Summary of results and conclusions

Queensland Government CGSS COAL21 FUND

Outline - Results

1. Description of the 5 High prospectivity basins in detail
2. Summary of low prospectivity basins
3. Discussion of potential for storage in unmineable coals and ECBM
4. Discussion of storage in depleted oil & gas fields

Basin prospectivity based on ranking methodology

HIGH PROSPECTIVITY

High Prospectivity Basins

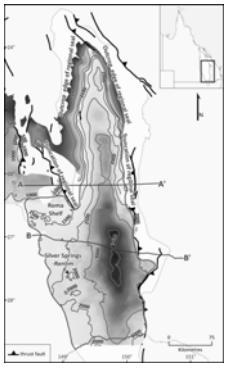
- Contain at least one reservoir-seal interval with demonstrated effectiveness for injection, storage and containment of CO_2 (i.e. have a total ranking score ≥ 13).
- Twenty reservoirs from five basin areas (Bowen, Cooper, Eromanga, Galilee and Surat basins)
- Most reservoirs have either produced hydrocarbons, and/or are major groundwater aquifers.
- Have sufficient data sets to establish their prospectivity.

High Prospectivity basins based on the ranking methodology

HIGH PROSPECTIVITY

Southern Bowen Basin

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

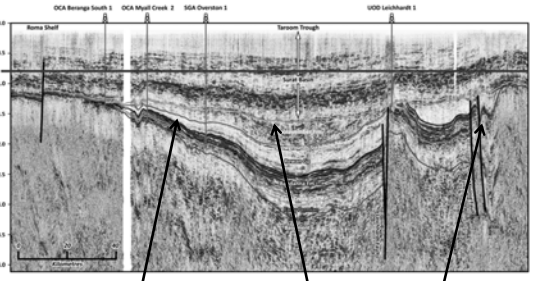


Depth (m) to Snake Creek/ Moolayember Fms = base regional seal. SBEA map series from QDEEDI

HIGH PROSPECTIVITY

Southern Bowen Basin

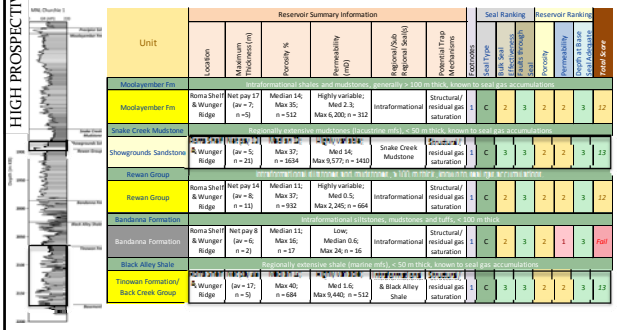
B B'



- Most basin area >800 mGL and at suitable depth for supercritical CO_2 storage.
- Moolaymeber Formation & Snake Creek Mudstone form regional seal for the underlying Triassic reservoirs (Showgrounds Sandstone & Rewan Group).
- Potential for residual gas saturation trapping on gently dipping western flank – best quality reservoirs sourced from western cratonic province. Containment problem where regional seal pinches-out.
- Some large faulted anticlines on eastern flank. Containment issue due to truncated, steeply dipping strata and large thrust faults. Poor reservoir quality due to proximity to eastern volcanic arc.

HIGH PROSPECTIVITY

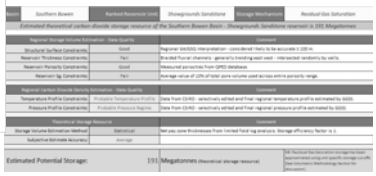
Southern Bowen Basin



- 5 reservoir units were ranked – best potential units are the Showgrounds Sandstone sealed by the Snake Creek Mudstone and Tinowon Formation sealed by the Black Alley Shale.
- These reservoirs are well sealed but have highly variable reservoir quality.

HIGH PROSPECTIVITY

Southern Bowen Basin



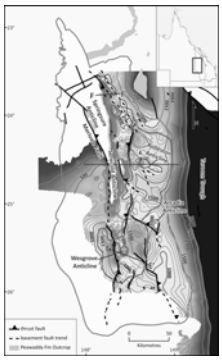
- Volumetric calculations were completed for 3 reservoir units (Showgrounds Sandstone, Rewan Formation and Tinowan Formation).
- Reservoir net pay zone thicknesses from WCR's and average porosity from QPED database used in calculations.
- Total theoretical storage volume 363 Mt
- Greatest theoretical capacity in Showgrounds Sandstone (191 Mt)

Showgrounds Sandstone storage area- Roma Shelf/Wunger Ridge

HIGH PROSPECTIVITY

Western Bowen Basin

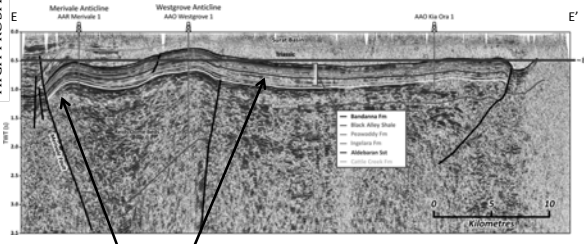
Potential geological storage area in the Western Bowen Basin (blue polygon) & locations of major emissions nodes



Structural elements on depth to base Peawaddy Fm equivalent. SBEA map series from QDEEDI.

