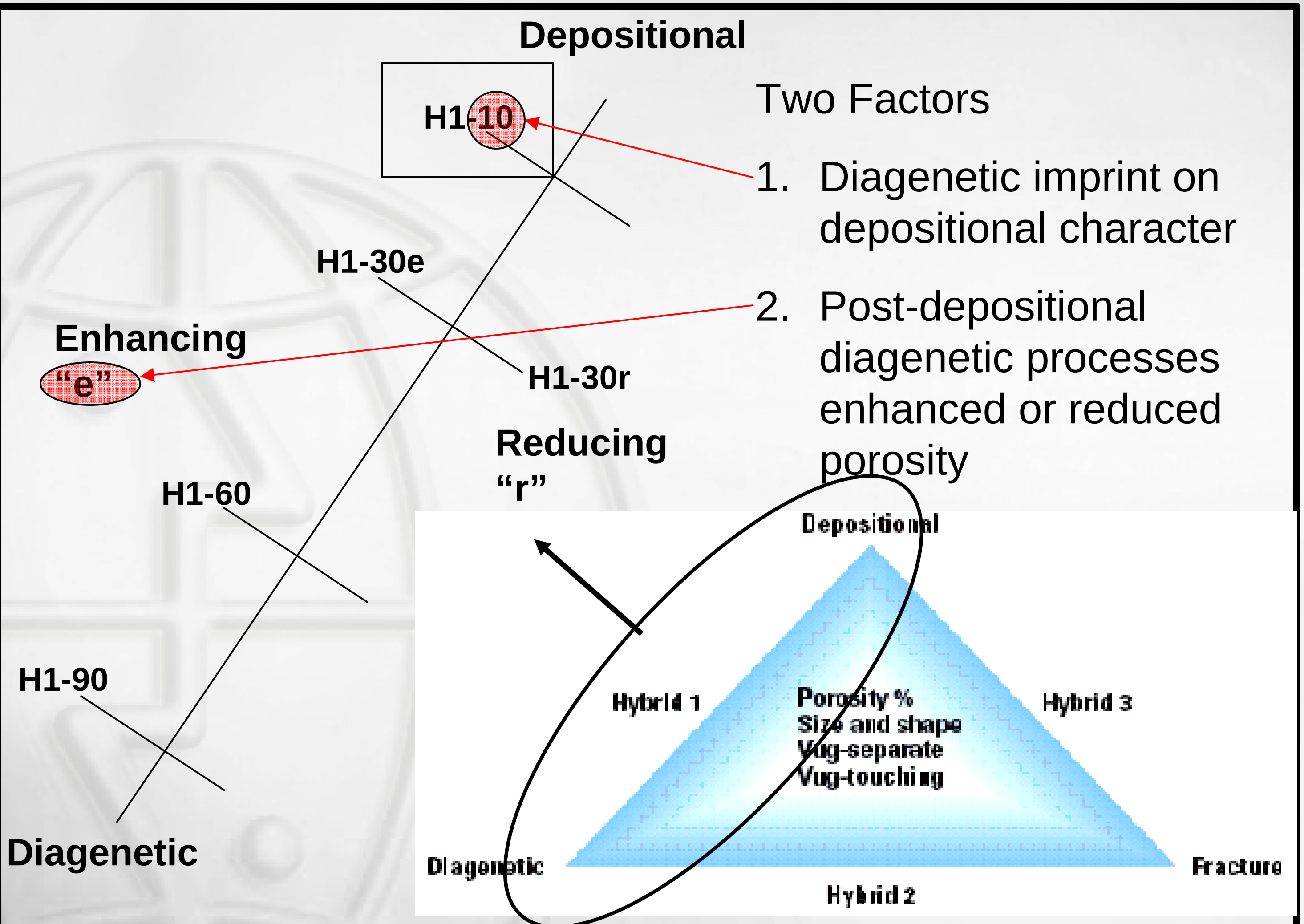
Pore Type Classification-

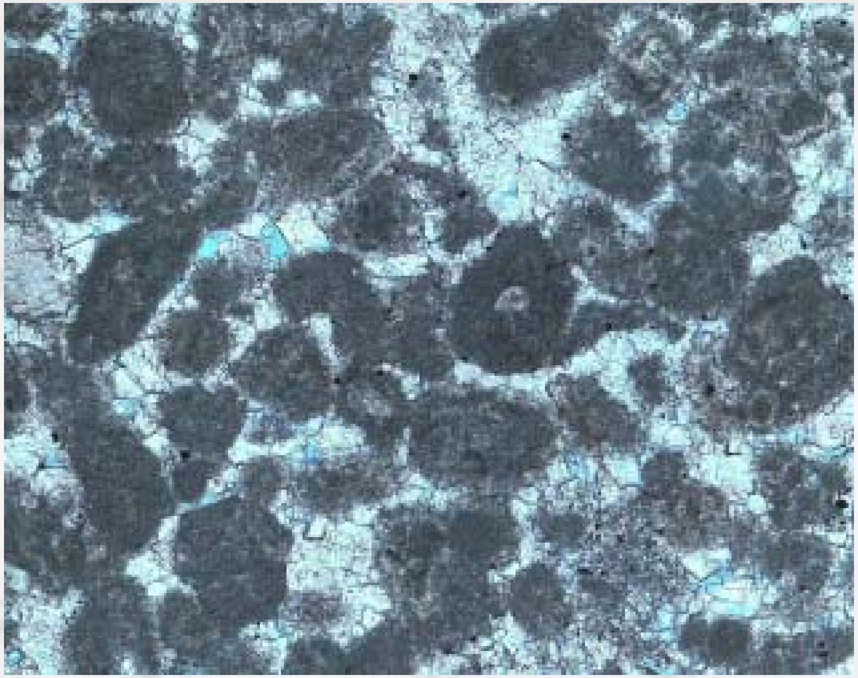
Need a more detailed scale for Hybrid 1 pore types



