Hydraulic fracturing to improve coal drainage

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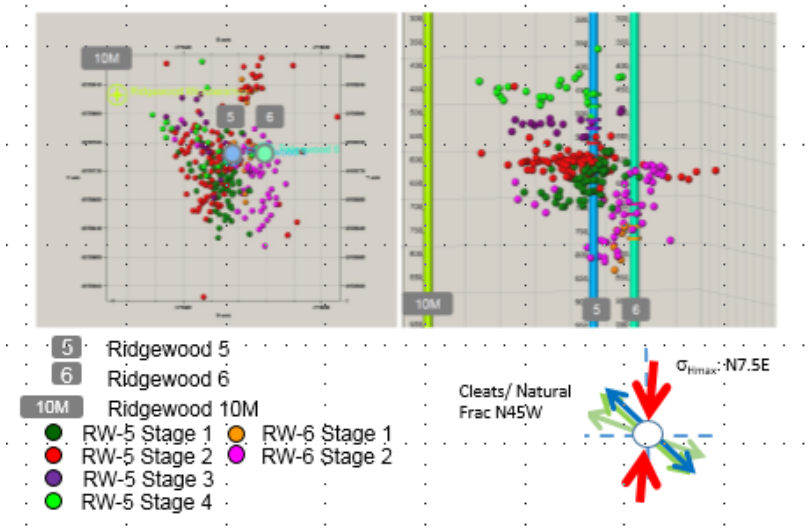
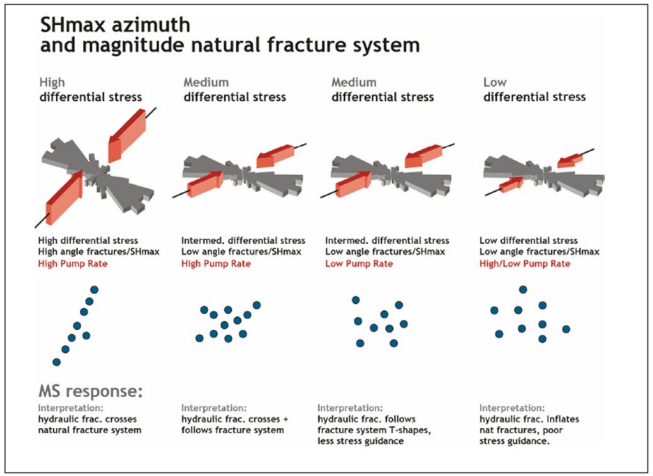
Coals, stress and fracturing

- Typically, Bowen Basin is in a stress regime dominated by high, anisotropic, horizontal strains ($\varepsilon_{h\text{-}min}$, $\varepsilon_{H\text{-}Max}$)
- Differential strains and elastic properties of coal often places coal in a normal stress state ($\sigma_{h\text{-}min}<\sigma_{H\text{-}Max}<\sigma_{Vertical}$) relative to bounding rocks in reverse ($\sigma_{Vertical}>\sigma_{H\text{-}Max}>\sigma_{h\text{-}min}$) or strike-slip regimes ($\sigma_{H\text{-}Max}>\sigma_{Vertical}>\sigma_{h\text{-}min}$)
- Differential drainage in the coal can reduce the in-situ stress in the coal from normal state to nearly isotropic stress state
- The hydraulic fracture will stay contained but exhibit complexity based on cleat/natural fracture alignment (paleo stress conditions) relative to prevailing stress azimuths
- Horizontal surface-to-inseam wells increase coal drainage
- Managing the fracture propagation and allowing greater fines controls requires new thinking to well orientation and placement in mining areas
- Steel casing is still avoided by using indirect placement

Implications of flaws on fracs in high deviatory stress



Johnson, Jr. R.L. et al., SPE 133063, 2010



Flottman et al, SPE 167064, 2013

Fractures can and will often open and initially propagate with low viscosity short injections in the natural fracture direction and exhibit closure pressures that are the normal stress acting on the face of the fracture

