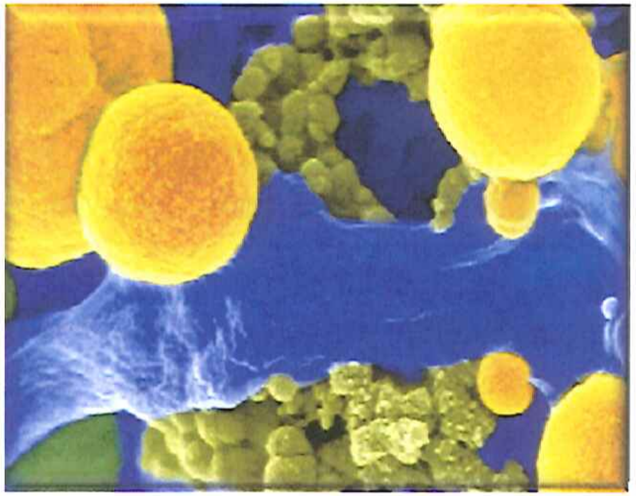

"What's that stink?"

SINCLAIR KNIGHT MERZ

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Sulfate Reducing Bacteria (SRB)

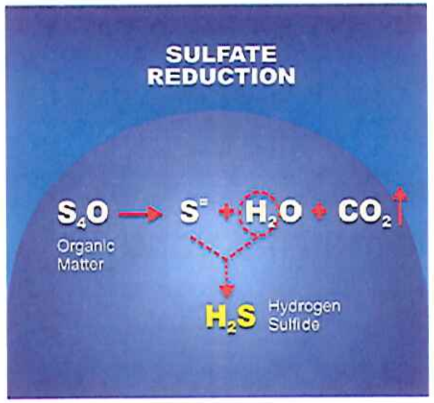
Dr. Richard Cresswell
Practice Leader: Coal Seam Gas related Groundwater

achieve outstanding client success

What are Sulfate Reducing Bacteria (SRB)?

- Oldest form of micro-organisms traced back 3.5 billion years
- Contributed to the sulfur cycle soon after life on Earth, and also part of the carbon cycle
- Anaerobic micro-organisms which 'breathe' sulfate rather than oxygen
- Produces hydrogen sulfide gas (H_2S)

  – rotten eggs smell

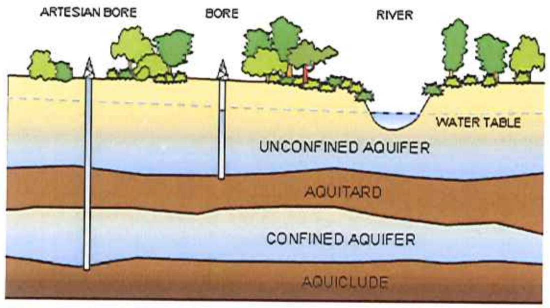


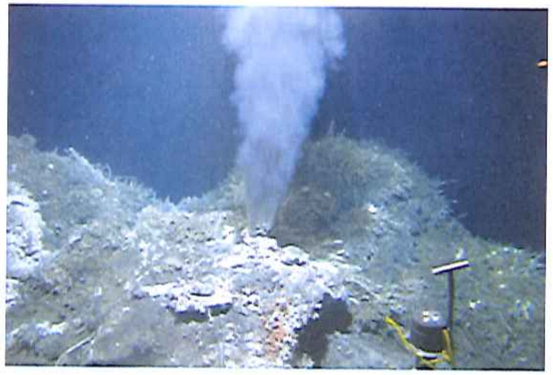
Where are SRB found?

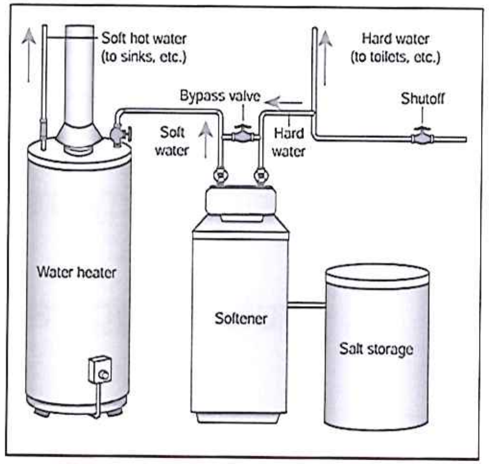
- Most commonly found in environments where no oxygen is present (anoxic conditions)
- Environments where sulfate is present

For example:

- Surface water
- Deep groundwater
- Seawater
- Plumbing systems
- Water softeners
- Water heaters
- Deep sea hydrothermal vents
- Human gut







How do they survive?

- SRB compete with similar micro-organisms (eg: methanogens, which produce methane) for organic compounds and hydrogen to produce energy.
- The presence of sulfate enables SRB to out-compete methanogens

→ As a result, sulfate enriched groundwater inhibits methane production within coal seams.

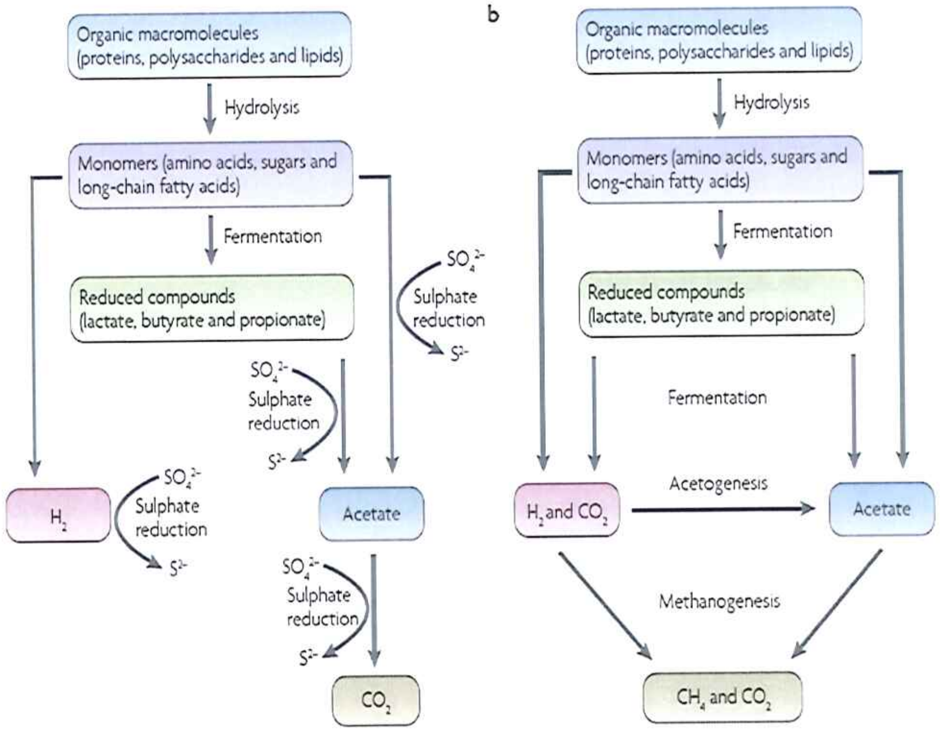


Figure 1. The sequential pattern of microbial degradation of complex organic matter in anoxic environments in the presence (a) and absence (b) of sulfate (Muyzer & Stams, 2008).

