ACARP Project C14011

Hydraulic Fracturing for Gas Recovery and Its Impact on Subsequent Coal Mining

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Overview

- Objective / Outcomes
- Background to Project
- Approach
- Review of Experience in USA & Australia
- Numerical Modelling Results
- Issues Identified in Risk Review
- Findings and Recommendations

Objective

To understand the effect that seam gas stimulation, particularly full-scale hydraulic fracture stimulation treatments, has on the future mineability of coal seams.

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Outcomes

No significant impacts noted in USA or Australia

Record keeping necessary to determine where holes are and the completion and abandonment details need to be controlled

Background

- Queensland Petroleum and Gas Bill
  - Includes policy and regulations controlling the interaction between Coal Bed Methane (CBM) operators and underground coal mining companies in areas where there may be potential for overlapping operations.
  - Queensland Resource Council (QRC) had opportunity to review this bill.
- QRC was concerned that production hydraulic fracturing routinely used by CBM operators has the potential to affect the roof and floor stability in future underground operations.
- This ACARP Project was initiated to investigate the potential impacts of hydraulic fracture stimulation on the subsequent safe and efficient mining of the coal

Approach

- Review experience to date of mined through hydraulic fractures in USA and Australia
- Use hydraulic fracturing models and geomechanical models of strata behaviour to determine the nature and significance of potential impacts
- Identify and assess the potential impacts through a risk review process
- Recommend strategies to manage and further investigate potential impacts

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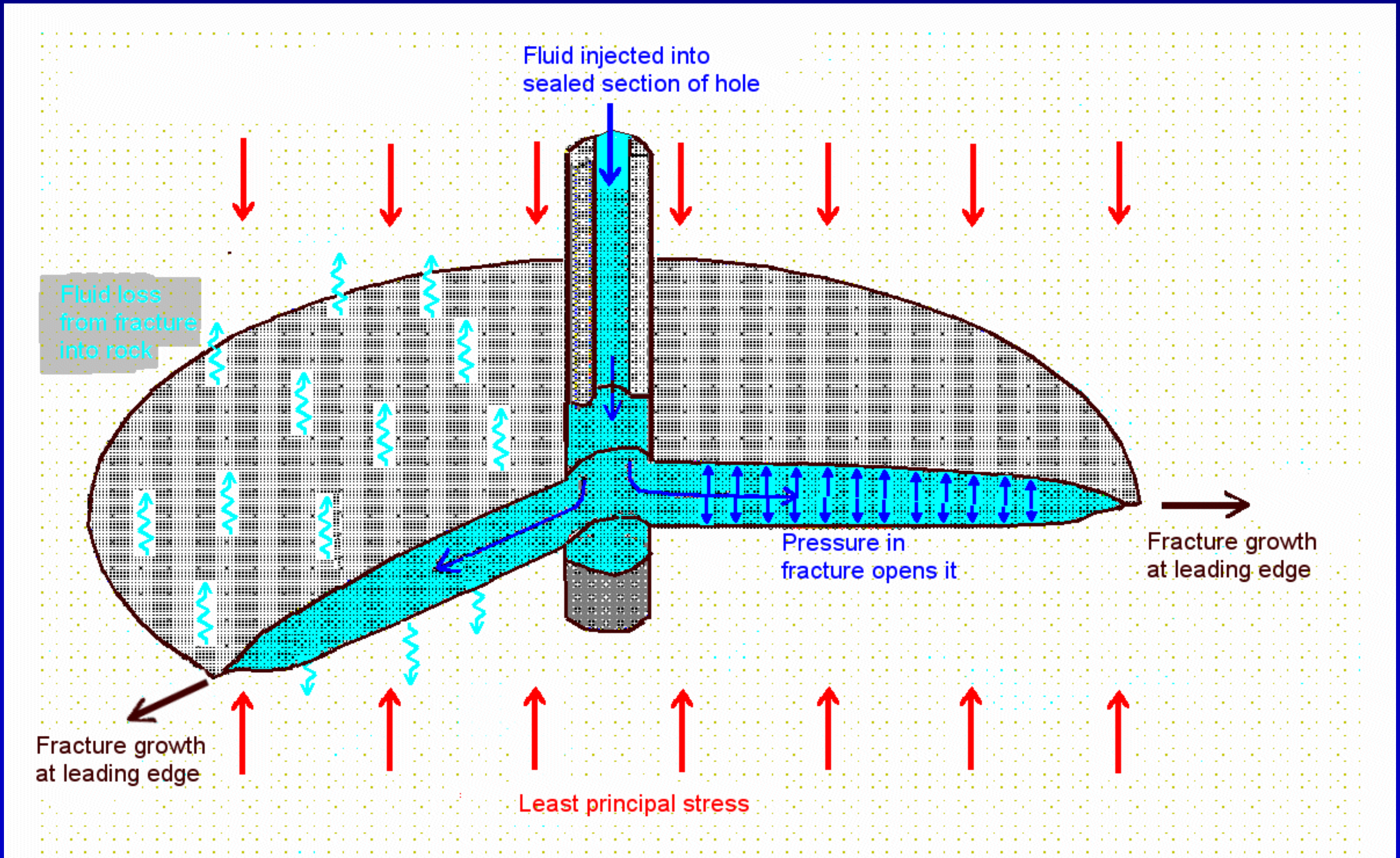
Hydraulic Fracturing



Hydraulic fracturing uses a pressurised fluid to generate a single, essentially circular / planar fracture (in an ideal uniform stressfield)

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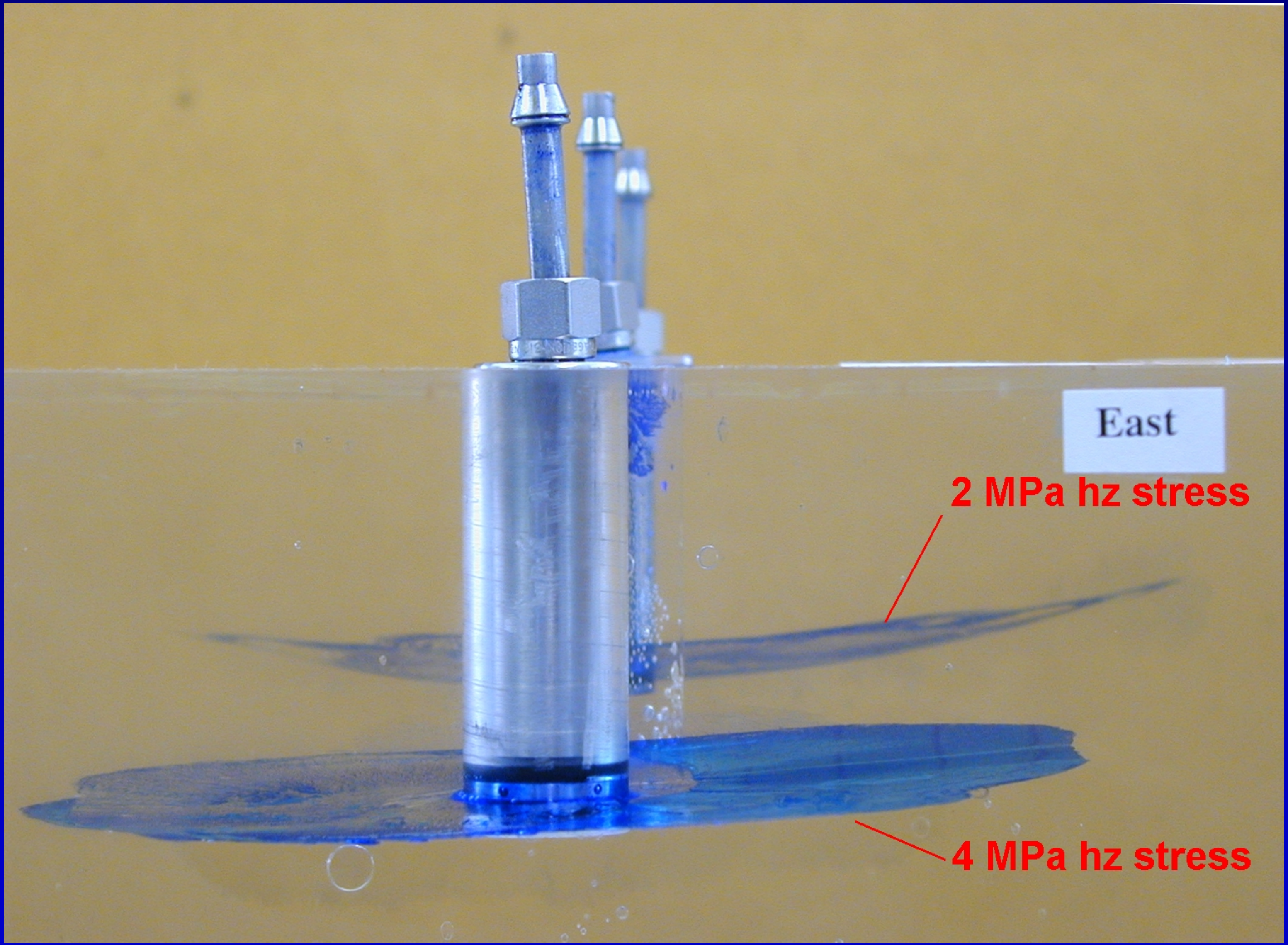

