Fluid Flow Property Estimation Using a Pore Network Modeling Approach

MS 1.27: Pore Scale Processes and Upscaling of Flow and (Reactive) Transport in Porous Media

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Introduction

Pore network modeling is a technique that has been booming in recent years, and several authors have used it to obtain properties which are common obtained from laboratory tests and/or experimental correlations. However, most of the research to date has tended to focus on studying only one medium and its discretization rather than trying to generate multiple equivalent media. The latter is a key aspect to understand a whole system by means of a reliability window for objective properties.

Objectives

1. Introduce a methodological approach based on pore network modeling to estimate fluid flow properties: porosity, absolute permeability and capillary pressure.
2. Lay the groundwork for future research into random networks.
3. Highlight the spatial dependence importance among pore network properties.

Methodology

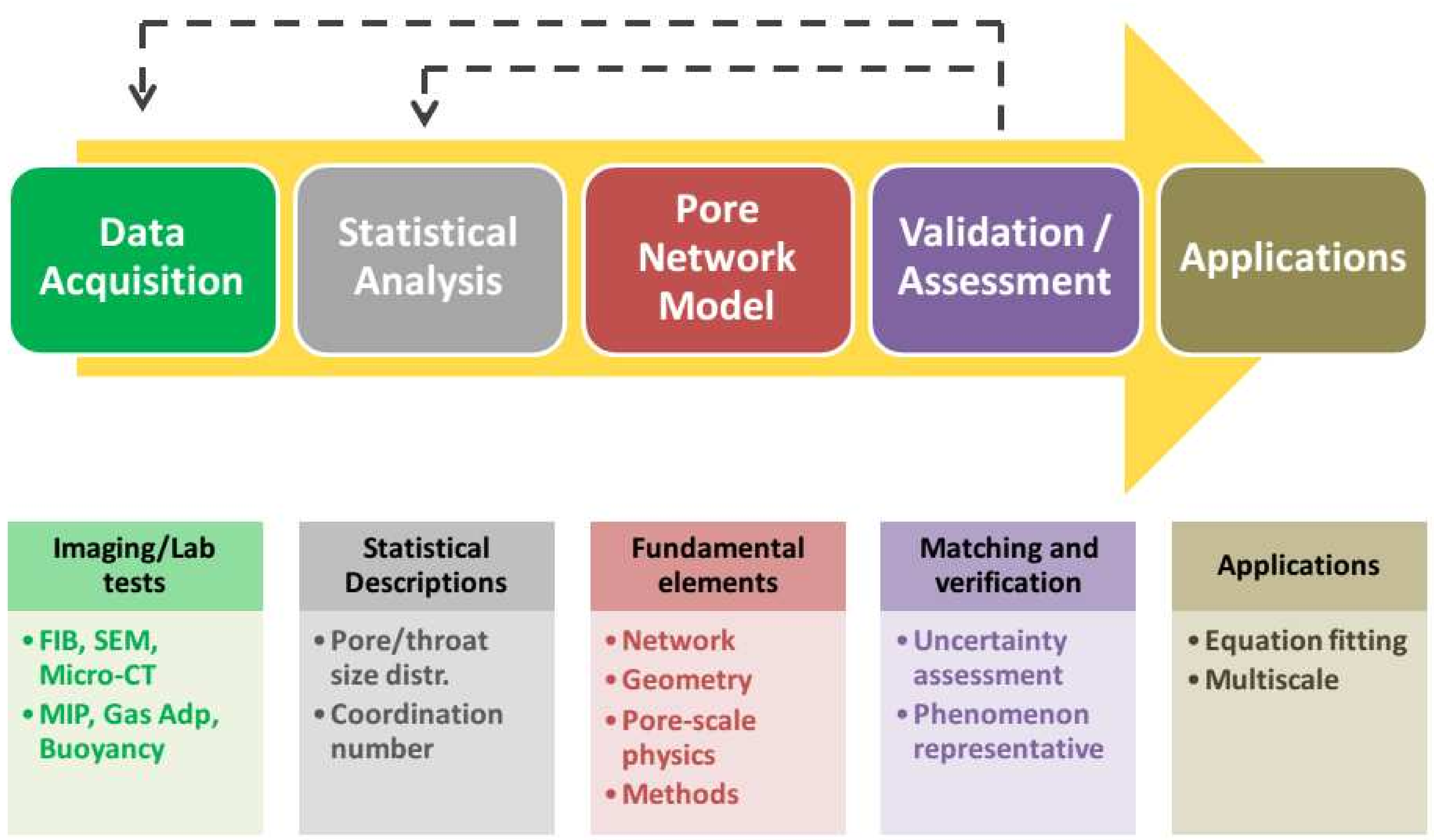

Figure 1: Methodological approach based on pore network modeling.

