Response of Relative Permeability to Coal Wettability through Steady-State Core Flooding Measurements

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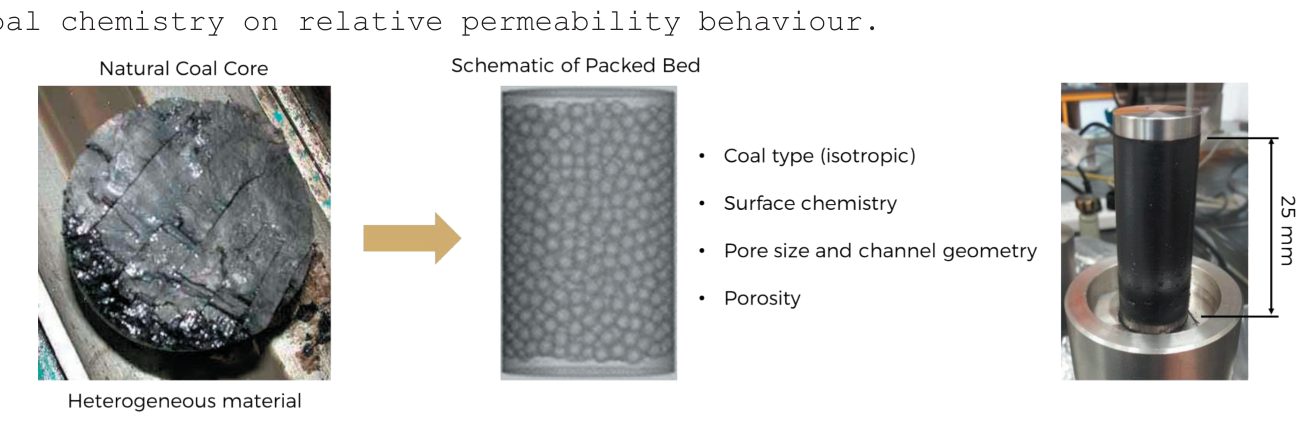
Abstract

The relative permeability behaviours of gas and water in coal are primary factors in the productivity of a coal seam gas reservoir. In this paper we report experiments with packed coal cores made from two medium rank coals from the Bowen Basin, Queensland: C-143 with a low plasticity (R = 1.16 %) and C-148 with a high plasticity (R = 1.18 %). Both packed cores were constructed from coal particles within the size range between 53 – 212 μm, which produced bed void fractions of approximately 19 %. Absolute permeabilities to N_2 corrected according to Klinkenberg effect were in the range 0.16 mD to 0.27 mD. The relative permeability curves suggest that the low plasticity coal had a more water-wet behaviour than the high plasticity coal.

Research Aims

1. 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.
2. Develop new laboratory measurement techniques to measure relative permeability in coal to allow systematic investigation of the effect of coal chemistry on relative permeability behaviour.



Coal Properties

Table 1: Proximate and petrographics analysis of coal samples C-143 and C-148 from Bowen Basin, Queensland - Australia.

Proximate		C-143	C-148
Moisture	%ad	1.4	1.8
Ash	%ad	10.6	7.5
Volatile Matter	%ad	23.8	21.8
Fixed Carbon	%ad	64.2	68.9
Petrographics			
Telovitrinite	Vol.%	79.3	48
Detrovitrinite	Vol.%	3.8	4.2
Other Vitrinites			
Sporinite	Vol.%	0	0.2
Other Liptinites			
Fusinite	Vol.%	1.5	1.3
Semifusinite	Vol.%	10.5	40.2
Inertodetrinite	Vol.%	0.4	1.7
Mineral Matter	Vol.%	4.5	4.4

Core Flooding Experiments

The measurement procedure to obtain a set of relative permeability curves for gas and water included four stages:

1. Measurement of absolute permeability using N_2
2. Saturation of the core with a 4 wt.% KCl brine
3. Liquid drainage
4. Imbibition by injection of a 4 wt.% KCl brine

