Non-traditional Techniques for Microporosity Evaluation in a Low-Permeability Carbonate Reservoir From a Giant Reservoir Offshore Abu Dhabi, U.A.E*

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Abstract

Recently, matrix related microporosity has been recognized as an important control on transmissivity and storage capacity of hydrocarbons. With the advancement of completion technologies for low-permeability reservoirs, quantifying the matrix-related micro-porosity, understanding pore size and pore throat distributions as well as tortuosity has become increasingly important. Traditional methodologies for porosity characterization developed for conventional reservoirs are often inadequate for low permeability, microporous reservoirs. This study focuses on microporosity characterization in carbonate mudstones and wackestones. Low permeability core plugs from a Lower Cretaceous aged reservoir were evaluated and 5 distinct reservoir facies were identified based on detailed core and thin section description. Porosity is estimated for each lithofacies by petrographic image analysis as well as a new technique for porosity determination from QEMSCAN® (quantitative evaluation of minerals and porosity by scanning electron microscopy) analysis (Jobe et al 2013, in prep). Estimated porosities are compared to measured porosity from a CMS-300® (core measurement system) automated permeameter. Furthermore, porosity and pore throat distributions are determined by Mercury porosimetry and Nitrogen gas adsorption experiments in order to capture both micro- and nanopore distributions. A comparison of porosities from each analytical technique is presented. In addition to porosity, the permeability and specific surface areas are measured and tortuosities are calculated. Results of the study show distinct differences in porosity, permeability, surface area and tortuosity among the lithofacies, despite their seemingly similar mudstone to wackestone textures. Pore size distributions indicate bimodal pore distributions that are in the micro to nanoporosity range. In general the porosities reported from Mercury porosimetry, nitrogen gas adsorption and CMS-300® experiments agree with those determined by QEMSCAN® analysis, yet all are significantly higher than those reported by petrographic image analysis. This discrepancy indicates that there is a significant portion of micro- to nano- scale porosity not captured by traditional optical microscopy. Pore size and shape distributions, while different for each sample, agree qualitatively across all analytical techniques. Calculated tortuosities were also distinct for each sample; the samples with the most nanoporosity had the lowest tortuosities, while heterogeneous samples consistently had the highest tortuosities. The results of this microporosity evaluation indicate that each lithofacies has a unique set of values for porosity, pore size distribution and tortuosity. These parameters are what control fluid flow in the matrix and therefore the different lithofacies will have distinctly different fluid flow responses in a reservoir.

References Cited

Granier, B., A.S. Al Suwaidi, R. Busnardo, S.K. Aziz, and R. Schroeder, 2003, New insight on the stratigraphy of the “Upper Thamama” in offshore Abu Dhabi (U.A.E.): Notebooks on Geology, p. 1-17.

Sharland, P.R., R. Archer, D.M. Casey, R.B. Davies, S.H. Hall, A.P. Heward, A.D. Horbury, and M.D. Simmons, 2001, Arabian Plate sequence stratigraphy: GeoArabia Special Publication, v. 2, 371 p.

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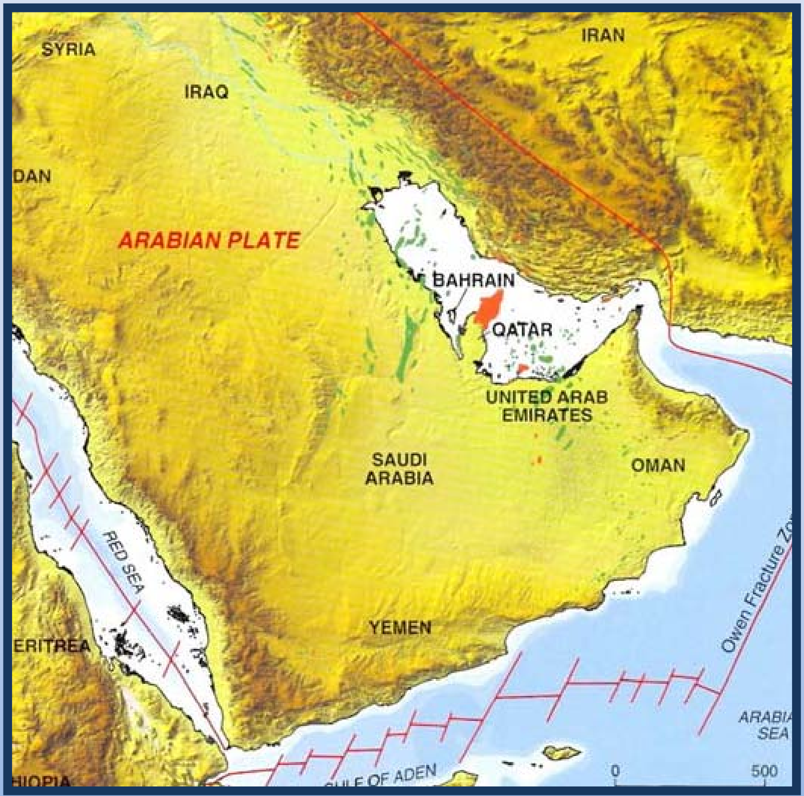
AAPG/SEPM Annual Meeting