Study case

The recreation of mercury intrusion in a carbonate sample is pursued. Same laboratory's conditions are considered. However, since image analysis service could not be accessed, open information is used.

Table 1: Carbonate samples reported in literature.

Property	Gharbi(2012)	Freire(2016)	Study case	C2
Mean coordination number	2.97	2.6+-0.2	—	2.37
Max. pore diameter $[\mu m]$	99.48	100	—	111
Min. pore diameter $[\mu m]$	—	10	—	0.5
Max. throat diameter $[\mu m]$	10.17	31+-2	—	11
Min. throat diameter $[\mu m]$	—	22+-2	—	6
Porosity [%]	13.05	12+-2	**14.7**	16.8
Permeability $[m^2]$	5.69E-13	—	**1.57E-14 - 3.94E-14**	1.55E-13

The image of a generic carbonate, called C2, and its extracted network are considered (ICL, 2014).

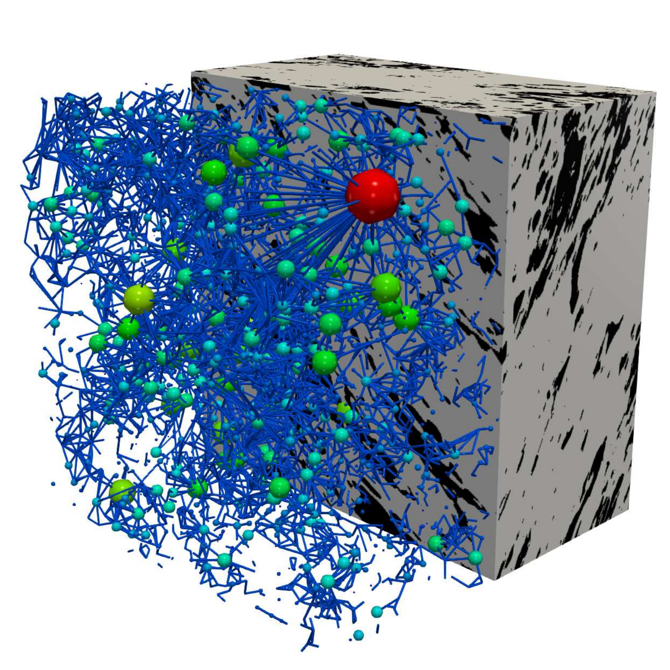

Figure 2: Carbonate C2.

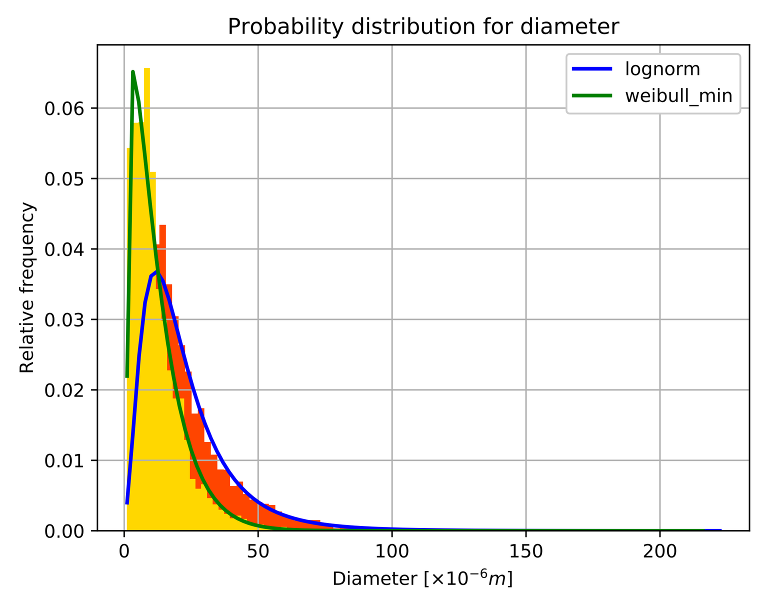

Figure 3: Orange: pores, yellow: throats.

A statistical analysis to explore the networks topological properties and the mediums geometric properties is performed, and probability distributions (PD) are fitted.

Table 2: Probability distribution parameters.

		Fitted				Altered		
Property	PD	Shape	Loc.	Scale	SSE	Shape	Loc.	Scale
Pores	Lognormal	0.61	-2.95	21.31	0.06	**0.6**	**-2**	**39**
Throats	Weibull	1.15	1.07	11.85	0.0014	**0.9**	**1**	**30**

Assuming the C2 topology to be invariant and pore/throat diameters from PD, 100 pore network models were generated using *OpenPNM*, an open source pore-network modeling project. The pore networks were used to recreate both flow and mercury intrusion. The conditions and fluid properties of an experimental test were considered.

