The effect of rank, lithotype and roughness on contact angle measurements in coal cleats

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Research Aims

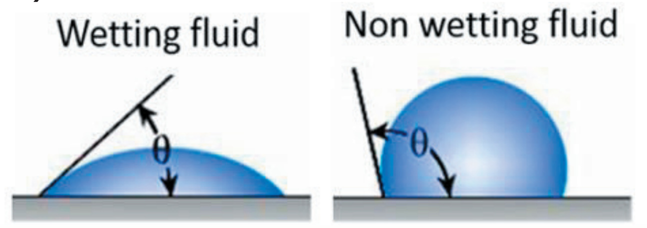
This project seeks to understand the effect of coal roughness, rank and lithotype banding on coal cleat wettability.

The results of this study may help develop better models of the physics of gas-water flow and improve relative permeability models.

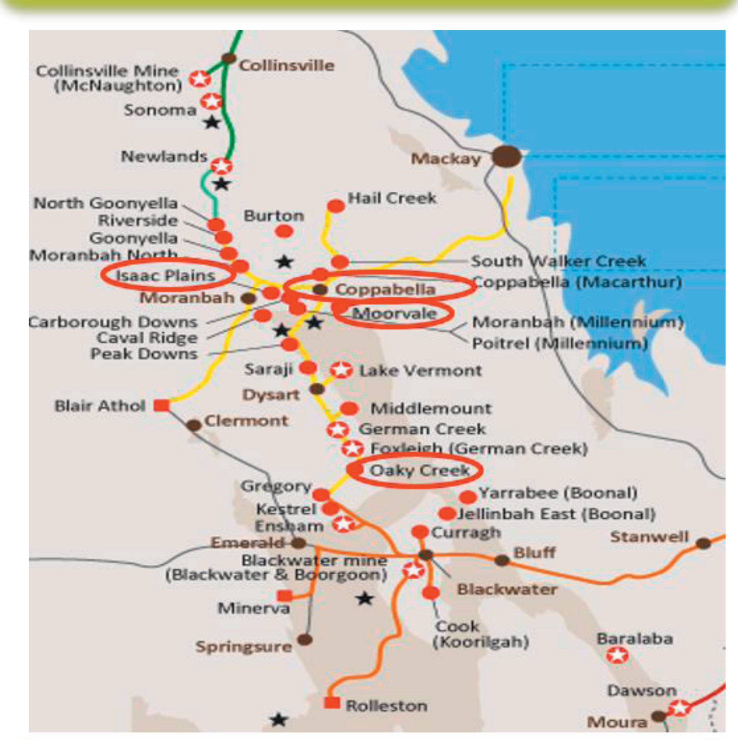
Wettability and Relative Permeability

Coal may have a mixed wetting state: gas wet, water wet and intermediate based on mineralisation, pressure, gas desorption and pH.

The common method to describe wettability is to measure contact angle (θ) of a polished surface by a sessile drop: *This method doesn't capture heterogeneity or geometry of coal cleats very well.*



Coal Samples



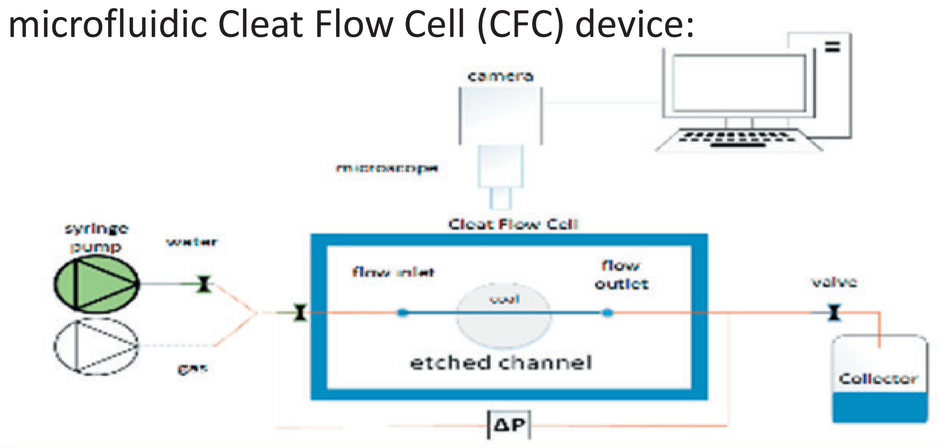
Methodology

Artificial cleats using bulk coal with widths of 20-30 µm prepared by Reactive Ion Etching (RIE).

