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QUEENSLAND CO² GEOLOGICAL STORAGE ATLAS – RESULTS

Outline

1. Atlas Scope
2. Assessment results from 5 High Prospectivity basins
3. Summary of low prospectivity basins
4. Summary of unsuitable basins
5. Discussion of storage in depleted oil & gas fields
6. Discussion of potential for storage in unmineable coals and ECBM

Queensland CO² Storage Atlas

- Aim to identify with highest possible certainty prospective basins for geological storage in onshore Queensland (16 basins).
- Geological assessment – excludes existing resources or site economics
- Options assessed include: regional reservoirs (saline reservoirs & aquifers); depleted oil & gas fields; deep unmineable coal seams; and salt caverns.
- Greatest potential in regional reservoirs using migration assisted storage (MAS) – focus of presentation.

High Prospectivity Areas – Summary

- Contain at least one reservoir-seal interval with demonstrated effectiveness for injection, storage and containment of CO² (i.e. have a total ranking score ≥ 13).
- Twenty reservoirs from five basin areas (Bowen, Cooper, Eromanga, Galilee and Surat basins).
- Most reservoirs have either produced hydrocarbons, and/or are major groundwater aquifers.
- Have sufficient data sets to establish their prospectivity.

Southern Bowen Basin

- Large north-south trending foredeep located close to major emission hubs.
- Mature hydrocarbon province in Queensland: ~94 conventional fields (6SP resources ~ 400 Bcf gas & 10 MMbbl oil) – most near depleted; 5 commercial CSG fields (~650 Bcf).
- Maximum potential storage area defined over western flank (Roma Shof/Shongy Ridge area) where most conventional hydrocarbons are trapped.

Potential geological storage area in the Southern Bowen Basin (blue polygons) & locations of major emissions nodes

- Lacustrine mudstones from Moolayember Formation (Showground Sandstone & Eromanga) form regional seal for the underlying Tertiary fluvial sandstones (Showground Sandstone & Eromanga Group).
- Potential for residual gas saturation trapping on gently dipping western flank – best quality reservoirs sourced from western basins province. Containment problem where regional seal pinches out.
- Some large faulted anticlines on eastern flank. Containment issue due to truncated, steeply dipping stria and large thrust faults. Poor reservoir quality due to proximity to eastern volcanic arc.
Volumetric calculations were completed for 3 reservoir units that are the Showgrounds Sandstone sealed by the Snake Creek Mudstone and Triassic Limestone formation sealed by the Black Allay Shale.

- These reservoirs are well sealed but have highly variable reservoir quality.

**High Prospectivity**

- **9** reservoir units were assessed – only high prospectivity unit is the Aldebaran Sandstone.
- Reservoir well sealed but highly variable, generally low permeability sandstones.

**Southern Denison Trough**

- **Potential for residual gas saturation trapping where CO₂ is injected into saddles and migrates updip into fault propagation anticlines.**
- Series of high-quality seals formed in Late Permian marine shales; seals preserved in southern Denison Trough but often truncated and subsurface exposed in northern trough.
- Gas produced from low-permeability reservoir in Late Permian fluvial delta, coastal and shallow marine sandstones (Aldebaran Sandstone, Freitag Formation, Catharina Sandstone and Mantuan Formation).

**Western Bowen Basin**

- Inverted extensional basin located close to major emission hubs.
- Mature hydrocarbon province in Queensland: 13 conventional gas fields (GIP resources 314 Bcf) – tight gas fields with recent reserves growth; 2 world-class CSG fields (225 Bcf)
- Maximum potential storage areas defined over northern and southern parts of Denison Trough where conventional hydrocarbons are trapped.