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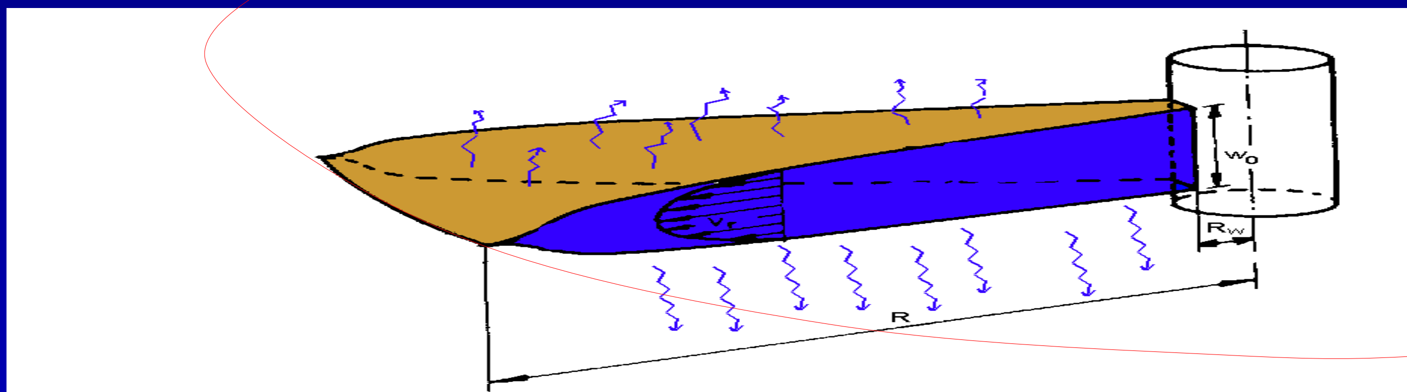
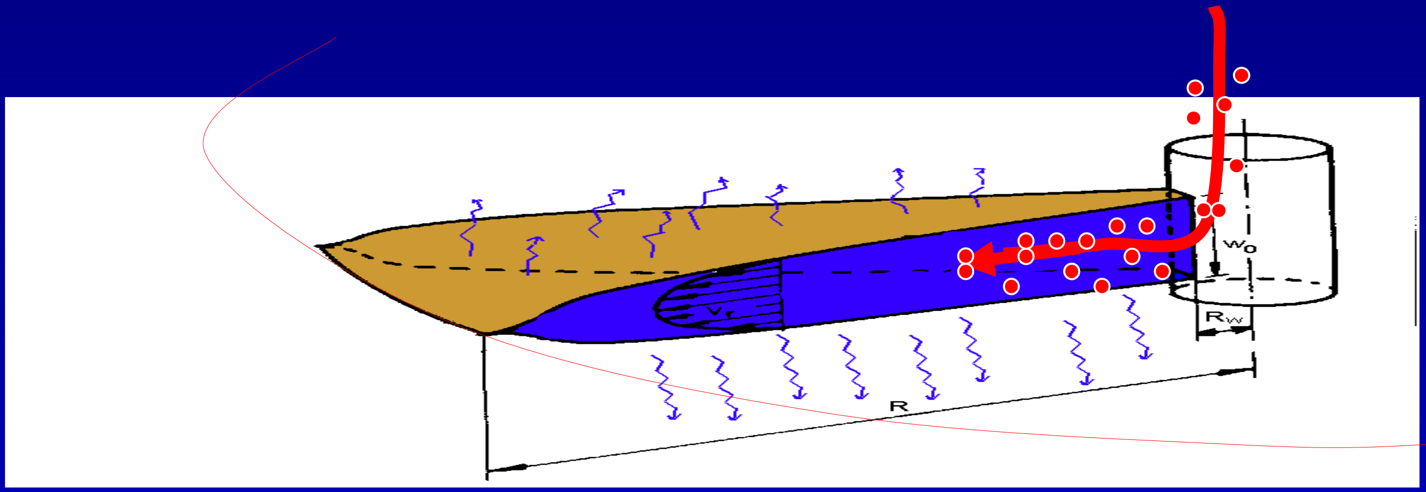
Sand Propped Hydraulic Fracturing



Sand propping involves placing a graded sand in the fracture so that when the pressure is released, the fracture closes imperfectly and provides a drainage path to enhance gas drainage and overcome borehole damage

Sand Propped Hydraulic Fracturing



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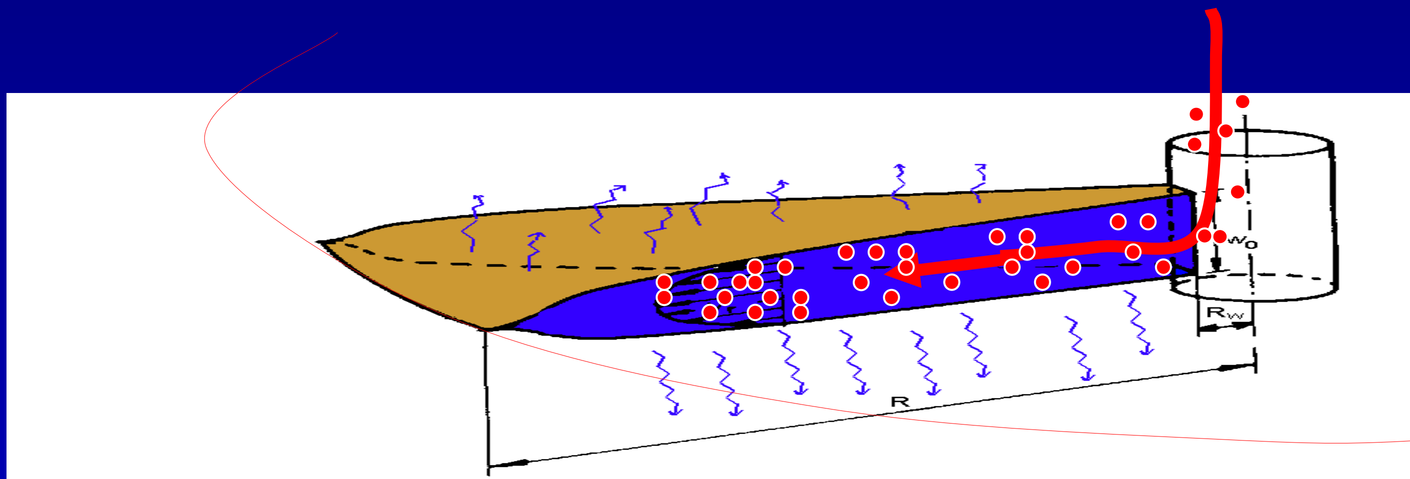

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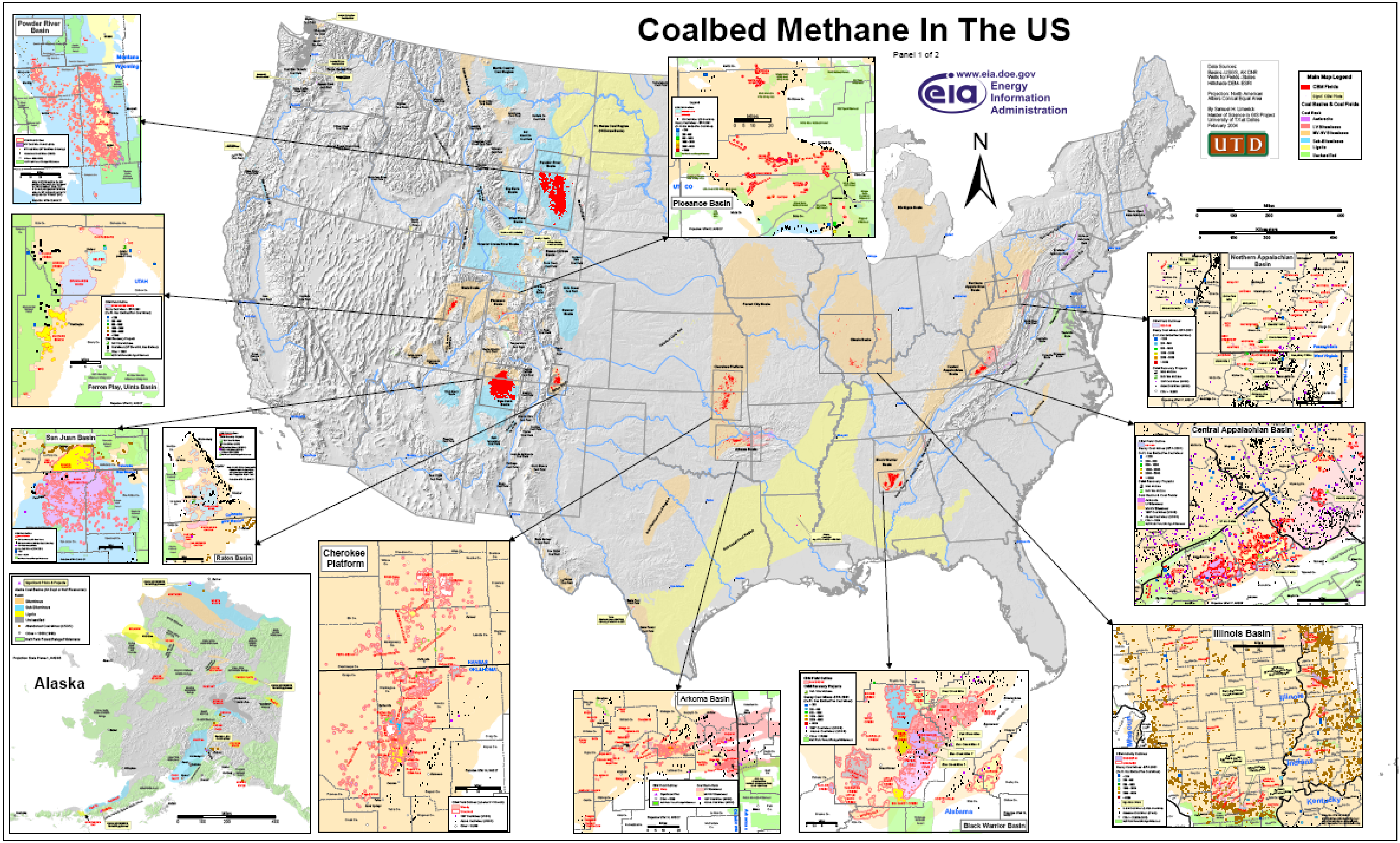