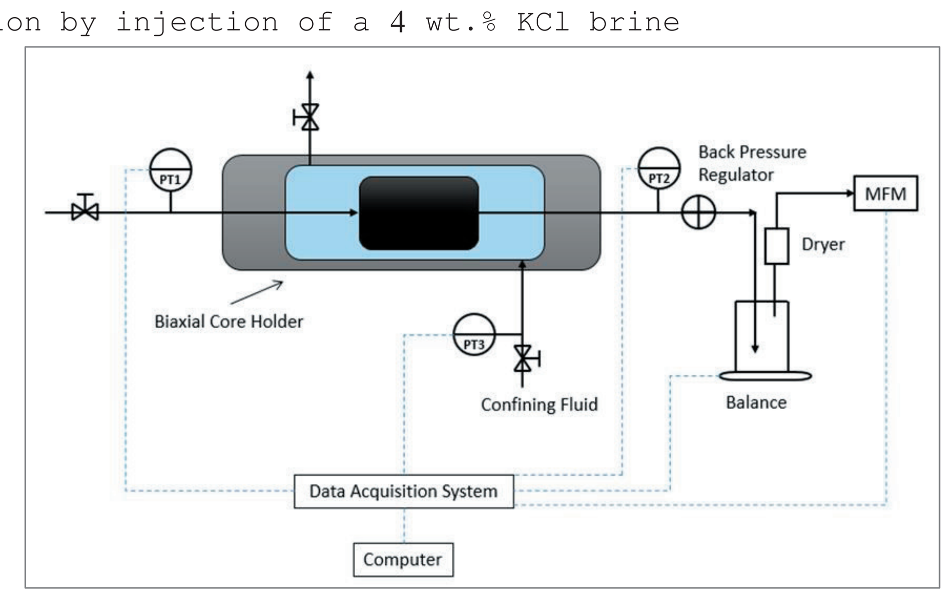


Fig. 1: Schematic of the core flooding apparatus used for steady-state relative permeability measurements of packed coal beds. The key equations used to calculate permeability were:

$$k_g = \left(\frac{500{,}000}{3}\right)\left[\frac{8Q_g L\mu P_g}{\pi D^2 (P_1^2 - P_2^2)}\right] \quad k_L = \left(\frac{500{,}000}{3}\right)\left[\frac{4Q_P L\mu}{\pi D^2 (P_1 - P_2)}\right] \quad k_{eg} = k_a\left(1 + \frac{B}{P_m}\right)$$

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Absolute Permeability Results

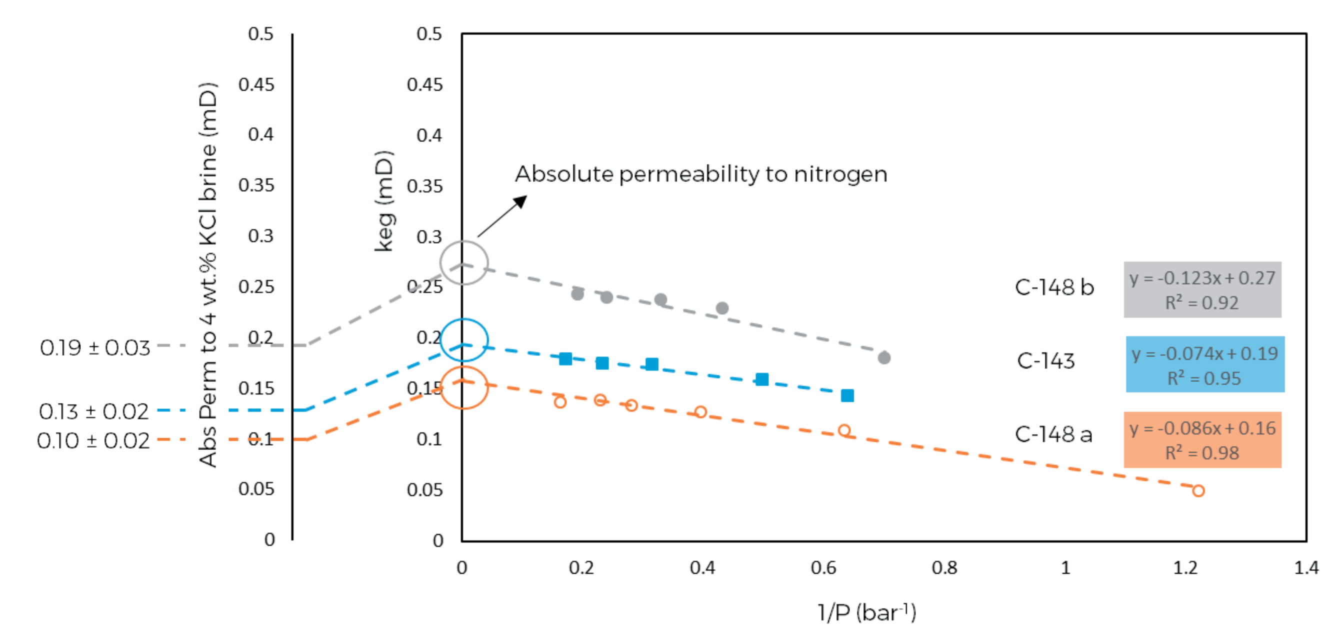

Fig. 2: Klinkenberg relationship for absolute permeability to nitrogen for coal C-143 (Pc=70 bar) and C-148 a (Pc=70 bar) and b (Pc=30 bar) and its correspondent absolute permeability to brine (4 wt.% KCl).

