Depleted reservoir geomechanics: Wellbore stability as a function of stress, strength and bulk coal properties

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Introduction

Drilling experience in horizontal CSG wells in the Bowen Basin suggest that coal bulk strength is impacted by reservoir depletion.

- Desorption-induced shrinkage changes the net effective stress, resulting in wellbore stability issues
- Must optimise azimuth with respect to in situ stress and fractures to maximise drainage and stability
- Widening of cleats and change in gas saturation in them can reduce the bulk strength of the coal
- In shallow wells, rising ECD can exceed the breakdown pressure, causing tensile failure

This research has developed novel analytical techniques for investigating tensile breakdown and borehole breakout in depleted coals, and applied advanced finite element modelling to quantify the influence of coal heterogeneity on bulk coal properties.

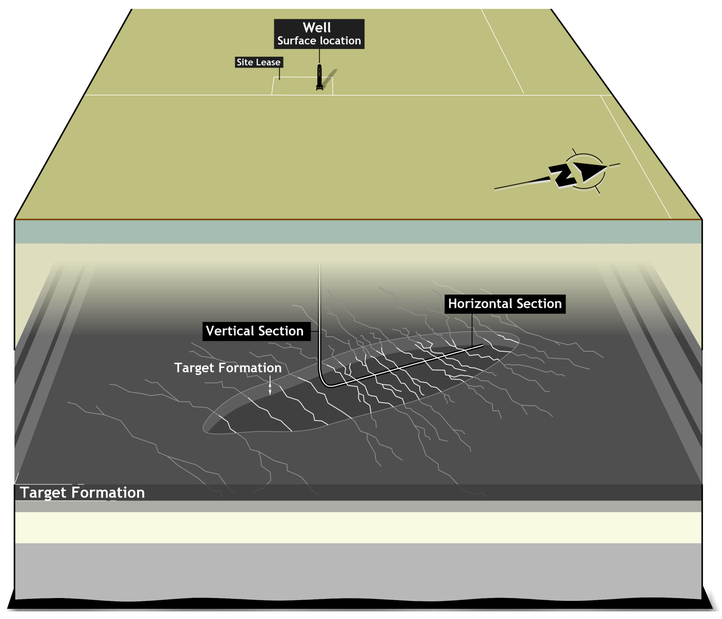

Figure 1: Schematic representation of a horizontal well drilled orthogonal to the primary cleat network for optimal drainage. Wellbore stability issues commonly require a compromise in the choice of drilling azimuth.

Method

The analysis workflow offers a choice of coal shrinkage model (e.g. Cui-Bustin, Gray), failure criterion (e.g. Mohr-Coulomb, Mogi-Coulomb), and implicit solution scheme for efficient convergence of results.