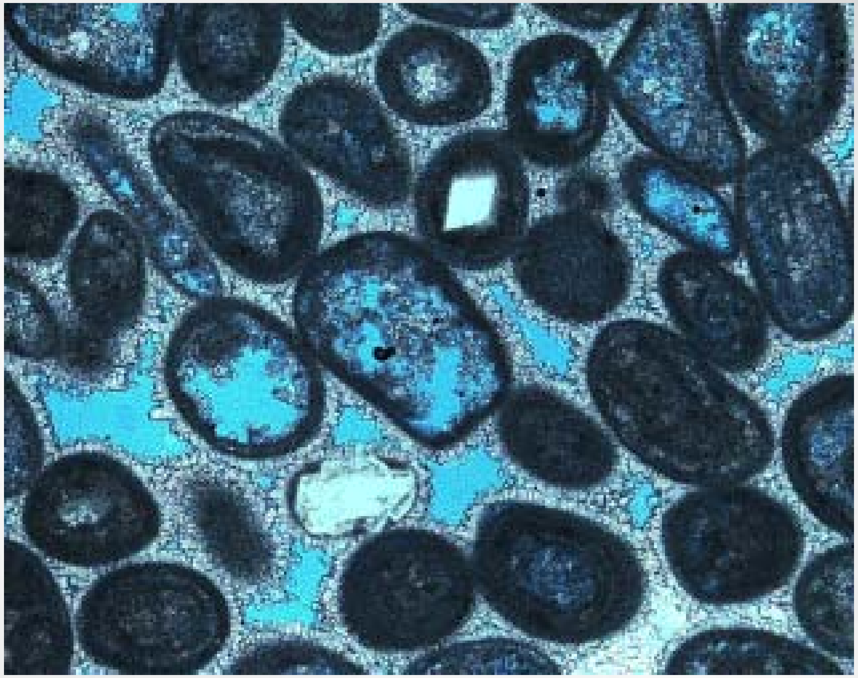
Two Factors

1. Diagenetic imprint on depositional character
2. Post-depositional diagenetic processes enhanced or reduced porosity

Pore Type Classification



Hybrid 1 30% reducing



Hybrid 1 30% enhancing

DEPOSITIONAL ⟶ Hybrids with varying degrees of diagenetic influence i.e. enhancing or reducing 10 - 90% ⟶ DIAGENETIC

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Pore Type Classification

Depositional

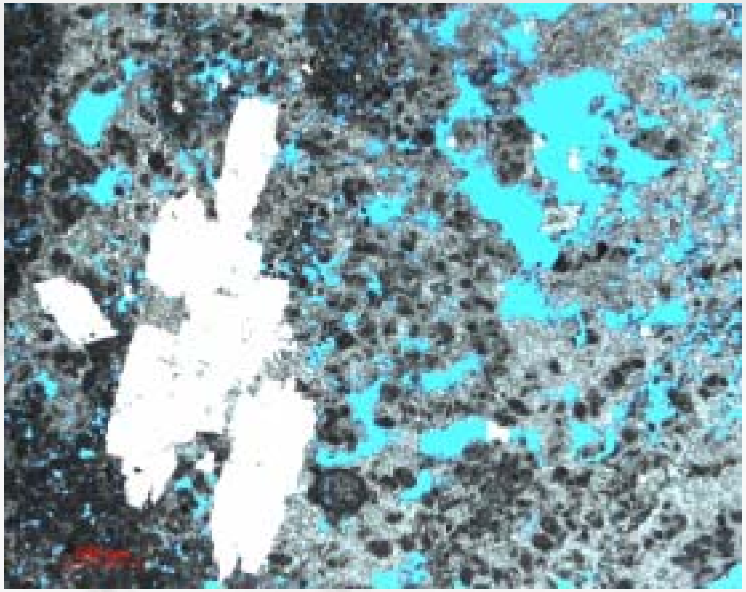
H1-10e

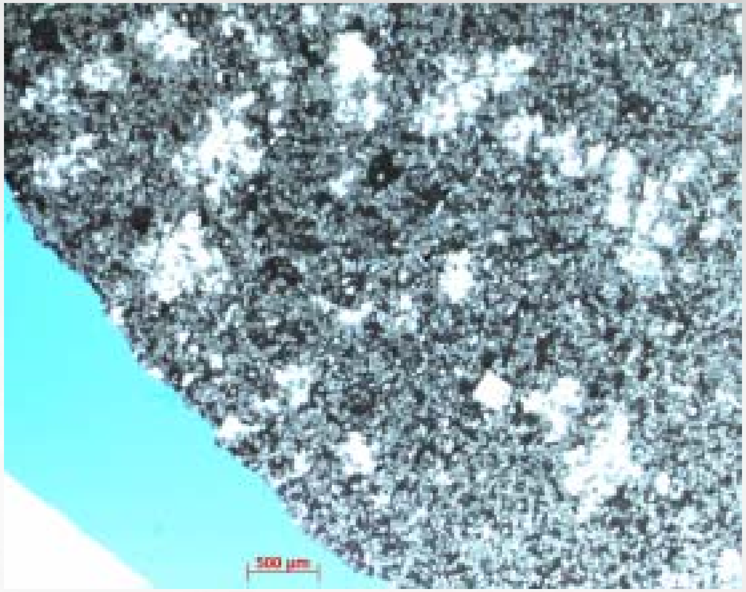
H1-60e

H1-60r

H1-90e

Diagenetic





Pore Type Classification- Example of detailed classification chart

Pore Type-Porosity Factors	Causes (in order of abundance)	Facies		Pore Type	Pore Type Occurrence
Enhanced (e)	A. Dissolution of solid rock, pore filling and rim cements, and replacement mineral grains	Grain Supported	G/P 1	H1-30e	3
				H1-60e	4
				H1-90e	1
			G/P 2	H1-10e	5
			P/W	H1-30e	4
				H1-30e	1
				Diag	1
	B. Dolomite grain replacement	Dolostone		Diag	1