Nine lithotype concentrates were pressed into discs with artificial cleats with widths of 80µm.

Apparatus

Flow of gas-water interfaces through cleats observed in a microfluidic Cleat Flow Cell (CFC) device:



SEM: Natural versus RIE versus Pressed cleat

We observed that vitrinite-rich bands were of a smoother texture than inertinite-rich bands in both a natural cleat and in the etched cleats.

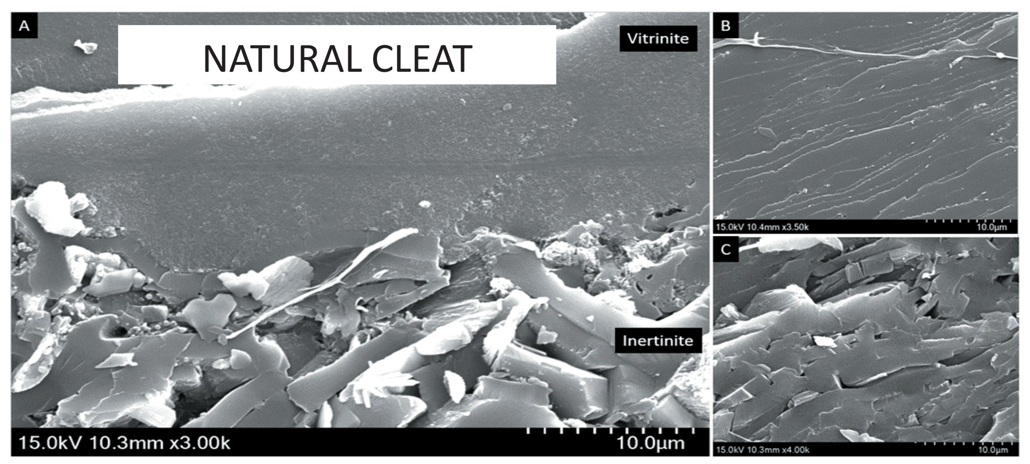


Fig.1: (A) Boundary between "smooth" vitrinite band and "rough" inertinite band in a **natural** cleat (IPN). **(B)** Vitrinite band. **(C)** Inertinite band.

