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Borehole permeability damage and its impacts on gas drainage

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Outline

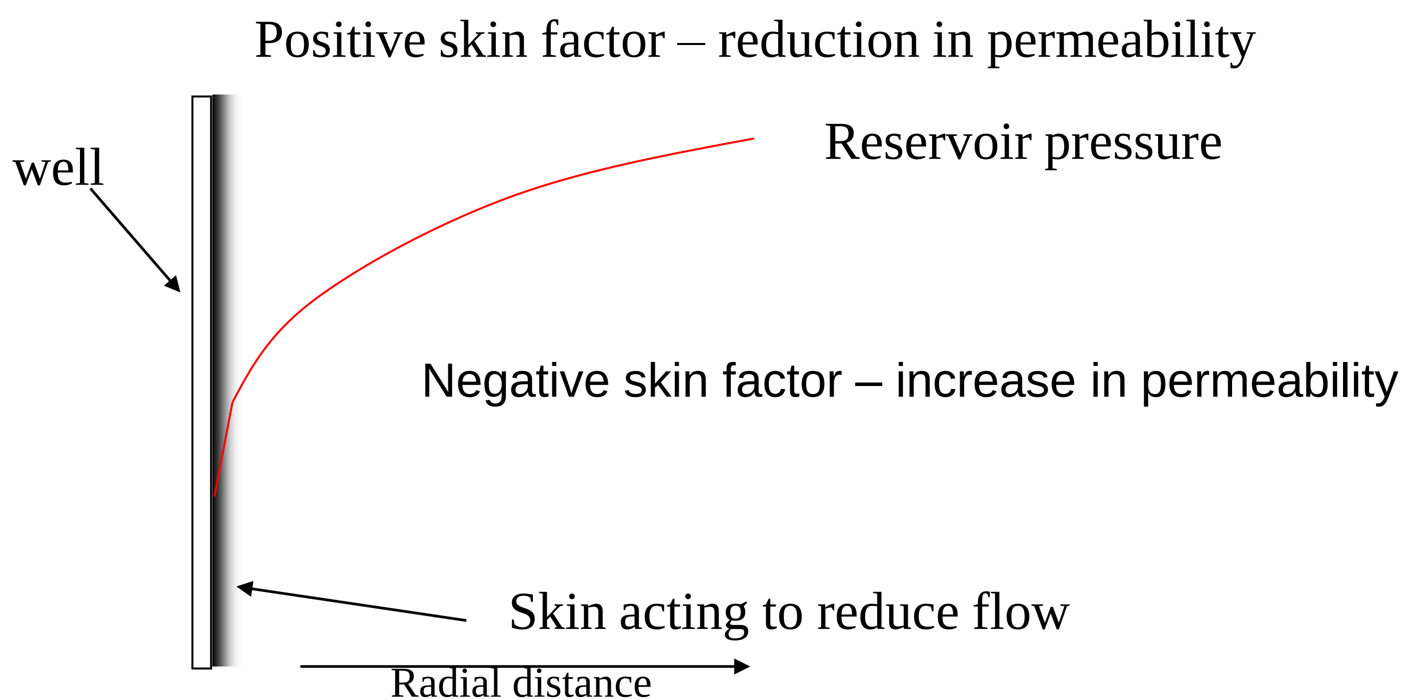
- **What is formation damage?**
- **Damage mechanisms in coal**
- **Evidence of damage**
- **Investigations into damage mechanisms**
- **Conclusions**