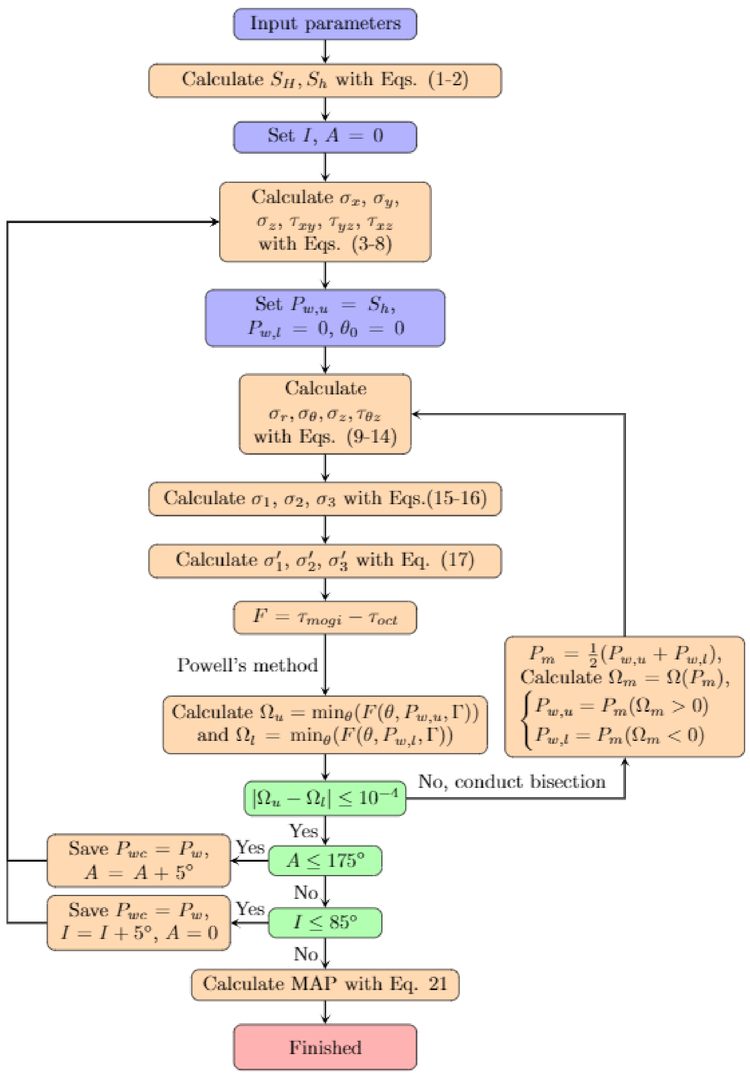

Figure 2: Flow chart of the wellbore stability analysis tool.

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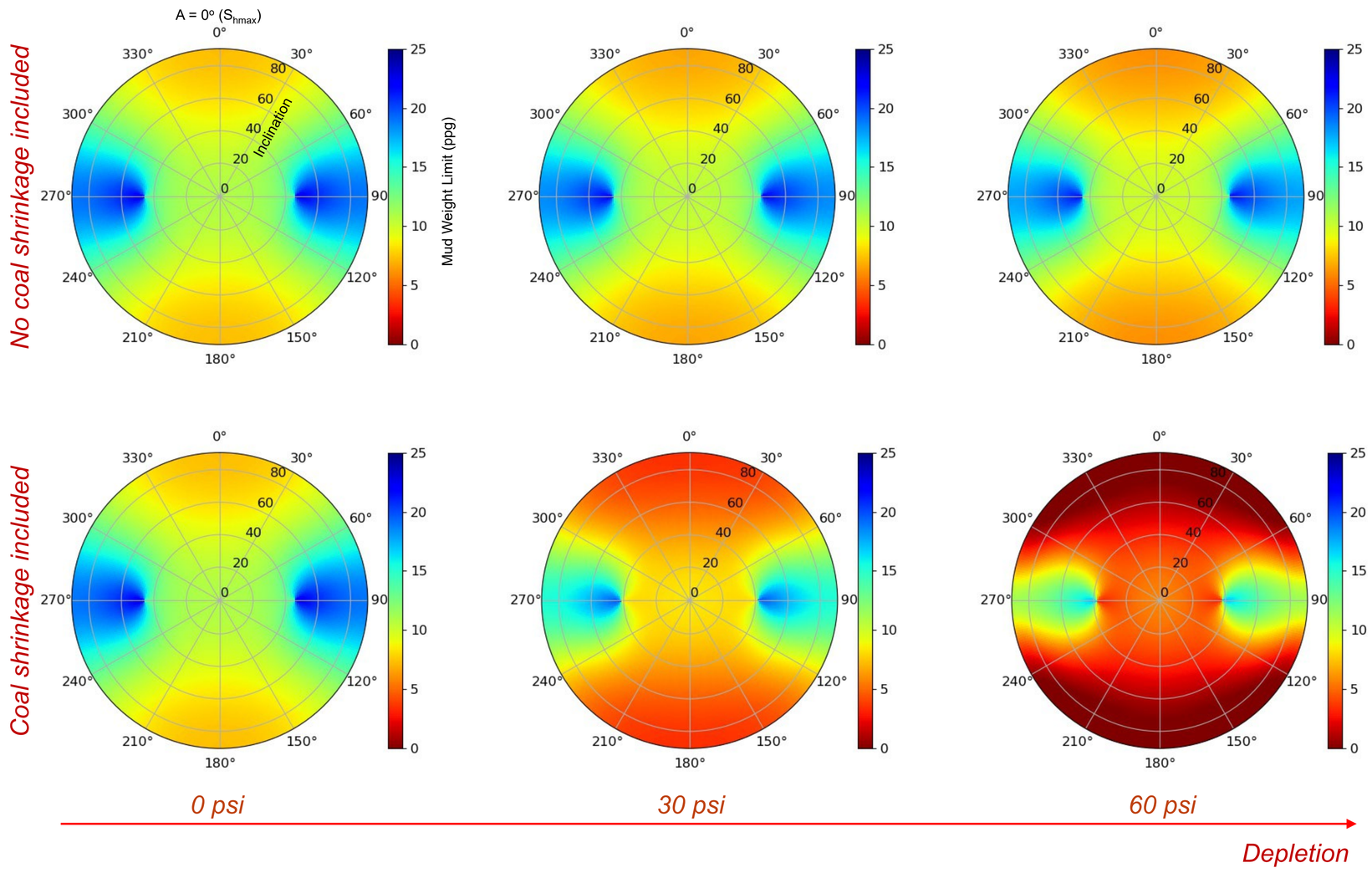