Current CBM Areas in USA

(from Energy Information Administration, Dept of Energy, US Govt)

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Review US Experience

Type of mine	Production (metric tonnes)	Number of mines
Underground (active) mines - total	320.05 Mt*	580***
Surface (active) mines - total	651.25 Mt**	714 ***

Sources: *UNFCCC (2005a); ** Schwochow (1997): *** GeoHive (2004)

Mine Name	Mine Location	Total Emissions Avoided 2003	Methane Use Option
Blue Creek No. 4, 5, 7	Alabama	232 MM m^3 (3.31 MMTCO2)	Pipeline Sales
Oak Grove	Alabama	42.7 MM m^3 (0.61 MMTCO2)	Pipeline Sales
Shoal Creek	Alabama	10.3 MM m^3 (0.15 MMTCO2)	Pipeline Sales
Mine X*	Colorado	0.40 MM m^3 (0.01 MMTCO2)	Mine Heating
San Juan	New Mexico	0.40 MM m^3 (0.01 MMTCO2)	Pipeline Sales
Blacksville No. 1	Pennsylvania	34.0 MM m^3 (0.48 MMTCO2)	Pipeline Sales
Buchanan No. 1 VP #8	Virginia	785 MM m^3 (11.2 MMTCO2)	Pipeline Sales, On-Site Use, Power Generation
Federal No. 2	West Virginia	8.5 MM m^3 (0.12 MMTCO2)	Pipeline Sales, Power Generation (planned)
US Steel No. 50	West Virginia	15.7 MM m^3 (0.22 MMTCO2)	Pipeline Sales

*Mine X has requested that they remain anonymous at this time.
Source: USEPA (2004a)

(from Methane to Markets – CMM Global Overview 2005 - Draft)

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Current US Fracturing Practice

- Foam based fluids - 70% N_2 and 8 cp linear gel base.
- Pumped at 35 bpm with 20/40 and 16/30 mesh sand. Place 3,000 to 5,000 lbs per net foot of seam.
- 5 stages per well with 2 to 3 seams per stage.
- Some slick water treatments at 30 bmp also done.
- Some cross-linked gels

Abandonment Strategies

- Case across mineable seams using fibreglass casing
- Re-enter well and cut steel casing ahead of mining so that it can be extracted underground. Alternatively, can mill casing completely out
- Cement plugs are typically 15-50m length above and below seams
- Not practical to mill casing ahead of mining because there are too many seams that aren't mined and not necessary if hole passes through a pillar

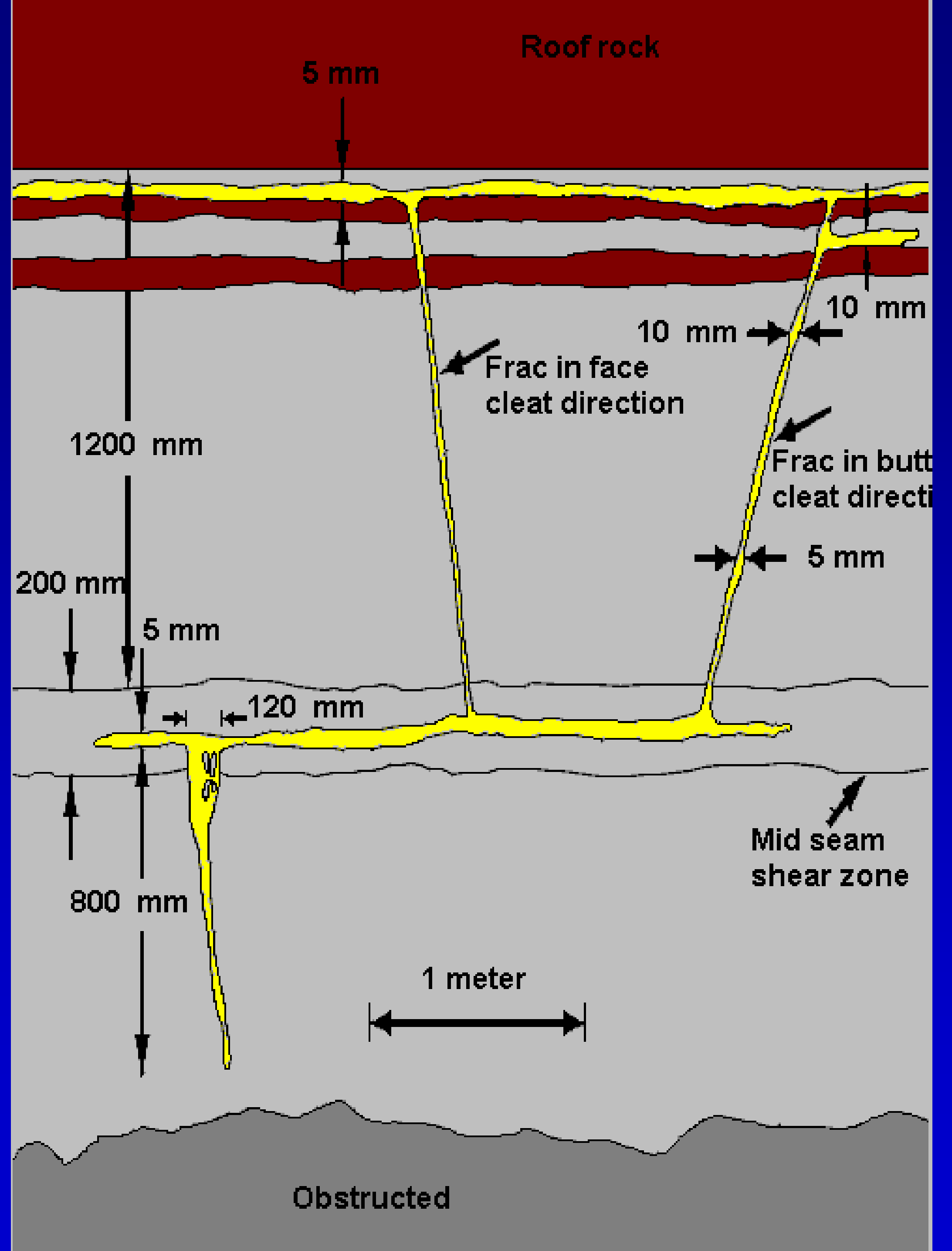
Fracturing and Mining

- CONSOL have mined 400 to 600 hydraulic fractures out of a total of 1900. They documented first 200 or so internally until they decided there was no issue.
- JW Resources have mined about 250 fracs out of 500 total
- Oak Grove have mined about 200 wells with fracs
- Consol believe northern West Virginia cannot be fractured. NIOSH strongly disagree with this and cite Emerald mine experience

Australian Experience

- Have mined 9+ large hydraulic fractures in coal, only one of which was full scale (ECC90)
- Two fractures in 1981 at Appin were not found on mining
- Nine recent fractures are well documented
- ECC90 was 27bpm crosslinked gel frac
- 624 small sand propped fractures placed in LW9 at Dartbrook (in 2002) and later mined

Hydraulic fractures can be complex in geometry with multiple branches and both horizontal and vertical parts