Acknowledgement

- **This work is supported by ACARP under project C14038**

Background

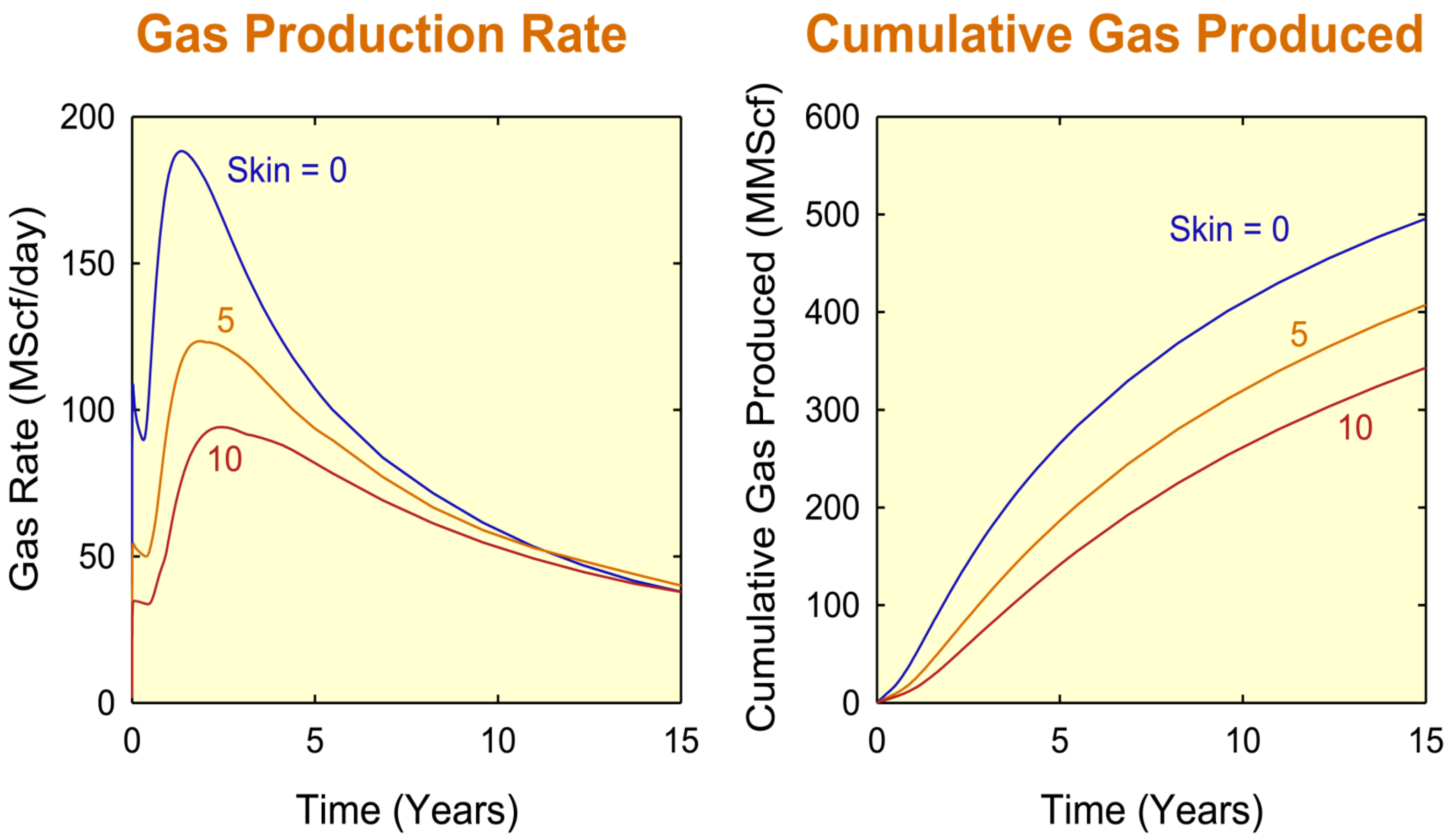
- **Borehole permeability damage**
  - A region within the formation in proximity to a borehole with a reduced or enhanced permeability
  - Also know as borehole skin



Background

- **Positive skin acts to impede flow into the borehole**
    - Inhibit gas and water drainage
- **A common problem with wells in petroleum engineering**
- **Poorly understood in coal**
- **Project objectives**
    - Review the potential role of borehole skin in coal and identify ways to manage it

Hypothetical example – SIMED simulation of gas drainage rate with respect to skin factor



Causes of formation damage

- **A lot of experience with wells in non-coal formations**
  - Common mechanisms with oil and gas production
    - Drilling fluid/mud interaction with the formation, clogging the pore system and lowering perm
    - Migration of drilling fines into the formation and clogging of pore system (overbalanced drilling)
    - Mineralization
      - Groundwater saturated in dissolved minerals
      - Precipitation on the borehole wall/near borehole region
    - Relative permeabilty effects
      - Gas blocking
        - Presence of gas in cleat system lowers water relative permeability and thus rate of water outflow
      - Water blocking
        - Water blocks gas flow

- **Little information available on coal**

- **Other possibilities – important for coal?**
  - Possible fines migration during production and clogging of cleat system near borehole
    - fines production during gas desorption?
    - Lack of information on this
  - Permeability that is stress sensitive
    - Clearly demonstrated in a wide range of studies
    - Will mean a permeability reduction towards gas drainage boreholes – but unknown effects