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Pore and Pore-throat size Correlations and Petrophysical Attributes- Work Flow

Pore Size-

Petrographic Image Analysis

Aquire Digital Images:

20-30 adjacent fields-of-view

~4-5mm at 25x

→

Process Digital Images:

Define area of interest

Select objects with false color (pores)

Measure objects i.e. **pore size in area *mm*²**

Pore-throat Size

Mercury-Injection Capillary Pressure

→

1. Median pore aperture diameter →**pore-throat size in area *µm*²**
2. Capillary pressure → **J-functions**
3. Cumulative Intrusion → **Lorenz Curves**

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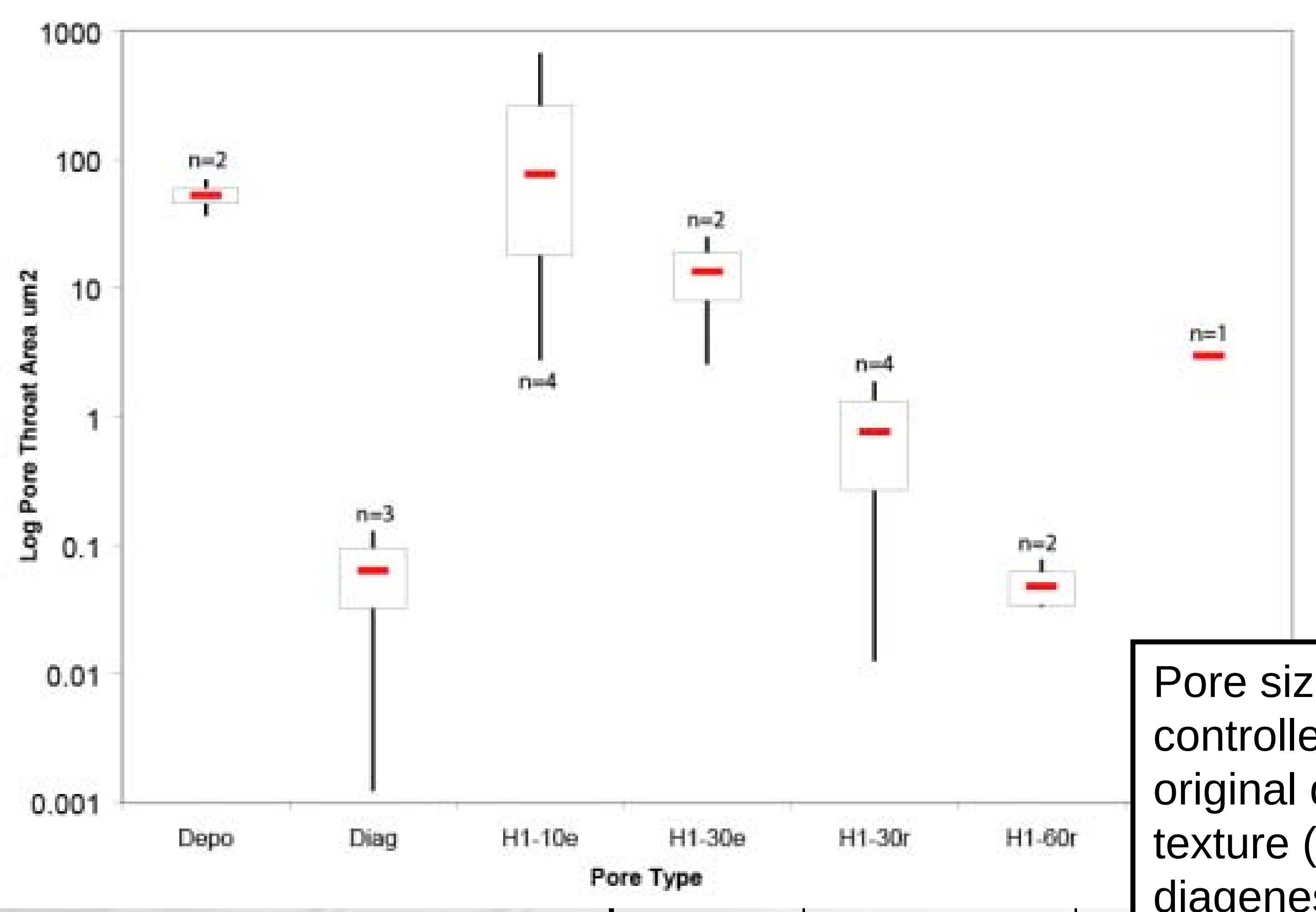
Pore and Pore-throat size Correlations and Petrophysical Attributes- 1. Categorize pore/pore-throat areas by pore type



	e/ e 2	Packstone/ Wackestone
1		
2		
3		
4		1
		1
5		

Diag			

Pore size is primarily controlled by the original depositional texture (facies), while diagenesis has secondary control.

Pore and Pore-throat size Correlations and Petrophysical Attributes- 2a. Quick-look tables to determine pore size ranges by facies

		Pore Type	
Facies	**Depositional**	**Enhanced**	**Reduced**
Oolitic Grainstone	>0.0001mm^2	<0.00005mm^2	<0.00005mm^2
Oncolitic Grainstone	<0.00005 to >0.0001 mm^2	<0.00005 to 0.0001 mm^2	<0.00005 to >0.0001 mm^2
Packstone/ Wackstone	<0.00005mm^2	<0.00005mm^2	<0.00005mm^2
Dolostone	Below Detection	Below Detection	Below Detection

Pore size is primarily controlled by the original depositional texture (facies), while diagenesis has secondary control.