Mapped section through hydraulic fracture in well ECC90 at Central Colliery

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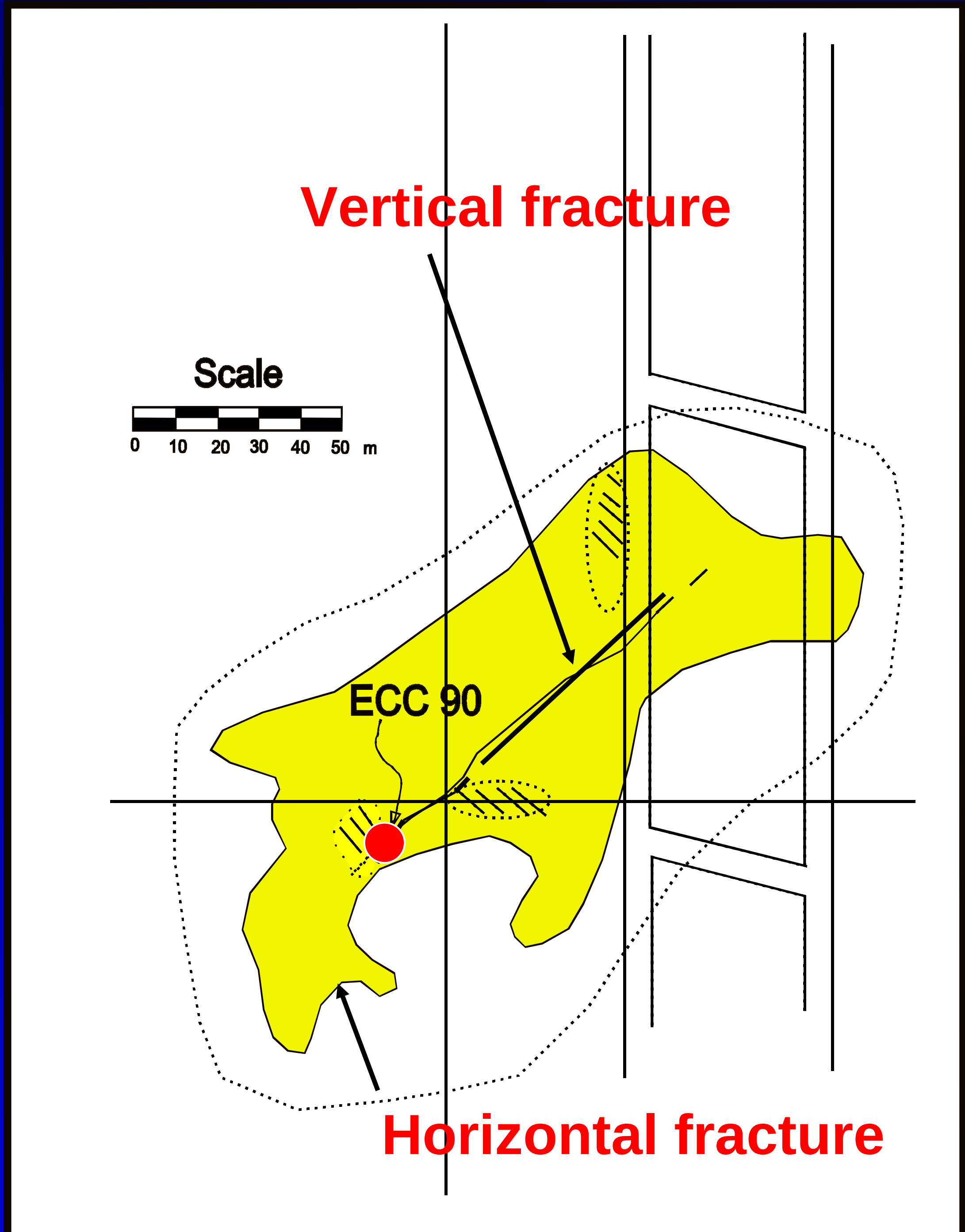
ECC90 was treated using a borate crosslinked gel at 27 bpm

A large horizontal fracture was created with an underlying vertical branch



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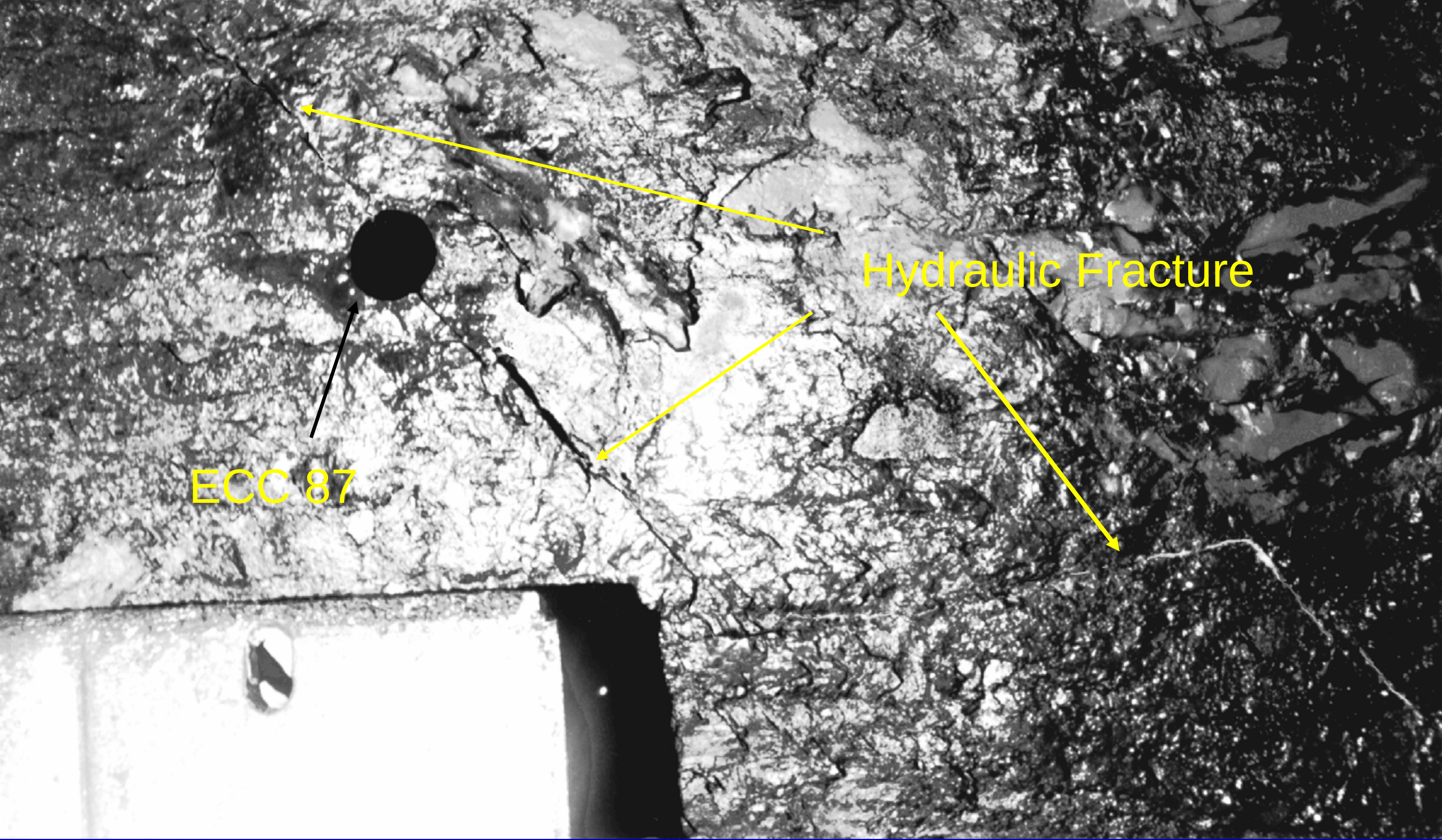

Hydraulic fracture in roof rock near borehole ECC 87

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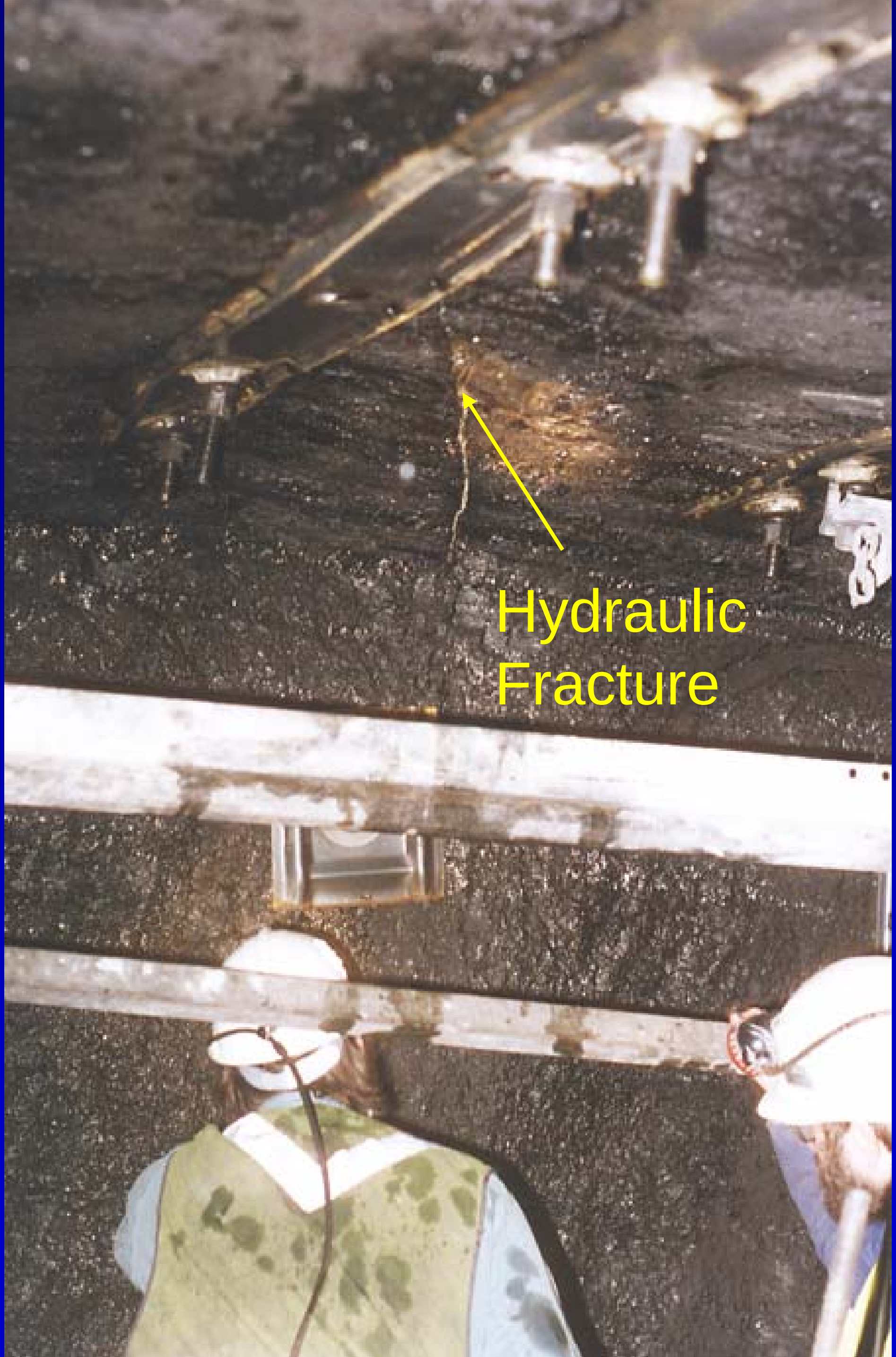
Dartbrook Mine.