Mechanisms for formation damage

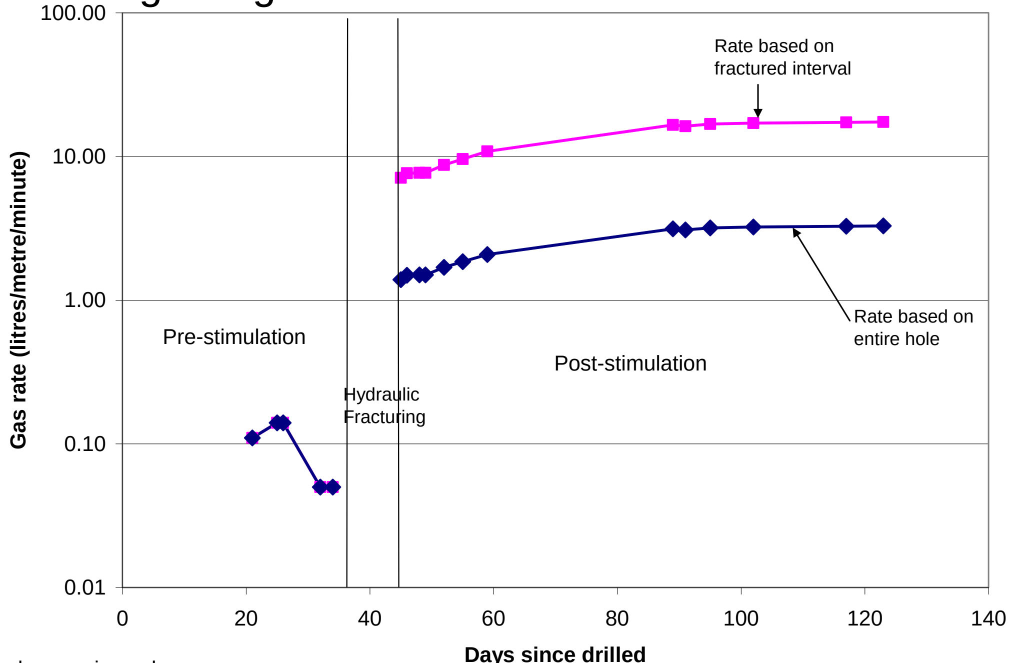
- **Drilling induced**
  - Drilling fines - difficulties in cleaning out
  - Drilling fluids – muds
- **Drainage induced**
  - mineralisation

Evidence for skin in gas drainage boreholes

- **Jeffrey and Meaney 1997**
  - Combination of production and well tests at Dartbrook
  - Vertical well – significant skin (~8)
- **Jeffrey et al. 2005**
  - Skin estimated from gas drainage pre and post fracture treatment of underground drilled horizontal well
  - skin (~20)
- **Other unpublished modelling work (personnel communication)**
  - Large skins experienced for some MRD holes in coal (extreme case surface to inseam ~60-80 – determined from reservoir simulation history matching)
- **Recent West Cliff well testing work (skin -0.8 – 0.9) (Wold, Connell and Choi, 2007)**
  - Seam drained of gas and water
  - skin determined by injection test (water injected into borehole)
  - small effective stress gradient around well; i.e. injection pressure
  - Test should provide a good measure of skin because of the use of monitoring well data from injection test in analysis