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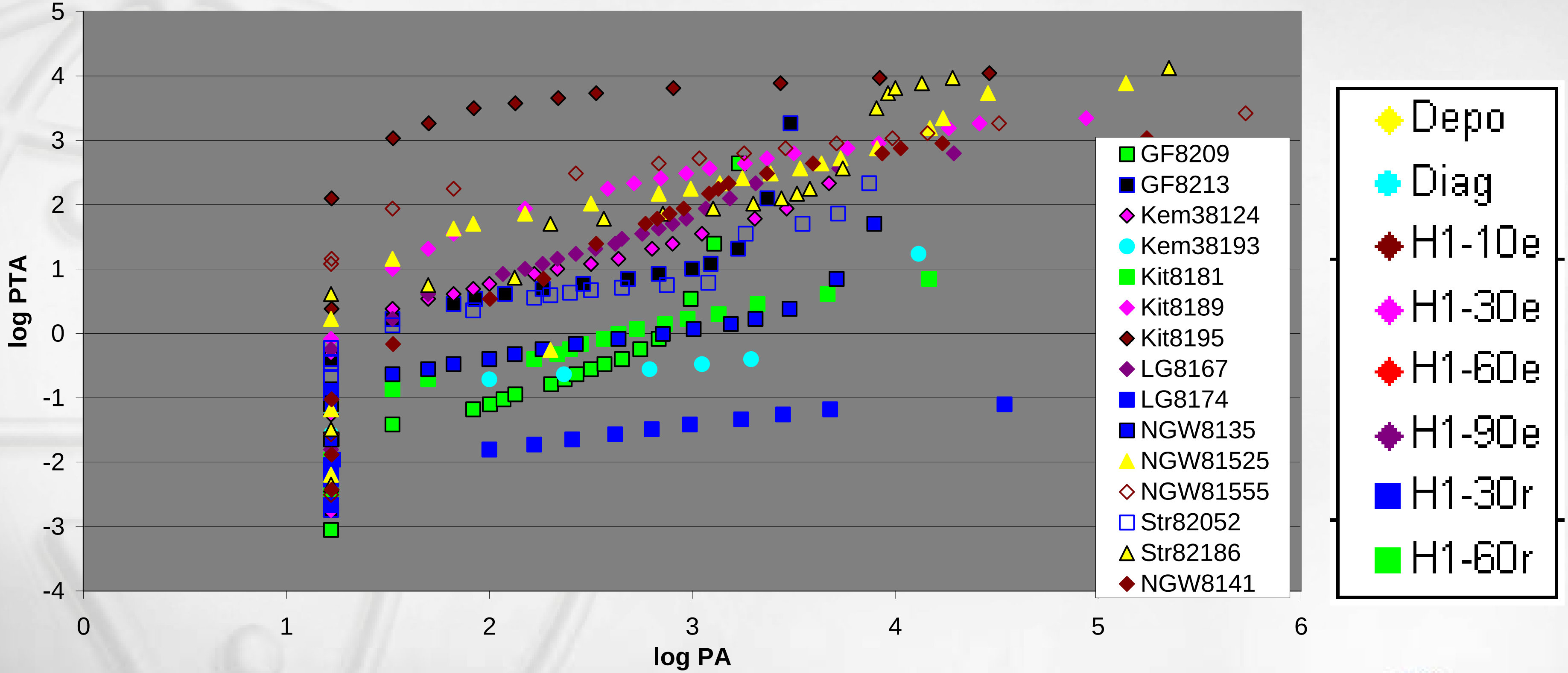
Pore and Pore-throat size Correlations and Petrophysical Attributes- 2. Quick-look table to determine pore-throat size ranges by pore type

		Pore Type	
	Depositional	**Enhanced**	**Reduced**
Pore-Throat Size (*µm²*)	20 to 100µm²	1 to 100µm²	<1 to 20µm²

Diagenetic pore-throat enhancement does not generally increase the throat size beyond that of the original depositional size, but prevents them from becoming closed-off.

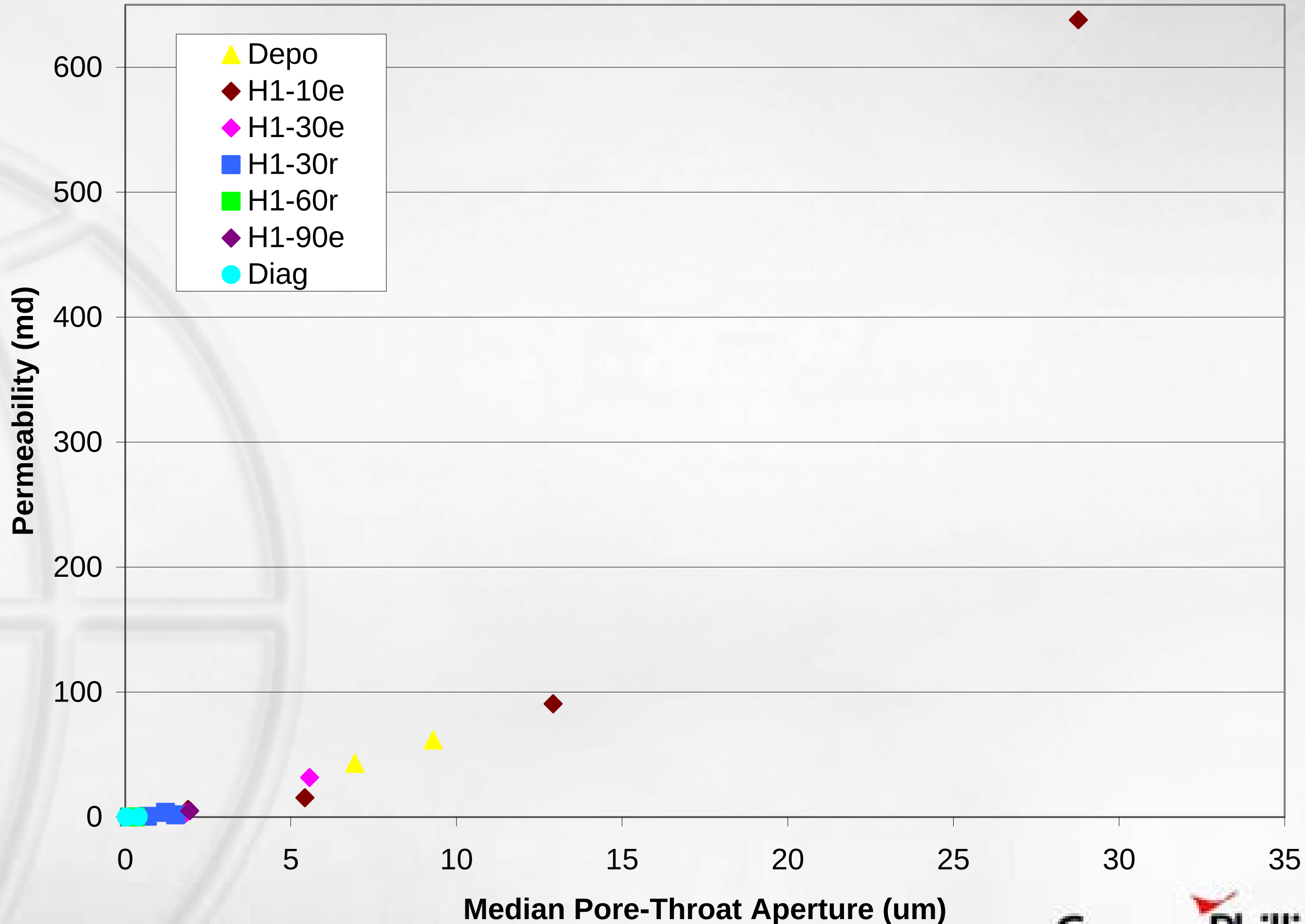
Pore and Pore-throat size Correlations and Petrophysical Attributes- 3. Relating pore size to pore-throat size