HIGH PROSPECTIVITY

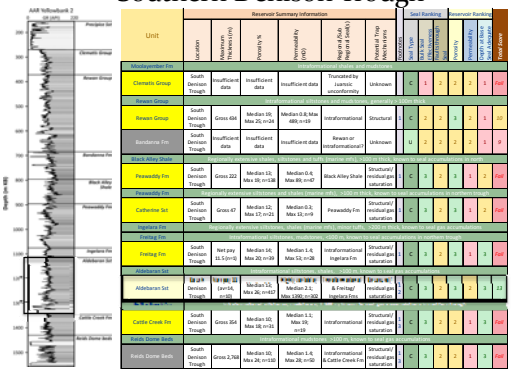
Western Bowen Basin



- Large fault propagation anticlines provide structural traps for gas fields that filled to spill point defined by bounding faults.
- Potential for residual gas saturation trapping where CO_2 is injected into saddles and migrates updip into anticlines.
- Series of regional seals formed in Late Permian marine shales; seals preserved in southern Denison Trough but often truncated and subaerially exposed in northern trough.
- Gas produced from low permeability reservoirs in Late Permian fluvial-deltaic, coastal and shallow marine sandstones (Aldebaran Sandstone, Freitag Formation, Catherine Sandstone and Mantuan Formation).

HIGH PROSPECTIVITY

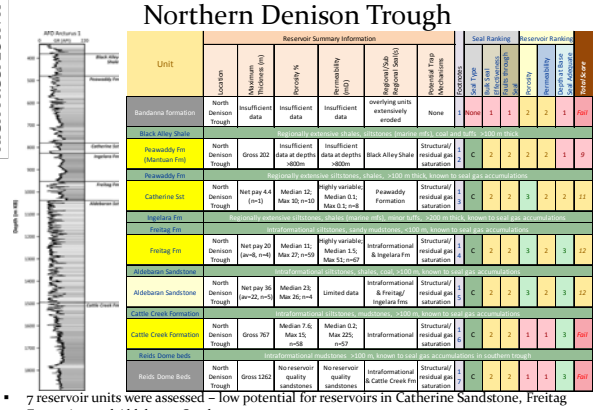
Southern Denison Trough



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

HIGH PROSPECTIVITY

Northern Denison Trough

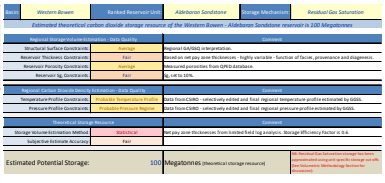


- 7 reservoir units were assessed – low potential for reservoirs in Catherine Sandstone, Freitag Formation and Aldebaran Sandstone.
- Generally low permeability reservoirs; structural traps present but seals often truncated.

HIGH PROSPECTIVITY

Western Bowen Basin

Aldebaran Sandstone potential storage area – southern Denison Trough

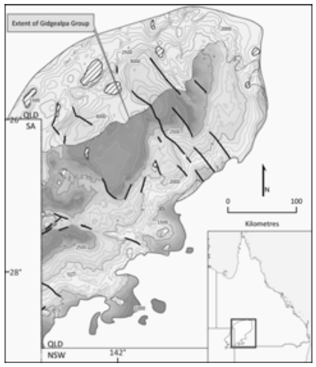


- Volumetric calculations were completed for 4 reservoir units (Aldebaran sandstone – sth Denison Trough; Aldebaran Sandstone nth Denison Trough; Freitag Fm; Catherine Sandstone).
- Reservoir net pay zone thicknesses from WCRs & average porosity from QPED database used in calculations.
- Total theoretical storage volume 250 Mt
- Greatest theoretical capacity in Aldebaran Sandstone over southern Denison Trough (100 Mt).
- Injectivity into low permeability reservoirs main uncertainty.

HIGH PROSPECTIVITY

Cooper Basin

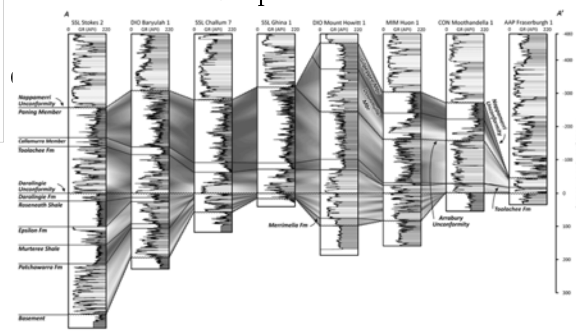
Potential geological storage area in the Cooper Basin (blue polygon) & locations of major emissions nodes



Depth structure map (mSS) of 'P' horizon (top Toolachee Fm/base Nappamerri)

HIGH PROSPECTIVITY

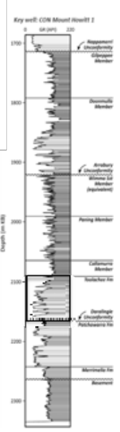
Cooper Basin



- Basin at suitable depths for supercritical injection of CO_2, and has trapped hydrocarbons
- Reservoirs tight (80% failure at depths >2400 mSS) - best in regional fluvial sandstones from Toolachee sealed by Callamurra Member.
- Dry structures may provide opportunities if fault seal issues resolved, depleted fields aren't likely to be available in the near future but Challum field has the largest capacity.