Evidence for formation damage in coal

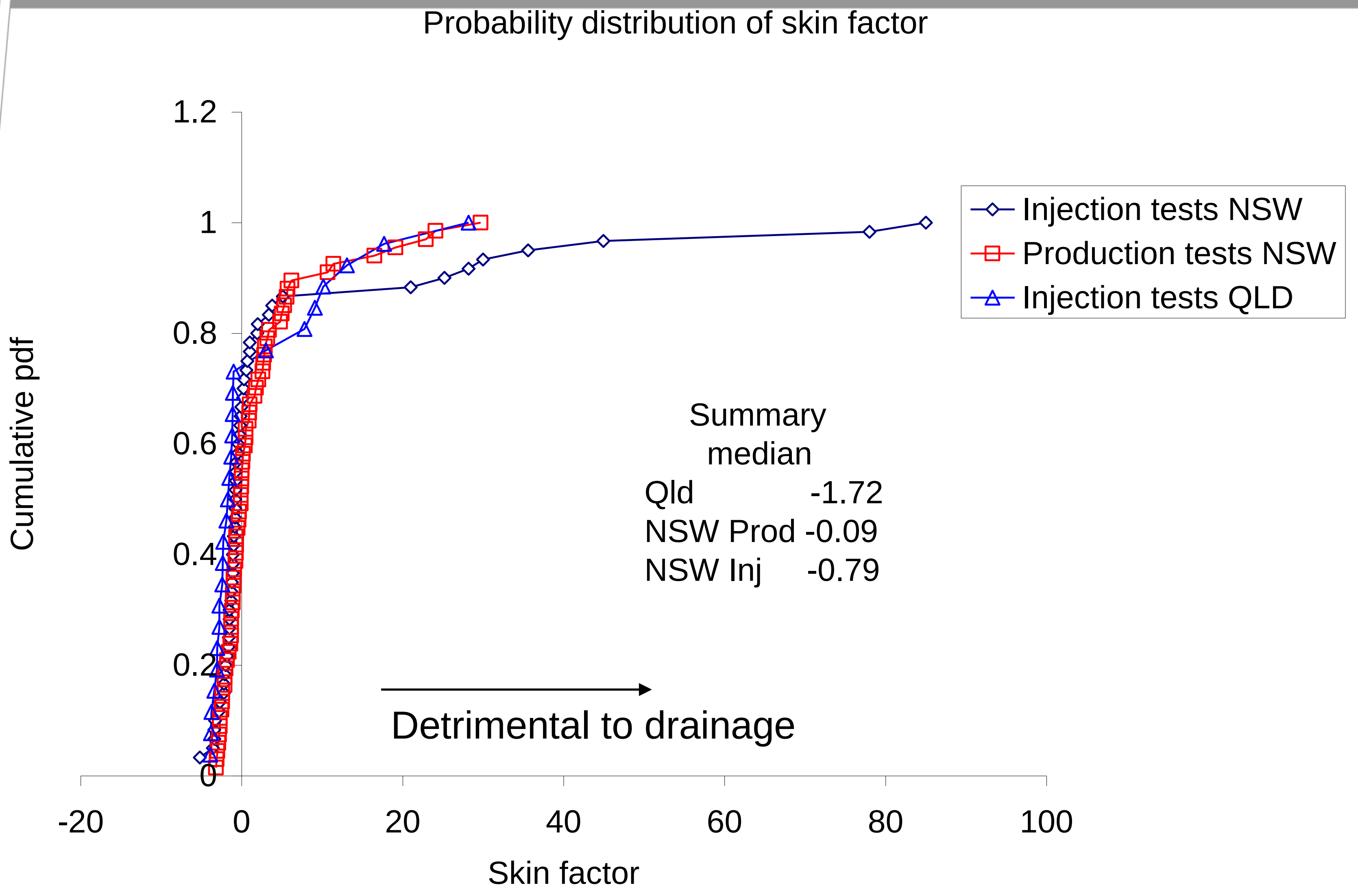
- **Dartbrook – Jeffrey et al. (2005)**
  - Low permeability coals high CO2 content
  - under gas drainage using inseam boreholes - sand propped hydraulic fractures were placed at regular intervals
  - Induced fracture bypassed a near-borehole skin
  - Gas rate increased x100
  - Large skin factor of ~20 determined through history matching using SIMED