Pittsburgh, PA

21 May 2013

Geologic Setting

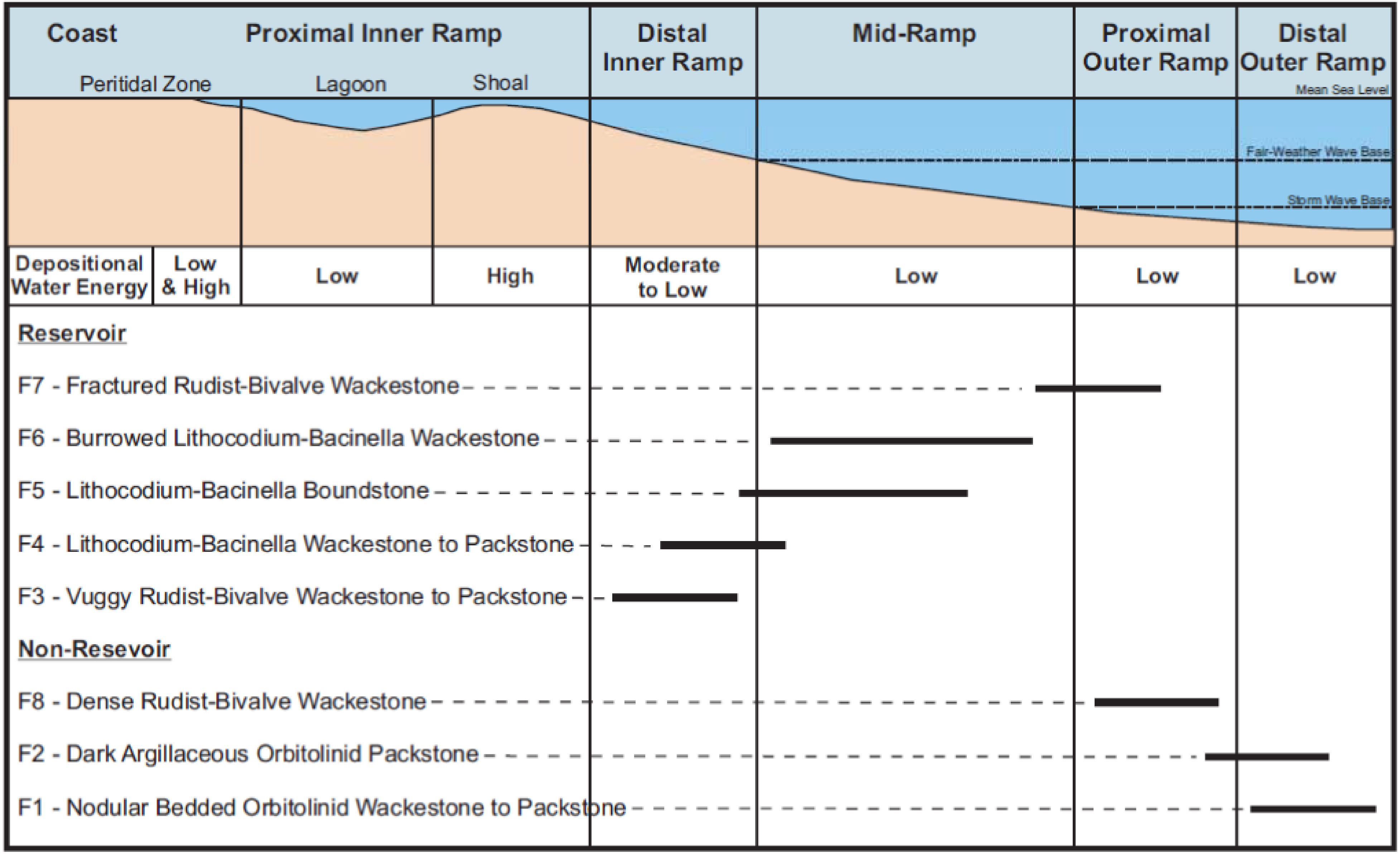


Sharland, 2001

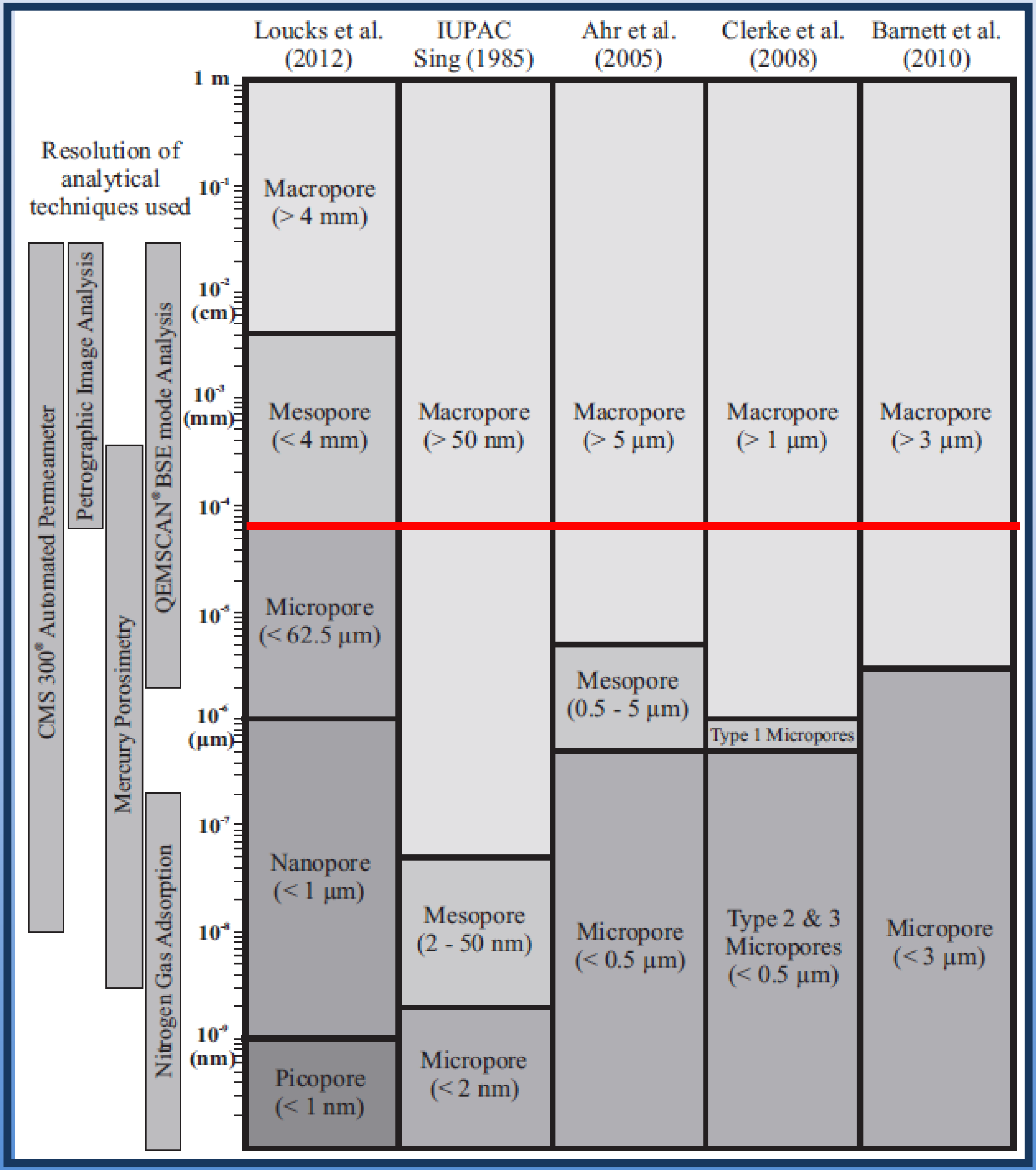
"Giant Oil Field Offshore Abu Dhabi"

Granier *et al.*, 2003

Depositional Model



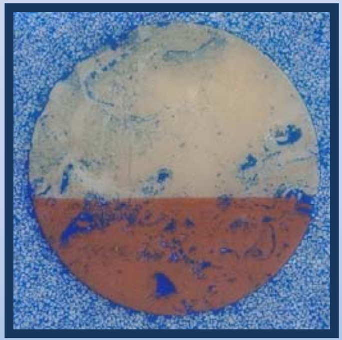
Microporosity



Necessitates the use of non-traditional techniques for microporosity evaluation

Data Set

5 lime mud dominated lithofacies – ranging from vuggy wackestones to tight mud/wackestones