HIGH PROSPECTIVITY

Cooper Basin

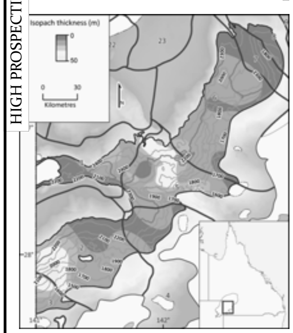


Unit	Reservoir Summary Information: Location	Maximum Thickness (m)	Porosity %	Permeability (mD)	Regional/Sub Regional Seal(s)	Potential Trap Mechanisms	Footnotes	Seal Ranking: Seal Type	Bulk Seal Effectiveness	Faults through Seal	Reservoir Ranking: Porosity	Permeability	Depth at Base Seal Adequate	Total Score
Gilpeppee Member	Grey-green siltstone and mudstone, only northern of JNP, to a maximum ~100 m thick.													
Doonmulla Member	northern sub-basin	~180	Average 8.4 Max 14.0 n=7	Average ~30 Max 205 n=7	Gilpeppee Member	Structural RGS	1	C	3	2	2	2	3	12
Wimma Sandstone Member	north-western edge of basin	~100	Average 11.1 Max 26.3 n=36	Average 1.7 Max 11 n=36	Doonmulla/ Gilpeppee	Structural RGS	2	U	2	2	2	2	3	11
Paning Member	Maximum thickness ~150 m. There may be reservoir options in this unit but generally fairly poor reservoir quality.													
Callamurra Member	170 m maximum thickness, thins to the north and in places < 50 m thick.													
Toolachee Formation	basinwide	190	Average [illegible] Max 22.9 n=1163	Average [illegible] Max 7100 n=1163	Callamurra Member	Structural RGS	3	C	3	2	2	3	3	13
Daralingie Formation	south of JNP trend	96	Probably as above	Probably as above	Toolachee/ Callamurra	Structural RGS	4	U	2	2	2	2	3	11
Roseneath Shale	Significant development south of JNP; maximum thickness 99 m generally 50-80 m thick.													
Epsilon Formation	south of JNP trend	92	Average 13.8 Max 17.9 n=17	Average 5.72 Max 20.2 n=17	multiple	Structural RGS	4	C	3	2	3	2	3	13
Murteree Shale	Significant development south of JNP; maximum thickness 71 m generally ~50 m thick.													
Patchawarra Formation	basinwide	400	Average 8.65 Max 21.1 n=844	Average 47.5 Max 3478 n=844	multiple	Structural RGS	5	C	3	2	2	2	3	12
Tirrawarra Sandstone	basinwide but patchy	70	Average 7.4 Max 10 n=27	Average 0.65 Max 4.4 n=27	multiple	Structural RGS	6	U	2	2	1	1	3	Fail
Merrimelia Formation	basinwide but patchy	84	Probably Poor	Probably Poor	multiple	Structural RGS	6	U	2	2	1	1	3	Fail

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

HIGH PROSPECTIVITY

Cooper Basin



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

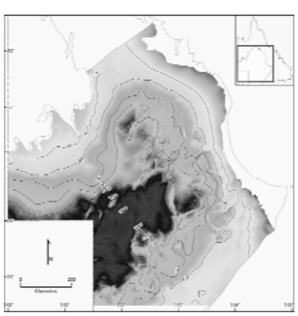
Regional Storage Volume Estimation - Data Quality		Comment
Structural Surface Constraints	Good	[illegible]
Reservoir Thickness Constraints	Good	[illegible]
Reservoir Porosity Constraints	Fair	[illegible]
Reservoir Sg Constraints	Poor	[illegible]
Regional Carbon Dioxide Density Estimation - Data Quality		**Comment**
Temperature Profile Constraints	[illegible]	[illegible]
Pressure Profile Constraints	[illegible]	[illegible]
Theoretical Storage Resource		**Comment**
Storage Volume Estimation Method	[illegible]	[illegible]
Subjective Estimate Accuracy	[illegible]	[illegible]
Estimated Potential Storage: 172	Megatonnes [illegible]	[illegible]

- Volumetric calculations were completed for one reservoir unit the Toolachee Formation
- Reservoir thickness was derived from isopach mapping (using Interpretation from Draper et al 2002)
- Calculated theoretical storage volume: 172 Mt.
- No estimate is made for the Patchawarra Fm but it is likely to be similar to the Toolachee Formation

HIGH PROSPECTIVITY

Eromanga Basin

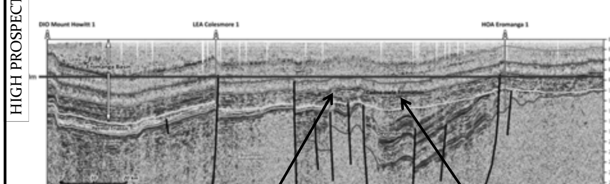
Potential geological storage area in the Eromanga Basin (blue polygon) & locations of major emissions nodes



Depth structure map (mSS) of the 'C' horizon (top Cadna-owie Formation)

HIGH PROSPECTIVITY

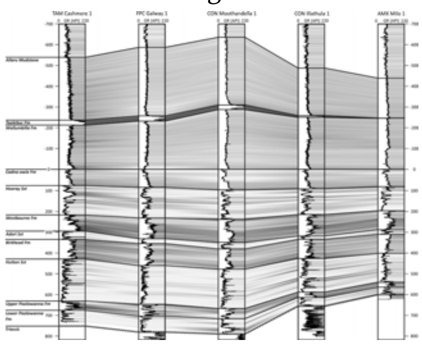
Eromanga Basin



- The occurrence of regionally extensive, vertically-stacked reservoirs and a thick regional seal succession indicates that the Eromanga Basin has the geological components suitable for the storage of the CO_2.
- 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.
- The location of the 800mGL level at the base of the regional seal succession indicates that a large proportion of the basin is suitable for supercritical CO_2 storage.