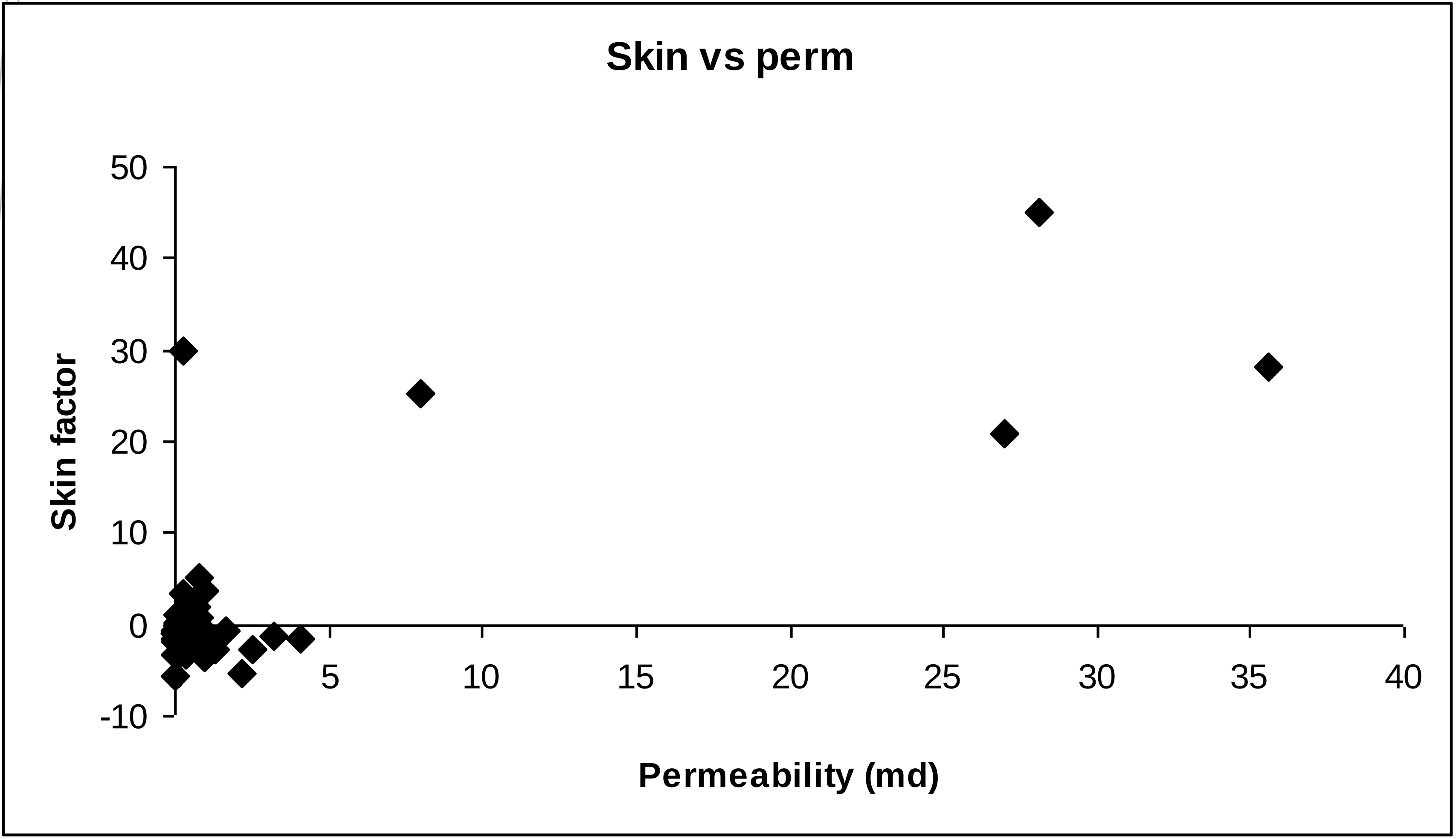
Evidence for formation damage in coals

- **A review was conducted of well test reports**
  - Well tests to determine permeability often also report the skin factor
  - A large number of well tests as part of coal seam methane resource evaluation have been conducted and are publicly available
  - NSW DIGS database
  - QLD QDEX database
  - These are (almost all) single well tests in vertical wells involving saturated water flow (injection-falloff tests)
    - May not reflect skin during gas drainage
    - Will indicate skin as a result of drilling or water flow related processes
    - Involve relatively small pressure gradients (compared to gas drainage)
  - 153 well tests determined the skin factor

Evidence of formation damage in coal



Well test results



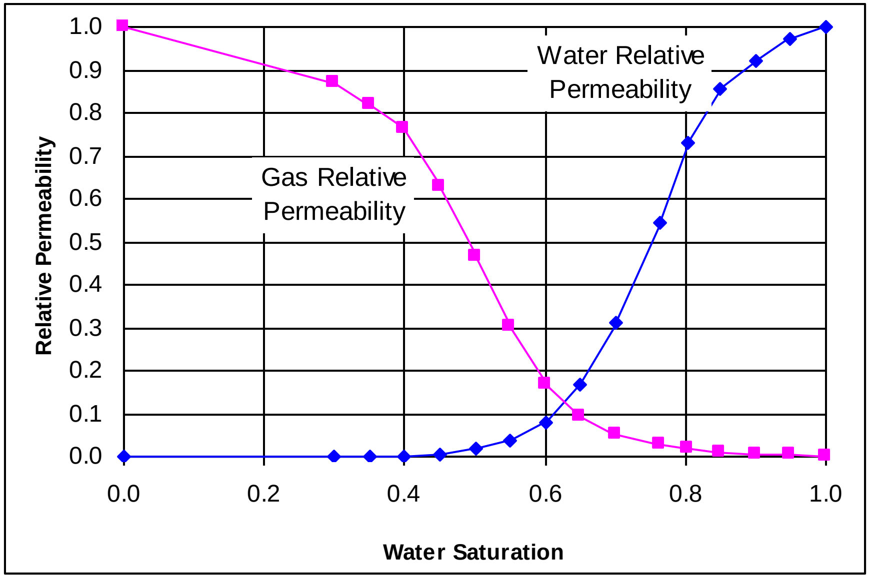
Mineralisation

- **For many coals**
  - Considerable evidence of mineralisation in cleats & fractures
  - Potential for precipitation to occur within gas drainage boreholes
    - In regions where the groundwater is saturated with minerals small evaporative losses lead to precipitation
    - Water chemistry changes brought on by pressure change can lead to precipitation of some minerals. CO_2 comes out of solution rapidly with a drop in pressure.
  - Minerals could act to impede gas/water flow into the well