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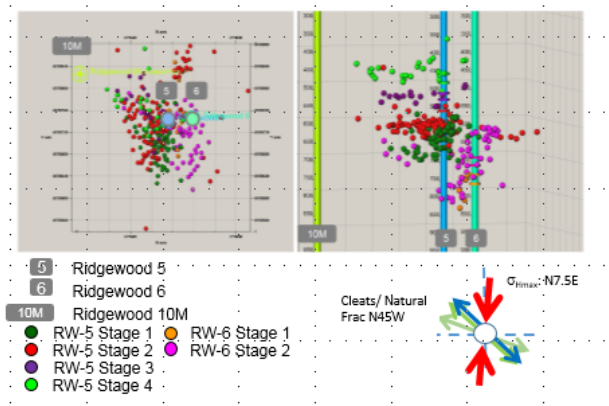
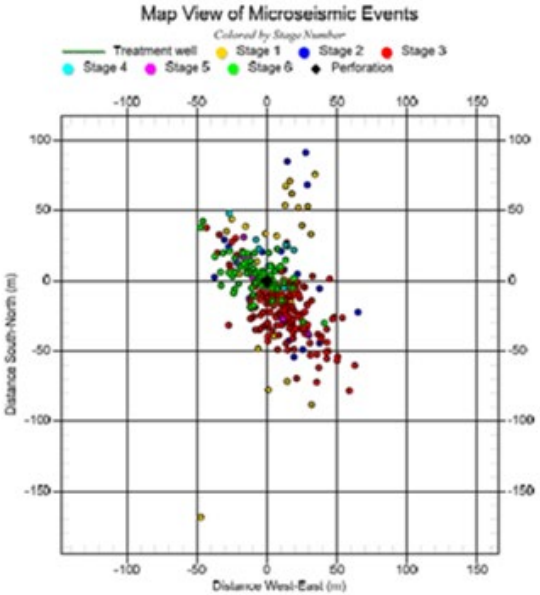
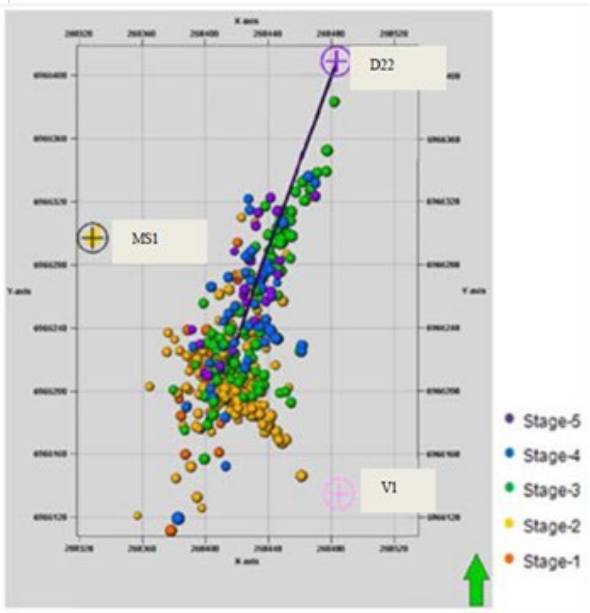
Drill in the $\sigma_{H\text{-}Max}$ direction improves stability….