Relative Permeability Results

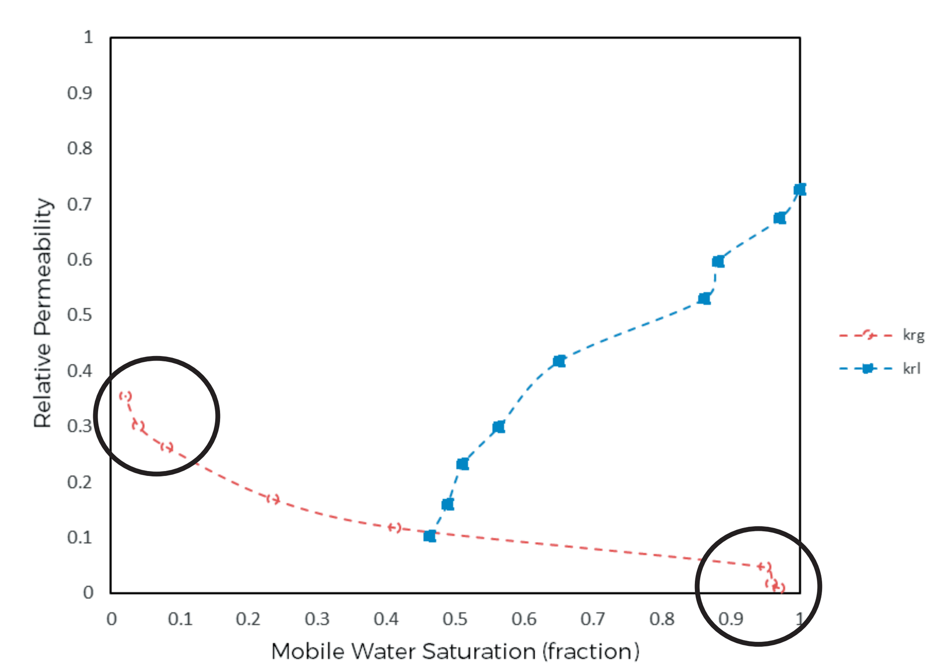

Fig. 3: Gas and water relative permeability versus mobile water saturation, packed bed C-143 (Pc=70 bar).

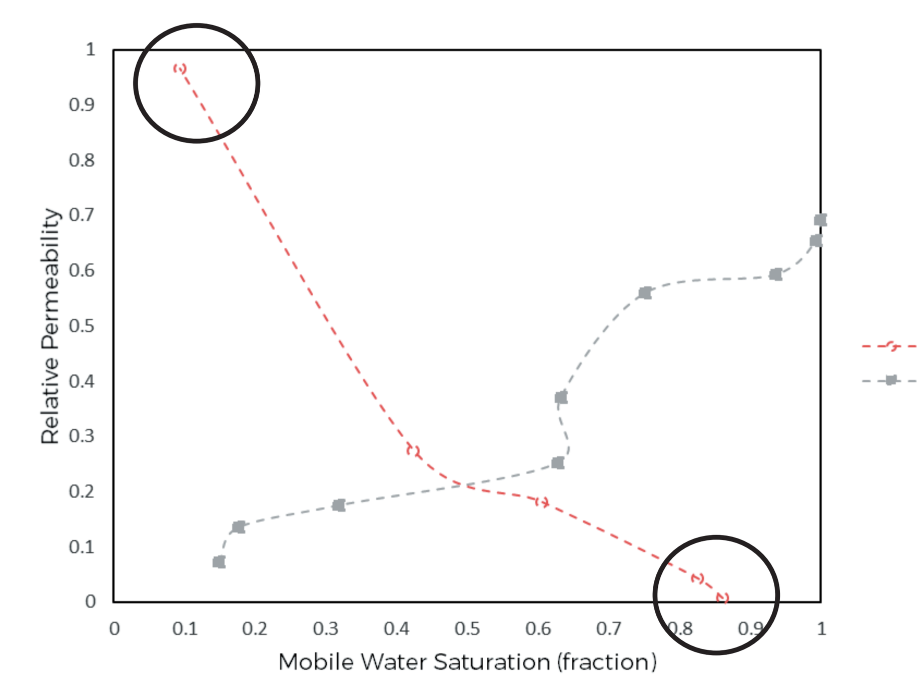

Fig. 4: Gas and water relative permeability versus mobile water saturation, packed bed C-148 (Pc=30 bar).

Conclusions and Future Work

1. The absolute permeability of the packed cores prepared with particle sizes of 53 – 212 μm were in a typical range measured for real coal cores from the Bowen Basin.
2. The relative permeability curves suggest that the semi-fusinite rich C-148 coal exhibits more water-wet behaviour than the vitrinite rich C-143.

Future work plans:

- Further develop the steady-state relative permeability methodologies to utilise X-ray computed tomography to measure brine saturation of the core (obtain S_w) during a core flood experiment. We have commissioned an X-ray transparent flow cell made of aluminium with an Xradia Versa 500 instrument.

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