Response of Relative Permeability to Coal Surface Chemistry through Steady-State Core Flooding Measurements using X-ray CT Scanner and Packed Bed Samples

Fabio Terzini Soares (PhD Candidate) - School of Chemical Engineering, The University of Queensland

Advisory team: Dr Tom Rufford, Dr Lei Ge and Prof Victor Rudolph

Introduction

Figure 1 illustrates a typical example of the inadequacy of laboratory measured relative permeabilities and the current models as a means to predict field production profiles. One issue is the heterogeneity of coal relative to sandstone or carbonate reservoirs. A more fundamental issue is the correlations omit many key dependencies, which for conventional reservoir rock systems may acceptably be considered constant or lumped within the saturation state parameter, but must be individually accounted in coal systems.

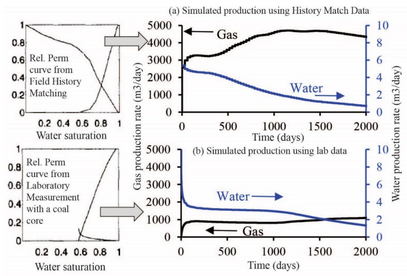


Figure 1. Relative permeability curves of field history data A) with simulated production data and B) simulated production data from relative permeability curves obtained from laboratory measurements (left side taken from Meaney & Paterson, 1996; right side from simulated studies conducted by Dr Chawarwan Khan)

Research Aims

1. Improve gas and liquid relative permeability predictions by experimentally measuring gas-liquid relative permeability taking into account surface chemistry of the coal.

2. Design and build an X-ray transparent core flood cell to calculate water saturation (Sw) during gas-liquid relative permeability measurements on (i) artificial packed bed cores, and (ii) real coal cores.

3. Study the effect of coal surface chemistry on relative permeability by using packed beds that provide homogeneous, isotropic pore structure with controllable pore size and channel geometry.

4. Carry out a sensitivity analysis using a hypothetical coal seam gas reservoir simulation model using Petrel and Eclipse to investigate the effects of surface chemistry on the gas and water production.

Methodology

- Coal location and properties:

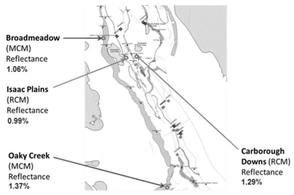


Figure 2. Location of each mine within the Bowen Basin, Queensland, Australia.

Table 1. Petrographic and proximate analyses for the four samples.

		Samples			
	Components (%)	IPN I	BRDM I	CD.LW II	OAK II
	R_{max}	0.99	1.06	1.29	1.37
	Vol. Vitrinite	31	73	28	67
Petrographic Analysis (air dried basis)	Vol. Liptinite	6	1	2	0
	Vol. Inertinite	56	22	55	14
	Vol. Mineral	7	4	15	20

- Core flooding:

- Aluminium core holder
- Stead-state
- 4 wt.% KI solution (contrast agent)

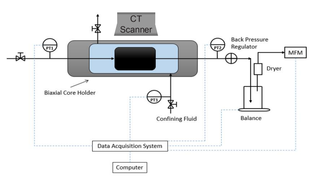


Fig. 3: Schematic of the core flooding apparatus used for steady-state relative permeability measurements.

- Gas and liquid effective permeability and water saturation calculation:

$$k_g = \left(\frac{500,000}{3}\right)\left[\frac{8Q_g L \mu_g P_g}{\pi D^2 \left(P_1^2 - P_2^2\right)}\right] \qquad k_L = \left(\frac{500,000}{3}\right)\left[\frac{4Q_L L \mu_L}{\pi D^2 \left(P_1 - P_2\right)}\right] \qquad S_w = 1 - \left(\frac{CT_{fullysat} - CT_{imb\_x}}{CT_{fullysat} - CT_{dry}}\right)^{(1)}$$

(1) Based on grey-scale

Core Flooding Results

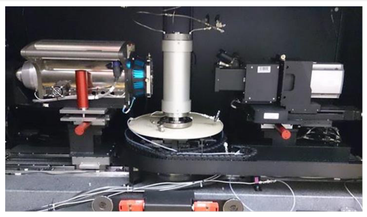


Figure 4. Photograph of x-ray transparent aluminium core holder (shown in vertical orientation) inside the Xradia XRM500 instrument.