HIGH PROSPECTIVITY

Eromanga Basin



- A thick regional seal succession and multiple intraformational seal units are present over the entire basin. The regional seal succession is 400 -700 m thick, comprises the Wallumbilla Formation, Toolebuc Formation and the Allaru Mudstone and consists predominantly mudstone interbedded with varying amounts of sandstone, limestone and siltstone.

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HIGH PROSPECTIVITY

Eromanga Basin

Formation	Reservoir Summary Information							Seal Ranking			Reservoir Ranking			
	Location	Maximum Thickness (m)	Porosity %	Permeability (mD)	Regional/Sub Regional Seal(s)	Potential Trap Styles	Footnotes	Seal Type	Bulk Seal Effectiveness	Faults through Seal	Porosity	Permeability	Depth at Base Seal Adequate	Total Score
Winton Formation	basinwide	1000	estimated at 10-25%	unknown, but likely to be favourable for injection	nil	structural		None	1	2	3	3	1	Fail
Mackunda Formation	basinwide	100	estimated at 10-25%	unknown	nil	structural		None	1	2	3	3	2	Fail
Allaru Mudstone	Regionally extensive succession up to 400 m thick; consists primarily of marine mudstone interbedded with siltstone.													
Wallumbilla Formation	Regionally extensive succession up to 350 m thick; consists primarily of interbedded marine mudstone and siltstone.													
Cadna-owie Formation (Wyandra Sandstone Member)	basinwide	20	10-25%; max > 25%	data indicates both low (<1mD) and moderate (10-100mD) facies	Allaru/ Wallumbilla	structural / migration		C	3	2	3	3	3	14
lower Cadna-owie Formation	Coarsening upward succession of mudstone, siltstone and sandstone up to 130 metres thick; demonstrated seal in hydrocarbon fields.													
Hooray Sandstone	basinwide	165	10-25%; max > 25%	mostly 1 - 100 mD; up to 5000 mD	multiple	structural / migration	1	C	2	2	3	3	3	13
Westbourne Formation	Interbedded sequence of siltstone, sandstone and claystone up to 160 metres thick; demonstrated seal in hydrocarbon fields.													
Adori Sandstone	basinwide	55	10-25%; max > 25%	variable, but mostly 10 - 2000 mD	multiple	structural / migration	1	C	2	2	3	3	3	13
Birkhead Formation	Interbedded sequence of siltstone, sandstone and claystone up to 110 metres; demonstrated seal in hydrocarbon fields.													
Hutton Sandstone	basinwide	210	10-25%; max > 25%	mostly 10 - 1000 mD; up to 5000 mD	multiple	structural / migration	1	C	2	2	3	3	3	13
upper Poolowanna Formation	Interbedded sequence of siltstone, sandstone and claystone up to 100 metres thick; demonstrated seal in hydrocarbon fields.													
lower Poolowanna Formation	central depocentre	120	10-20%; max > 20%	highly variable; 0.1 - 5000 mD	multiple	structural / migration	1	C	2	2	3	3	3	13

- 7 reservoir units were ranked – 5 of these are the 'traditional' reservoirs targeted for oil exploration and are below the regional seal units; 2 units are above the regional seal and 'fail' due to a number of factors.
- Those units below the regional seal are generally characterised by moderate-excellent reservoir quality.
- Bulk seal effectiveness of the intraformational seals (Birkhead, Westbourne etc) may be limited on a regional scale but may be effective locally (as is demonstrated by the occurrence of hydrocarbon accumulations).

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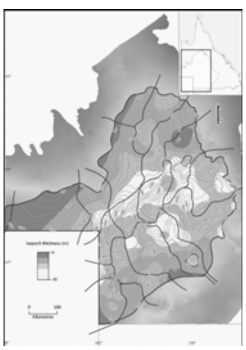
HIGH PROSPECTIVITY

Eromanga Basin



Adori Sandstone top depth-structure contours (mSS), isopach (m) and drainage cell areas

[illegible]		Comment
[illegible]	Good	[illegible]
[illegible]	Good	[illegible]
[illegible]	Poor	[illegible]
[illegible]	Poor	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
Estimated Potential Storage:	6,474	Megatonnes [illegible]

- The potential storage area is derived from the 450 mSS contour (top CO_2 supercritical zone) on the base of the regional seal succession (using the C Horizon).
- Volumetric calculations were completed for 5 reservoir units.
- Reservoir thickness was derived from isopach mapping (using QPED formation top data).
- 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 CO_2.

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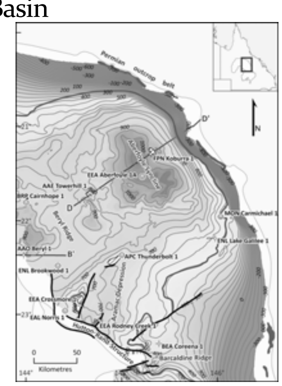
HIGH PROSPECTIVITY

Galilee Basin

Potential geological storage areas in the Galilee Basin (blue polygons) & locations of major emissions nodes



Top Permian depth-strucutre (mBSL) over the Koburra Trough.