Knowing pore-throat size and pore type can help to estimate pore size.



Pore and Pore-throat size Correlations and Petrophysical Attributes- 4. Pore-throat size and petrophysical parameters

Not only is the correlation between permeability and pore-throat very strong, but there is also a clear division by pore type.



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Pore and Pore-throat size Correlations and Petrophysical Attributes- 4. Pore-throat size and petrophysical parameters

Pore Type	**Permeability Quality**	**Flow Unit Quality**	**Permeability Range (md)**	**Pore-Throat Size Range (µm)**	**Notes**
Reduced	Low	Poor	0-2	0-1.5	Should apply consistently
Enhanced	Mediu	Moderate	2-40	1.5-6	For H1-10e pores depends on the PTS
Depositional and H1-10e	High	High	>40	>6	Should apply consistently for depo and H1-10e PTS >6µm

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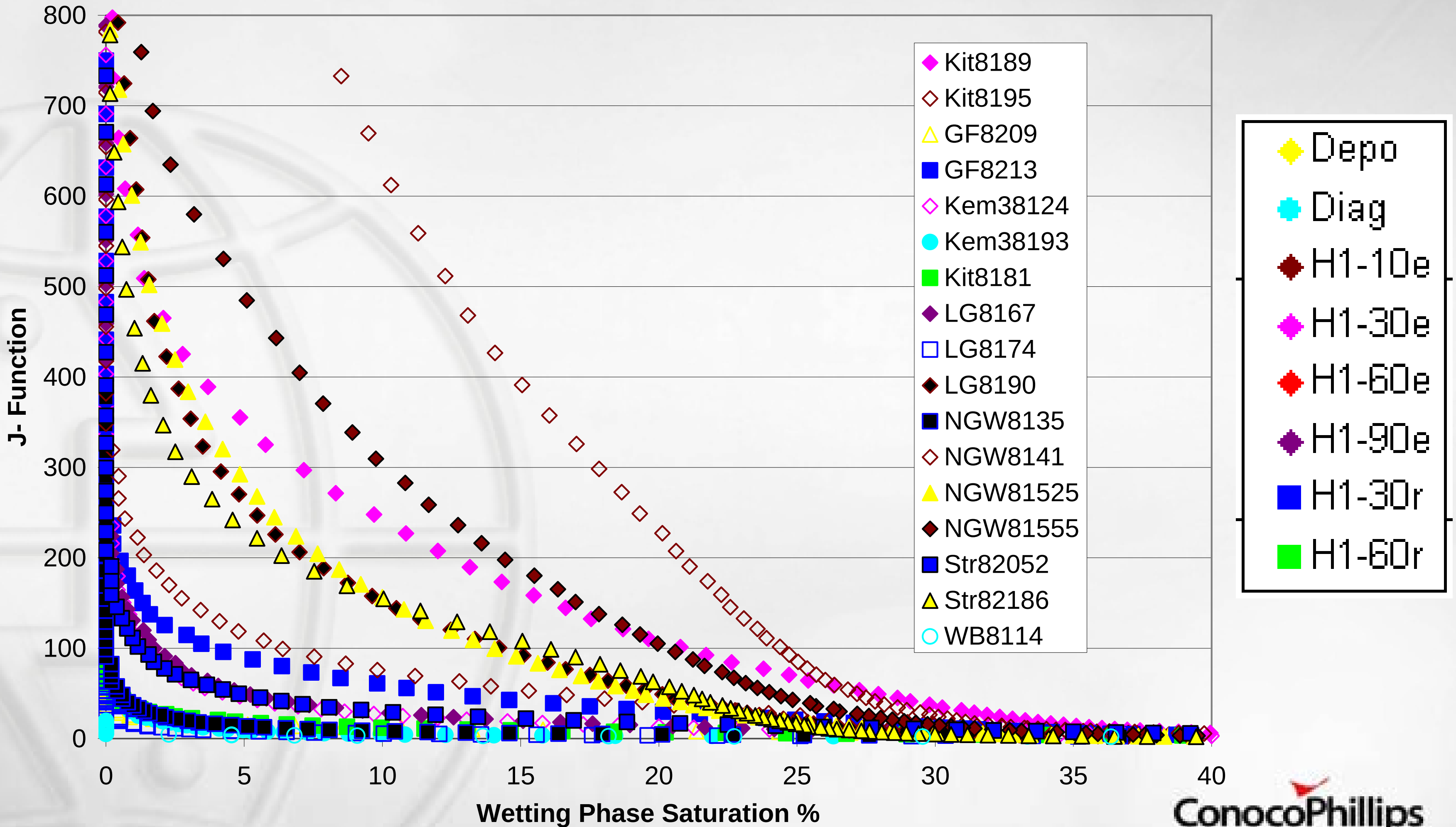
Pore and Pore-throat size Correlations and Petrophysical Attributes- 5. Pore Types and Dependent Rock Properties through J-Functions