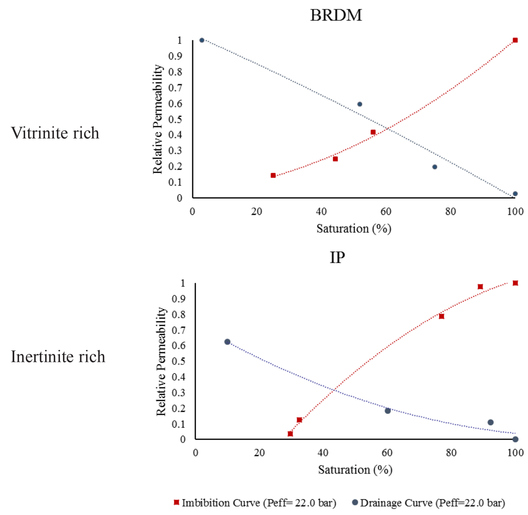
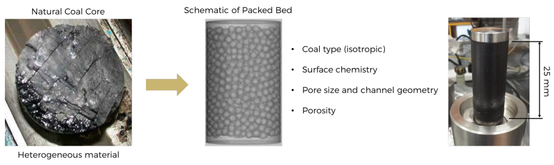


Fig 5. Relative permeability of BRDM (top) and IP (bottom) coal from Bowen Basin using packed beds.

Discussion

1. Packed bed method has enabled the construction of repeatable cores to study relative permeablity in isolation from the effects of natural coal cleat network geometries and heterogeneity.



2. An improved estimation of gas and water relative permeability taking into account surface chemistry is crucial for gas/ water production prediction (compared to the simplistic assumption that Sw= Kr).

3. The relative permeability curves suggest that the vitrinite rich coal (BRDM) had a more water-wet behaviour than the inertinite rich coal (IP).

4. The hypothetical simulation using Eclipse shows that the cummulative water production for the IP can be 40% higher than the BRDM over a period of 30 years og gas production, due to its water wet behaviour.

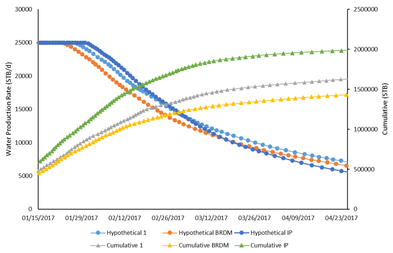


Fig 6. Water production for different scenarios (Eclipse).

[1] Al-Jubori, A., et al. (2009). Oilfield Review, Schlumberger. p. 4-13.
[2] Shen, J., et al. (2011). International Journal of Coal Geology. 86(2–3): p. 266-275.
[3] Saghaf, A., K. Pinetown, and H. Javanmard (2014). The Australasian Institute of Mining and Metallurgy & Mine Managers Association of Australia: Australia. p. 266-273.
[4] Mahoney, S.A., et al. (2015). Society of Petroleum Engineers.
[5] Zhang, J., et al. (2014). Transport in Porous Media. 106(3): p. 563-594.
[6] McPhee, C.A. and K.G. Arthur (1991). European Core Analysis Symposium, London. p. 371-391
[7] Meaney, K. and L. Paterson (1996). Society of Petroleum Engineers.

This research received funding from the UQ Centre for Coal Seam Gas and its industry partners (Arrow Energy, QGC/Shell, Santos and AP-LNG). Mr Terzini receives additional funding from the Brazilian Government via The National Council for Scientific and Technological Development (CNPq).

f.terzini@uq.edu.au

UQ-CCSG
Centre for Coal Seam Gas