F3

F4

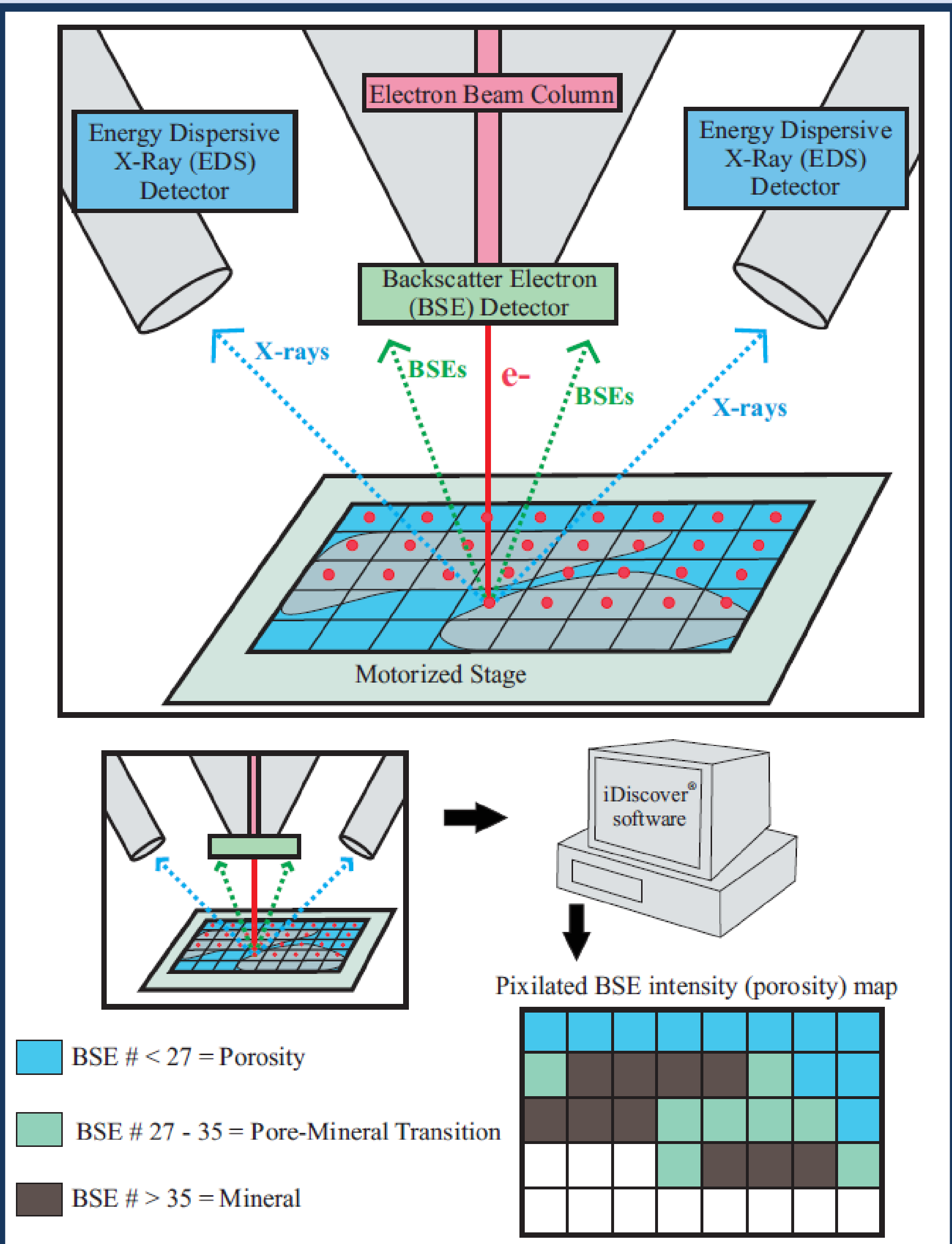
F5a

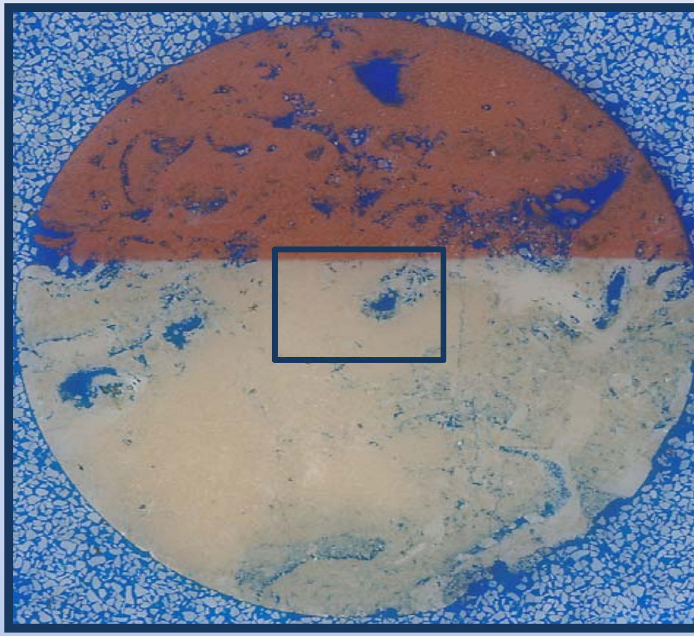
F5b

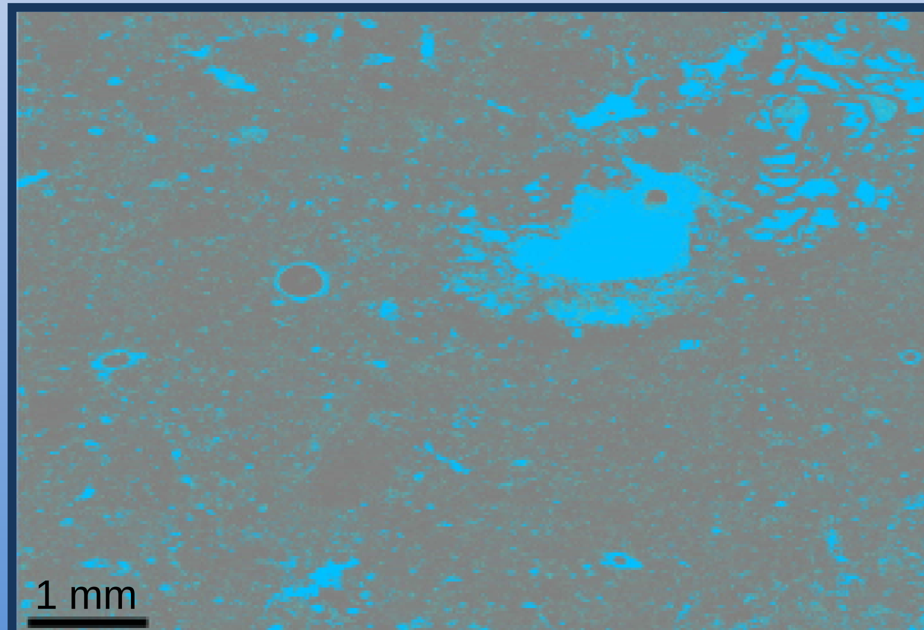
F6

F7

QEMSCAN ® -BSE mode

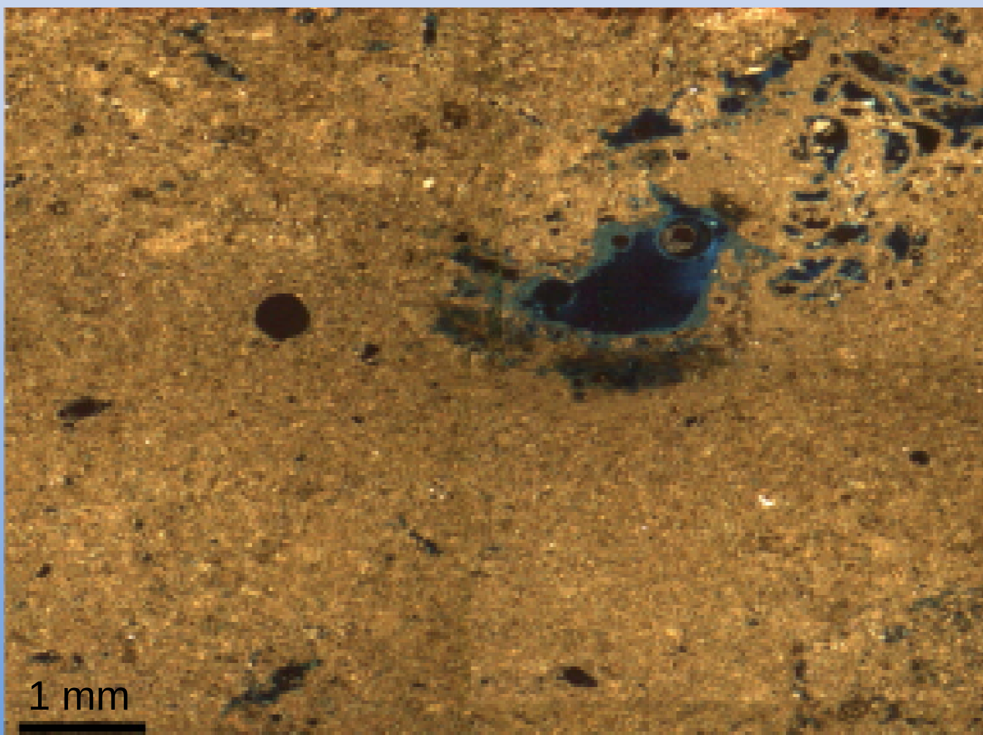


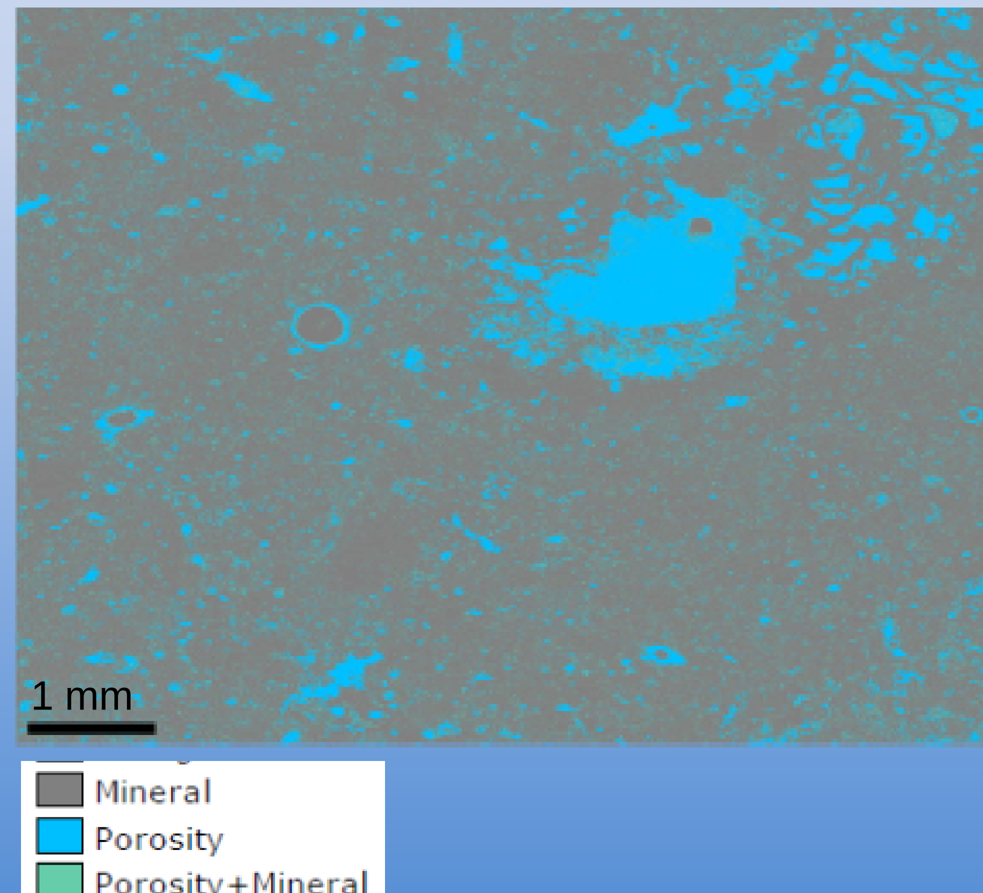




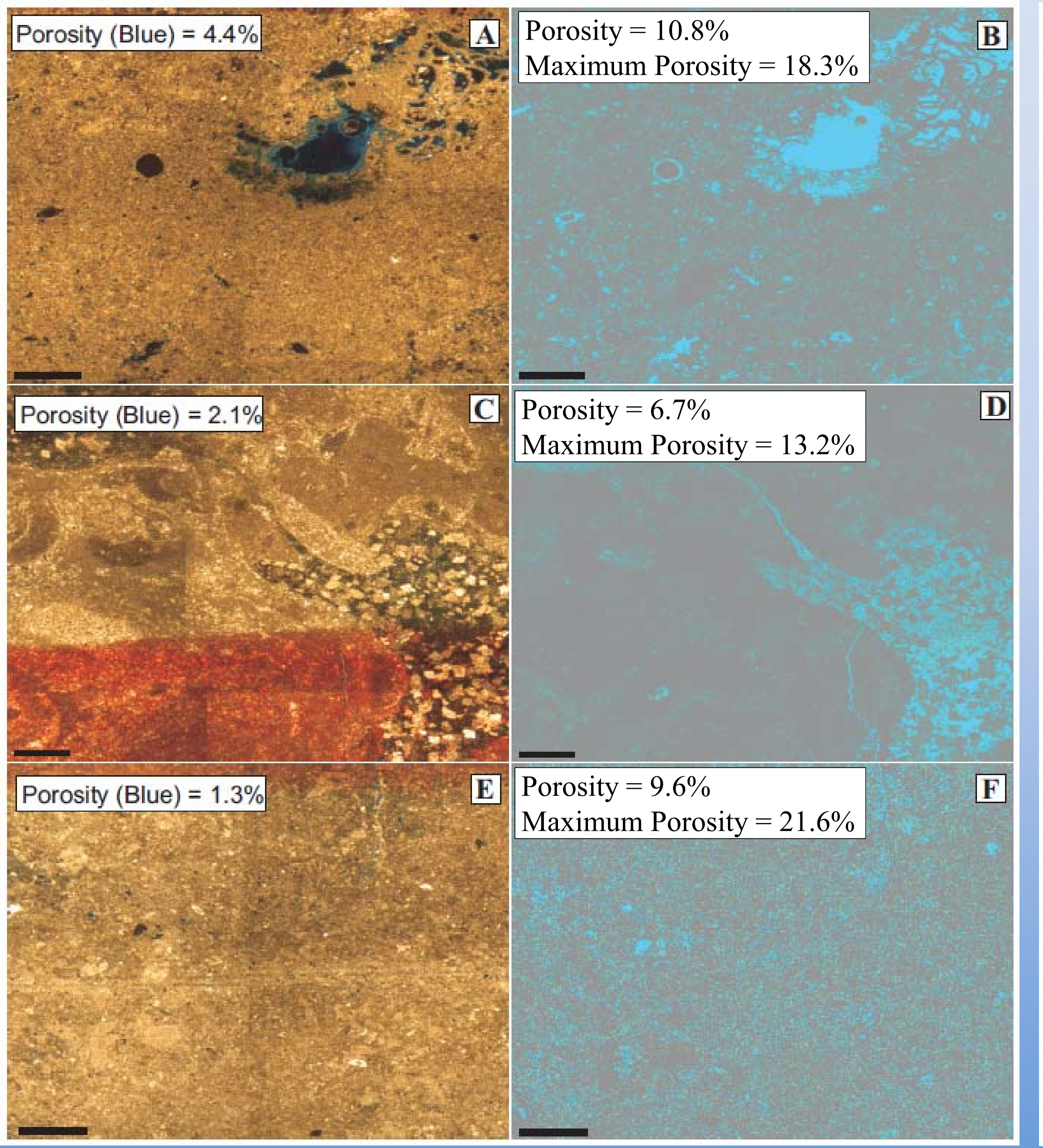
QEMSCAN-BSE mode

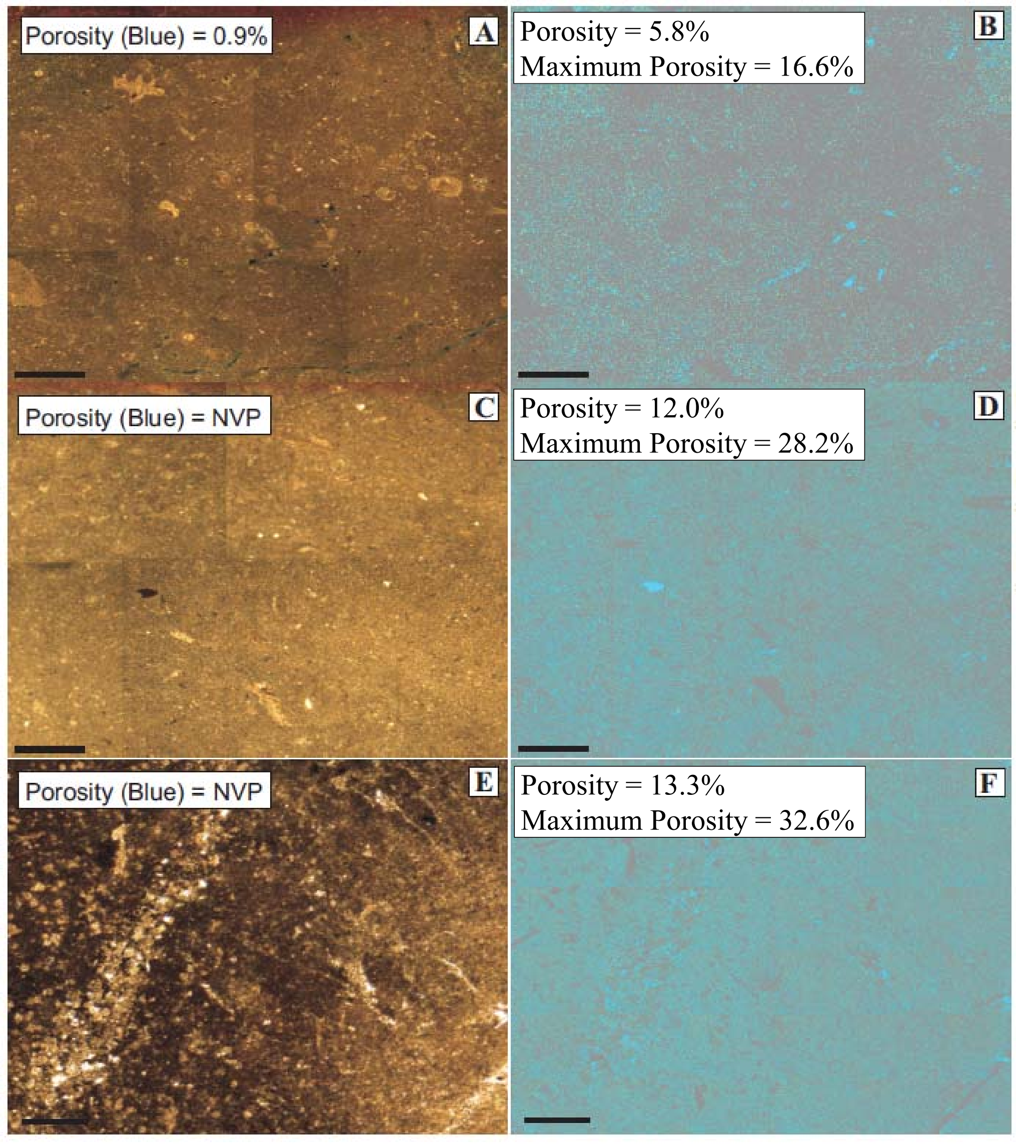