Hydraulic fracture in roof of A heading shortly after mining through DDH 139.



Summary of Experience

- USA experience of CBM mine throughs
  - CONSOL mined 400-600 of 1900 fracs in Central & Northern Appalachian without negative impacts
  - Some 450 out of 750 fracs in the Black Warrior Basin have been mined through without impact
  - No significant effects on the stability of underground coal operations from production hydraulic fracturing
  - Effective strategies/regulations in place to solve conflicts at least at a state level
  - Coal operators are actively encouraging CBM especially where they have a commercial interest in it

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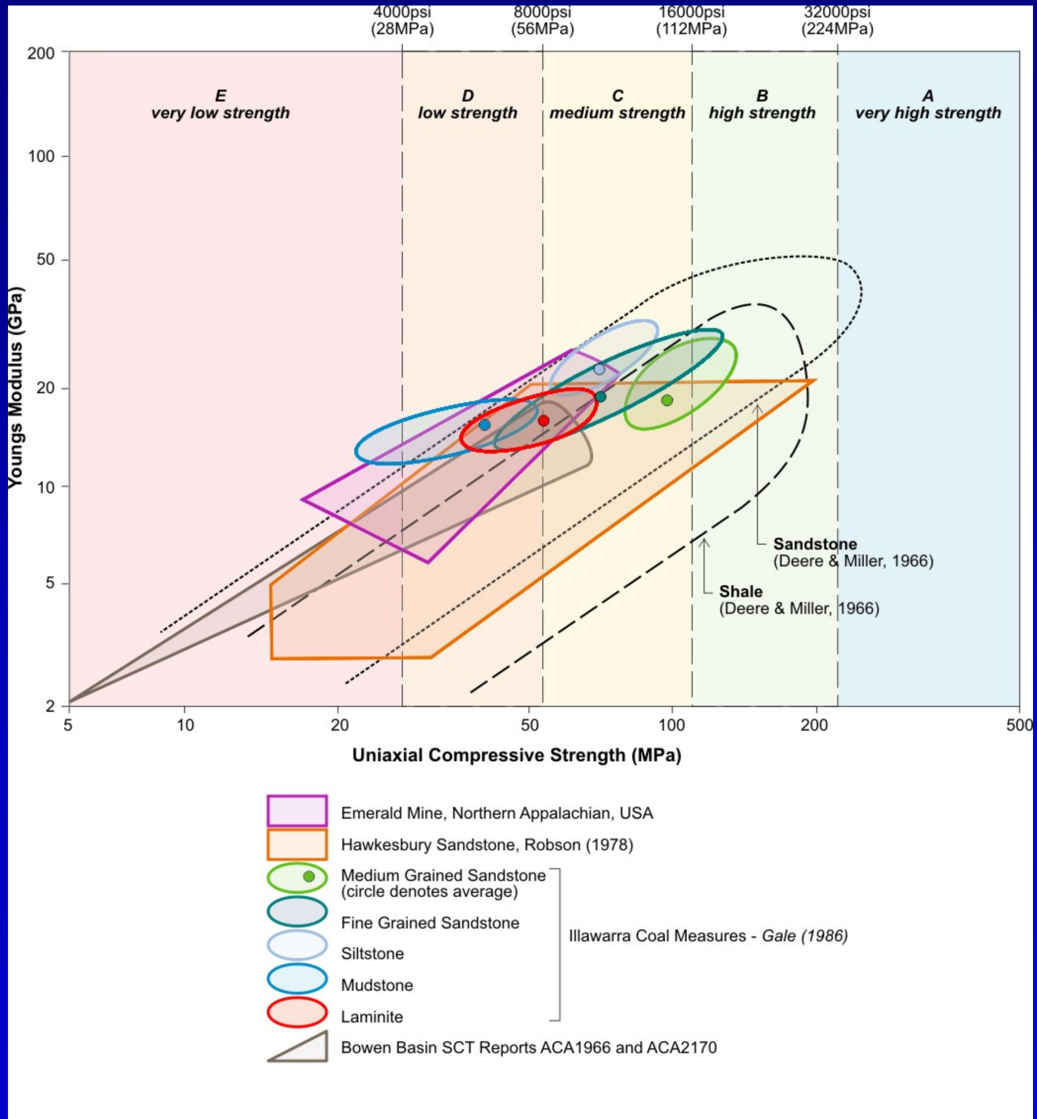
Summary of Experience

- Australian experience of CBM mine throughs
  - Limited to mine throughs of only a few full scale fractures (Jeffrey et al., 1992) and several hundred small-scale hydraulic fractures mined in both Queensland and NSW, mainly at Dartbrook.
  - No significant effects although some drying out of coal noted at Dartbrook because of the effectiveness of drainage

Material Property Comparison



Comparison of Rock Properties and E/UCS Plot

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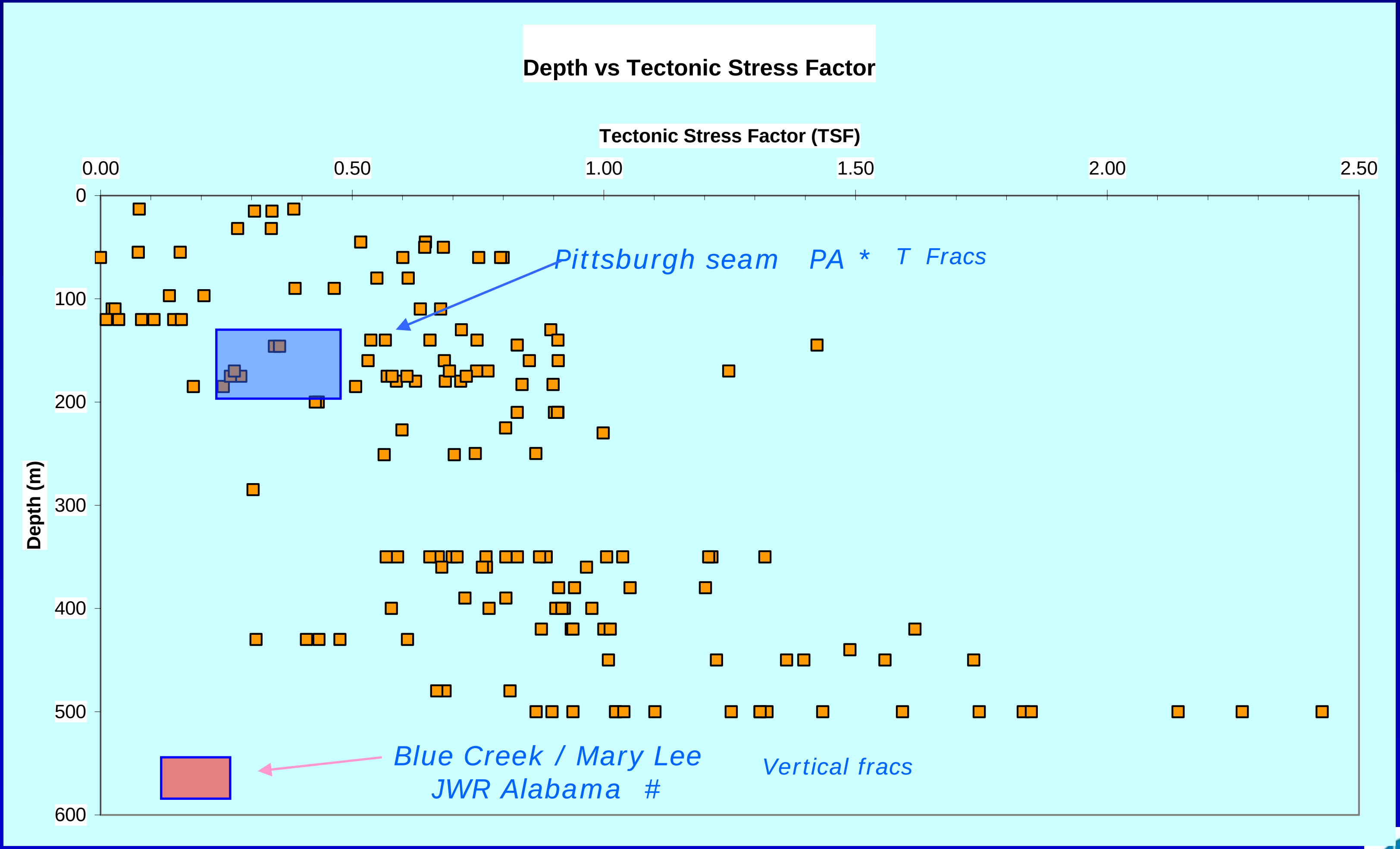
In Situ Stress Comparison