Phases

- Mercury ⟹ Flow
- Mercury and air ⟹ Mercury intrusion

Invading phase (non-wetting): mercury
Defending phase (wetting): air

Table 3: Fluid properties.

Property	Mercury	Air	Unit
Viscosity	1.53x10-3	1.84x10-5	kg/m.s
Surface tension	0.48		N/m
Contact angle	140		°

Pore networks: original information, fitted PD, and altered PD

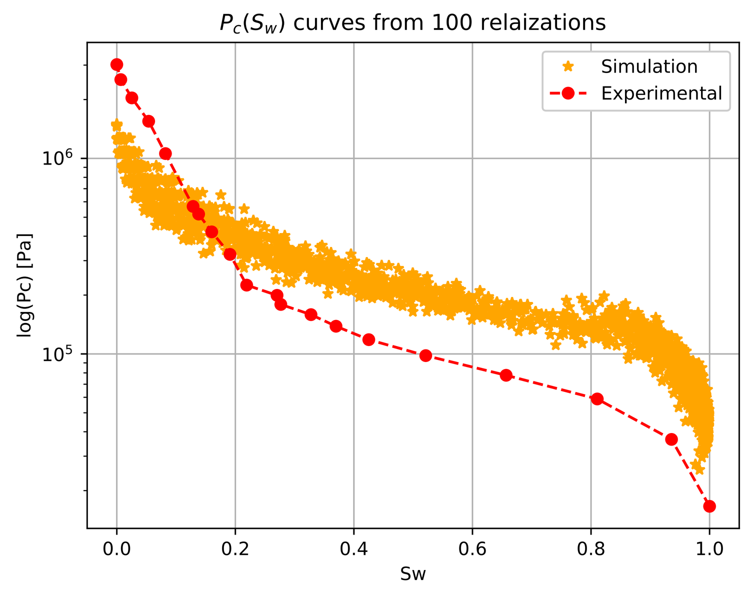

Figure 4: P_c using and the fitted probability distributions.

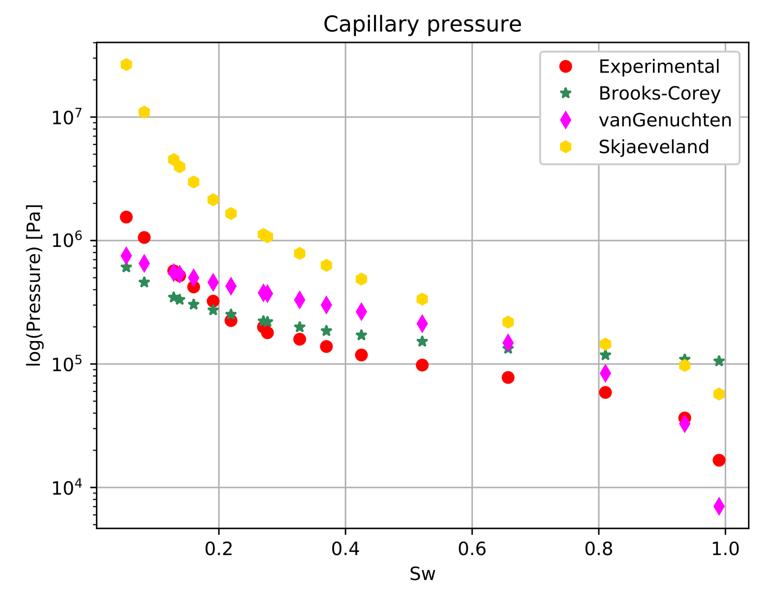

Figure 5: Fitting of $P_c(S_w)$ models.

Although pore networks generated from fitted PD meet C2's statistics, these networks do not recreate experimental capillary pressure (P_c) but have a similar trend. Based on altered PD's parameters, new pore networks which follow the experimental data are generated.

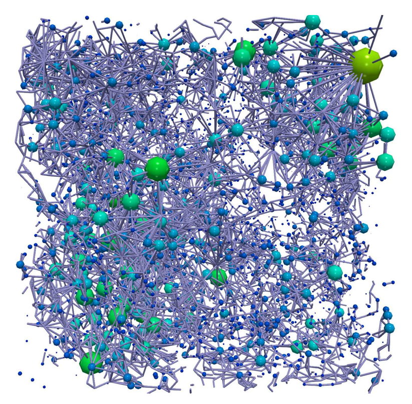

Figure 6: From C2 information.

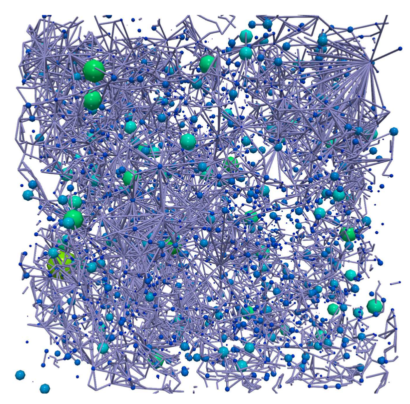

Figure 7: From fitted PD.