Sample	Rock Fabric	Dominant Pore Type	OM	QEMSCAN – BSE only		
			Porosity %	Porosity %	Pore – Mineral Transition %	Max Porosity %
F3	Rudist Wackestone	Inter/Intraparticle, moldic/shelter, Macro to Micropores	4.4	10.8	7.5	18.3





QEMSCAN® vs PIA

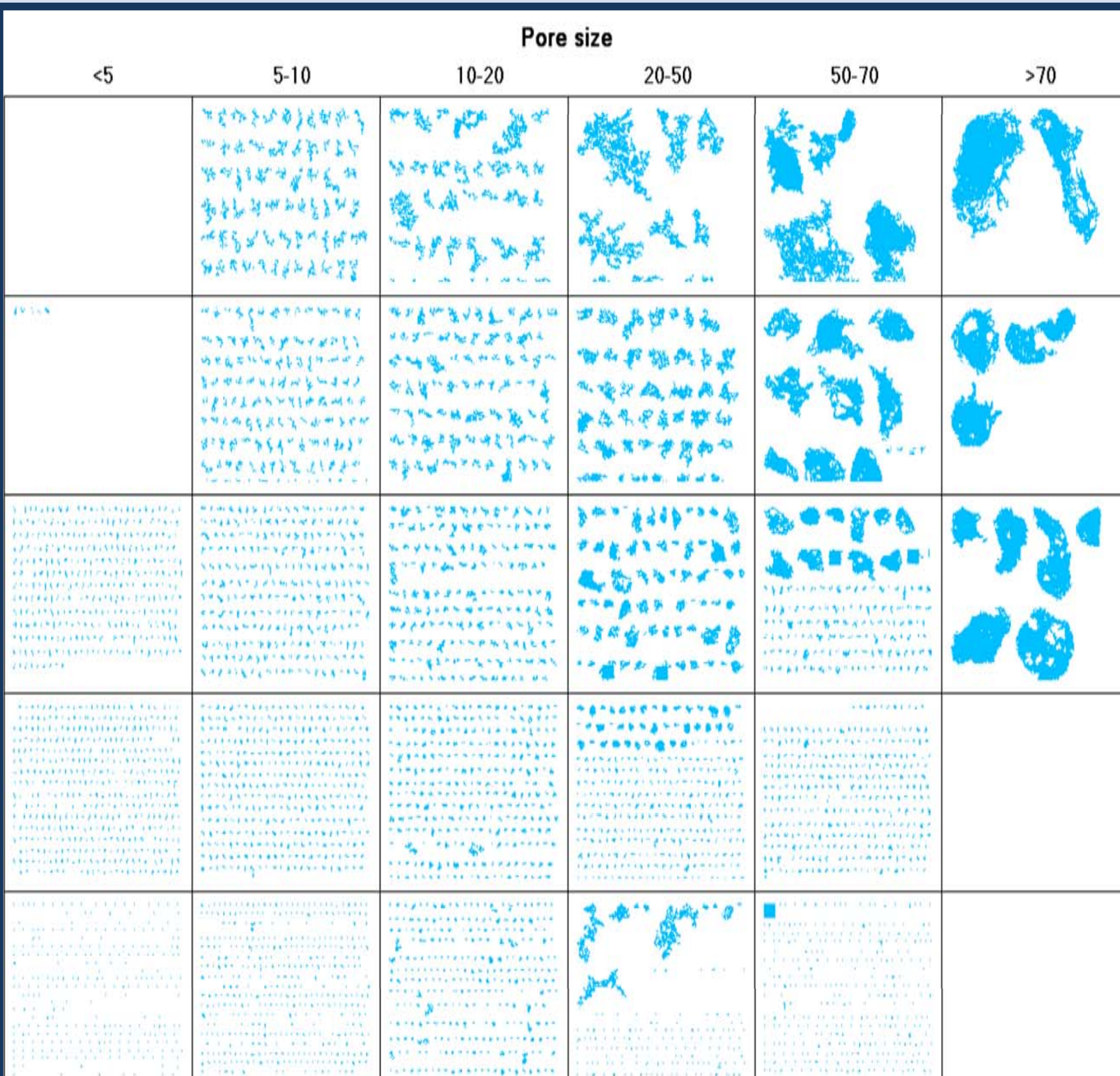




QEMSCAN-BSE mode

ADNOC

PI THE PETROLEUM INSTITUTE

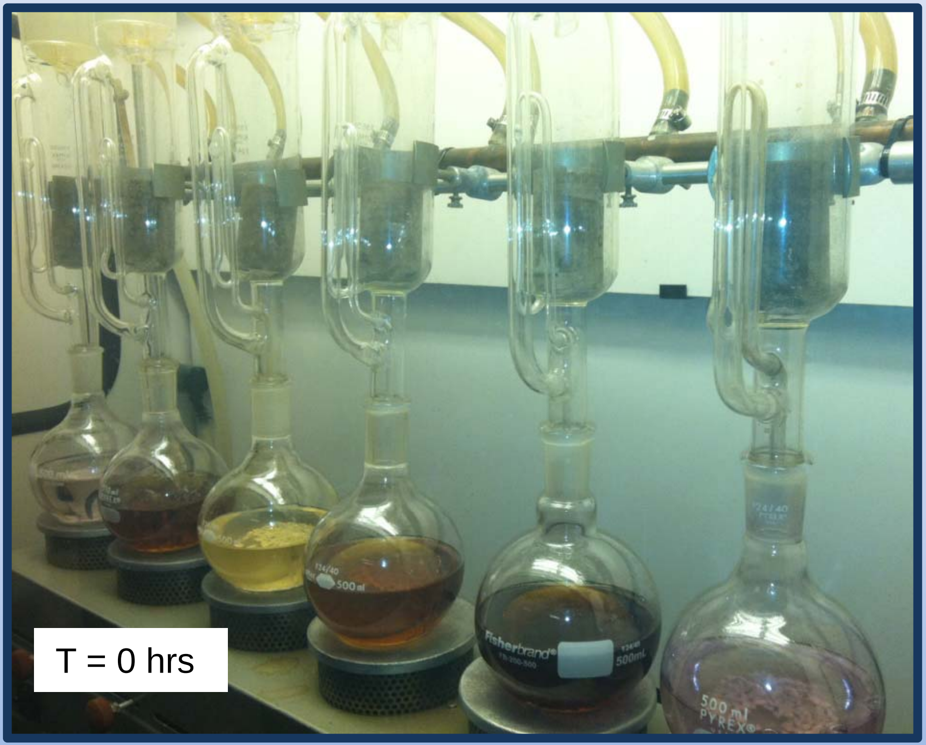


Sample	Rock Fabric	< 5 µm	5 - 10 µm	10 - 20 µm	20 - 50 µm	50 - 70 µm	> 70 µm
		Pore Size Distribution (Volume %)					
F3	Rudist Wackestone	20.4	19.6	13.2	17.4	6	23.4
F4	Lithocodium -Bacinella Wackestone	20	41.6	26.4	9.5	1.4	1.1
F5a	Lithocodium -Bacinella Boundstone	15.4	20.8	18.2	15.5	3.5	26.6
F5b	Lithocodium -Bacinella Boundstone	33.4	39.1	17.6	7.8	2.1	0
F6	Bioclastic Wackestone	15.5	58.6	23.6	2.2	0.1	0