Health effects from SRB?

- No direct health implications for SRB in water
  - Water alone containing H_2S (not sewage) does not cause disease
  - Australian Drinking Water Guidelines (ADWG, 2011) have no guidance of acceptable levels

- Health impacts generally arise from exposure to high concentrations of H_2S gas (acceptable limit is10ppm) or prolonged exposure at low concentrations
  - Rotten egg odour increases as the gas becomes more concentrated.

→ Dangerous at concentrations above 30ppm as the smell is difficult to identify.

Effects on groundwater wells

Negative:

- SRB cause corrosion of iron
- Significant sulfate levels can exist below the intake level of pumps & where water has become stagnant
- \- Remediate by cleaning pump and removing organic material (use chlorine and agitation)

Positive:

- SRB can remove sulfate and toxic metals from waste water streams
- \- Commonly used to remediate leachate water from acid waste and abandoned mines

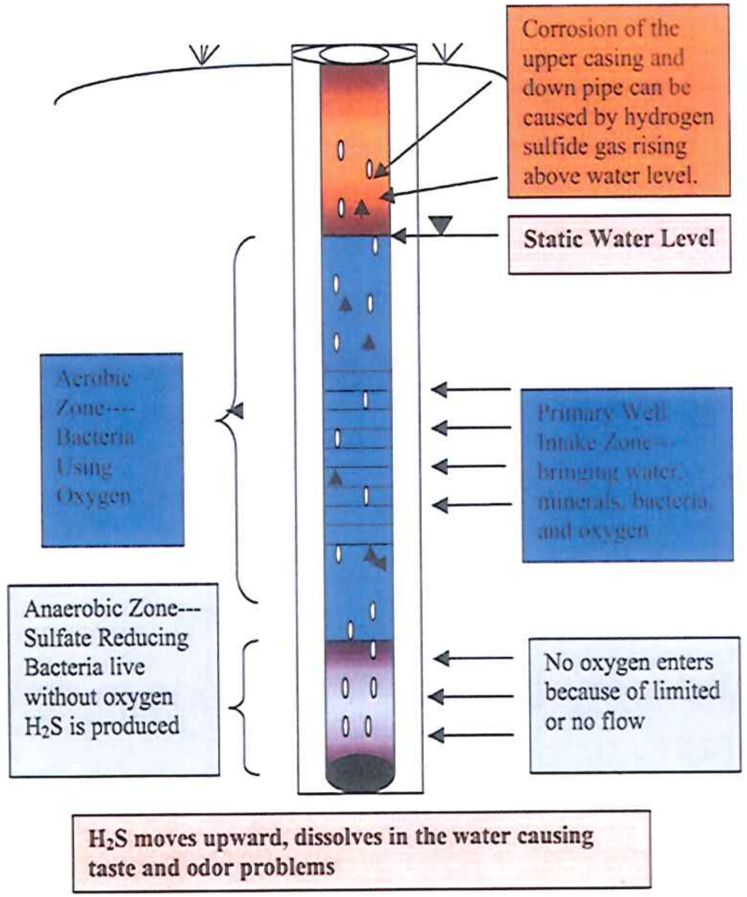


Figure 2: Typical well conditions (Schneiders, 2008)

SRB and Coal Seam Gas (CSG)

- Methane is not produced in coal seam groundwater containing sulfate concentrations above 500mg/L (Van Voast, 2003).
  H_2S gas is produced instead.

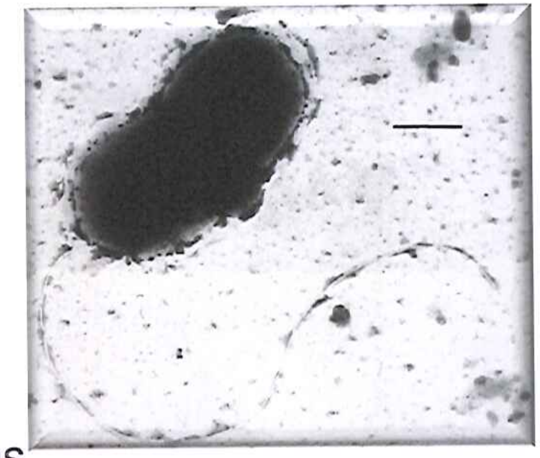
- However, natural geochemical processes remove sulfate from groundwater over time, which eventually depletes SRB.

⇩

Allows methanogenic bacteria to dominate and produce methane within the coal seam.

As a result, CSG wells are generally unrelated to wells which may contain SRB

Summary



Sulfate Reducing Bacteria:

- exist in anaerobic conditions where sulfate is present
- consume sulfate to produce H_2S gas
- require sulfate to survive and out-compete methanogens
- pose no direct health implications in water
  - however, H_2S produced is dangerous after prolonged exposure and exposure to high concentrations (above 10ppm)
- Negative effects: causes corrosion of iron
- Positive effects: SRB can be managed by cleaning and removing organic matter. Used to remove sulfate and toxic metals from waste water.
- Exclusivity generally exists between groundwater wells containing SRB, and CSG wells.

