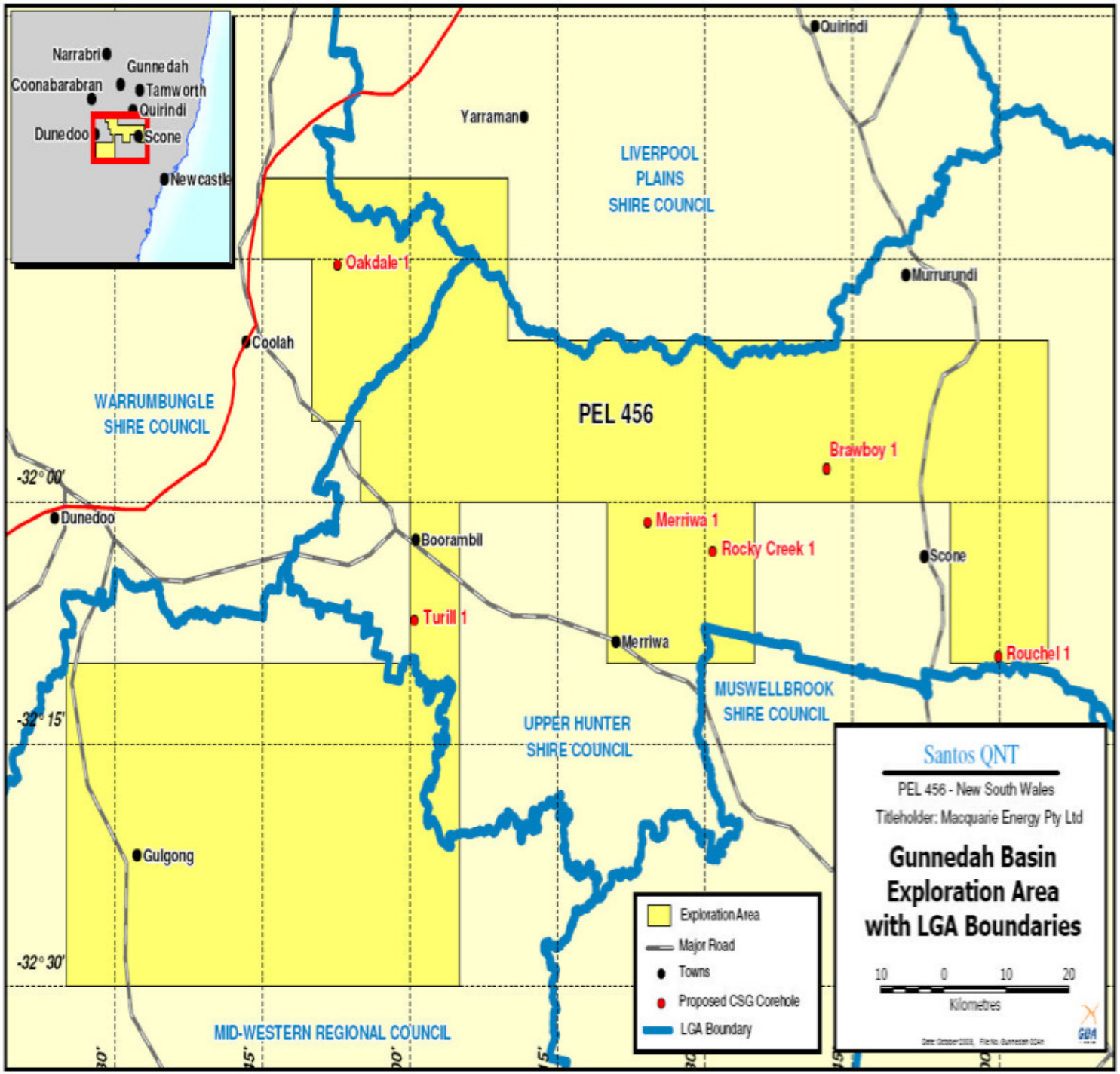
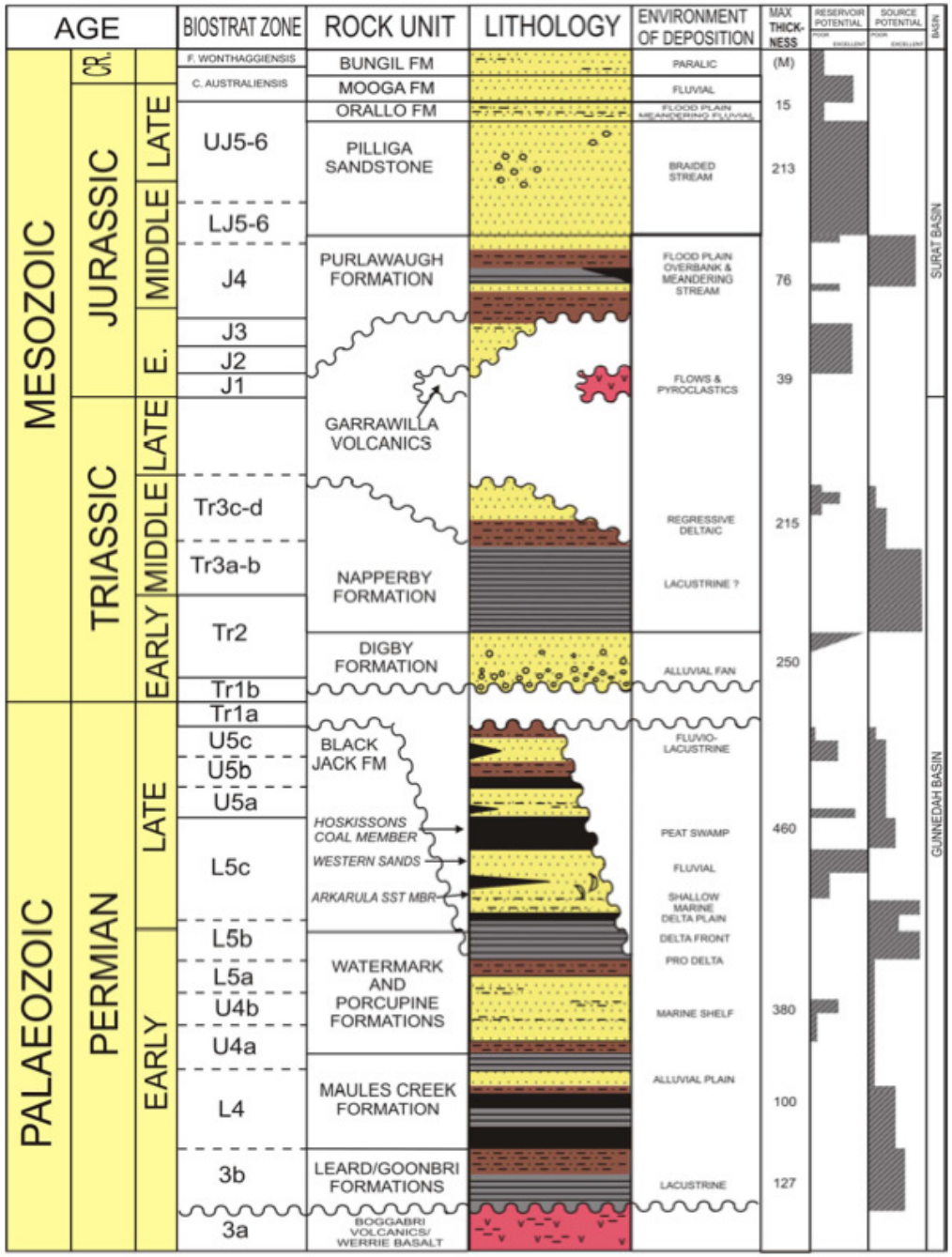