**Southern Bowen Basin**

- Volumetric calculations were completed for 3 reservoir units (Showgrounds Sandstone, Rewan Formation and Timxowen Formation).
- Reservoir net pay zone thicknesses from WGRF and average porosity from OPEI database used in calculations.
- Total maximum theoretical storage volume 363 Mt - greatest theoretical capacity in Showgrounds Sandstone (191 Mt).
**Western Bowen Basin**
- Large intracratonic basin (overlies Bowen Basin) located close to major emission hubs.
- Mature hydrocarbon province in Queensland: ~45 fields (OIP resources ~500 Bcf & 50 MMbibl oil) – most near depleted; 19 commercial CSG fields (~1140 Bcf)
- Groundwater heavily utilised in populated areas.
- Large maximum potential storage area defined over much of basin area (regionally extensive reservoirs and seals extend over broad structural depression – ideal for RGS trapping).

**Surat Basin**
- Shallow marine to lacustrine shales and siltstones from the Early Jurassic–upper Evergreen Formation and the Late Jurassic Westbourne Formation provide regional conventional seals for CO2 + several intraformational seals present.
- Regionally extensive fluvial sandstone units provide potential reservoirs throughout the basin.
- Volcanic, basic, and ultrabasic units are prominent in the Surat Basin, with the Precipice, Basal Evergreen, Basal Watagan, and Springdale formations (ranked 13–15) being the most important reservoir units in the basin. Four of these are the traditional reservoirs targeted for oil exploration and are below the regional seal units.
- Reservoirs that ranked 12 have good reservoir quality but they are < 850 m deep.
- 2 units failed due to lack of regional seal.

**Surat Basin**
- Volumetric calculations were completed for 4 reservoir units (Precipice, Basal Evergreen, Basal Watagan, Springdale) from WCRs & average porosity from QPFD database used in calculations.
- Reservoir net pay zone thicknesses from WCRs & average porosity from QPFD database used in calculations.
- Theoretical storage capacity using residual gas saturation trapping total is 2,962 Mt in the evaluated reservoirs – greatest capacity in Precipice Sandstone (1,289 Mt).

**Galilee Basin**
- Large and relatively shallow basin remotely located from major emission hubs.
- No commercial hydrocarbons discovered despite ~50 years exploration – current focus on CSG resources.
- Contains good quality groundwater resources.
- Several potential storage areas mapped over the northern and southern basin areas.
- Only regional well and seismic data available to evaluate storage potential.
**Galilee Basin**

- Main storage mechanism is residual gas migration trapping using low regional dip of strata in Sth Galilee, and southwest plunging faulted ridges in Sth Galilee Basin (potential fault seal breaches).
- Triassic & Late Permian strata from relatively continuous fluvial-lacustrine reservoir-seal units, and are potentially suitable for geological storage of CO₂ where they are preserved beneath the Eromanga Basin (truncated to the west).

**Northern Galilee Basin**

- 7 reservoir units were ranked - best potential units are the Clematis/Sst/Rewan fm sealed by Moolayember Formation, Betts Creek beds with unconventional Rewan Formation seal.
- These reservoirs have good-excellent & moderate-good measured porosity & permeability based on limited well data.

**Southern Galilee Basin**

- 6 reservoir units were ranked - best potential units are the Clematis/Rewan sealed by Moolayember Formation, Colinlea Sandstone sealed by Black Alley/Borderra Fm.
- These reservoirs have good-excellent measured porosity & permeability based on limited well data.

**Galilee Basin**

- Volumetric calculations were completed for 4 reservoir units (Clematis/Sst, Rewan Fm, Betts Creek beds and Colinlea Sst).
- Not possible to define reservoir formations or pay zones with regional well data coverage – reservoir data is largely unconstrained, storage volumes should therefore be used with caution.
- Large theoretical storage volumes: Southern Galilee 2,302 Mt; Northern Galilee Basin 1,128 Mt.
- Clematis Sandstone/Rewan Formation in Southern Galilee has estimated capacity of 882 Mt.
- Seal capacity & faults through seal key uncertainty – needs additional through /fully seal wells & modern seismic.

**Cooper Basin**

- Large intracratonic depocentre located very remotely from major emission hubs.
- Mature hydrocarbon province in Queensland: 81 conventional fields (OIP Resources ~1500 Bcf gas, 30 MMbbls oil) - most near-depleted.
- Maximum potential storage area defined over southwestern basin area where most hydrocarbons are trapped.