Minerals collected from borehole

Gas blocking

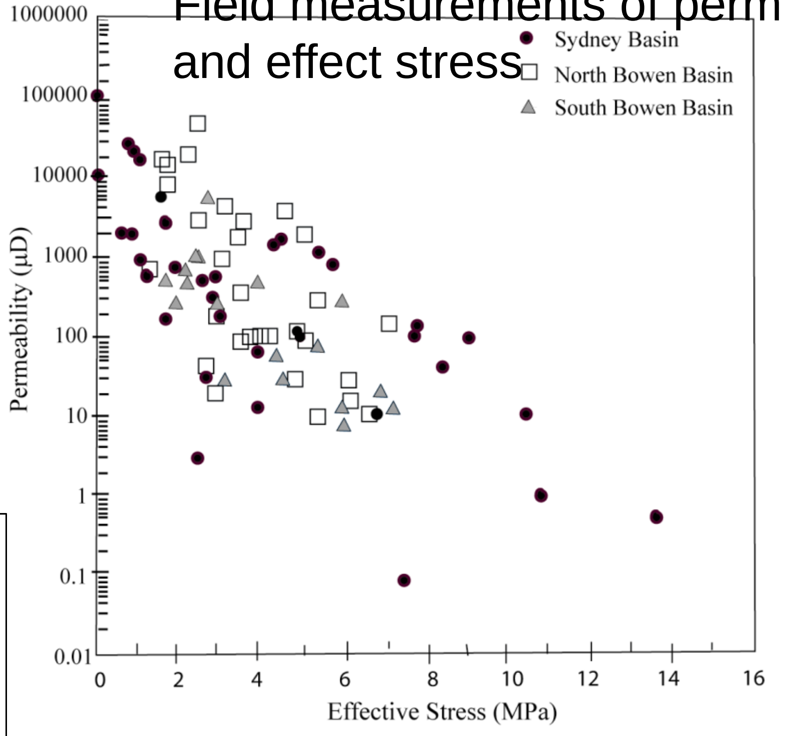
- **The rate of combined flow of water and gas is determined by their relative permeabilities**
  - Initially the seam is saturated with water
  - Lowering the pore pressure leads to gas desorption – to start with – the region closest to the well
  - The presence of gas lowers the flow rate of water
  - Water within the seam is then “held-up” and gas drainage delayed