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"Groundwater is the core issue"

Great Artesian Basin (GAB) in NSW

Dr. Richard Cresswell
Practice Leader: Coal Seam Gas related Groundwater

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First borehole in 1878

History of development

Pre-1960s

- Pastoral water use
- uncontrolled bores and pressure decline
- irrigation development in some areas

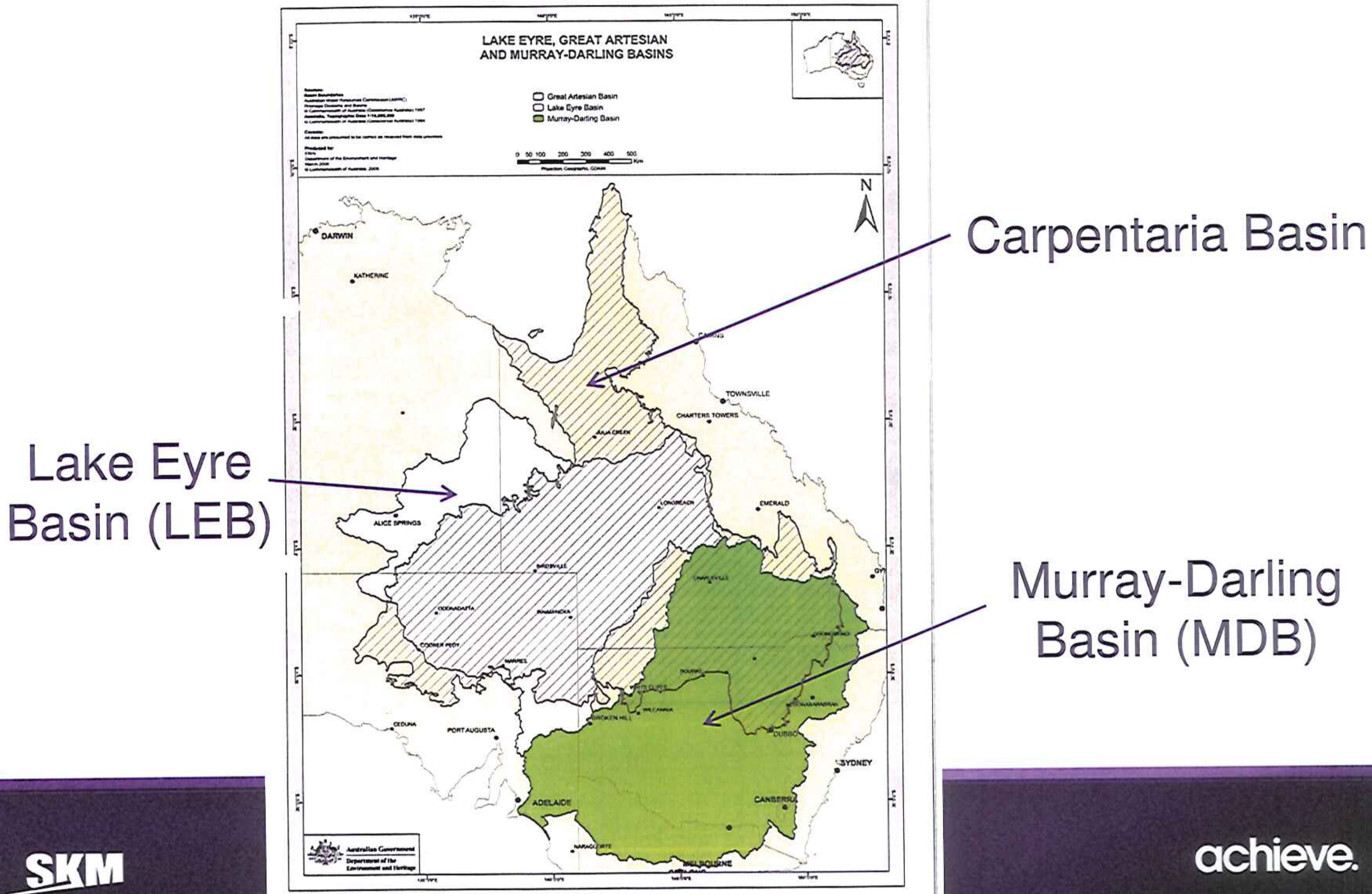
1970s - present

- Mining developments (Olympic Dam, etc.)
- Petroleum resources (natural gas, coal)
- Bore rehabilitation scheme
- EPBC Act, 1999 (protection of springs and habitats)

Outlook 2010 - 2050

- Increasing demand for coal seam gas (water extraction; disposal)
- Further mining development
- Climate change
- Compliance with EPBC Act

River basins and the GAB



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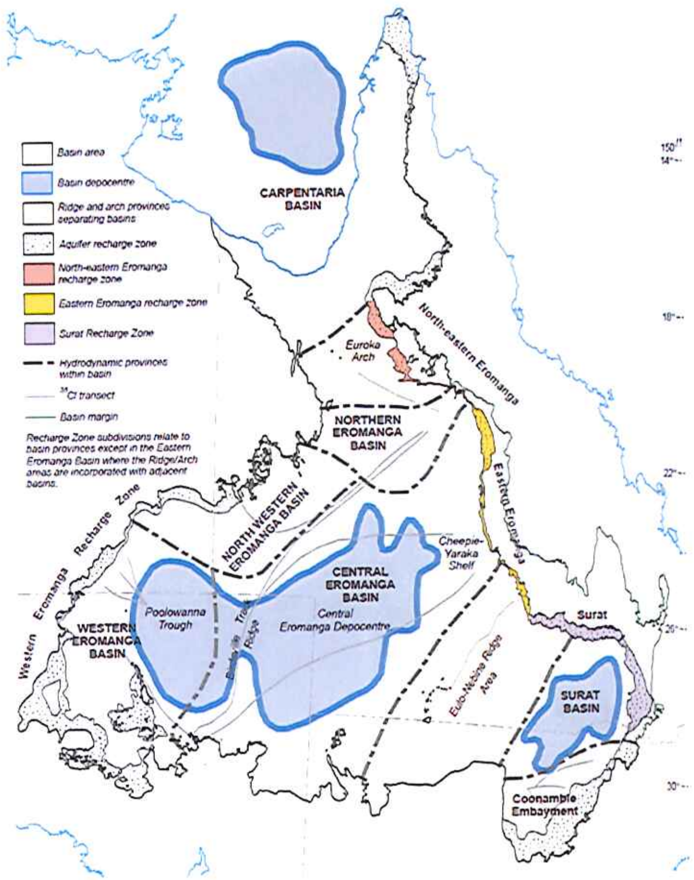
A few statistics

Area of the GAB	1.7×10^6 km^2
Max depth	3,000 m
Volume of water stored	8,700 km^3
Bore discharge (>5,000 bores)	5×10^8 m^3/yr
Total est. discharge	1.2×10^9 m^3/yr (???)
Estimate Recharge	1×10^9 m^3/yr
Water age	Up to 2 million years