Area 1: Johnson, Jr. R.L. et al., SPE 133063, 2010





Area 2: Bentley et al, SPE 167053, 2013

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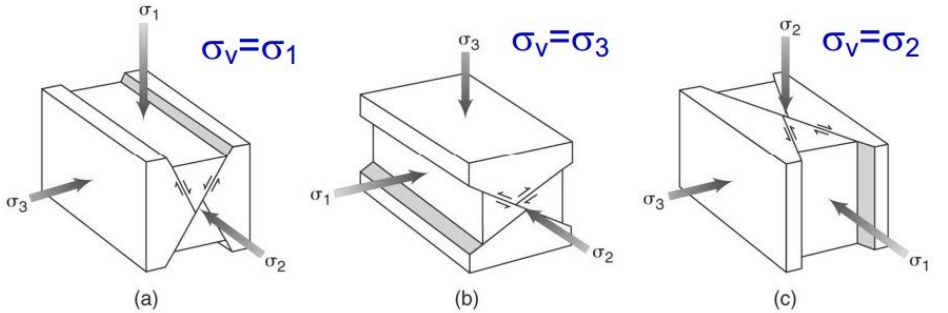
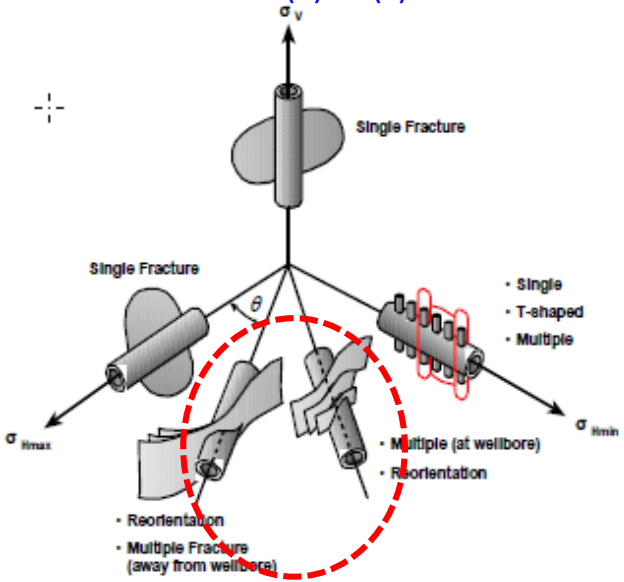


(Vertical Fractures) (Horizontal Fractures) (Vertical Fractures)

After Anderson, 1905

Case (a) or (c)



After Soliman, SPE 86992, 2004

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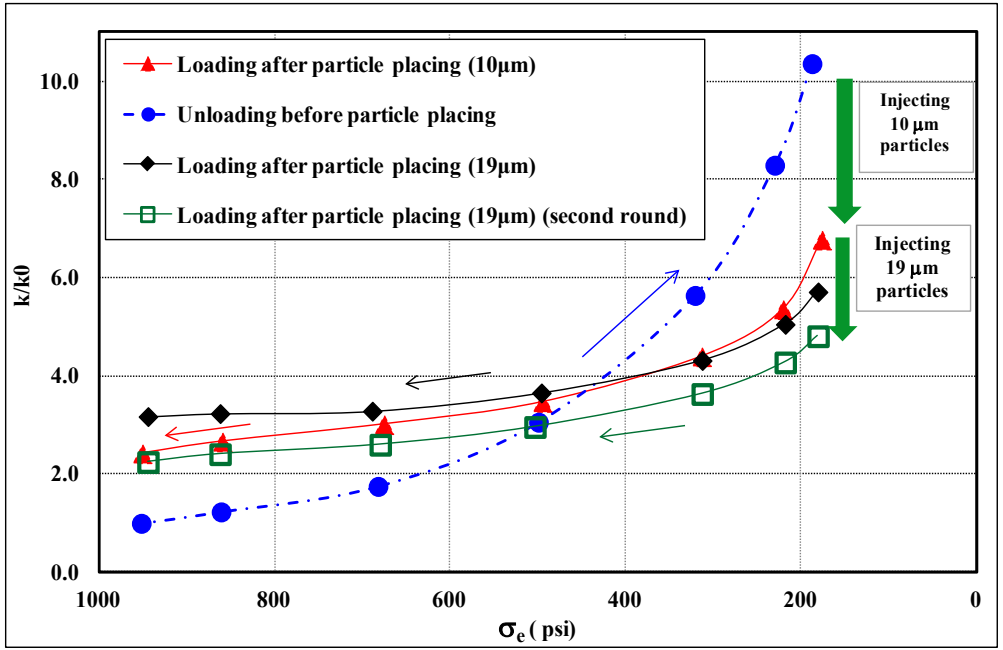
What else can we do…micro-proppant injection to improve recovery in fractured reservoirs