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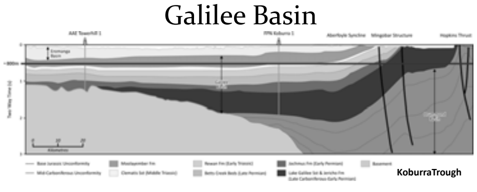
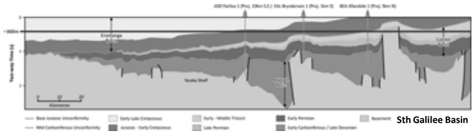
HIGH PROSPECTIVITY

Galilee Basin





- Triassic & Late Permian strata from relatively continuous reservoir-seal units, and are potentially suitable for geological storage of CO_2 where they are preserved beneath the Eromanga Basin (truncated to the west).
- Main storage mechanism is residual gas migration trapping using low regional dip of strata in Koburra Trough, and southwest plunging faulted ridges in sth Galilee Basin –potential fault seal breaches. Anticlines with fault-independent closure provide smaller storage options. Potential stratigraphic trapping in Early Permian strata.
- Permian strata generally >800 mBGL; Triassic Moolayember Formation (regional seal) <800 mBGL over most of Koburra Trough.

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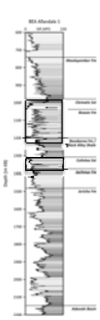
HIGH PROSPECTIVITY

Southern Galilee Basin



Unit	Reservoir Summary Information							Seal Ranking			Reservoir Ranking			
	Location	Maximum Thickness (m)	Porosity %	Permeability (mD)	Regional/Sub Regional Seal(s)	Potential Trap Mechanisms	Footnotes	Seal Type	Bulk Seal Effectiveness	Faults through Seal	Porosity	Permeability	Depth at Base Seal Adequate	Total Score
Moolayember Formation	Fluvial and lacustrine mudstones, siltstones and sandstones (>50 m thick)													
Clematis Sandstone	Southern Galilee	[illegible] (Gross)	Median [illegible] Max 28 Count = 20	Median [illegible] Max 1,747 Count = 16	[illegible] Formation	[illegible] residual gas saturation	1 2 3	C	2	2	3	3	3	13
Rewan Formation	Southern Galilee	181 (Gross)	Median 23 Max 30 Count = 33	Median 87 Max 4,770 Count = 24	Moolayember Formation	Structural/ residual gas saturation	1 2 3	U	2	2	3	3	3	13
Bandanna/Black Alley	[illegible]													
Colinlea Sandstone	Southern Galilee	[illegible] (Gross)	Median [illegible] Max 28 Count = 24	Median [illegible] Max 5,738 Count = 23	[illegible] Bandanna	[illegible] residual gas saturation	1 2 3	C	2	2	3	3	3	13
Jochmus Formation	[illegible] Galilee	[illegible] (Gross)	[illegible] Max 26 Count = 7	[illegible] Max 147 Count = 7	[illegible] Bandanna	[illegible] residual gas saturation	1 3	U	2	2	3	2	3	12
Jericho Formation	Several thick intraformational fluvial and lacustrine siltstone and mudstone intervals (>50 m thick)													
Jericho Formation	Southern Galilee	736 (Gross)	Median 11 Max 25 Count = 30	Median 10 Max 436 Count = 19	Intraformational	Structural/ residual gas saturation	1 4	C	3	2	2	2	3	12

- 6 reservoir units were ranked – best potential units are the Clematis/Rewan sealed by Moolayember Formation; Colinlea Sandstone sealed by Black Alley/Bandanna Fm.
- These reservoirs have good-excellent measured porosity & permeability, however well data coverage too sparse to map reservoir fairways.
- Early Permian units ranked as low potential due to generally poor reservoir quality.

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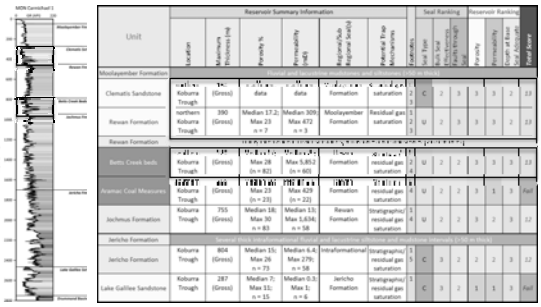
HIGH PROSPECTIVITY

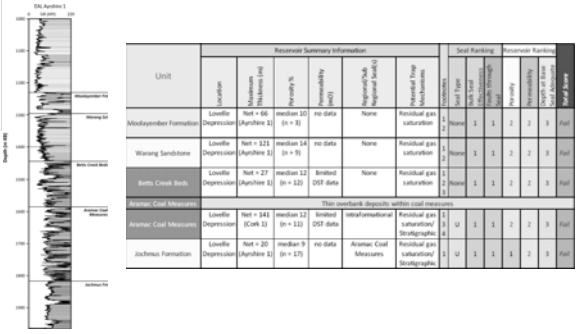
Koburra Trough



- 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, however <u>well data coverage too sparse to map reservoir fairways</u>.
- Early Permian units ranked as unsuitable-low potential - generally poor reservoir quality.