** interbedded coal roof .*

 # variable

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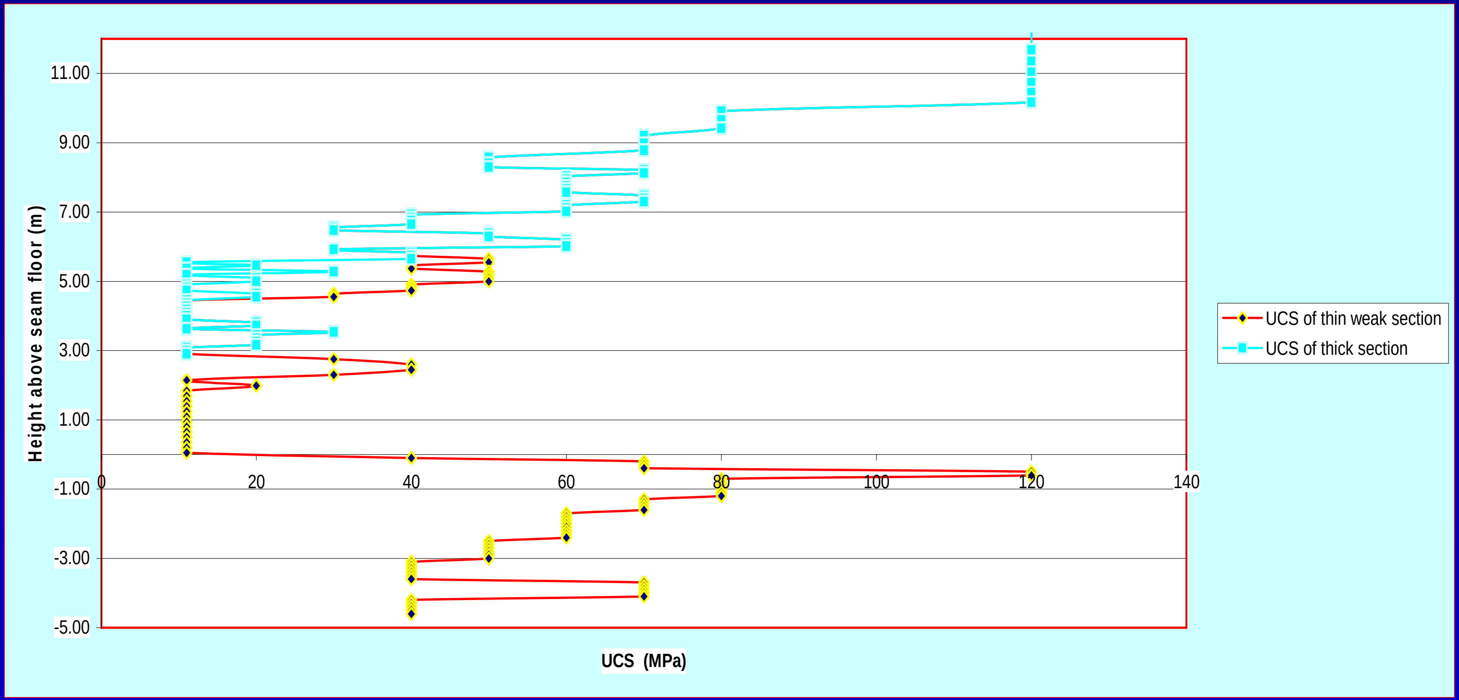
Strength Properties of Pittsburgh Seam



Near Seam section "similar" to Australia

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General Geology

T shaped Fracture

40 m

250 m

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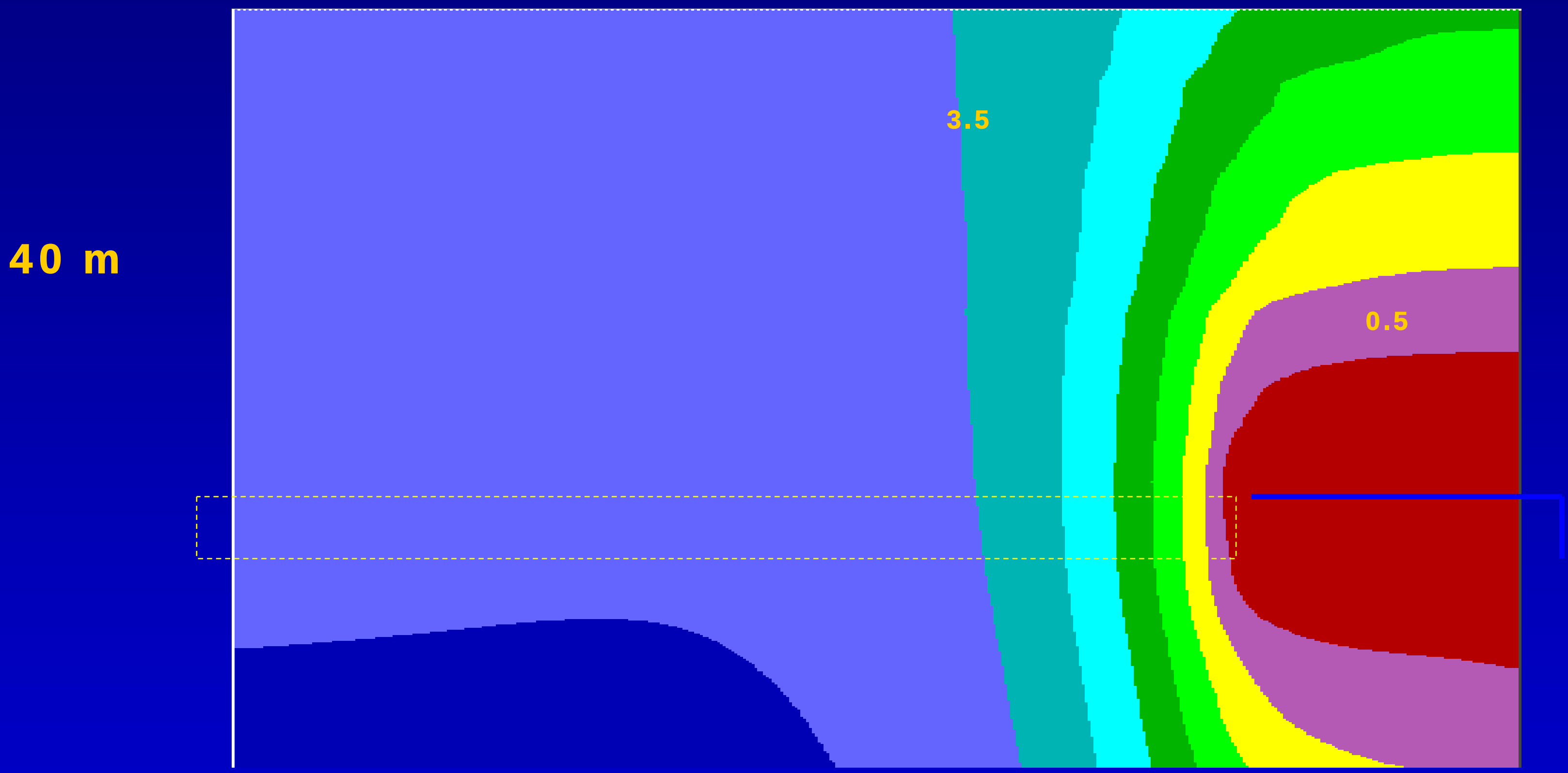
Pore Water Pressure During Gas Production