Narrabri
Gunnedah
Coonabarabran
Tamworth
Quirindi
Dunedoo
Scone
Newcastle
Yarraman
Quirindi
LIVERPOOL PLAINS SHIRE COUNCIL
Oakdale 1
Murrurundi
Coolah
WARRUMBUNGLE SHIRE COUNCIL
PEL 456
Brawboy 1
-32° 00'
Dunedoo
Boorambil
Merriwa 1
Rocky Creek 1
Scone
Turill 1
Merriwa
Rouchel 1
MUSWELLBROOK SHIRE COUNCIL
-32° 15'
UPPER HUNTER SHIRE COUNCIL
Gulgong
-32° 30'
MID-WESTERN REGIONAL COUNCIL
Exploration Area
Major Road
Towns
Proposed CSG Corehole
LGA Boundary
Santos QNT
PEL 456 - New South Wales
Titleholder: Macquarie Energy Pty Ltd
Gunnedah Basin Exploration Area with LGA Boundaries
10 0 10 20
Kilometres

STRATIGRAPHIC TABLE



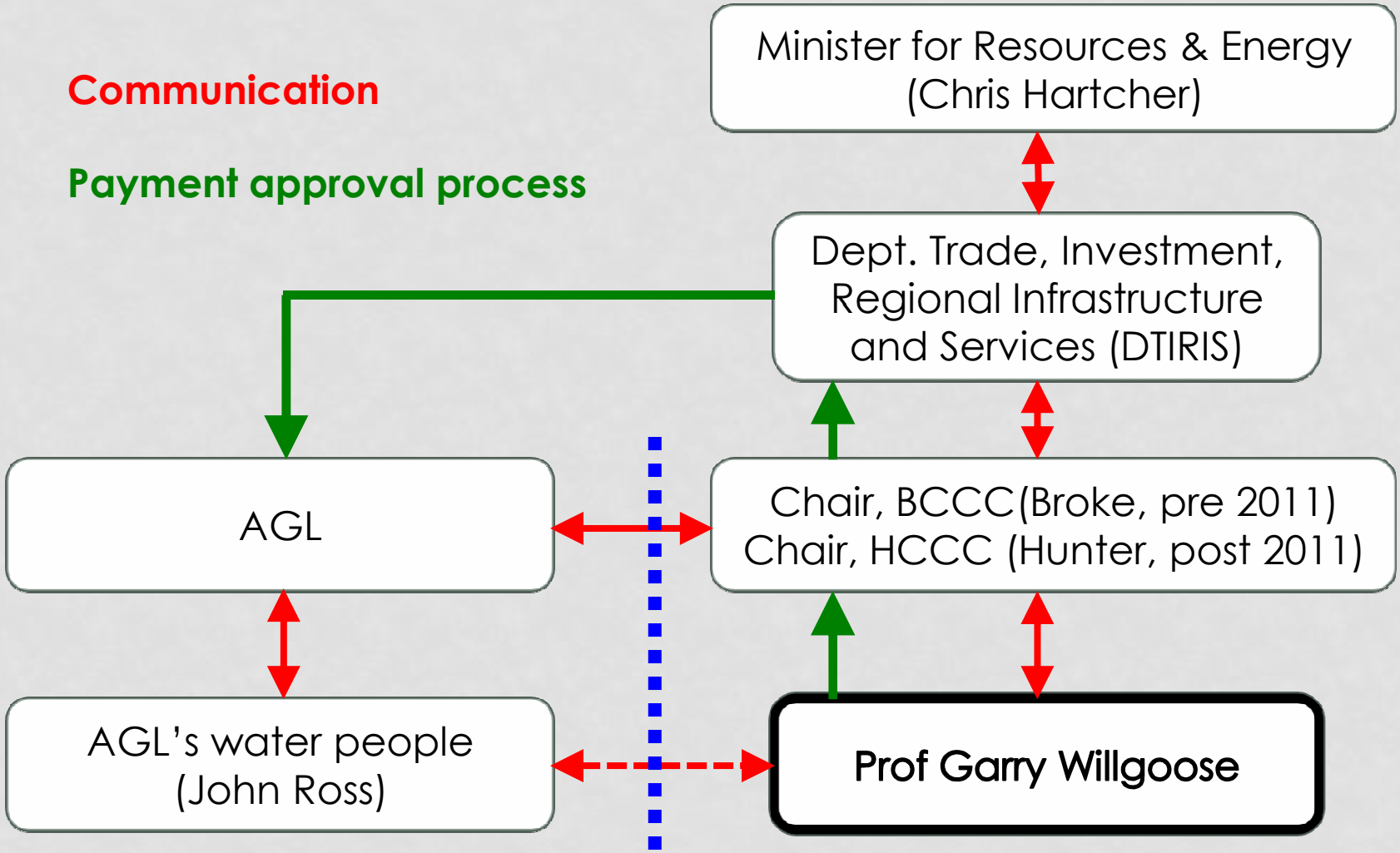
WATER ISSUES AND COAL SEAM GAS: AN INDEPENDENT VIEW