Implications

- Rapid, quantitative data
- Images features at a sub-micron scale
- More reliable than traditional point counts
- Pore size and shape analysis possible
- Reserves calculations – total storage capacity
- Microporous mudrock characterization
- Can we validate these values independently?

Sample Preparation


T = 0 hrs


T = 24 hrs

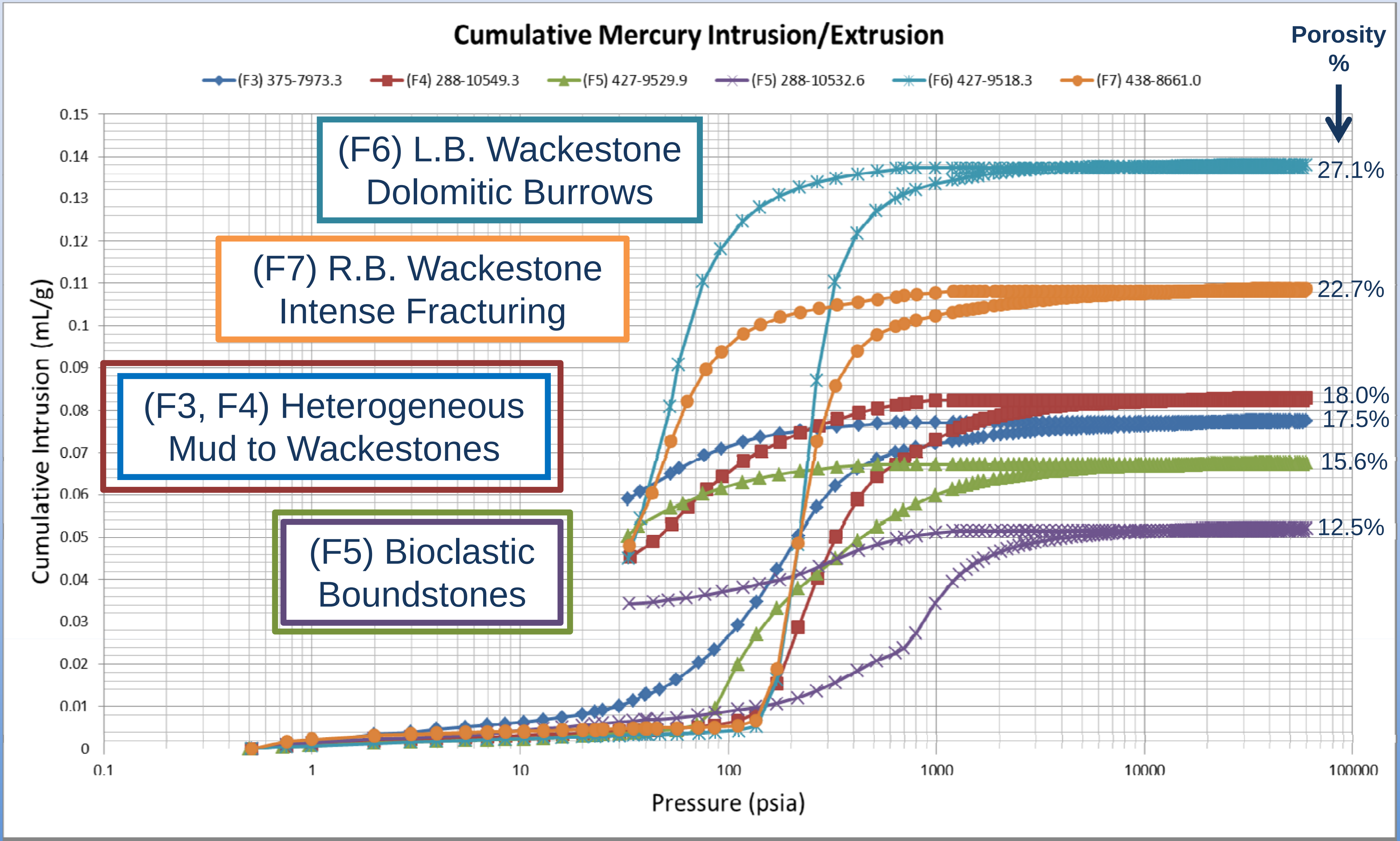
Mercury Porosimetry, CMS 300 and N_2 Gas Absorption experiments require cleaned, dried and degassed samples.

Core plugs were flushed with Toluene via soxhlet for approximately 150 hours to remove residual hydrocarbon