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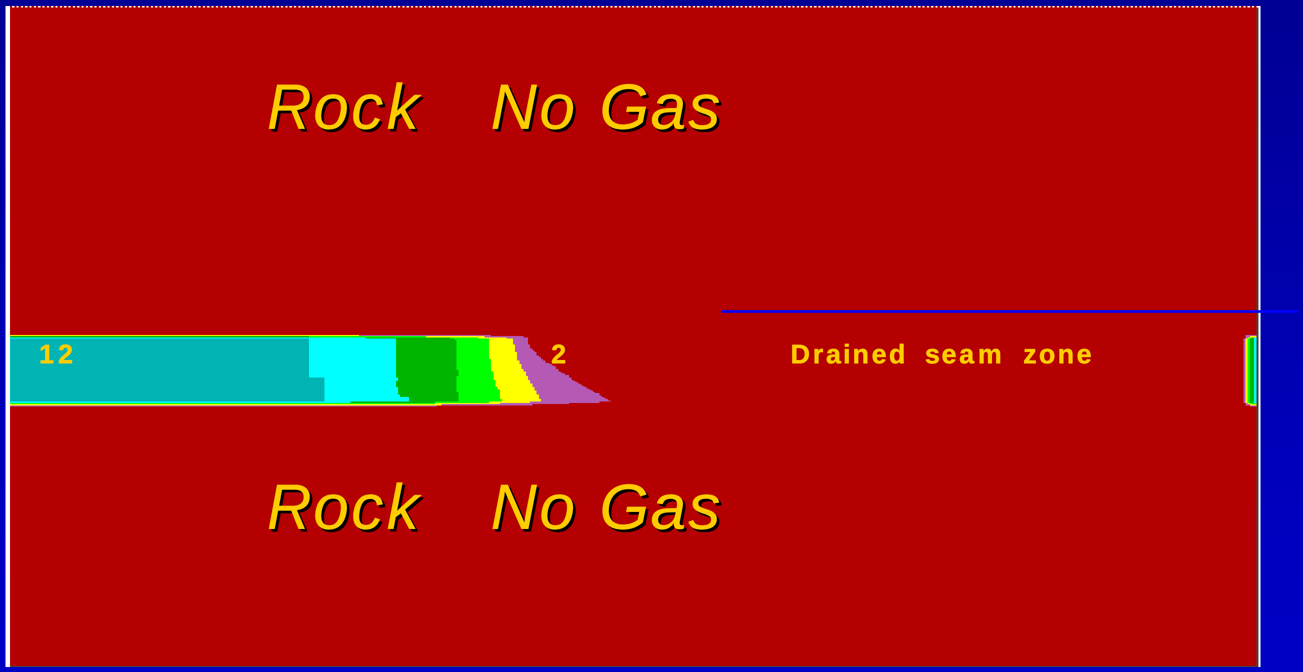
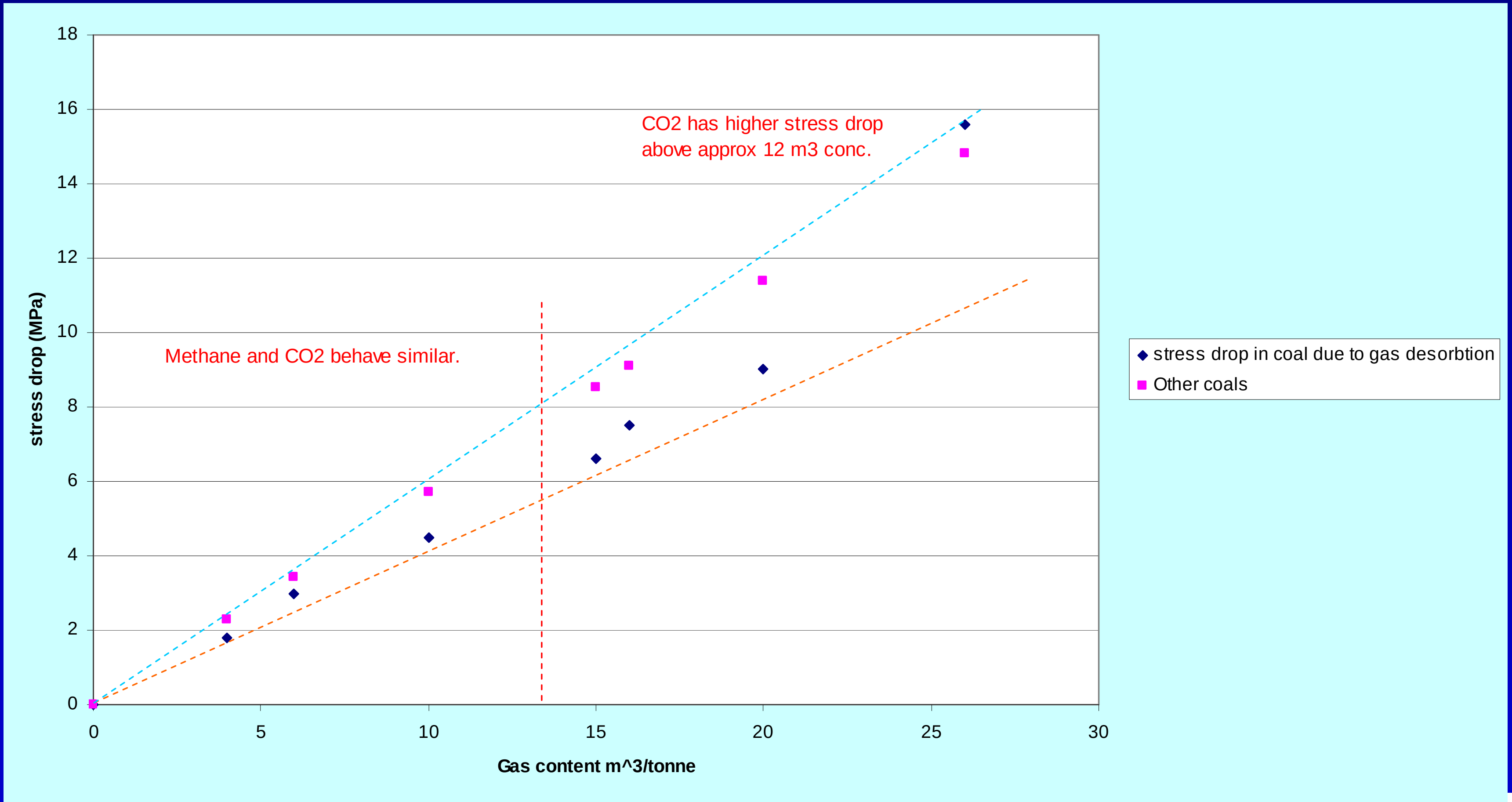
Gas Content after Production



Stress Changes due to Gas Desorption Volumetric Strain



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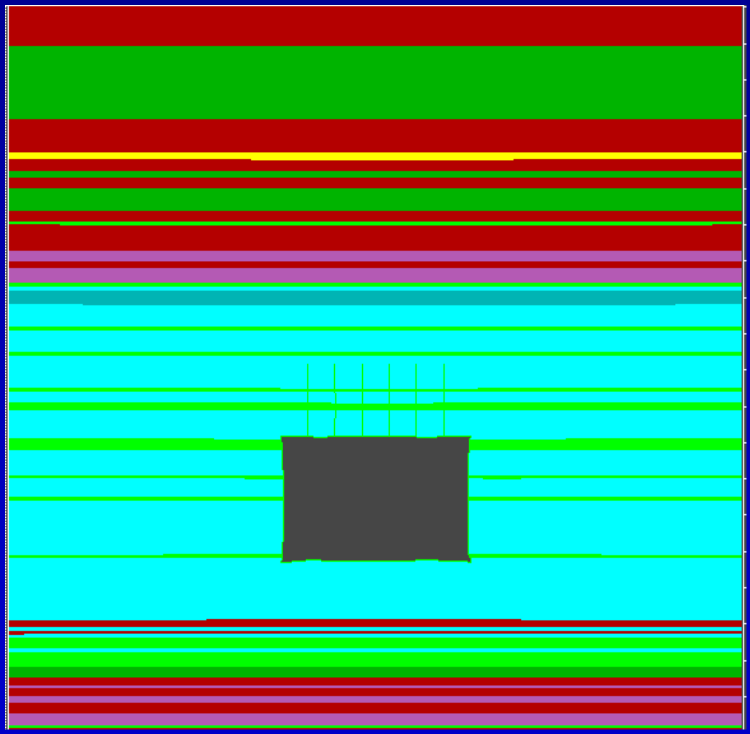
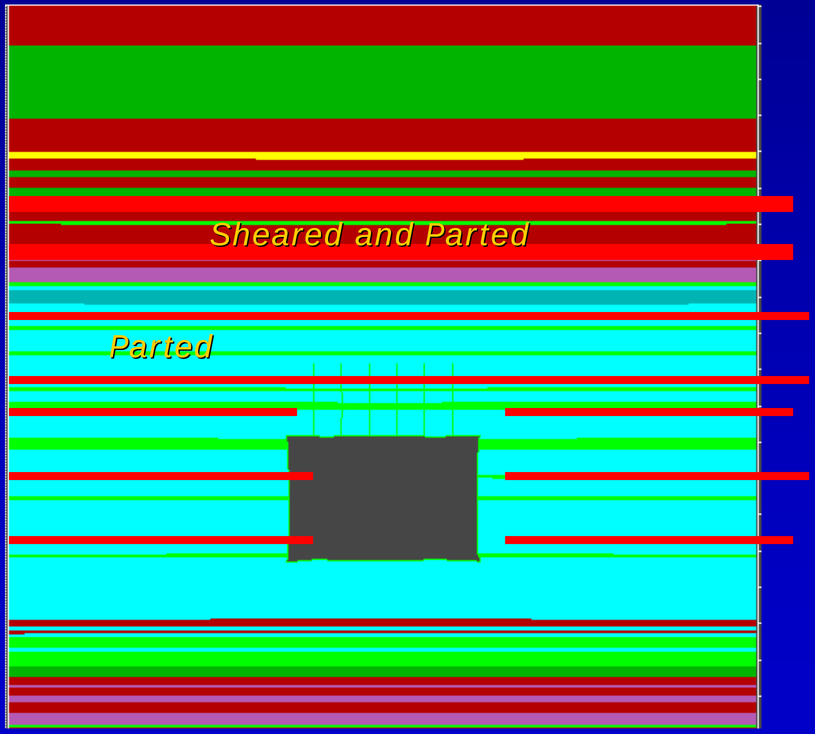
Simulated Effects of T shaped Fracture System