PROF GARRY WILLGOOSE,
THE UNIVERSITY OF NEWCASTLE

QUALIFICATIONS AS A PEER REVIEWER

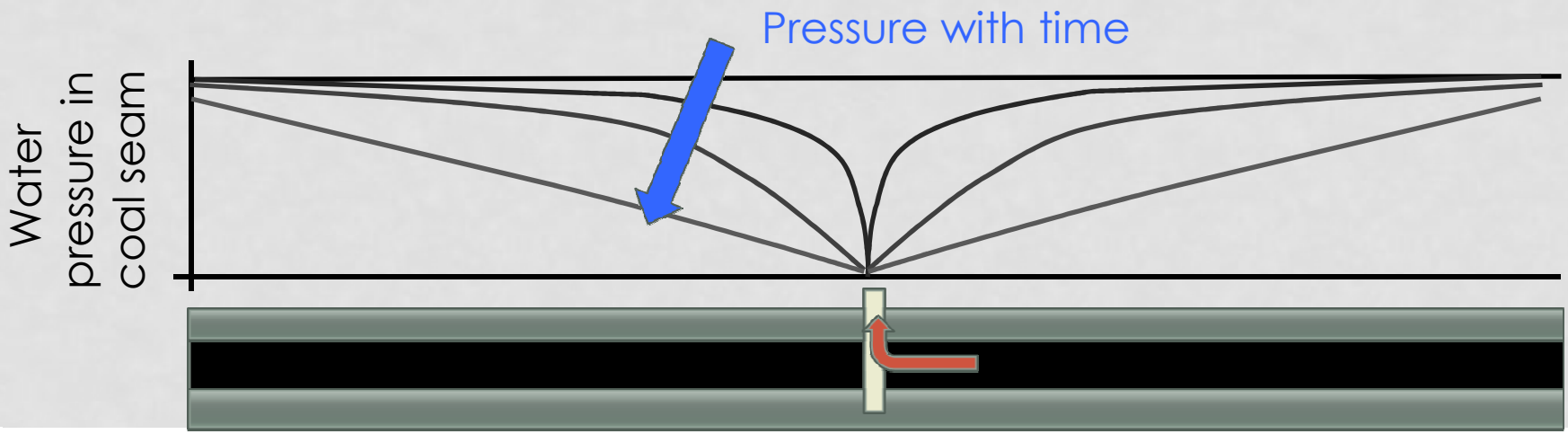
- Professor of Environmental Engineering, U. Newcastle.
- Masters & PhD from MIT (Boston) in 1980s.
  - Top 3 groundwater university in USA.
- 20 years researching groundwater-surfacewater-climate interactions.
- Former Deputy Director of Earth and Biosphere Research Institute (Yorkshire).
  - Climate change impacts on the environment.
- ARC Australian Professorial Fellow (2006-10) (1 of 120)
  - Impact of climate change on hydrology, soils and ecology.
- 20 years advising Australian and NSW government agencies on strategic hydrology issues.