Figure 3: Results of the analysis of a CSG well in the Baralaba formation, showing the mud weight limits that prevent tensile breakdown. The top row of results does not include desorption-induced shrinkage but the bottom row does. The applied depletion increases from left to right. Analysis showed that all results are sensitive to coal isotherm and that coal shrinkage greatly influences tensile fracture initiation for depleted reservoirs. When depletion is 60 psi, the mud weight limit decreases resulting in minimum mud weight of approximately zero for some wells / areas (i.e. un-drillable). This implies limits on late life recovery factor and timing of development drilling

Results

Testing the influence of coal strength of tensile breakdown

Advanced finite element models were applied to test the influence of coal strength on tensile breakdown near wells.

- Coal cleats incorporated as planes of weakness, with Mohr-Coulomb properties derived from experiment (cohesion = 142 kPa (20.6 psi), friction angle = 23°, tensile strength = 0 kPa)
- Cleat network parallel to S_H (i.e. A = 0°), and five azimuths simulated: A = 0°, 22.5°, 45°, 67.5°, 90°
- When A = 0°, top/bottom vertical fractures are joined by damage at sides due to cleats/well being parallel
- When A = 90°, top and bottom vertical fractures are no longer present, but the lateral damage persists even when cleats are perpendicular to the well
- Suggests no stable azimuth for ECD of 12 ppg with cleating present

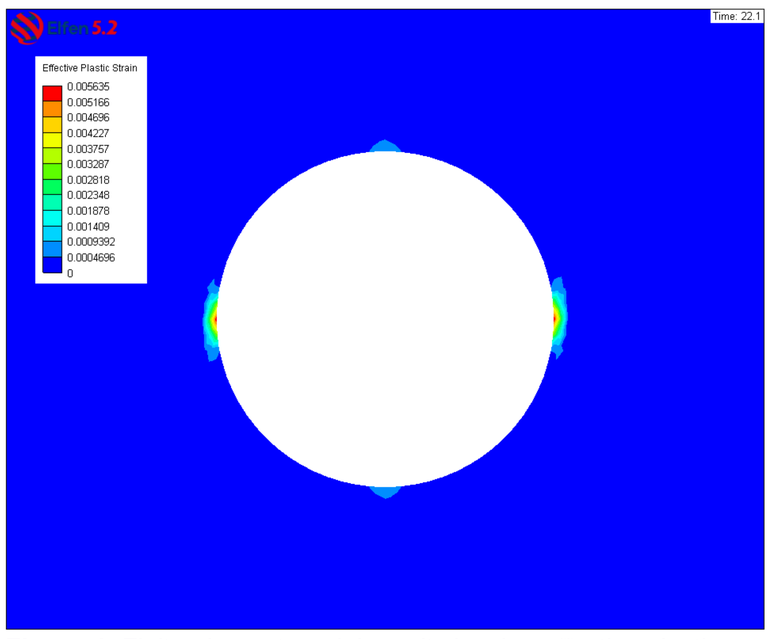

Figure 4: Finite element model result showing effective plastic strain around the well when drilling azimuth of A = 0° is combined with an ECD of 12 ppg. Depletion and coal shrinkage are not included, so as to isolate the coal strength in the analysis.

Input parameters for the highest coal shrinkage case study

Parameter	Value
Depth	450 m
Vertical stress	10.18 MPa
Maximum horizontal stress	8.27 MPa
Minimum horizontal stress	6.21 MPa
Initial pore pressure	4.37 MPa
Poisson's ratio	0.3
Young's modulus	3.28 GPa
Cohesion	167 kPa
Friction angle	55º
Biot's coefficient	0.9
Maximum swelling strain	0.03
Langmuir-type shrinkage pressure	3.45 MPa
Tensile strength	206.84 kPa

Conclusions

Optimal drilling of horizontal wells is complicated by the presence of dominant cleat networks and reservoir depletion. These have been studied in the context of a typical Baralaba formation well in the Bowen Basin.

1. Analytical modelling clearly showed the maximum allowable ECD was reduced by depletion and desorption-induced shrinkage – it thus important that the Langmuir properties of coal are well understood
2. The maximum predicted ECDs of ~20 ppg are higher than field experience would suggest, possibly due to the coal matrix strength properties (derived from experiments) being higher than bulk properties
3. FEM showed that the presence of a primary cleat network further degraded the stability of a horizontal well at all azimuths – spalling failures observed when well and cleats are parallel

Future research will combine cleats with depletion in the FEM analysis, sensitivity analysis of the cleat properties on the bulk response of the coal, and the investigation of more experimentally-derived coal shrinkage properties

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