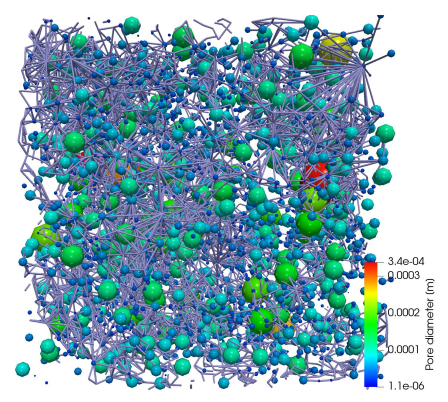

Figure 8: From altered PD.

Results

Table 4: Porosity and permeability statistics.

Property	Min	Q1.	Med	Mean	Q1	Max
ϕ (%)	13.1	14	14.5	14.5	15	17
K $\times 10^{-14} [m]$	0.32	3.51	6.05	7.24	8.95	35.8

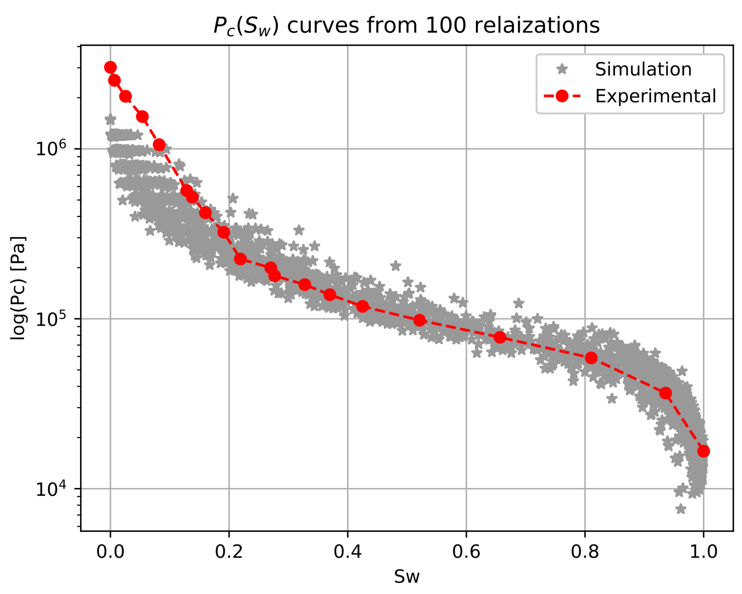

Figure 9: Experimental and simulated P_c.

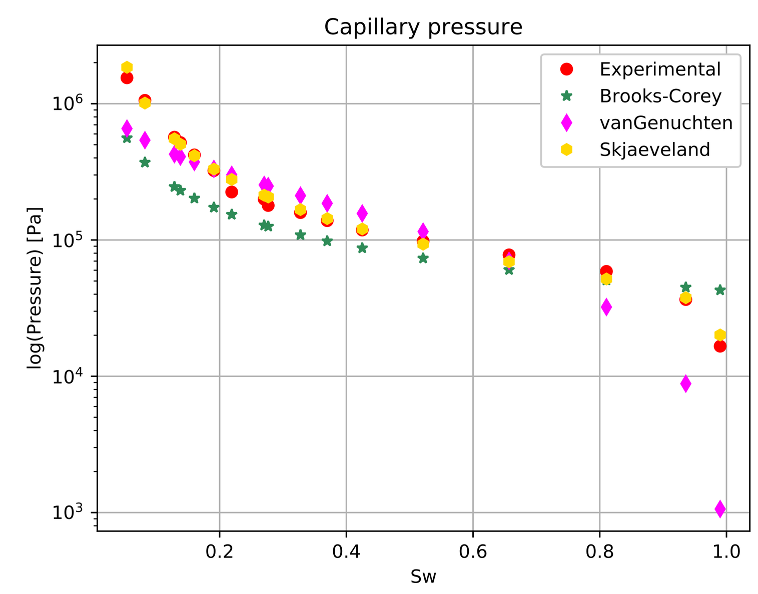

Figure 10: Fitting of $P_c(S_w)$ models.

Conclusions and future work

- This work has shown a methodology to study phenomena at pore scale. The methodology allows us to generate systematically pore network models, then use them as a tool for obtaining porosity, absolute permeability, and capillary pressure curves.
- From the proposed methodology, $P_c(S_w)$ models have been fitted which attempt to reproduce experimental data.
- The study contributes to our understanding of statistical analysis importance. The statistical analysis comprises the basis of random pore network generation.

Acknowledgements

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References

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