I WORK FOR THE HCCC ON ALL WATER RELATED ISSUES



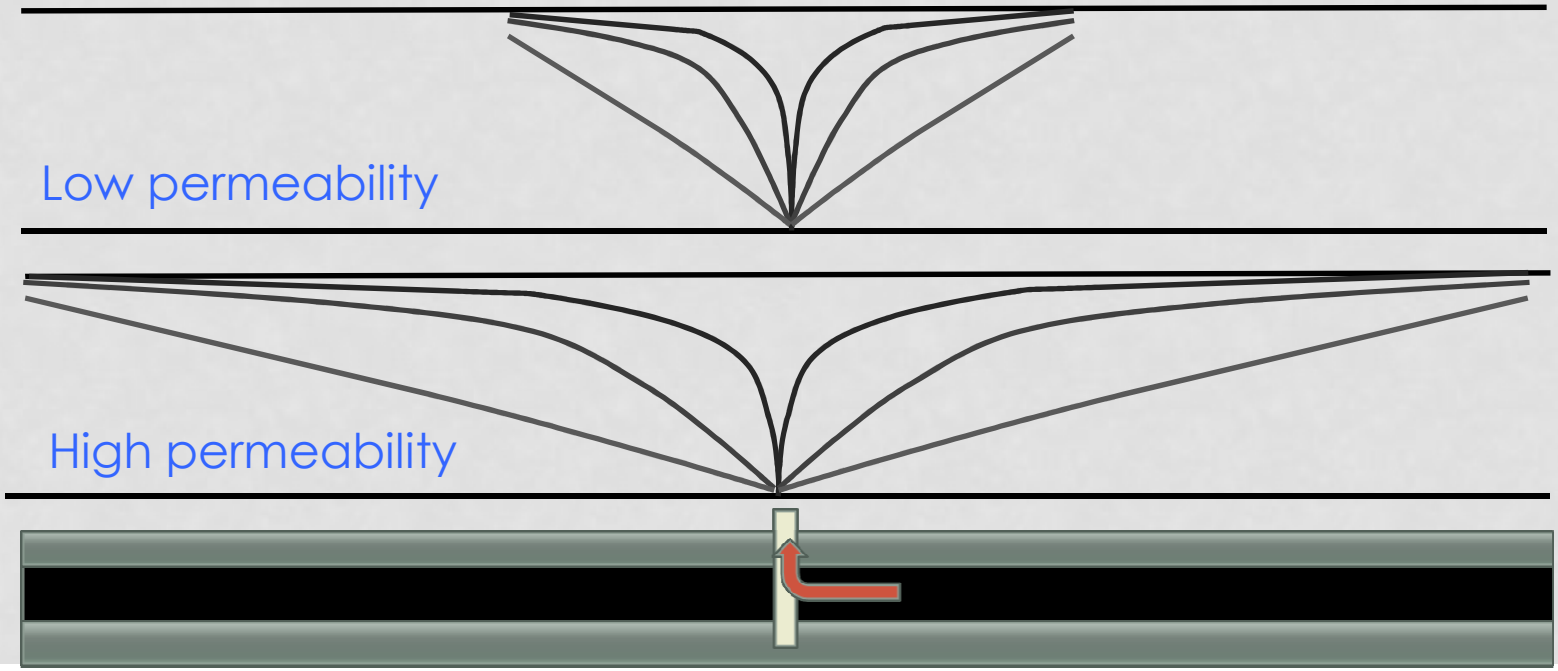
THE CSG EXTRACTION PROCESS

- The coal seam gas is released when the pressure in the aquifer is reduced (just like a soft drink bottle) by pumping water out of the coal seam. The gas collects in the pores of the rock until it can flow out of the pores into the well.
- Two stages:
  - Release of gas from within the coal into the pores in the coal
  - Flow of the gas through the pores to the well where it is collected.