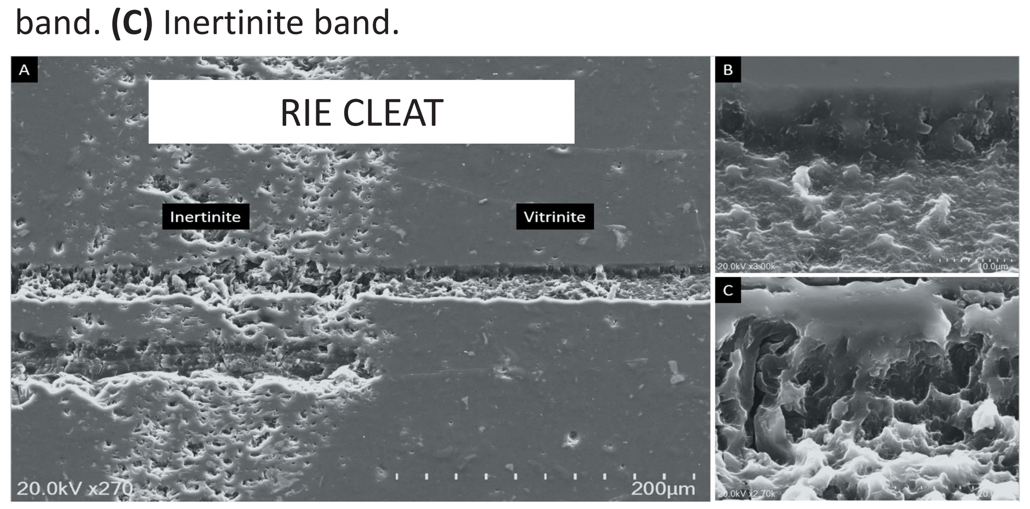


Fig. 2: (A). Boundary between vitrinite band and inertinite band in the **etched** IPN cleat. **(B)** Vitrinite etched cleat **(C)** Inertinite etched cleat.

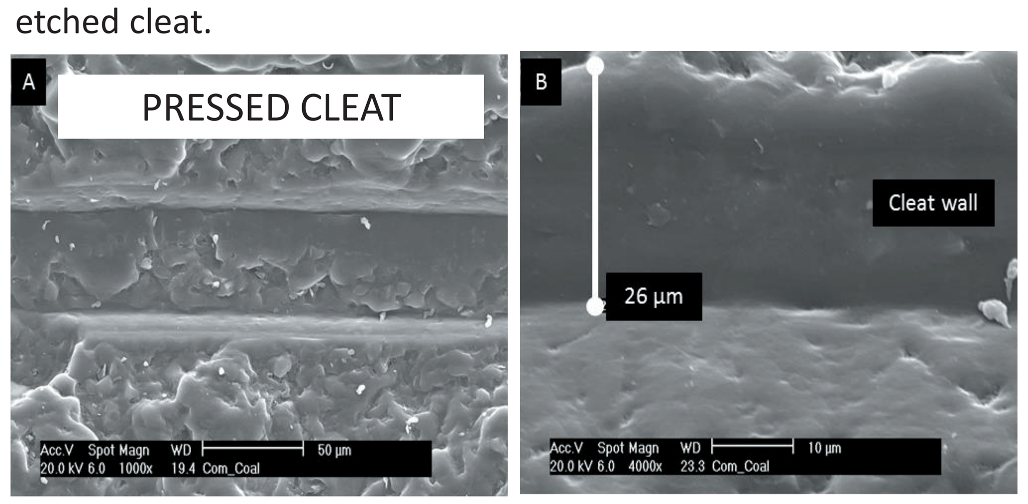


Fig. 3: (A). Pressed disc cleat using crushed coal lithotype concentrate. **(B)** Pressed disc cleat wall and floor.