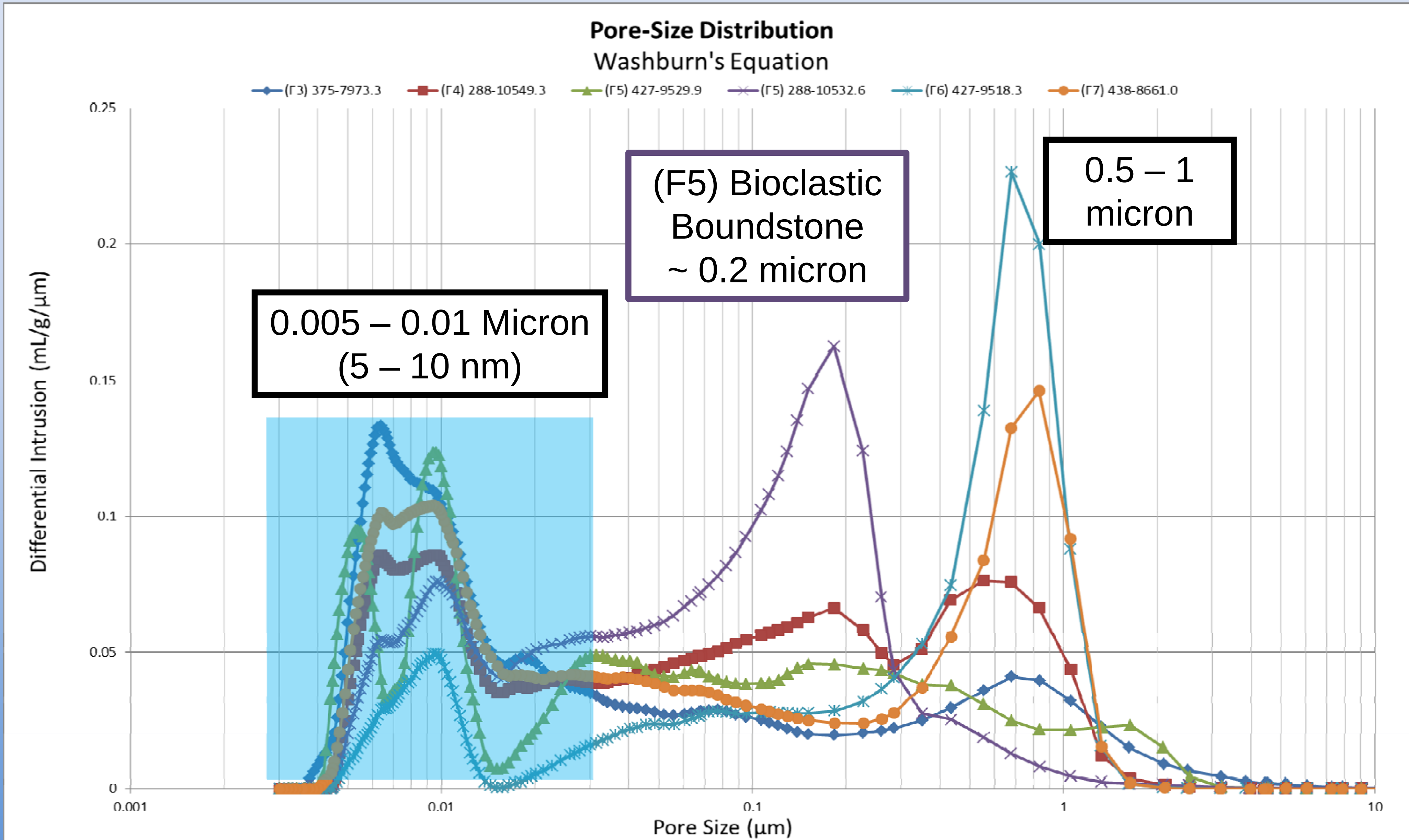

T = 36 hrs


T = 150 hrs

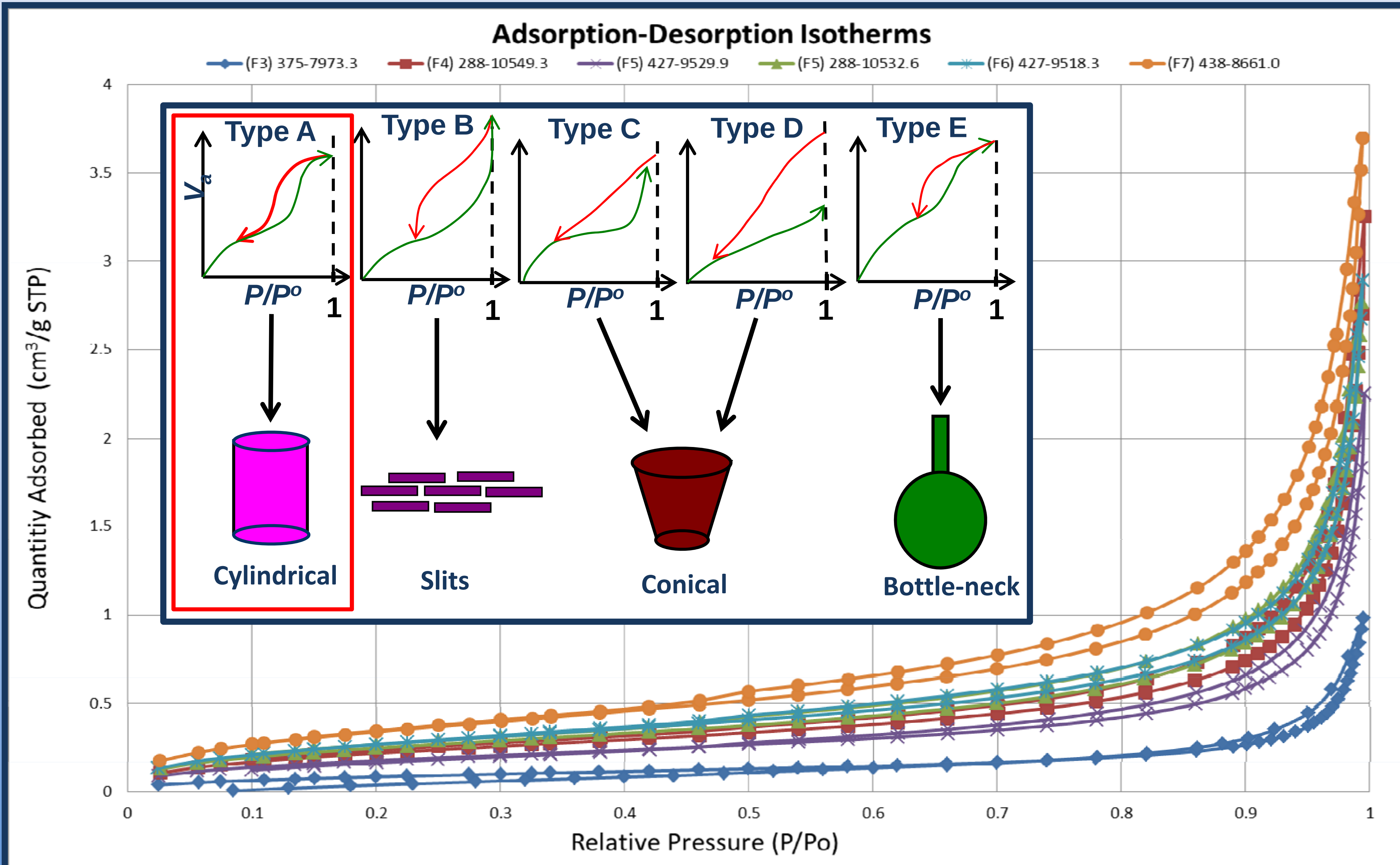
Mercury Porosimetry



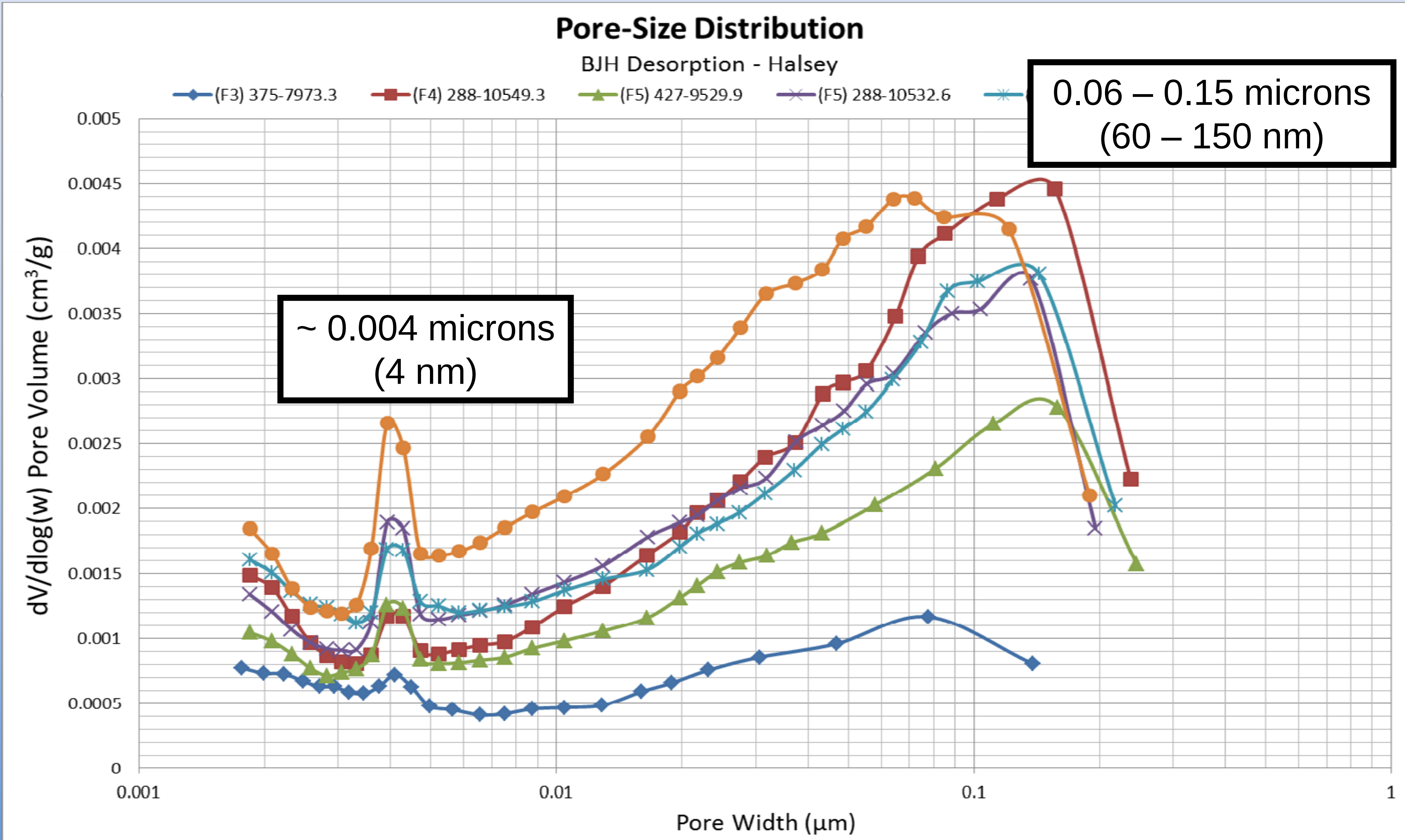
Mercury Porosimetry



N_2 Gas Adsorption



N_2 Gas Adsorption

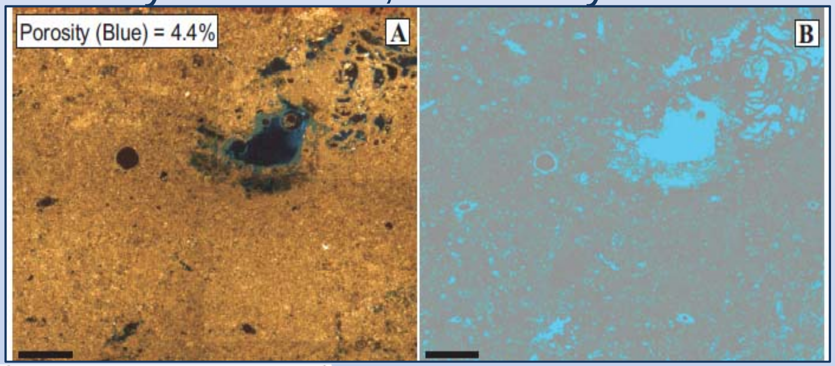


Porosity Comparison

Facies		Petrographic Image Analysis	CMS 300	QEMSCAN-BSE		Hg	N2	Hg + N2	Tortuosity τ
				Porosity	Max Porosity				
F3	**Vuggy** R. B. Wacke- to packstone	4.4	19.1	10.8	18.3	17.5	0.48	18.0	2.701
F4	**Stylolitic** L.B. Mud- to Wackestone	1.3	21.8	9.6	21.6	18.0	1.43	19.4	2.495
F5a	Lithocodium Bacinella **Boundstone**	2.1	17.6	6.7	13.2	15.6	1.0	16.6	2.839
F5b	Lithocodium Bacinella **Boundstone**	0.9	17.0	5.8	16.6	12.5	1.21	13.7	2.894
F6	**Dolomitic Burrowed** L.B. Wackestone	NVP	23.7	13.2	32.6	27.1	1.28	28.4	2.363
F7	**Fractured** R.B. Wackestone	NVP	20.8	12.0	28.2	22.7	1.65	24.4	2.564

Pore Architecture

Vuggy Rudist Wackestone
Porosity = 18-19%, Tortuosity = 2.701