Delineation of GAB and regions



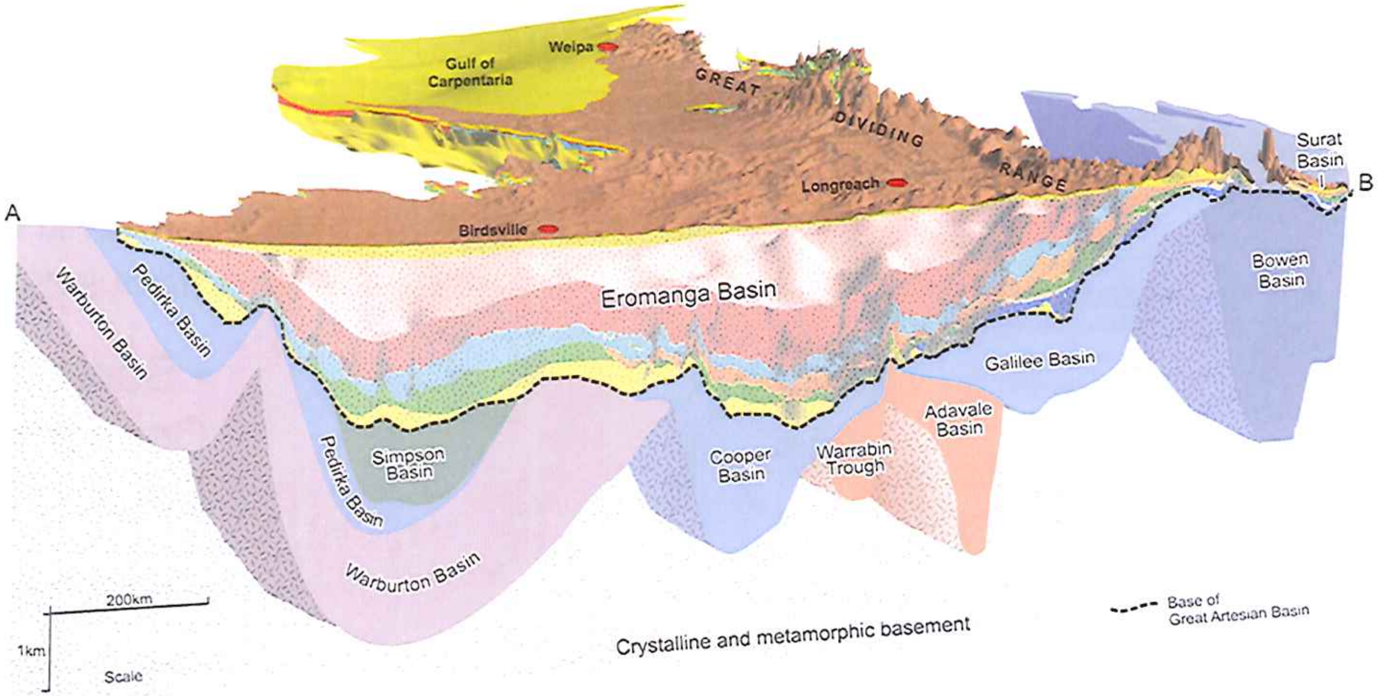
4 regions

Delineated on the basis of structural boundaries and flow systems:

- Surat (incl. Coonamble Embayment)
- Eromanga (Central)
- Eromanga (West)
- Carpentaria

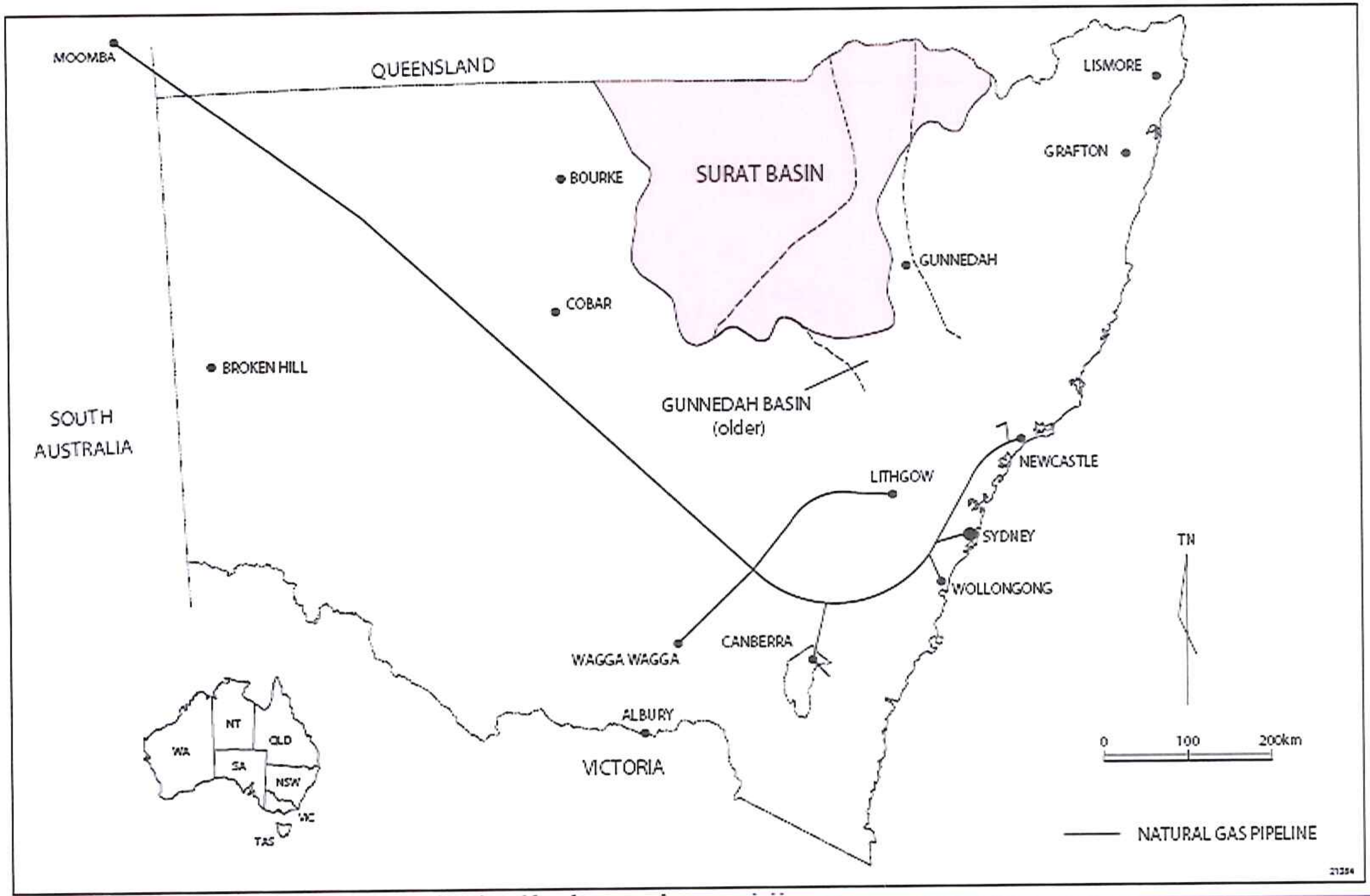
Updating the Conceptualisation of the GAB