Results of Imbibition Experiment

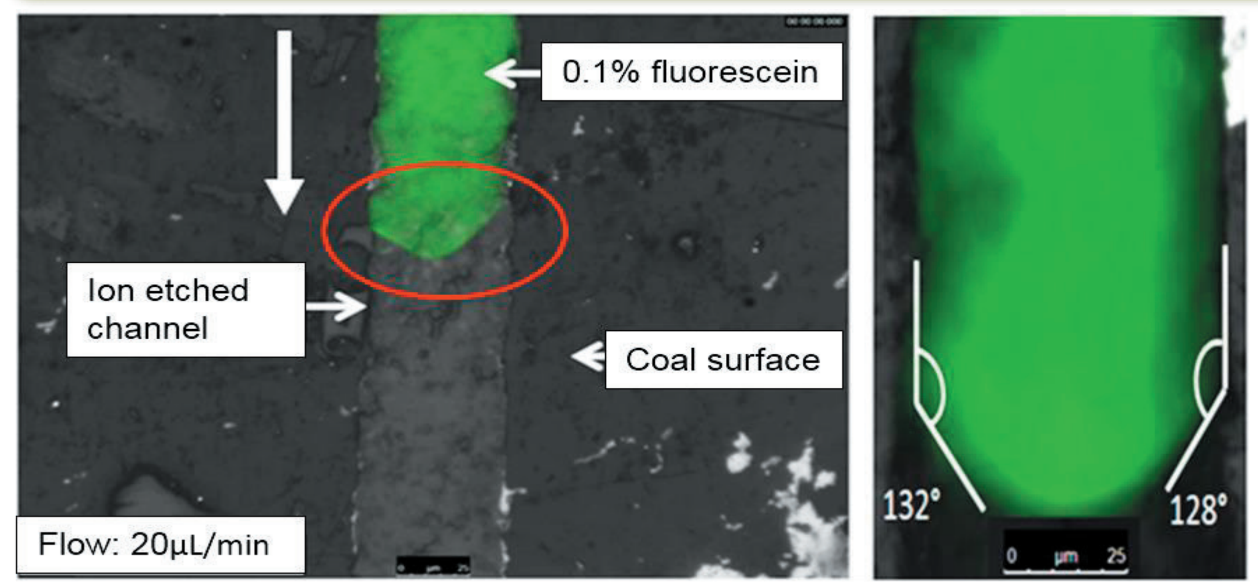


Fig. 4: Imbibition experiment showing a continuous water phase displacing gas in the etched cleat (OAK).

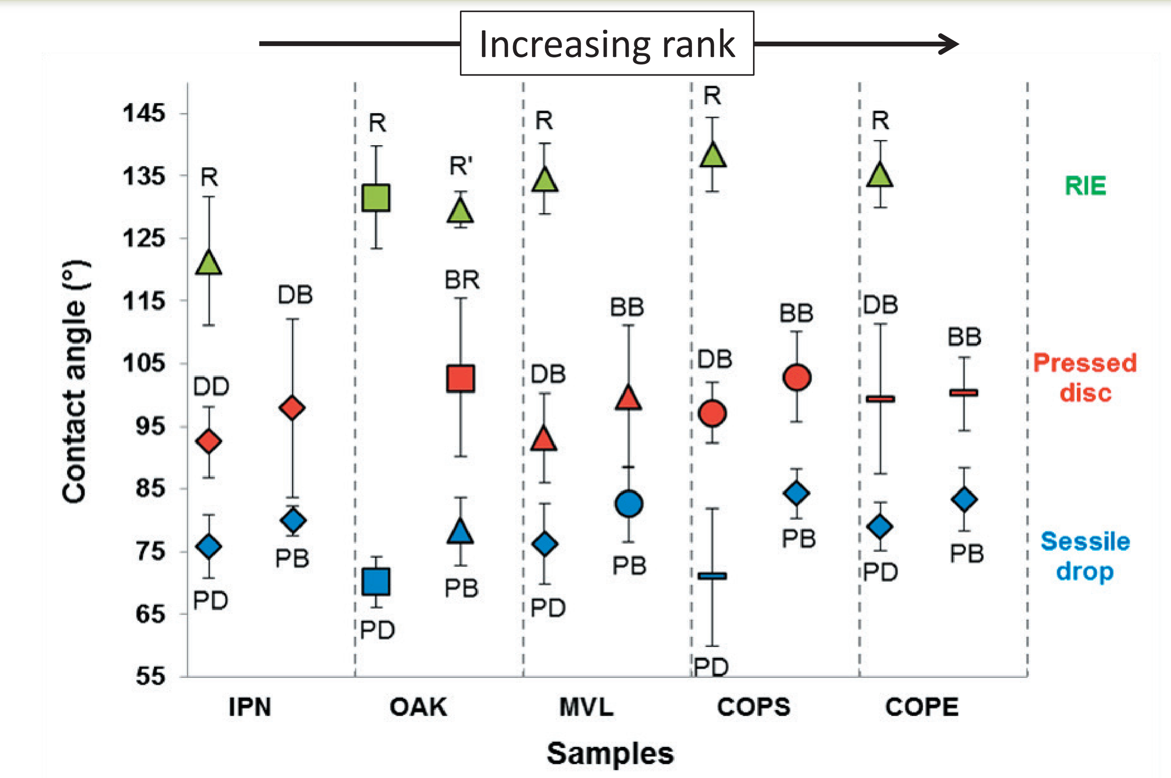


Fig. 5: Contact angles, and therefore hydrophobicity, changed with rank, lithotype and surface roughness. Sample codes: R – inertinite band, R' – vitrinite band, DD – 90% inertinite, DB – 60% inertinite, BB – 30% inertinite, BR – 10% inertinite, PD – polished dull coal, PB – polished bright coal.