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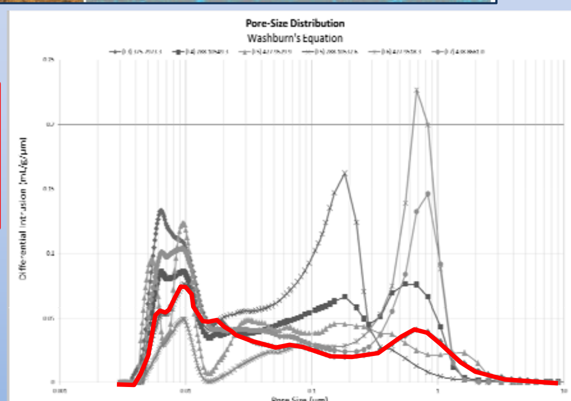
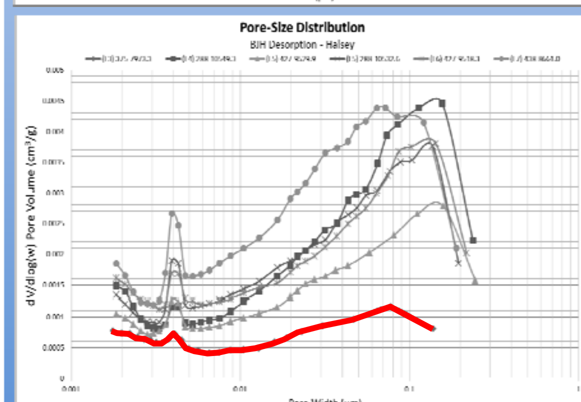
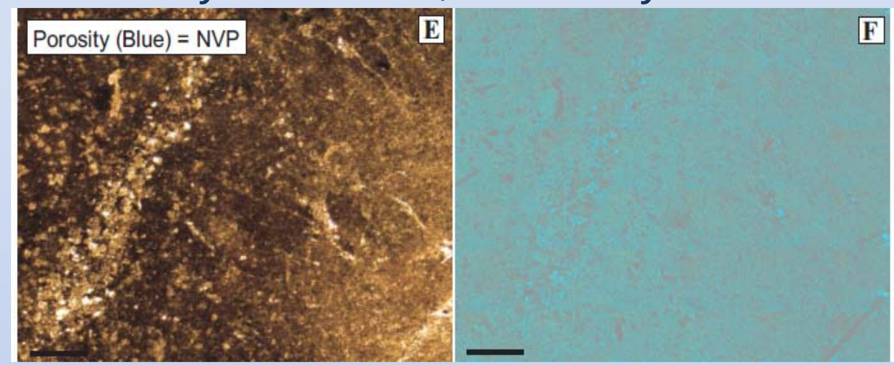




Bioclastic wackestone (**dolomitic burrows**)
Porosity = 23-32%, Tortuosity = 2.363



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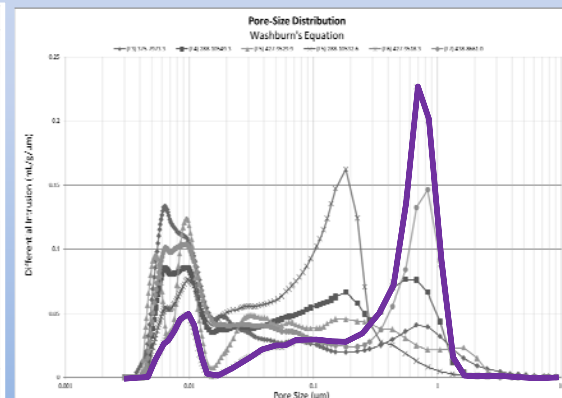

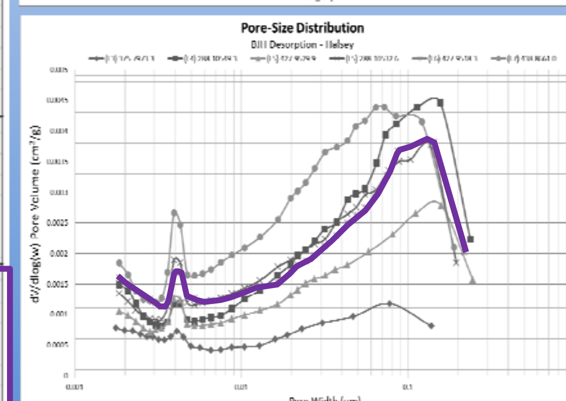

Summary

• QEMSCAN technology is a rapid analysis tool capable of high resolution microporosity quantification.

• Mercury porosimetry and gas absorption experiments are able to validate the high porosity values reported by QEMSCAN porosity mapping

• Porosity estimates from all techniques indicate a significant amount of storage capacity (~20%) within the micro to nanopores.

• Pore size distributions at a variety of scales show similar trends across all analytical techniques and are able to capture relative heterogeneity in the samples.