HIGH PROSPECTIVITY

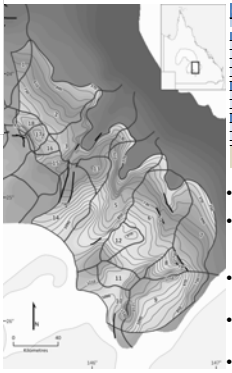
Lovelle Trough



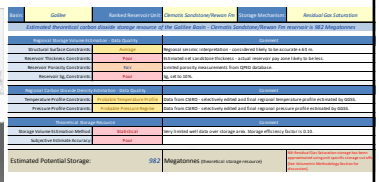
- 7 reservoir units were ranked – unsuitable to due to poor reservoir quality and absence of an effective seal (coal measures more likely to form baffles rather than unconventional seals).

HIGH PROSPECTIVITY

Galilee Basin



Southern Galilee Clematis Sst/Rewan Fm depth (mSS) structure surface with drainage cells

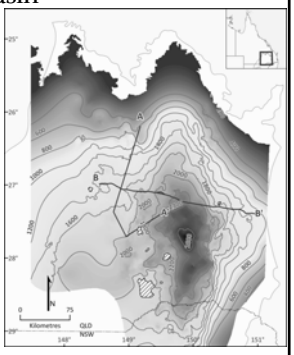


- Volumetric calculations were completed for 4 reservoir units.
- <u>Not possible to define reservoir fairways or pay zones</u> with regional well data coverage – reservoir data is largely unconstrained, storage volumes should therefore be used with caution.
- Large theoretical storage volumes: Southern Galilee 2,302 Mt ; Koburra Trough 1,128 Mt.
- Clematis Sandstone/Rewan Formation in Southern Galilee has estimated capacity of 982 Mt.
- Seal capacity & faults through seal key uncertainty – <u>needs addressing through fully cored wells & modern seismic.</u>

HIGH PROSPECTIVITY

Surat Basin

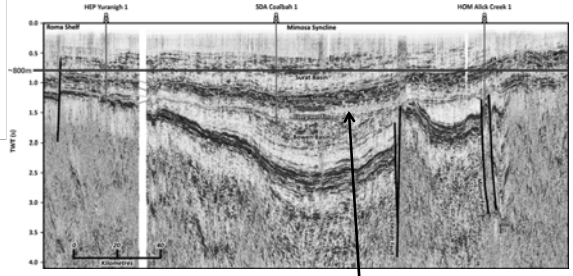
Potential geological storage areas in the Surat Basin (blue polygons) & locations of major emissions nodes



Depth-structure map to top Evergreen Fm regional seal. Dry structures also shown.

HIGH PROSPECTIVITY

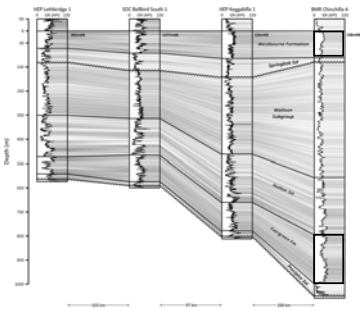
Surat Basin



- A broad structural depression " the Mimosa Syncline" has gently dipping strata to the W & NW providing a structural architecture that favors slow, long-range migration of CO_2, maximising the potential for residual gas saturation trapping
- The upper Evergreen Formation acts as a regional seal for the underlying Early Jurassic reservoirs (Precipice, Basal Evergreen & Boxvale sandstones).
- The location of the 800 mGL level at the base of the regional seal succession indicates that a large proportion of the basin is suitable for supercritical CO_2 storage.

HIGH PROSPECTIVITY

Surat Basin



- Two potential regional conventional seals for CO_2: the Early Jurassic upper Evergreen Formation and the Late Jurassic Westbourne Formation.
- There are also intervals of less or non-porous/impermeable units sands associated with siltstone, shales and occasional coal that act as intraformational seals within the Precipice Sandstone, Hutton Sandstone and Walloon Coal Measures.
- Regionally-extensive sandstone units provide potential reservoirs throughout the basin.