Measuring Roughness in the Cleats

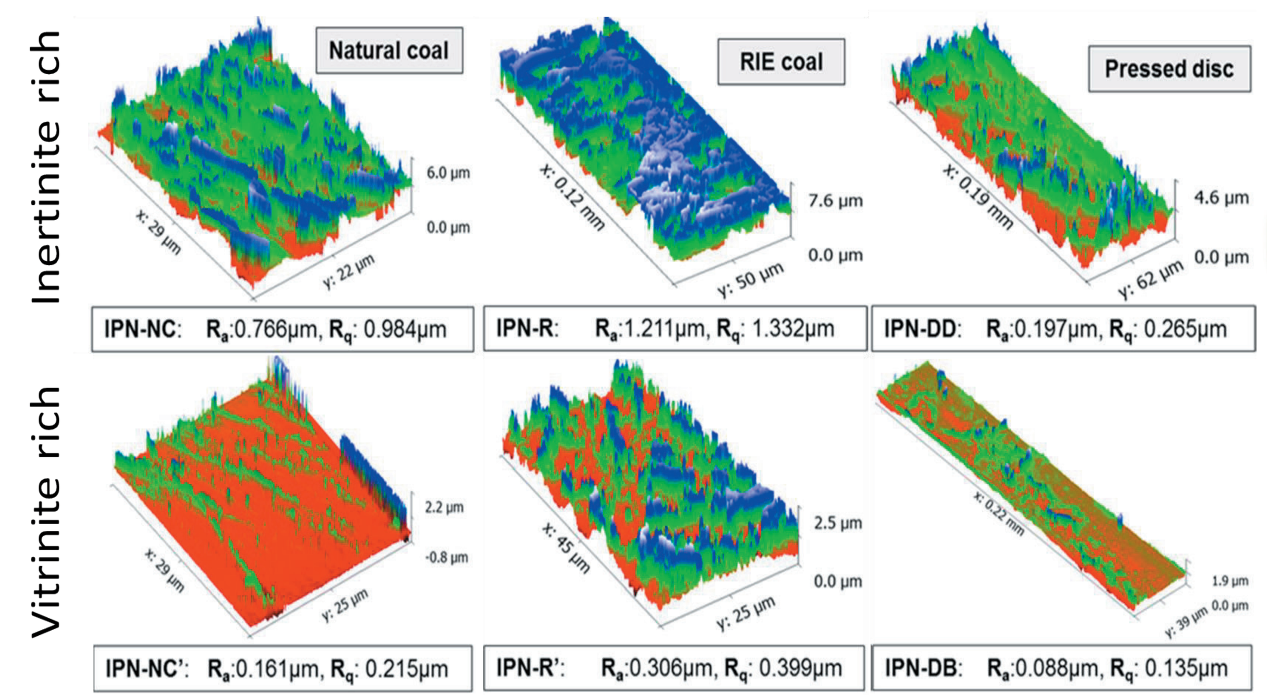


Fig. 6: 3D images generated from SEM scans of coal channel surfaces using the software package Gwyddion. A roughness value (R_a and R_q) were calculated for each sample. Larger R_a and R_q values indicate a rougher surface.