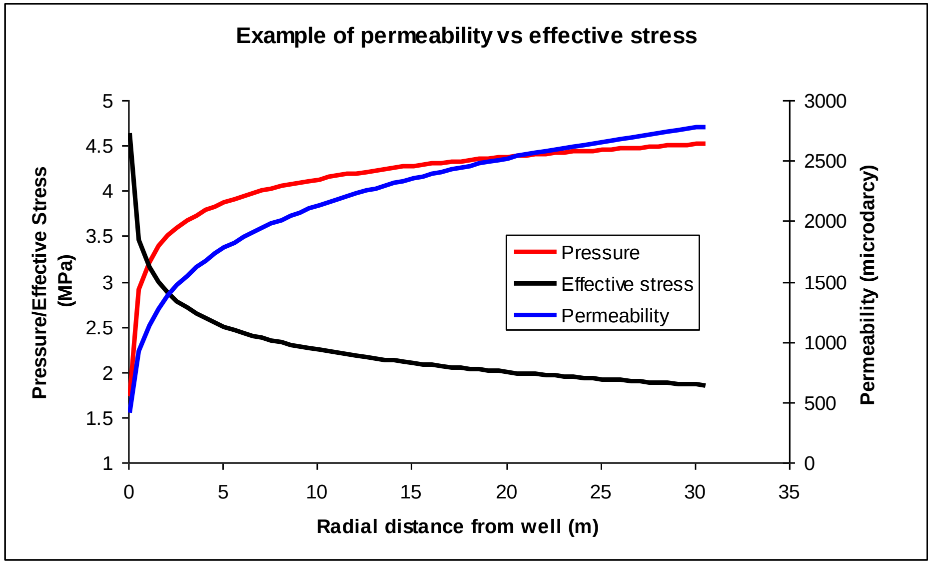


Stress sensitivity of coal permeability

- Coal permeability varies with effective stress

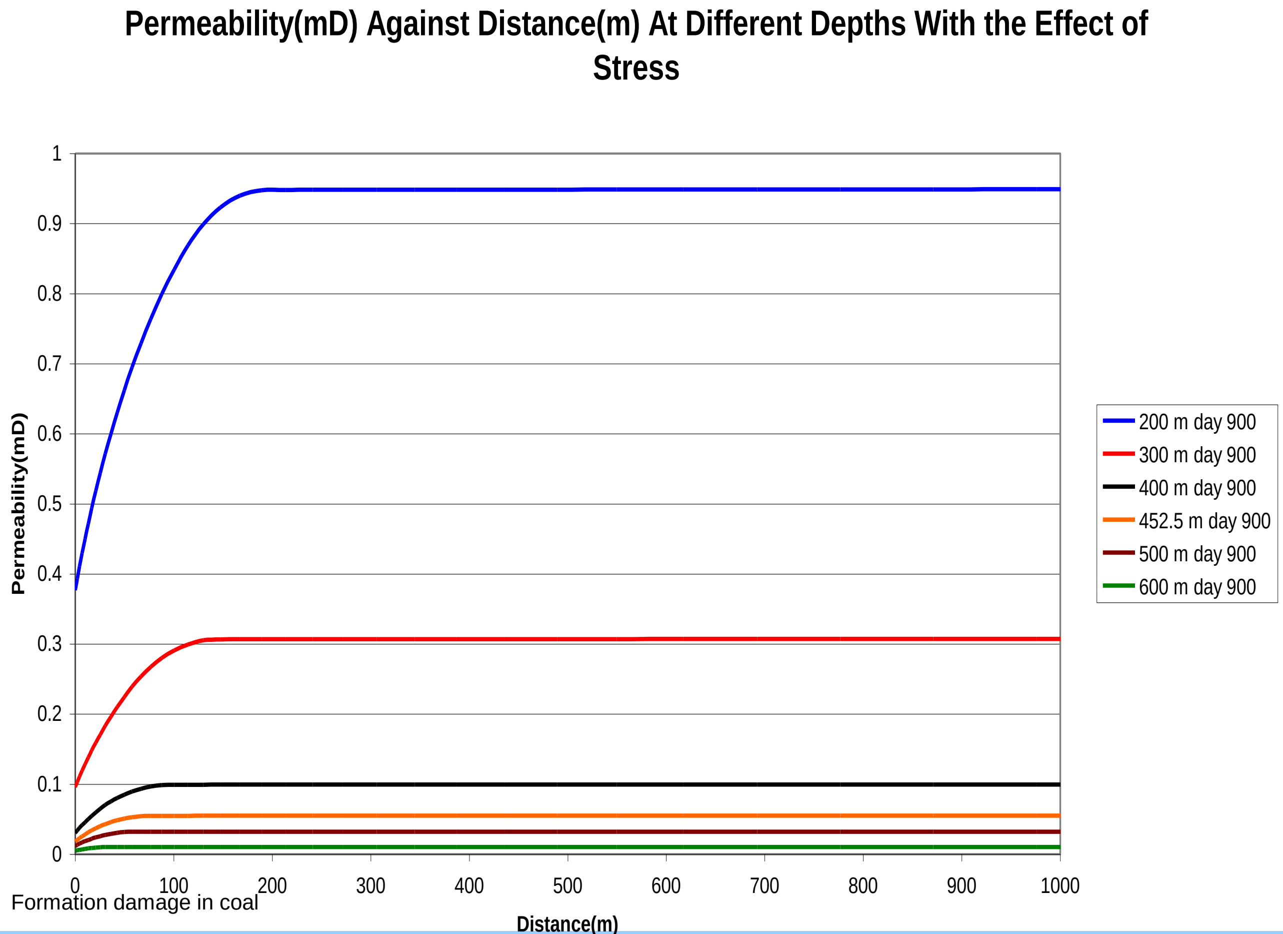
- Lowering the pore pressure to drain coals leads to increased effective stress towards the borehole