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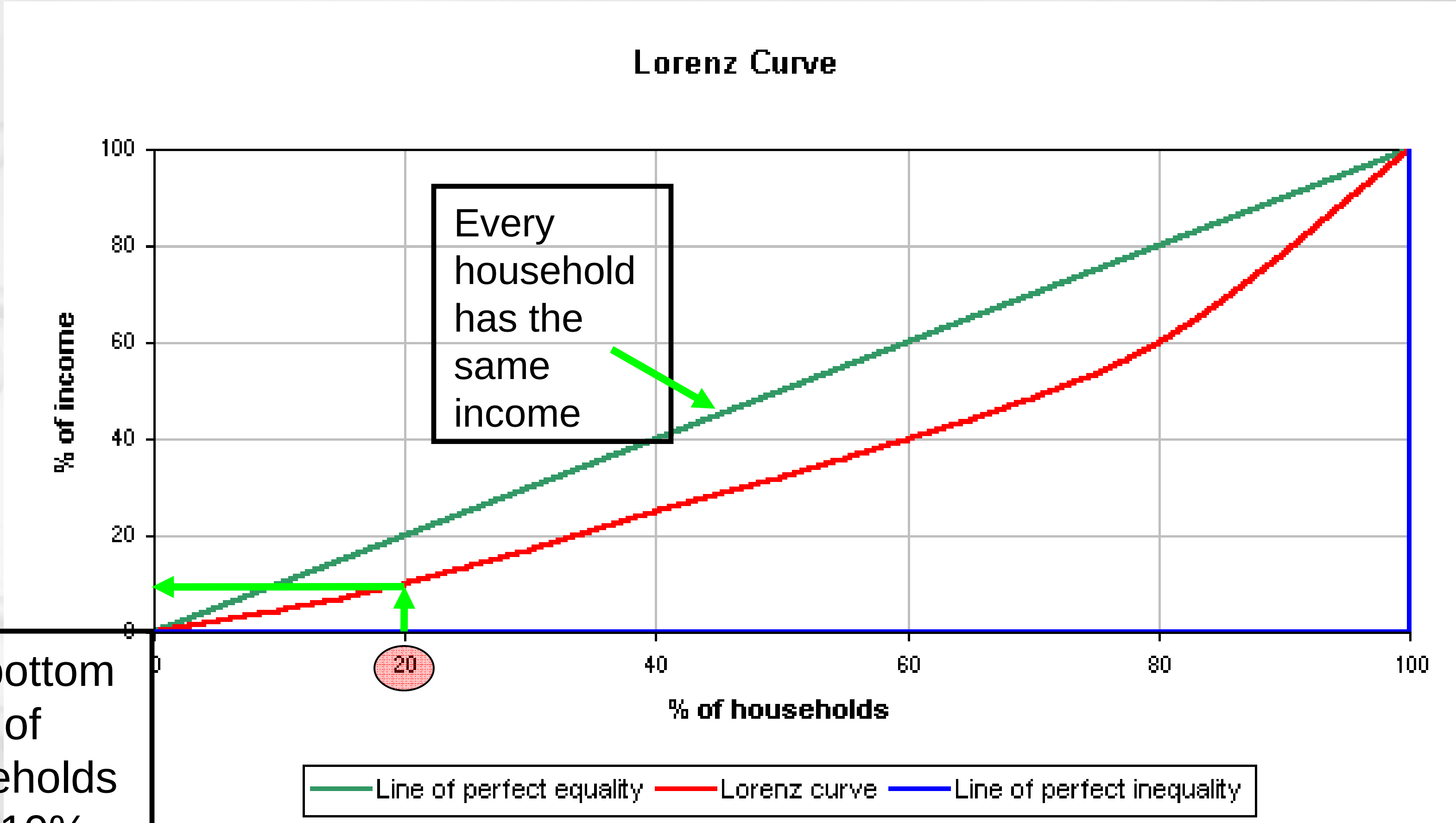
Pore-throat size and Flow- Lorenz Curves