Results of Drainage Experiment

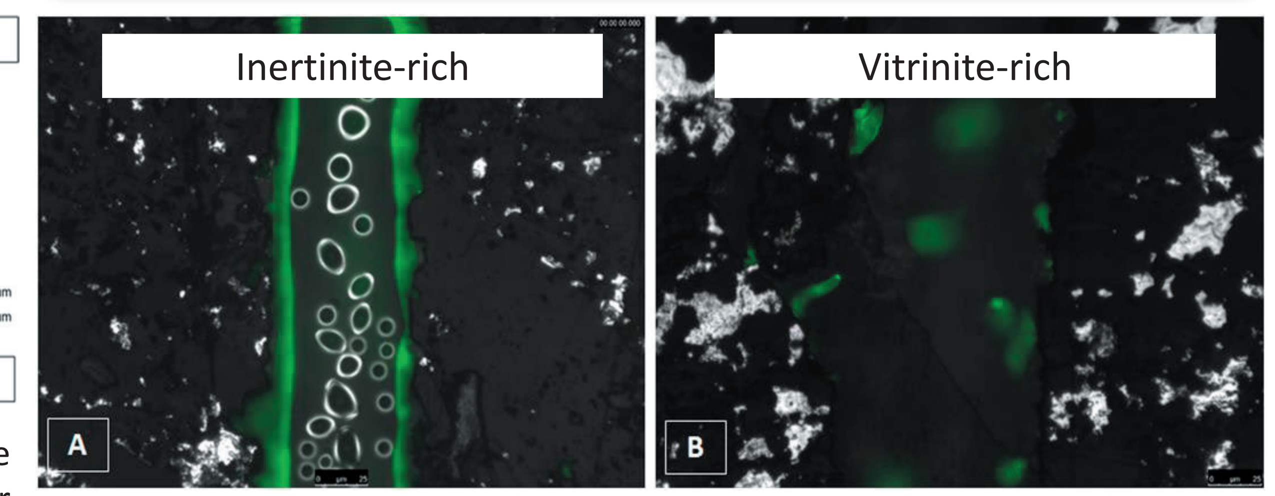
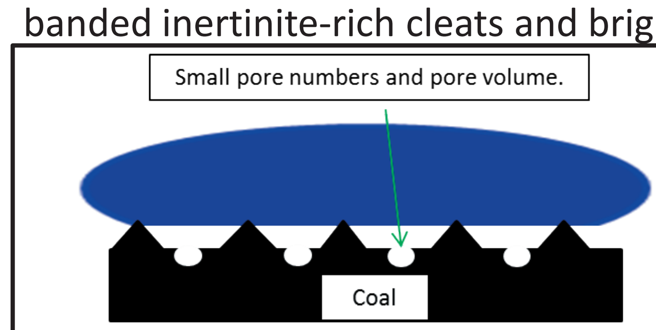


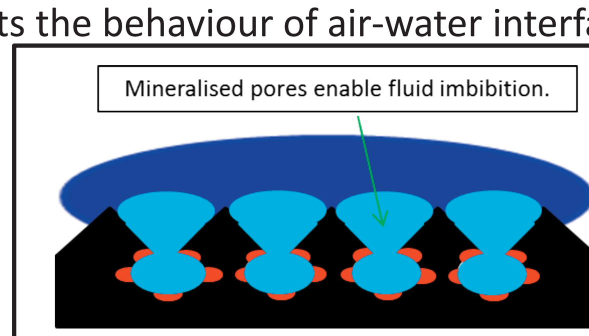
Fig. 7 (A). A residual water film in drained inertinite-rich bands of IPN coal, but **(B)** such a film was not observed in vitrinite-rich bands of the same coal.

Summary & Conclusions

Residual water saturation may be lithotype dependant. Variations in the pore texture of cleat walls and matrix mineralisation between dull banded inertinite-rich cleats and bright banded vitrinite rich cleats affects the behaviour of air-water interfaces.



Vitrinite bands are less rough and gas may adhere more effectively to the smaller, discreet, pores on the coal surface simulating a lotus effect; which results in a lower breakthrough pressure to move a water slug through the vitrinite rich band than inertinite.



Inertinite rich bands have greater roughness, porosity and mineralisation that enhance water penetration into smaller pores off the main cleat. While the main etched channel is still considered hydrophobic, the liquid phase would imbibe during drainage creating a residual film, or petal effect, as seen in Fig. 7.

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