HIGH PROSPECTIVITY

Surat Basin

Unit	Reservoir Summary Information						Footnotes	Seal Ranking			Reservoir Ranking			Total Score
	Location	Maximum Thickness (m)	Porosity%	Permeability (mD)	Regional/Sub Regional Seal(s)	Potential Trap Mechanisms		Seal Type	Bulk Seal Effectiveness	Faults through Seal	Porosity	Permeability	Depth at Base Seal Adequate	
Griman Creek Formation	Basinwide	346 (gross)	Median 29; Max 33; n=27	Variable; Med 74; Max 994; n=27	Nil	Structural & Residual gas saturation		None	1	3	3	3	1	Fail
Surat Siltstone	Basinwide	125 (gross)	Median 25.5; Max 28; n=4	Variable; Med 66; Max 309; n=2	Nil	Structural & Residual gas saturation		None	1	3	3	3	1	Fail
Wallumbilla formation	Interbedded marine mudstone and siltstone, > 100 m thick													
Bungil Formation	Basinwide	195 (gross)	Median 27; Max 92; n=78	Median 23.9; Max 4,130; n=70	Wallumbilla Formation	Structural & Residual gas saturation	1	C	3	3	3	3	1	13
Mooga Sandstone	Basinwide	178 (gross)	Median 23.6; Max 35.8; n=69	Median 45; Max 5,820; n=65	Wallumbilla Formation	Structural & Residual gas saturation	1, 2	U	2	3	3	3	1	12
Orallo Formation	Basinwide	226 (gross)	Median 27.8; Max 37; n=83	Median 311.5; Max 6,324; n=80	Wallumbilla Formation	Structural & Residual gas saturation	1, 2	U	2	3	3	3	1	12
Gubberamunda Sandstone	Basinwide	73 (gross)	Median 26.4; Max 31.8; n=5	Median 150; Max 8,720; n=5	Wallumbilla Formation	Structural & Residual gas saturation	1, 2	U	2	3	2	2	1	10
Westbourne Formation	Interbedded siltstone, sandstone and claystone up to 153 m thick, known to seal hydrocarbons													
Springbok Sandstone	Basinwide	116 (gross)	Median 23.1; Max 30.2; n=15	Median 7.8; Max 496; n=15	Interformational & Westbourne	Structural & Residual gas saturation	3	C	2	3	3	2	3	13
Walloon Subgroup	Interbedded siltstone, sandstone, claystone and coal up to 420 m thick, known to seal hydrocarbons													
Hutton Sandstone	Basinwide	275 (gross)	Median 17.8; Max 34.3 n=1,649	Variable; Med 98; Max 13,600; n=2,451	Interformational & Walloon	Structural & Residual gas saturation	3	C	2	3	3	3	3	14
Evergreen Formation	Sequence of mudstone, fine grained sandstone, siltstone and shale <100 m thick, known to seal hydrocarbons													
Boxvale Member	Roma Shelf	25 (gross)	Median 15.9; Max 33.4; n=475	Highly variable; Med 7.1; Max 7,380; n=426	Evergreen	Structural & Residual gas saturation	4	C	3	3	3	2	3	14
Basal Evergreen Unit	Roma Shelf	41 (gross)	Median 17.8; Max 33.4; n=32	Highly variable; Med 5.6; Max 3,420; n=32	Evergreen	Structural & Residual gas saturation	4	C	3	3	3	2	3	14
Precipice Sandstone	Roma Shelf	82 (gross)	Median 17; Max 33.9; n=900	Highly variable; Med 8.4; Max 7,908; n=833	Evergreen	Structural & Residual gas saturation	4	C	3	3	3	2	3	14
Precipice Sandstone	Mimosa Syncline	138.7 (gross)	Median 17.8; Max 36.9; n=802	Variable; Med 59.5; Max 2,000; n=750	Evergreen & Interformational	Structural & Residual gas saturation	4	C	3	3	3	3	3	15

- The Precipice, Basal Evergreen, Boxvale, Hutton and Springbok (ranked 13-15) are 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 < 800 m deep.
- 2 units failed due to lack of regional seal.

HIGH PROSPECTIVITY

Surat Basin

Precipice Sandstone reservoir map showing depth (mSS) structure surface. Also shown are drainage cell interpretations and gas fields (red circles)

Basin:	Surat	Ranked Reservoir Unit:	Precipice Sandstone	Storage Mechanism:	Residual Gas Saturation
Estimated theoretical carbon dioxide storage resource of the Surat Basin - Precipice Sandstone reservoir is 1289 Megatonnes					

Regional Storage Volume Estimation - Data Quality		Comment
Structural Surface Constraints:	Good	Regional GA/GSQ interpretation - considered likely to be accurate to within ±100m.
Reservoir Thickness Constraints:	Good	Net pay zone thicknesses from limited field log analysis.
Reservoir Porosity Constraints:	Very Good	Measured porosities from QPED database.
Reservoir S_{gr} Constraints:	Fair	S_{gr} set to 10%.
Regional Carbon Dioxide Density Estimation - Data Quality		**Comment**
Temperature Profile Constraints:	Probable Temperature Profile	Data from CSIRO - selectively edited and final regional temperature profile estimated by GGSS.
Pressure Profile Constraints:	Probable Pressure Regime	Data from CSIRO - selectively edited and final regional pressure profile estimated by GGSS.
Theoretical Storage Resource		**Comment**
Storage Volume Estimation Method:	Statistical	Net pay zone thicknesses from limited field log analysis. Storage efficiency factor is 1.
Subjective Estimate Accuracy:	Average	
Estimated Potential Storage:	1,289	Megatonnes (theoretical storage resource). NB: Residual Gas Saturation storage has been approximated using unit specific storage cut-offs (See Volumetric Methodology Section for discussion).

- Volumetric calculations were completed for 4 reservoir units (i.e. Precipice, Basal Evergreen, Boxvale, Hutton)
- Theoretical storage capacity using residual gas saturation trapping totals 2,962 Mt in the evaluated reservoirs – greatest capacity in Precipice Sandstone (1,289 Mt).
- Other storage options are limited to depleted oil and gas fields, which only provide ~ 16 Mt of storage capacity.