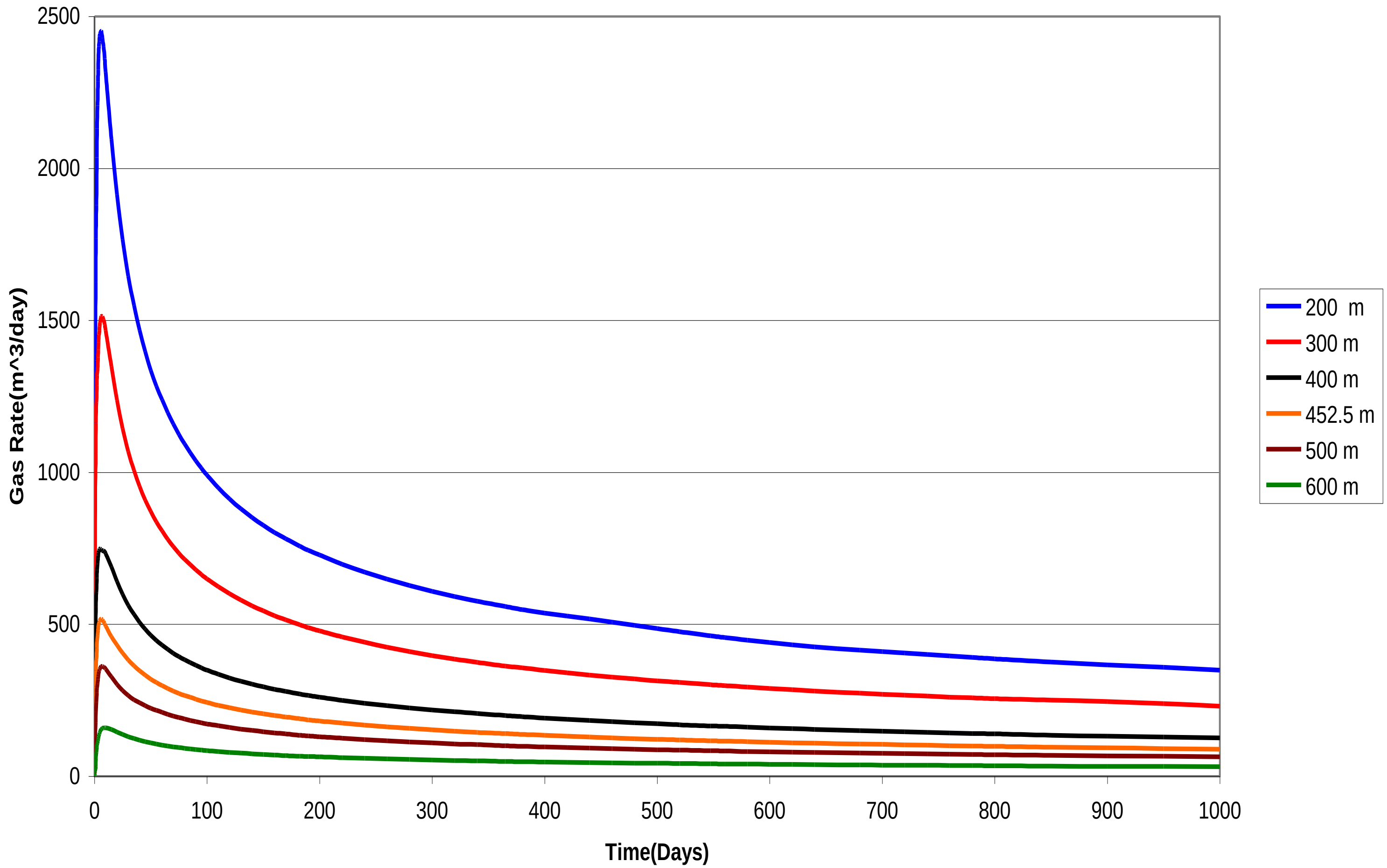


Role of permeability vs effective stress in gas drainage

- **Simulations of gas drainage using SIMED**
  - Using permeability vs effective stress relationships established from field work
  - Investigations into the variation with depth
- **If the perm vs stress behaviour is not correctly accounted for it would be characterised as skin in the analyses**



Relationship Between Gas Rate(m^3/day) and Time(day) at Different Depths With the Effect of Stress



Coal fines migration during drilling

- **Fines produced during drilling are forced into the surrounding coal clogging cleats**
- **Overbalanced drilling**
  - fluid pressure in the borehole > formation
- **Underground inseam boreholes**
  - Are drilled open to atmosphere, so underbalanced
  - However water is supplied at pressure to the drill motor
    - Water pressure should be < formation pressure
- **Medium Radius Horizontal**
  - Potential for overbalanced conditions to develop
  - A key issue if these boreholes are to be effective for gas drainage
  - Most drilling companies have become aware of this – use techniques that lower the borehole pressure
  - More difficult to clean out
  - However the skin factors can only be determined through history matching – needs careful simulation work – data is very limited
  - We are not able to carryout well tests on MRD holes

Conclusions

- **Positive borehole skin will act to impede gas drainage; increasing drainage lead times etc**
- **There is evidence that skin can (sometimes) be significant in coal drainage boreholes**
- **A review of Injection-falloff testing of vertical boreholes for NSW & Qld found 10-15% had skin factors >10 (peak gas rate for a skin factor of 10 reduced around 50%)**
- **Information on inseam boreholes and MRD holes is very limited**
- **Overbalanced drilling conditions will act to increase skin through coal fines migration**
  - Pressure in MRD holes during drilling needs to be carefully monitored along the length of the hole
- **For inseam holes the water pressure at the drill motor needs to be considered**
- **Need to characterise the skin in MRD holes and relate to drilling practices**