THE IMPORTANCE OF COAL PERMEABILITY

- If permeability is low then the rate of drawdown of the water pressure will be lower (and thus the release rate of gas from the coal to the pores) and the rate of flow of the gas to the well will be lower.
- If the rates are too low then fracking is used to make pathways (and increase the permeability)



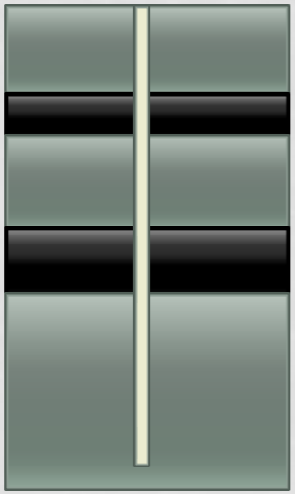
QLD AND NSW APPEAR TO BE DIFFERENT

- Hunter/Sydney/Gloucester/Gunnedah basins
  - Permian coals.
  - Not in Great Artesian Basin.
- Surat basin is younger (penetrates into northern NSW)
  - Jurassic.
  - In Great Artesian Basin.
- AGL results (Camden and Hunter) suggest that
  - Production water will be less, but salinity higher.
  - More fracking will be needed for wells in NSW because coal permeability is lower in NSW.

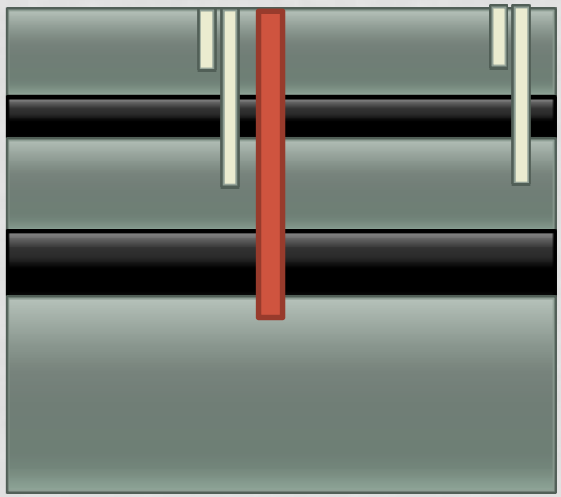
EXPLORATION STAGES

Exploration

Core hole (Stratigraphic hole). Just like coal exploration but deeper 600-1000m



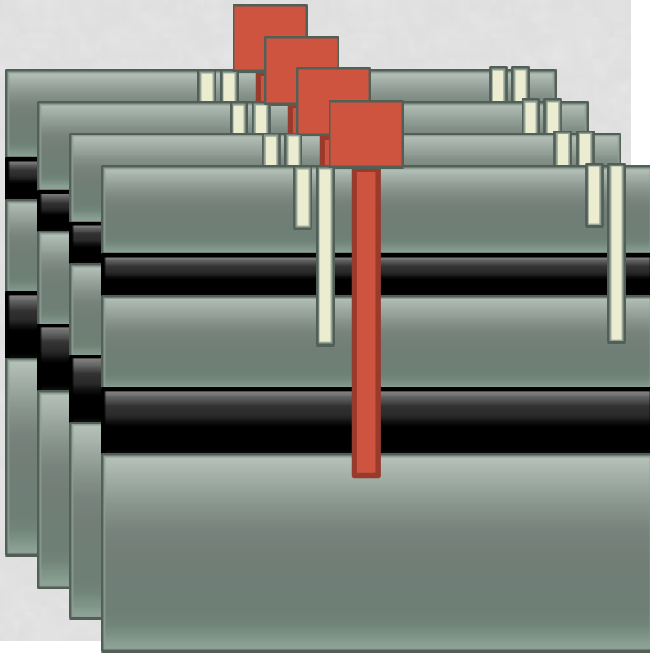
Flow testing. Production well. Adjacent monitorring wells. Will be fracked, if necessary (e.g. Broke was fracked). Trucked production water.