Originally developed to explain income distribution



The bottom 20 % of households have 10% of the total income

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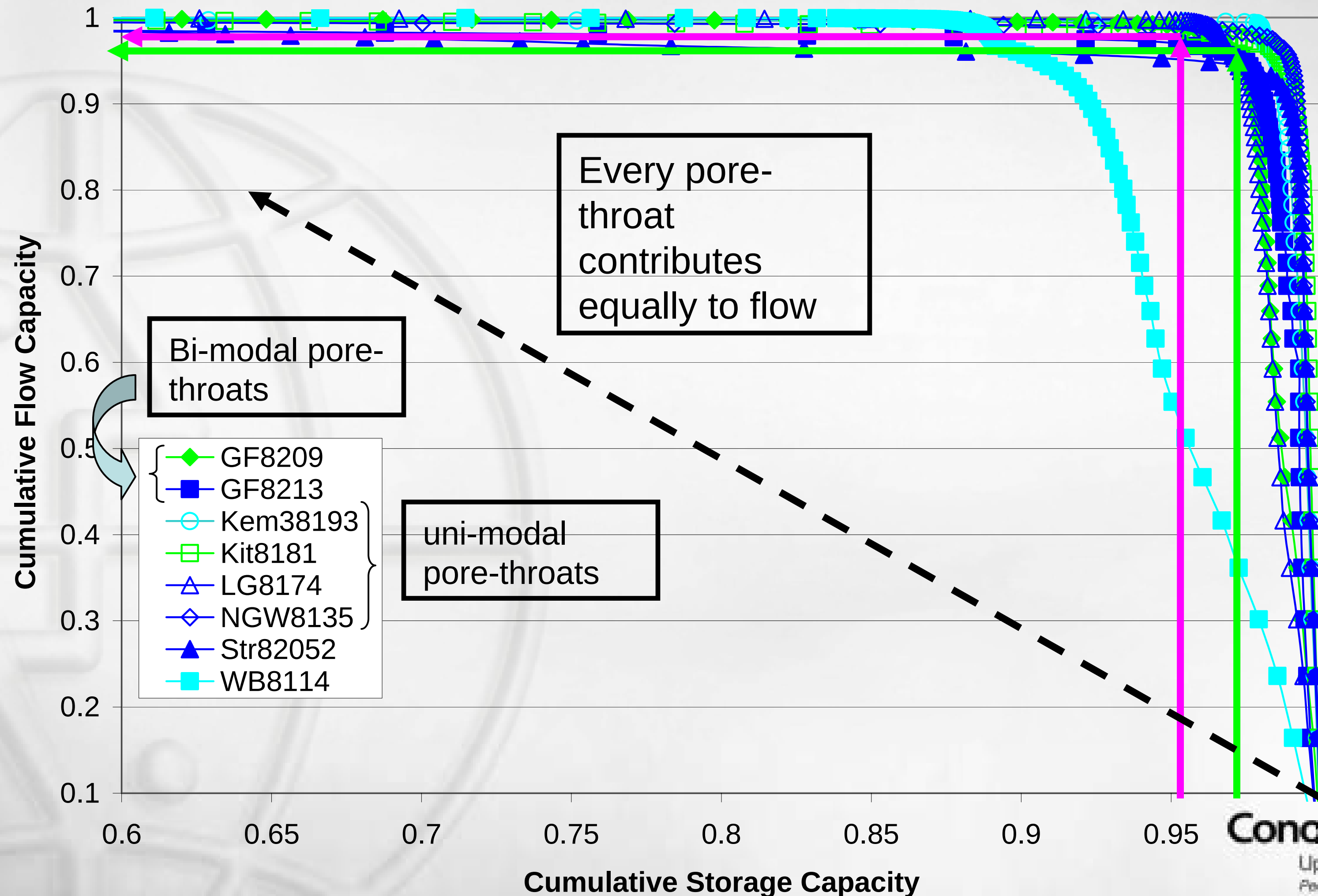
Pore-throat size and Flow- Lorenz Correlations

Reduced pore type fluid flow can be grouped by the number of pore-throat modes.