- Knowledge of the GAB is continually advancing

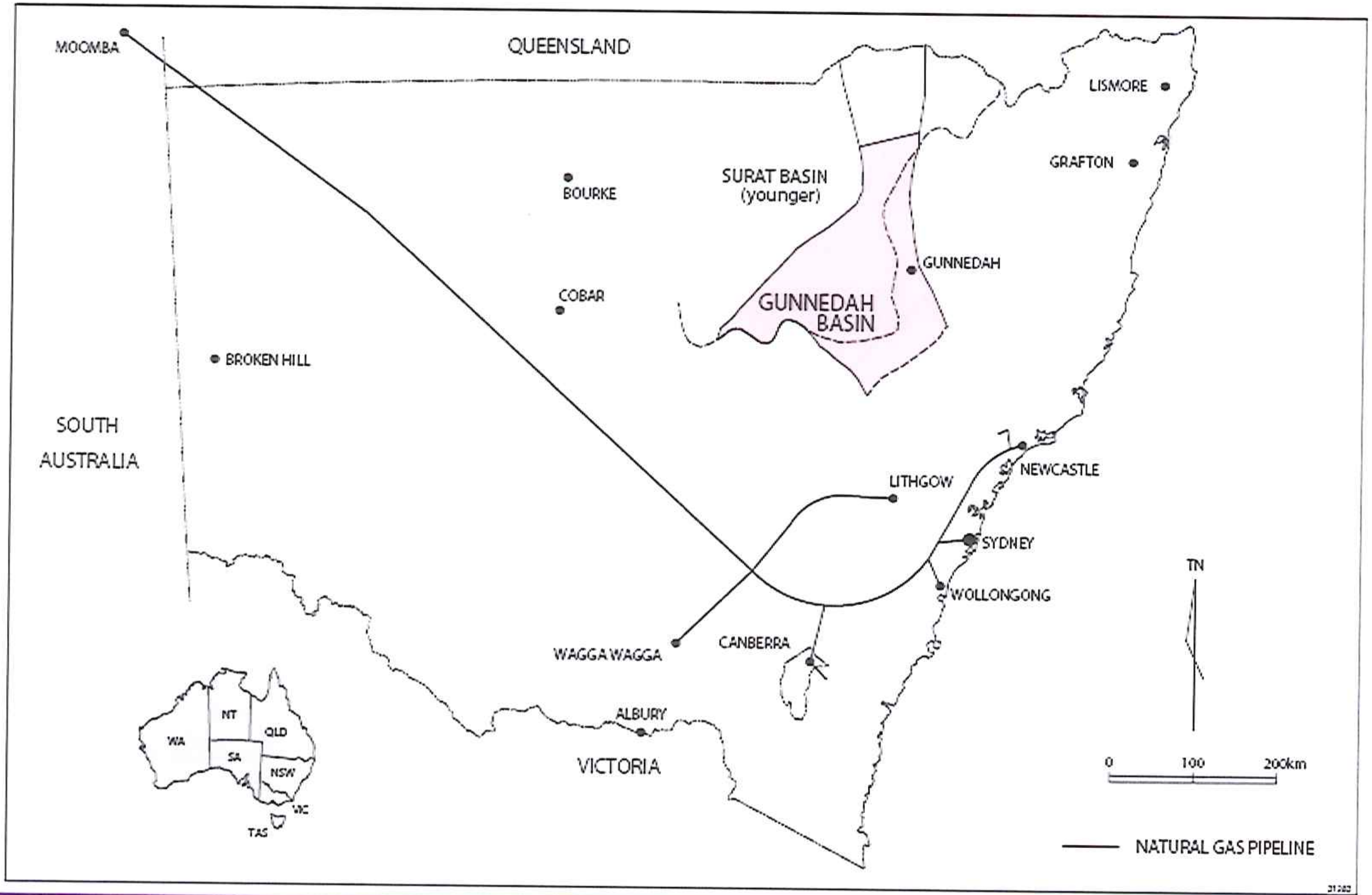


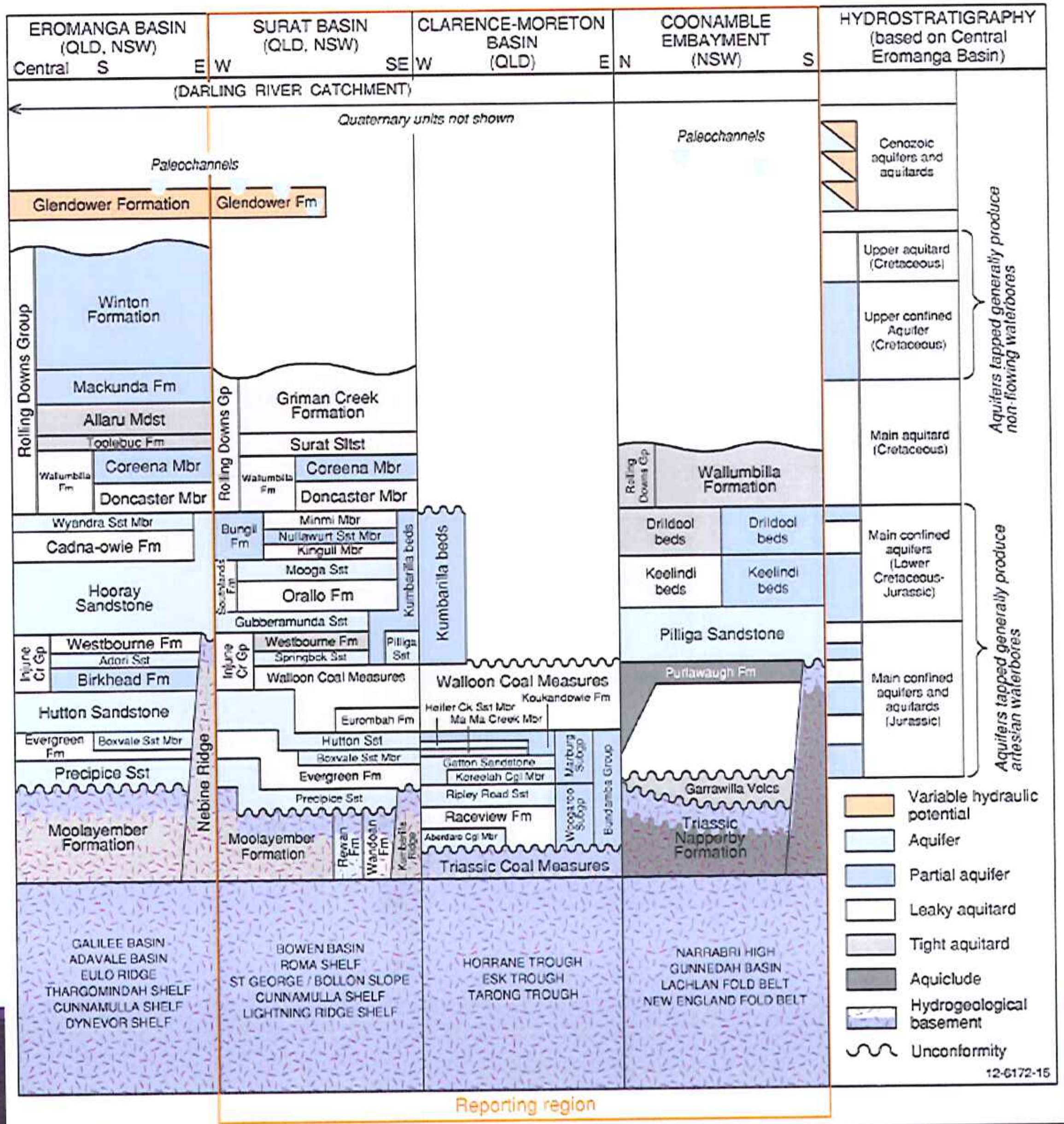
- New research provides a better understanding of the GAB
  - Enables future management to consider the complexity where appropriate
- The complex structure of the GAB governs groundwater conditions
  - Importance of potential vertical movement across layers