Proposed GATEWAY process

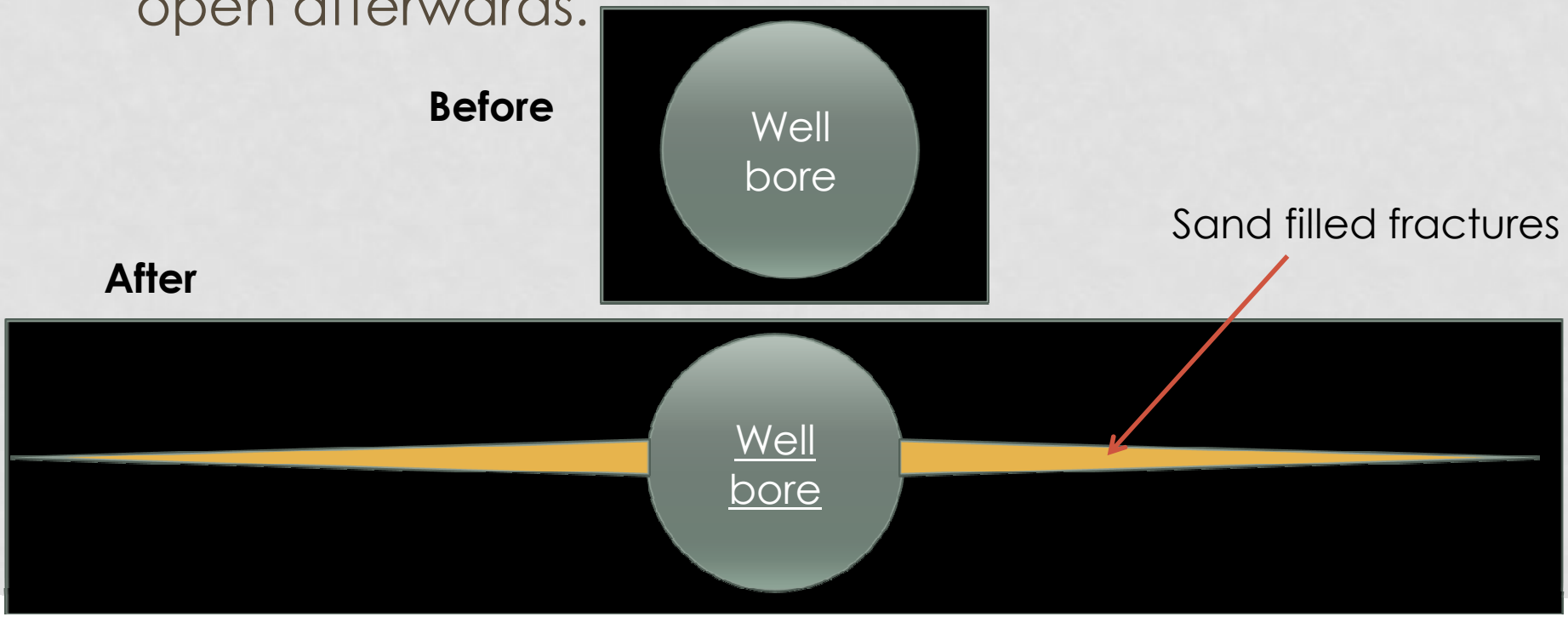
Production

Surface infrastructure. Multiple wells. Infrastructure for production water disposal.



FRACKING (1)

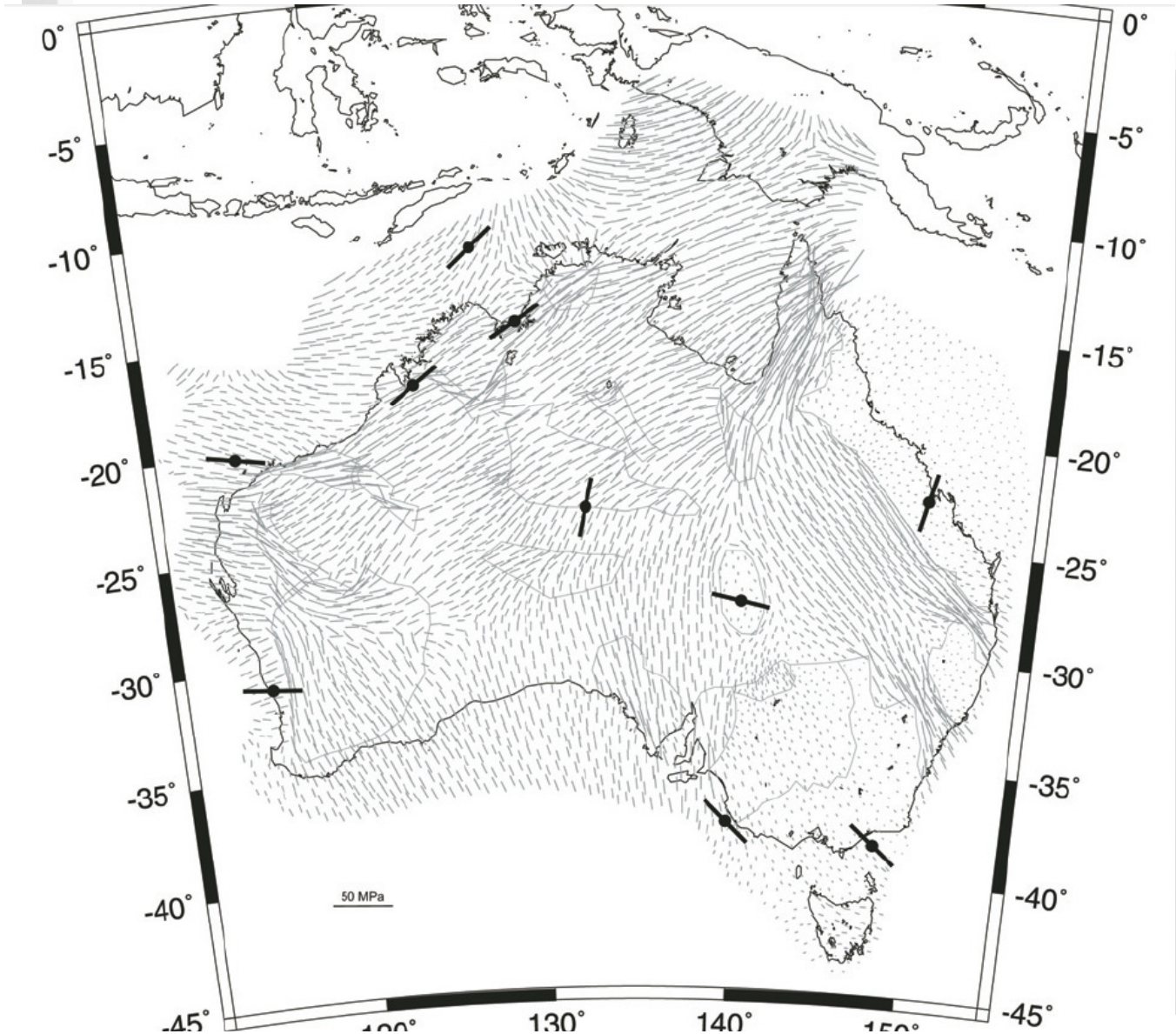
- A liquid (water for coal seam gas)with sand is pumped under pressure into the well and thus into the rock. It creates tensile forces in the rock and fractures it. The sand fills the fracture and keeps it open afterwards.