Sample # U-2 Salinity=0.1 M

After Keshavarz et al, SPE 167757, 2014

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Indirect hydraulic fracturing

- Uses the concept that placing a well outside the coal and fracturing into the coal will improve hydraulic fracturing in coal (Olsen et al., SPE 107985-MS, 2007).
- Uses casing in overlying or underlying intervals with cemented or rubber swell packer isolation accessing the coal through repeated floor or roof touches, respectively
- Indirect touches allow ready path for propagation without complexities in the overlying or underlying intervals
- Coal can be effectively fractured with multiple fractures and cleats and natural fractures propped using micro-proppants
- Indirect drainage is used in China (JAMG, unstimulated) and Cooper Basin (Strike)

Indirect hydraulic fracturing – Cooper Basin

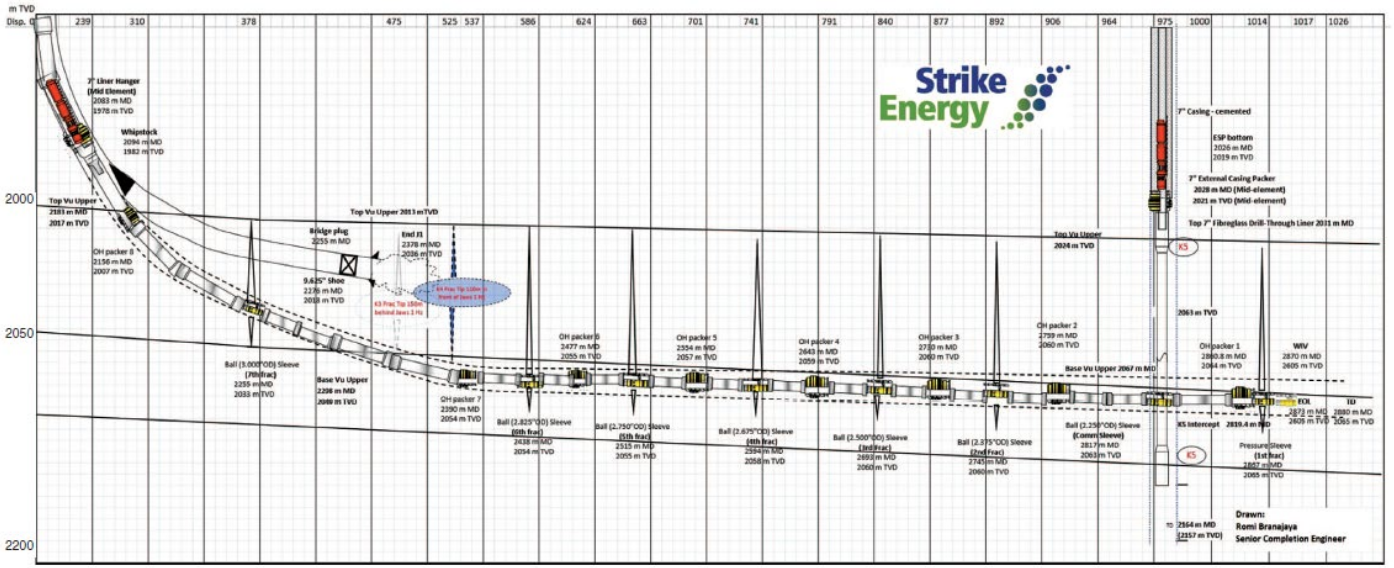

Fig. 1. Fracture stimulation liner assembly.