NSW Surat Basin



Gunnedah Basin




EROMANGA BASIN (QLD, NSW)
Central S E
SURAT BASIN (QLD, NSW)
W SE
CLARENCE-MORETON BASIN (QLD)
W E
COONAMBLE EMBAYMENT (NSW)
N S
HYDROSTRATIGRAPHY (based on Central Eromanga Basin)
(DARLING RIVER CATCHMENT)
Quaternary units not shown
Paleochannels
Glendower Formation
Glendower Fm
Rolling Downs Group
Winton Formation
Mackunda Fm
Allaru Mdst
Toolebuc Fm
Wallumbilla Fm
Coreena Mbr
Doncaster Mbr
Wyandra Sst Mbr
Cadna-owie Fm
Hooray Sandstone
Injune Cr Gp
Westbourne Fm
Adori Sst
Birkhead Fm
Hutton Sandstone
Evergreen Fm
Boxvale Sst Mbr
Precipice Sst
Moolayember Formation
Nebine Ridge
Rolling Downs Gp
Griman Creek Formation
Surat Sltst
Bungil Fm
Minmi Mbr
Nullawurt Sst Mbr
Kingull Mbr
Mooga Sst
Southlands Fm
Orallo Fm
Gubberamunda Sst
Springbok Sst
Walloon Coal Measures
Kumbarilla beds
Pilliga Sst
Eurombah Fm
Hutton Sst
Boxvale Sst Mbr
Evergreen Fm
Precipice Sst
Rewan Fm
Wandoan Fm
Kumbarilla Ridge
Walloon Coal Measures
Heifer Ck Sst Mbr
Koukandowie Fm
Ma Ma Creek Mbr
Gatton Sandstone
Koreelah Cgl Mbr
Marburg Subgp
Ripley Road Sst
Raceview Fm
Woogaroo Subgp
Bundamba Group
Aberdare Cgl Mbr
Triassic Coal Measures
Rolling Downs Gp
Wallumbilla Formation
Drildool beds
Keelindi beds
Pilliga Sandstone
Purlawaugh Fm
Garrawilla Volcs
Triassic Napperby Formation
GALILEE BASIN
ADAVALE BASIN
EULO RIDGE
THARGOMINDAH SHELF
CUNNAMULLA SHELF
DYNEVOR SHELF
BOWEN BASIN
ROMA SHELF
ST GEORGE / BOLLON SLOPE
CUNNAMULLA SHELF
LIGHTNING RIDGE SHELF
HORRANE TROUGH
ESK TROUGH
TARONG TROUGH
NARRABRI HIGH
GUNNEDAH BASIN
LACHLAN FOLD BELT
NEW ENGLAND FOLD BELT
Cenozoic aquifers and aquitards
Upper aquitard (Cretaceous)
Upper confined Aquifer (Cretaceous)
Main aquitard (Cretaceous)
Aquifers tapped generally produce non-flowing waterbores
Main confined aquifers (Lower Cretaceous-Jurassic)
Main confined aquifers and aquitards (Jurassic)
Aquifers tapped generally produce artesian waterbores
Variable hydraulic potential
Aquifer
Partial aquifer
Leaky aquitard
Tight aquitard
Aquiclude
Hydrogeological basement
Unconformity
12-6172-15
Reporting region