FRACKING (2)

- **The orientation of the fracture is at right angles to the minimum compressive stress in the rock.**
- The horizontal compressive stress comes from the movement of the tectonic plates on the earth's surface and varies from place to place.
- The vertical compressive stress is a function of how deep the rocks are.
- Generally for the depth of coal seam gas the fracture is vertical.

GEOLOGIC STRESS IN AUSTRALIA

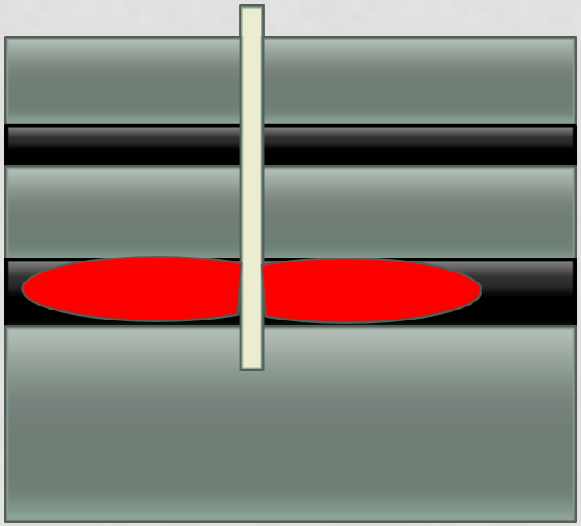


- Everywhere in Australia is different
- Fracking characteristics will be site dependent
- Qld is different from NSW

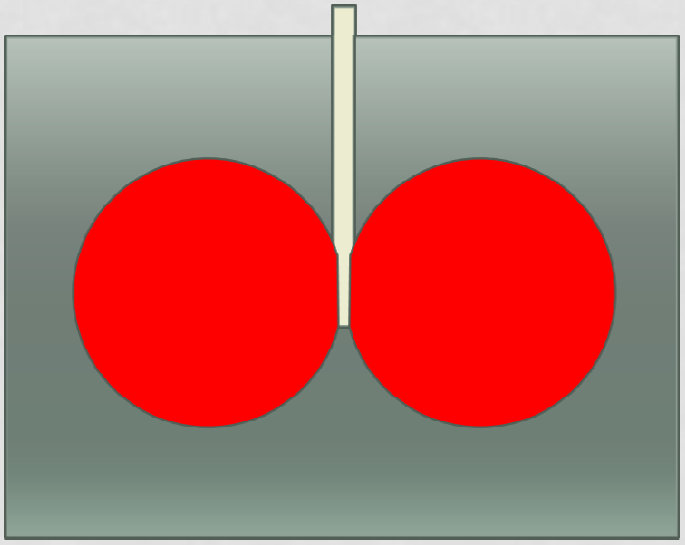
FRACKING: CSG VS SHALE GAS

- The layering of the geology is important to how high and low the fracture extends.
- In CSG the softer coal fractures first (and cleats open) with the harder layers above and below only being fractured at much higher pressures.
- In shale gas the fractures are not constrained vertically and extend as high as they are wide.
- Typical CSG frack dimensions 50m horizontal, 5-10mm wide.