Normal Section

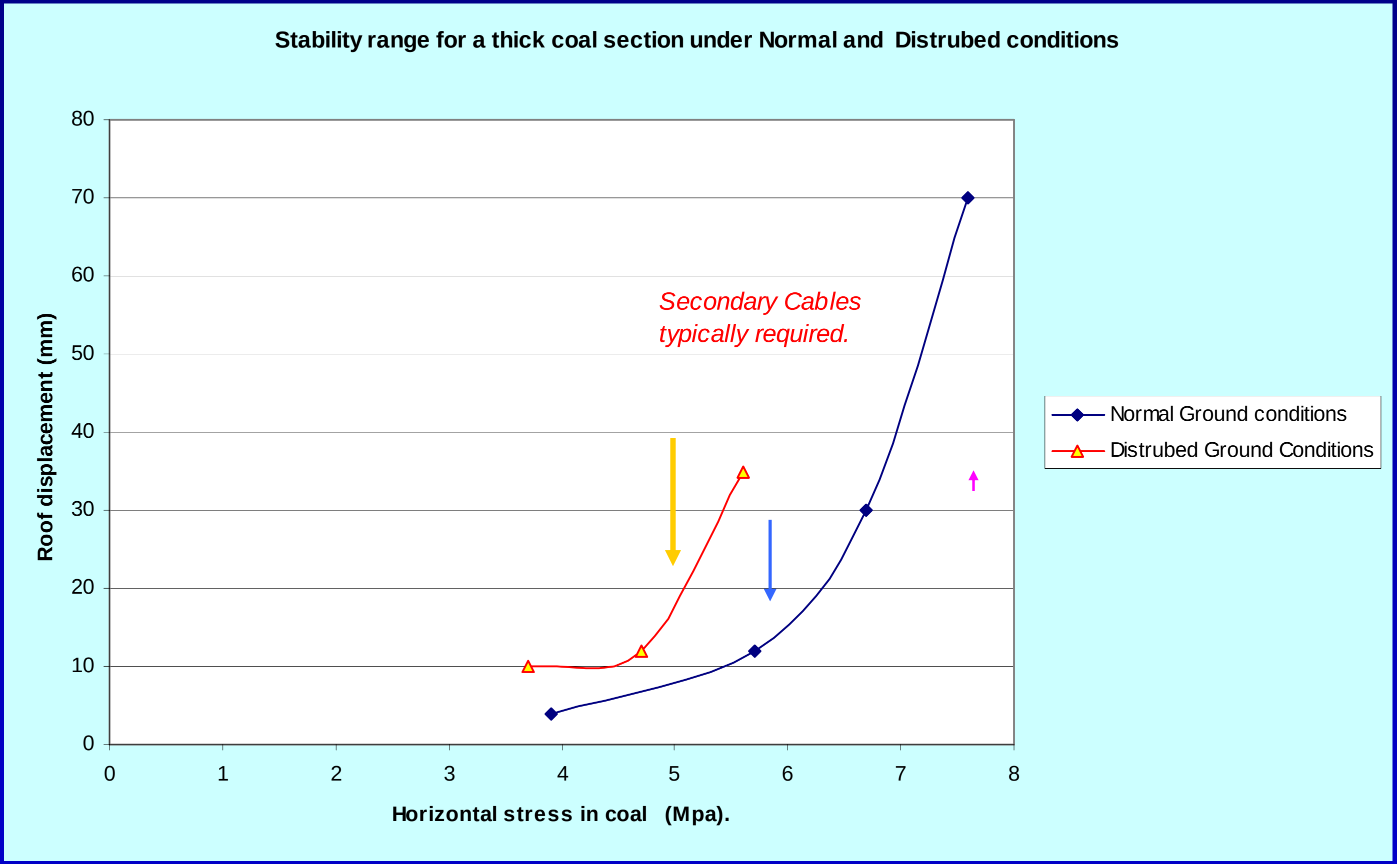


Disturbed Section



Horizontal Stress in Coal seam reduced by 2 MPa.

Stress and Deformation Characteristics



Disturbed Ground Weaker
BUT.....

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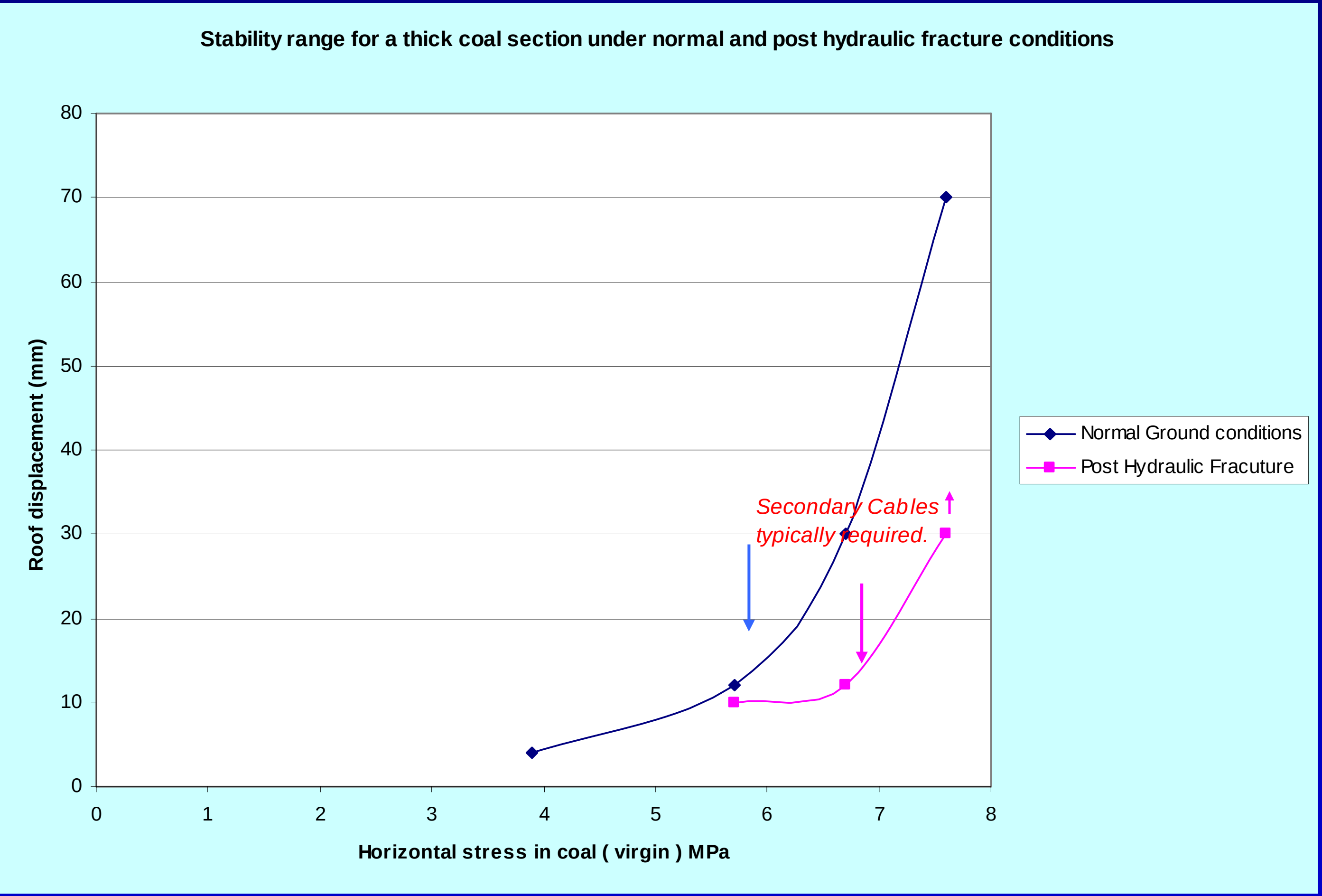
Comparison of Normal and Post Fracture Stability



Post-Frac ground more stable due to reduced horizontal stress

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Summary of Modelling Outcomes

- Fractures have minor mechanical impact that is expected to be within the range of general experience based on structured and unstructured ground conditions

- Increased gas capture and reduced horizontal stresses associated with shrinkage more than offsets any mechanical impacts of fractures

Issues Identified in Risk Review

- Mining into foreign objects such as casing

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- Mining into foreign objects such as casing
- Chemical contamination of seam from fraccing fluids
- Unsealed holes and impacts on ventilation
- Impacts on structural integrity of coal and roof strata
- Impacts associated with uneven stress distribution after gas drainage
- Various other minor issues that are within the range of normal mining experience

Findings and Recommendations

- Sand propped hydraulic fracturing and coal mining can (and do in the USA) successfully co-exist
- Key requirements for this are that government or other agency should maintain in perpetuity a record of where holes are located, and their completion, production and abandonment details for the benefit of future coal mining
- Holes do not need to be reamed out at coal seams ahead of coal mining but should be able to be reamed out if required

Findings and Recommendations

- Mechanical impacts of the fractures are minor and have not been reported to be an issue in any of the fracs that have been mined through in the USA or Australia
- Ventilation impacts are insignificant if holes are cemented above and below seam at abandonment
- Gas drainage is an advantage and improves mining conditions and reduces the potential for outburst or other gas related issues

Findings and Recommendations

- Chemicals used in fraccing are generally of no significance for future mining
- Commercial conflict may exist over historical rights to drain and utilise coal, but this is something that legislation can obviate
- Sand-propped hydraulic fracturing ahead of coal mining is generally beneficial to coal operations, particularly if the locations of holes is known and they have been abandoned so that re-entry is possible

Acknowledgements

- Thanks to ACARP for supporting the project and Roger Wischusen for project coordination
- Thanks also to Greg Poole, BHPB Illawarra Coal, and Ashley Edgar, Origin Energy, for their interest in the project and support throughout

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