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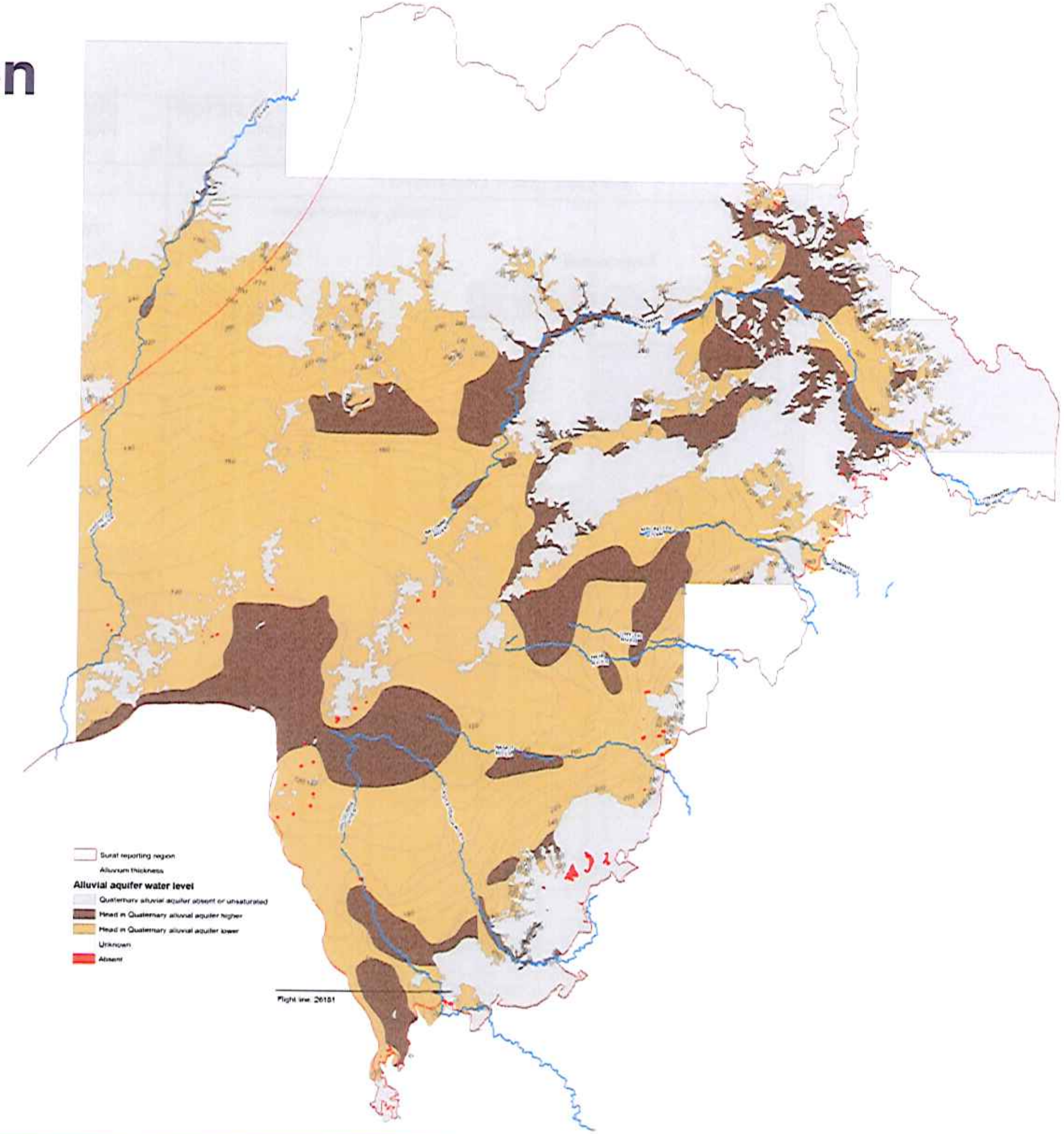
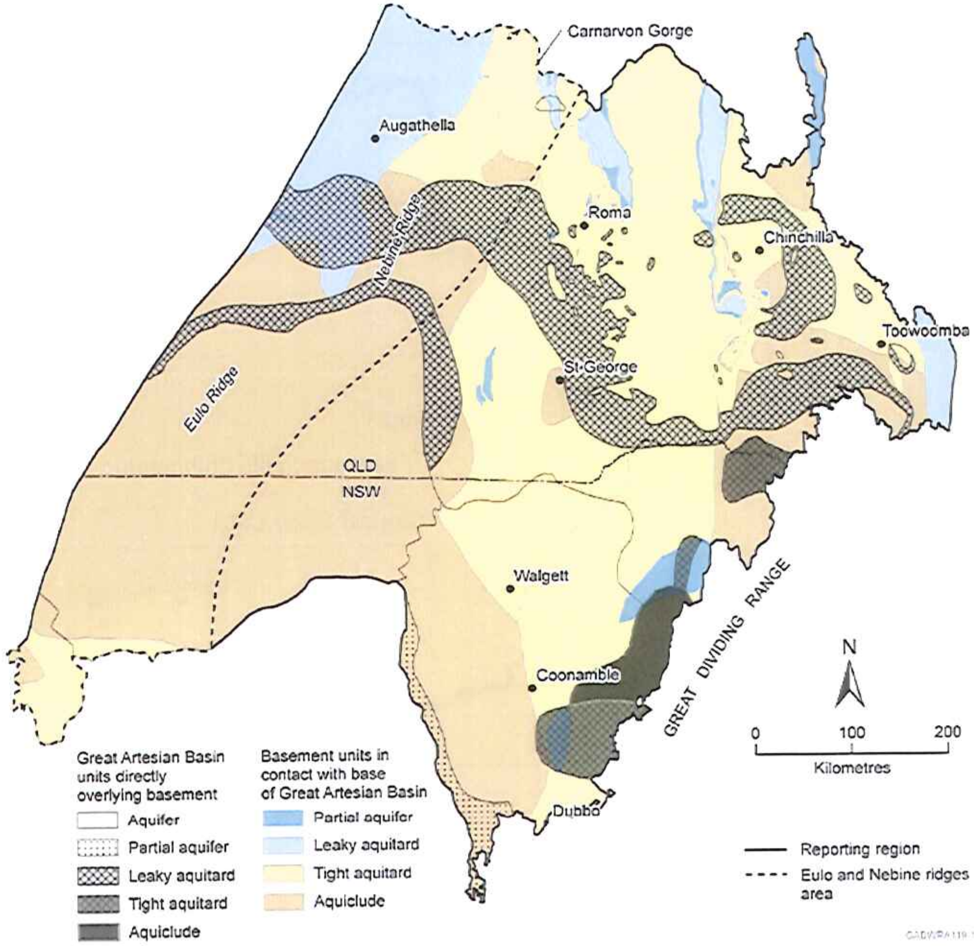
Connection between Surat Basin and alluvium

➔ Likely to be both recharge into and discharge from the GAB to overlying alluvial aquifers