Coal Seam Gas



Shale Gas



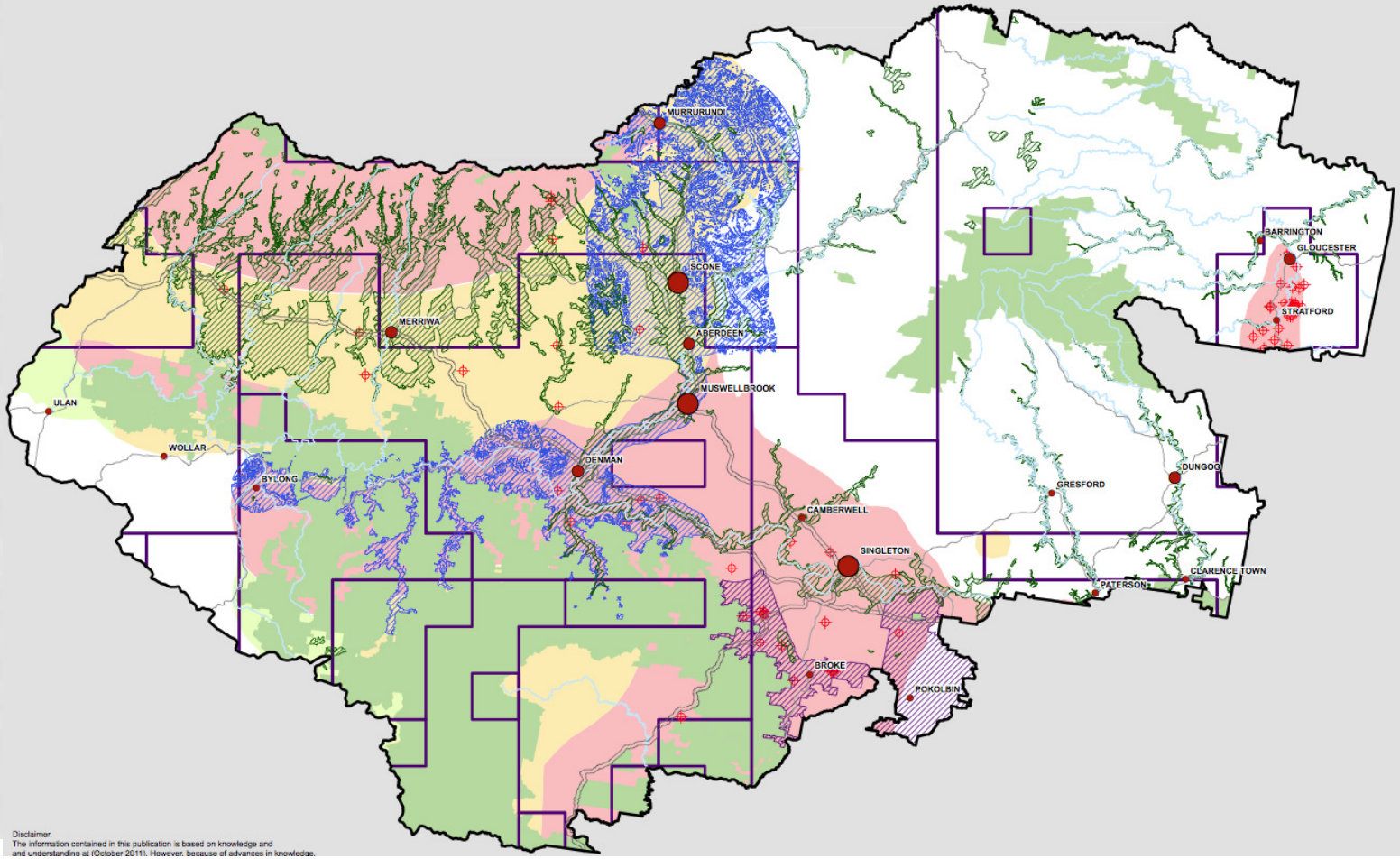
SO WHAT'S THE MAIN WATER IMPACT OF CSG?

- The coal seam needs to be depressurised by draining the water. This "produced" or "production" water has the characteristics of the coal seam. Most coal seams in NSW are highly saline (> 5000 mg/l), alkaline and sodic. This means the water is not suitable for irrigation or other productive use straight from the well.
- Production water has been the main problem in Qld and near Narrabri (Eastern Star). There are proposals to desalinate water for use in irrigation but to date only limited trials.
  - Santos @ Fairview in SE Qld, 100kl/day from 200 wells, world's largest CSG irrigation trial.s

SOME PUBLIC MISUNDERSTANDINGS

- **"Gasland":** Documentary on the water/gas/human health impacts of gas extraction. Almost all of the the case studies in the film are for shale gas (specifically the Marcellus shale in Pennsylvania).
- **Powder River Basin (Montana)**. This is coal seam gas from aquifers that are used for irrigation. Most of the impacts have not been from fraccing. In fact fraccing is relatively rare in Powder River because the permeabilities are quite high … that's the reason they are used for irrigation. The coal seam water at Powder River is quite fresh, while NSW seams are quite saline and not suitable for irrigation. So unlikely there will be direct conflicts in usage in NSW.
- Because geology is different impacts will be site specific. There is a need for site specific assessment of impacts.

LAND-USE CONFLICT IN UPPER HUNTER



UNRESOLVED TECHNICAL ISSUES

- Frack safety in variable geology
  - elasticity, pre-existing stress environment, tilted strata.
  - Safety of pre-existing exploration core holes.
- Lack of publically validated methods to demonstrate whether
  - a fracked well is safe post-fracking.
  - a bad fracked well can be remediated (e.g. grouting of dam foundations).
- Existing groundwater analysis tools inadequate for
  - Analysis of fracked wells (e.g. MODFLOW lacking).
  - Existing book groundwater parameters not appropriate for gas generating wells … underestimate production water.
- Long timescales of aquifer pressure recovery (100-1000 years).
  - Long enough that slow seepage through aquicludes may depressurise adjacent aquifers.