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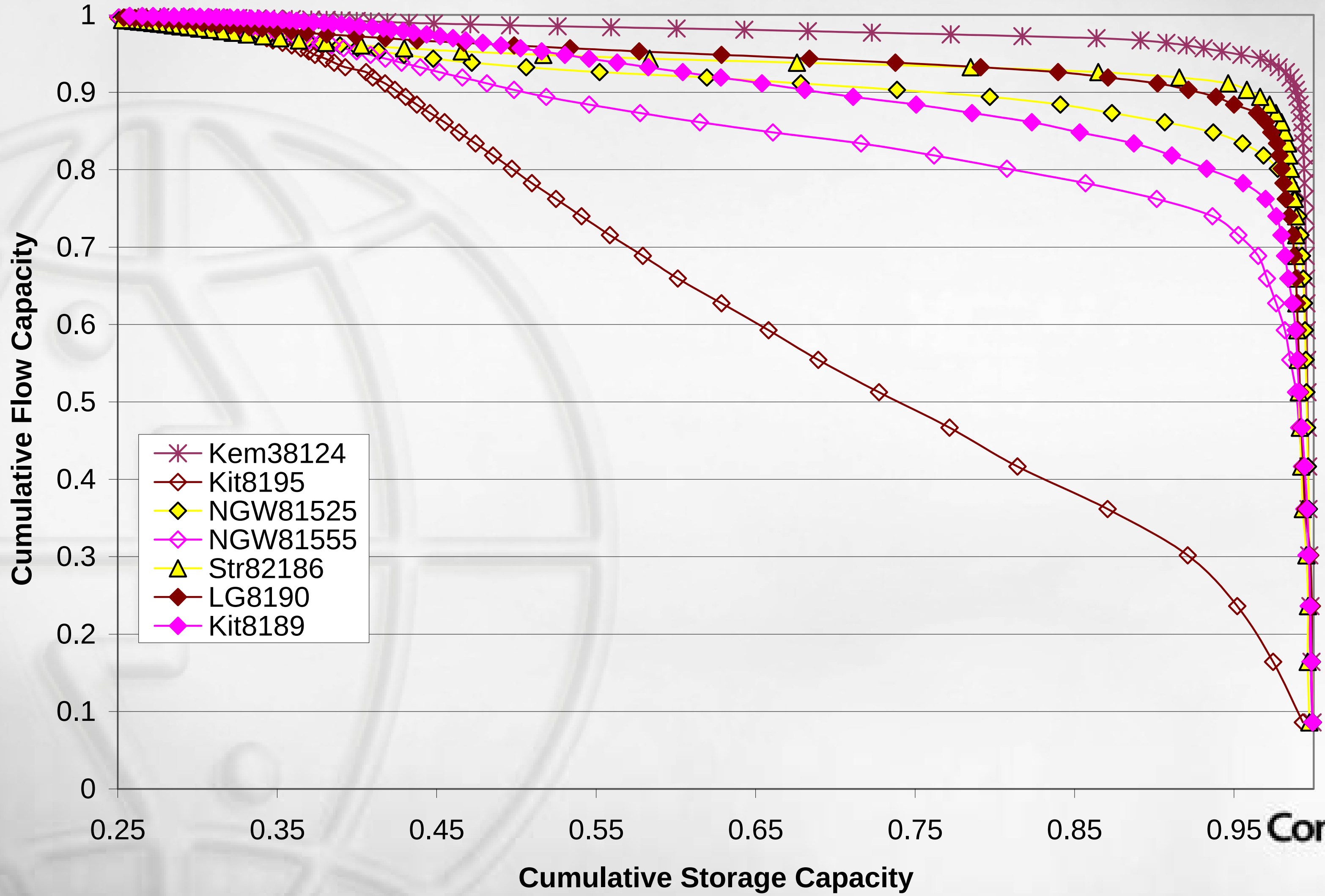
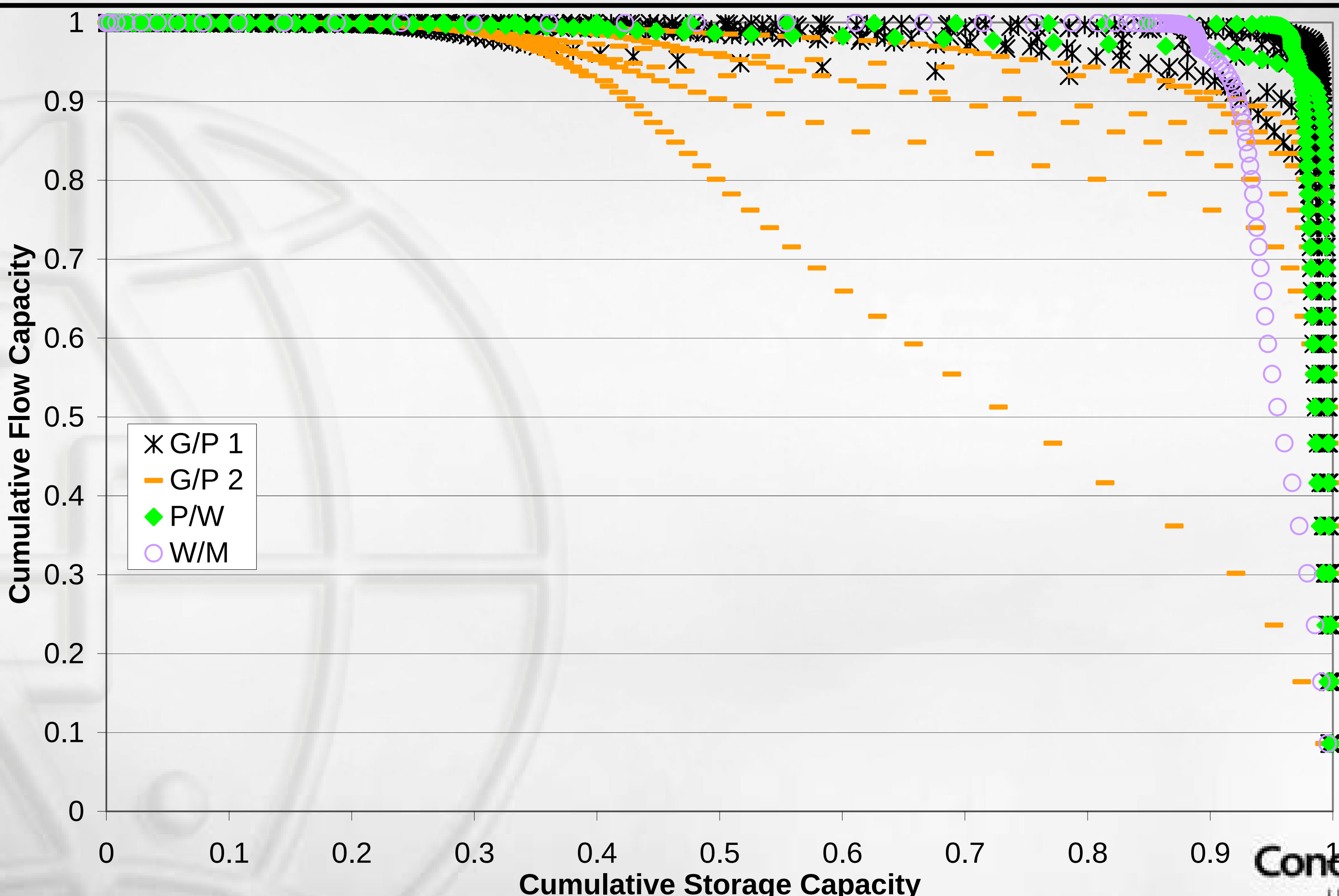
Pore-throat size and Flow- Lorenz Correlations

Enhanced is tricky.



Pore-throat size and Flow- Lorenz Correlations

Oolitic grainstone has more predictable fluid flow behavior, although oncolitic grainstone traps less fluid.



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Thus . . .

- Conclusion:
  - Pore typing through descriptive characterization of the degree and type of diagenetic processes distinctly separates different rock types by their dependent rock properties, petrophysical parameters, and flow capacity.
- Key is:
  - spatial distribution
- Why?
  - Both J-function and Lorenz curves show that enhanced and reduced pore type groups have distinctly unique dependent rock properties and fluid flow characteristics
- Goal:
  - With the help of a detailed chronostratigraphic study, correlate pore type locations across the field (from facies) and by extension determine the spatial distribution of the dependent rock properties and fluid flow behavior.

Acknowledgments

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