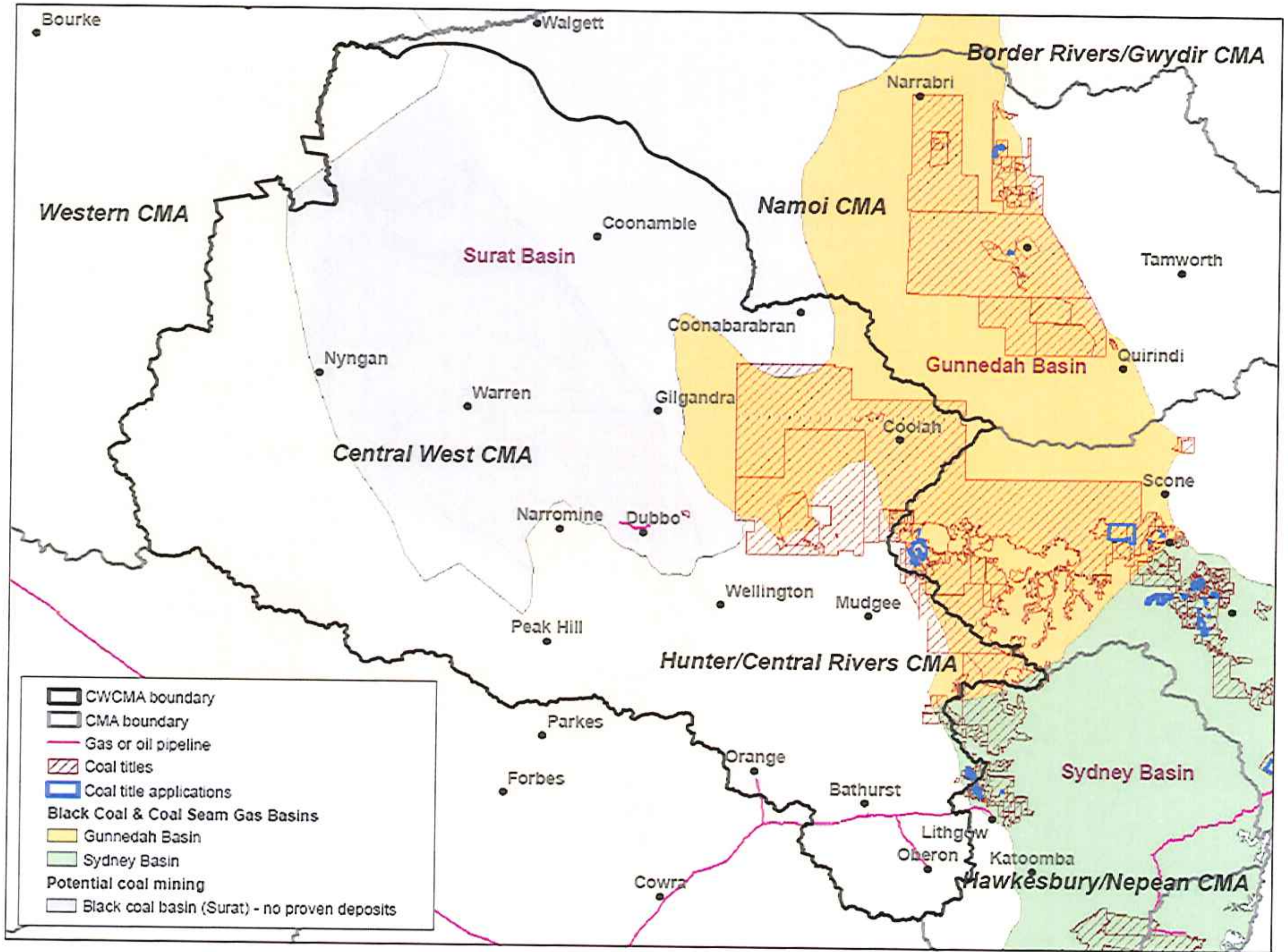


Connection between Surat Basin and underlying rocks

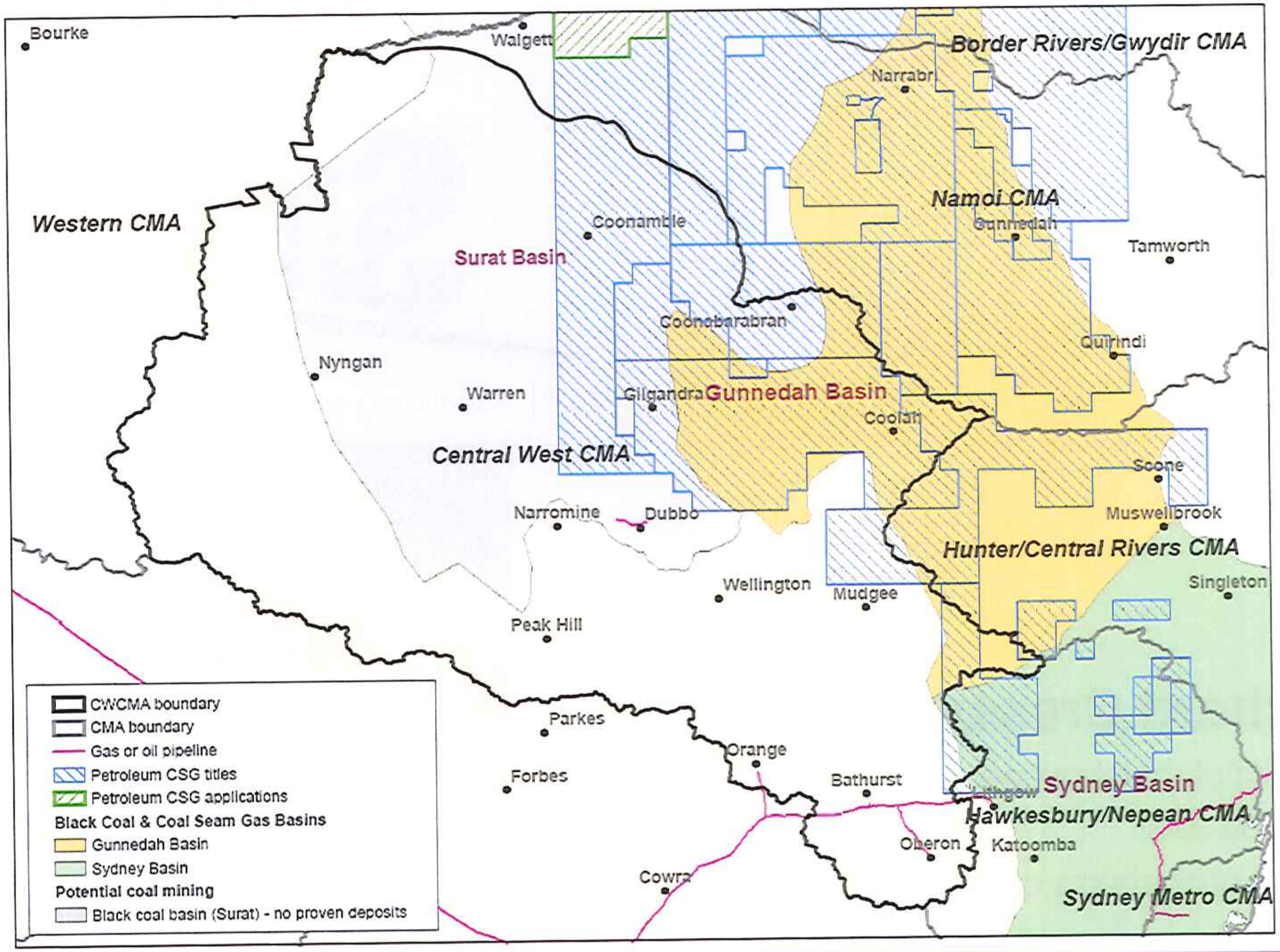
➔Some areas leak, others do not



Location of Coal Mining Activities



Location of Coal Seam Gas Titles



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