Branajaya et al., APPEA Journal, 2019

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Indirect hydraulic fracturing – Cooper Basin

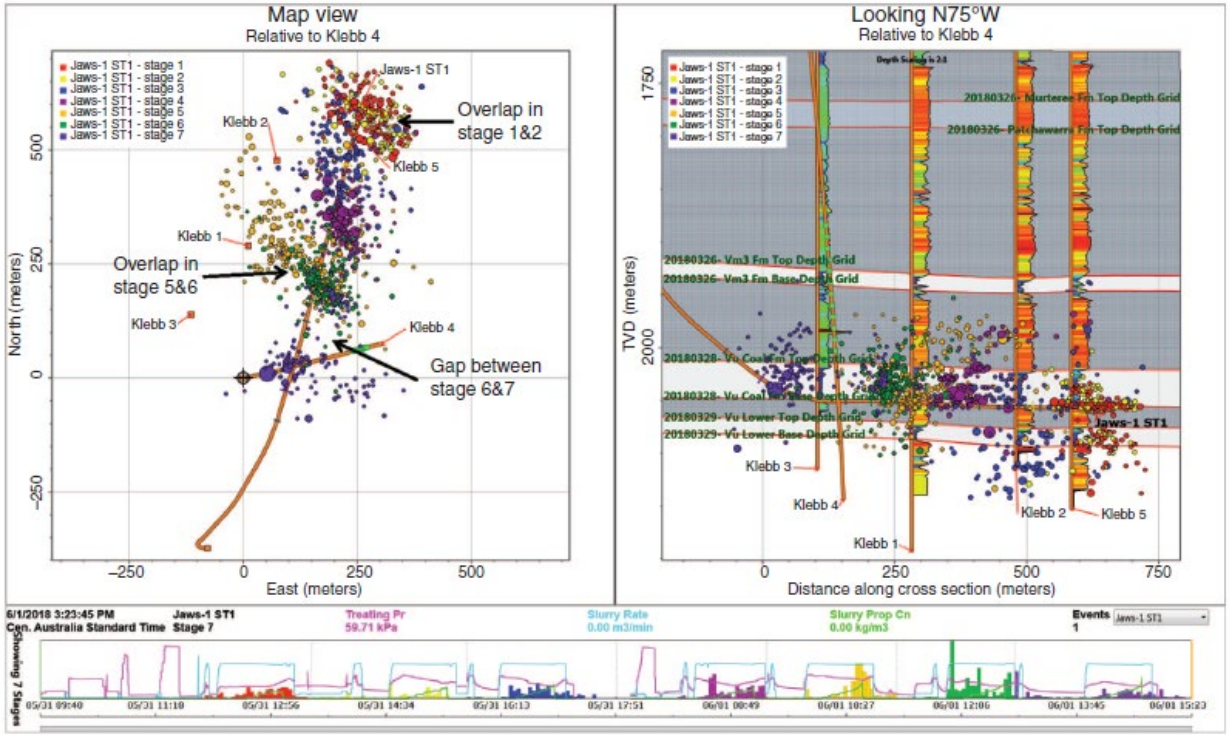

Fig. 3. Microseismic events by stage – seven stages, 1162 events.

Branajaya et al.,
APPEA Journal, 2019

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Summary

- Hydraulic fracturing from horizontal, uncased, uncemented coals is potentially unmanageable or uncertain (e.g., glass-reinforced epoxy casing & tools) from a diversion or production standpoint without steel casing
- Indirect hydraulic fracturing places the well outside the coal and allows fracturing into the coal through underlying or overlying intervals via repeated roof or floor touches, respectively
- Roof or floor touches provide the entry points and production conduits between the coal and the drainage well
- Multiple and selected staging can be used based on steel casing and conventional fracturing tools
- Application in the deep Cooper Basin Patchawarra coals was successful and offers an analogue
- Wells are cased for ease of clean-out with coiled-tubing