Potential geological storage area in the Cooper Basin (blue polygon) & locations of major emissions nodes.

- Gentle dip of structure towards basin flanks provides suitable conditions for RGS trapping of CO₂.
- Reservoirs generally tight (80% failure at depths ~2400 mSD - best in regional fluvial/sandstones from Toolebuc sealed by fluvial-lacustrine Callamurra Member.
**High Prospectivity**

**Cooper Basin**

- 7 reservoir units were ranked – best potential units are the Toolachee Fm and Epsilon Fm (latter not regionally extensive).
- Variable reservoir quality: main issue.

**Eromanga Basin**

- Large intracratonic basin remotely located from major emission hubs.
- Sub-mature oil province in Queensland: ~80 fields (OIP resource ~300 MMbbl oil) – several sub-economic pools also discovered.
- Groundwater heavily utilised in populated areas.
- Very large maximum potential storage area defined over much of basin area (regionally extensive reservoirs and seals at depths >800 m BG).

**Potential geological storage area in the Eromanga Basin**

- Orange: Toolachee Fm (mSS). Toolachee Fm top depth–structure contours (mGS), isopach (m) and drainage cell areas.

**Eromanga Basin**

- Ideal components for geological storage provided by thick regionally extensive regional seal interval comprising marine shales interbedded with varying amounts of sandstone, limestone and siltstone overlying vertically stacked fluvo-lacustrine to shallow marine reservoirs and intraformational seals.
- The presence of large anticlinal structures as well as flat-shallow dipping synclines and monoclines indicate that a range of both structural and residual gas saturation trapping mechanisms could be utilised.

**Hutton Sandstone**

- Volumetric calculations were completed for 5 reservoir units (Pilatoowarna Fm, Hutton Sst, Adore Sst, Hosay Sst & Wyandra Sst).
- Reservoir thickness was derived from isopach mapping (using QPED formation top data).
- Porosity vs depth function incorporated into calculations.
- The combined theoretical capacity for these reservoirs is massive (46,499 Mt) – reflects the extensive nature and thickness of reservoir units.
- Hutton Sandstone capacity is estimated at 12,262 Mt of CO₂.
Results: Low Prospectivity Basins

- 13 basins evaluated as having low prospectivity.
- Contain reservoir-seal intervals with uncertain effectiveness due to either limited data to evaluate their prospectivity, or high variability in the quality of reservoirs and seals.

Results: Unsuitable Basins

- 19 unsuitable basins are known to be unprospective as their reservoirs and/or seals are all below the minimum criteria.

Depleted Fields

- A maximum theoretical replacement volume (MTRV) calculated on original in place resources as reported by QDEED 2008.
- A MTRV of 374 Mt CO₂ is estimated for 295 gas and/or oil fields and 485 reported producing reservoir pools in Queensland.
- However, most large fields are still producing and are unlikely to be available for CO₂ storage in the near-future. Only 99 fields are either depleted or near-depleted (<5% original 2P reserves remaining), which have a combined MTRV of 64.6 Mt CO₂.

Potential Coal Storage Areas

- Potential storage areas defined in major coal basins (Bowen, Surat & Galilee basins) using depth cut-offs of >400 m (sub-economic depth for mining) and <1,000 m (permeability).
- Storage volumes have not been calculated – know that these will be unrealistically large – injectivity is real issue.
- Results show best potential is in CSM exploration sweet spots – mainly an option for ECBM recovery over the Comet Ridge & Dawson Valley.

Summary

- The greatest potential for storage is using RG trapping in regionally extensive reservoir-seal intervals rather than depleted fields or coal seams.
- Good opportunities for geological storage are most evident in the Bowen, Cooper, Chinchilla, Galilee and Surat basins, but:
  - Further drilling and exploration is required in many parts of these basins to fully document the quality of their storage prospectivity.
- Queensland Government have legislation (Greenhouse Gas Storage Act 2009) that will come into effect Feb 2010.
- Done to have gazetted round in place for permits to:
  - Explore for underground storage reservoirs
  - Storage of greenhouse gases to take place.

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