HIGH PROSPECTIVITY

Estimated Storage Volumes

LOW PROSPECTIVITY

Low Prospectivity Basins

- Contain reservoir-seal interval/s with uncertain effectiveness due to either limited data to evaluate their prospectivity, or high variability in the quality of reservoirs and seals.
- The total ranking score of the best reservoir-seal intervals in low prospectivity basins ranges from 8–12.
- 48 low prospectivity reservoirs from these 13 basins

Low Prospectivity basins based on the ranking methodology

LOW PROSPECTIVITY

Low Prospectivity Basins

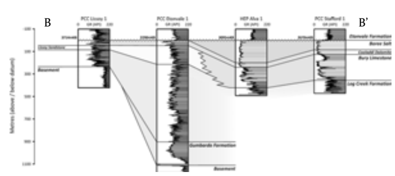
- Most appear to have unfavorable geological settings for large-scale CO_2 storage, but cannot be ranked as unsuitable due to insufficient data on reservoir and seal effectiveness.
- Several are located near major emissions nodes, and may warrant acquisition of new well and seismic data
- Although maximum theoretical storage volumes have been estimated, these have generally been calculated over multiple reservoir units and with insufficient constraints to assign any level of subjective estimated accuracy.
- It is likely that additional data would significantly decrease the size of potential storage areas and reduce the theoretical storage volumes for most low prospectivity basins.

Low Prospectivity basin maximum potential storage areas. Also shown are major emission nodes.

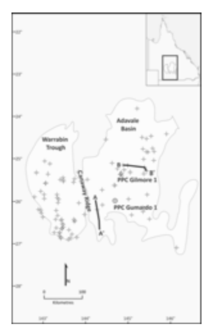
LOW PROSPECTIVITY

Adavale Basin

- Devonian rift-depocentre in central QLD
- Variable lithologies and reservoir quality, western margin different from the eastern margin
- Lissoy Sandstone main interval of interest- 2 dry gas accumulations
- Both structural and stratigraphic traps present
- 135 wells in Adavale and Warrabin but only 85 of these penetrate >100m of Devonian section



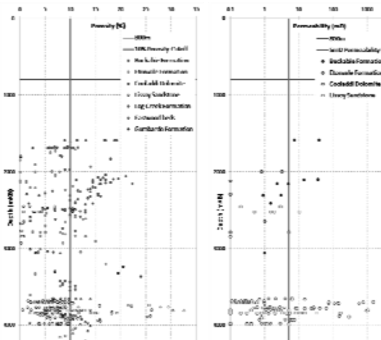
Well cross-section B-B' datumed at the top of the Cooladdi Dolomite/Boree Salt seal units.



Adavale Basin and Warrabin Trough location map showing wells and cross section locations.

LOW PROSPECTIVITY

Adavale Basin



Porosity and Permeabilty vs depth plots for the Adavale Basin. Note the variable reservoir quality in the Lissoy Sandstone.

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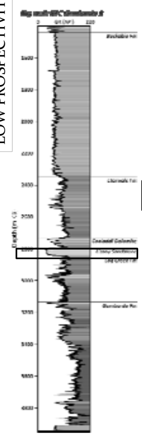
LOW PROSPECTIVITY

Adavale Basin



Unit	Location	Maximum Thickness (m)	Porosity %	Permeability (mD)	Regional/Sub Regional Seal(s)	Potential Trap Mechanisms	Footnotes	Seal Type	Bulk Seal Effectiveness	Faults through Seal	Porosity	Permeability	Depth at Base Seal Adequate	Total Score
Buckabie Formation	[illegible]	1680	Median 11; Max. 22, n=52	Median 5.9; Max 79, n=20	Overlying basin?	Structural/RGS	1	None	1	2	2	2	3	Fail
Etonvale Formation	[illegible] north and northwest	762	[illegible] Max. 37; [illegible]	[illegible] Max. 5; [illegible]	Overlying basin?	Structural/[illegible]	1	None	1	2	2	1	3	Fail
Boree Salt	Restricted to eastern Adavale [illegible] thick													
Cooladdi Dolomite	[illegible]													
Bury Limestone	Restricted to the eastern Adavale	[illegible]	[illegible]	Insufficient data	Cooladdi Dolomite and Boree Salt	Structural/RGS	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Fail
Lissoy Sandstone	Mainly in the central area of basin	[illegible]	Median 7.7; [illegible] n=271	Median 0.[illegible]; [illegible] n=171	Cooladdi Dolomite and Boree Salt	Structural/RGS	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Log Creek Formation	[illegible]	1500	Median 3.1, Max. [illegible] n=7	Max. 9; n=1	Intraformational?	Structural/RGS	4	U	2	2	1	2	[illegible]	Fail
Eastwood beds	Mainly in the north of Adavale	[illegible]	Median 0.1; Max. 8, [illegible]	Insufficient data	Intraformational?	Structural/RGS	4	U	[illegible]	[illegible]	1	[illegible]	[illegible]	Fail
Gumbardo Formation	Mainly in the eastern half of basin	755	Median 19.5; Max. 24, n=5	Max. [illegible]; n=1	Intraformational?	Structural/RGS	4	U	2	2	2	2	3	[illegible]

- The Lissoy Sandstone is the main hydrocarbon reservoir with proven reservoir/seal pair units. Reservoir quality is highly variable.
- The Gumbardo Formation may have coarse-grained clastic units with good porosity and possible intraformational seals, although very deep (4000+ m) in many areas.

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LOW PROSPECTIVITY

Adavale Basin

A basic storage capacity estimate was made using the following parametres (note this is not the same methodology as used for the High Prospectivity basins)

- area 3,256,897,900 m²
- injection depth ~3,315–3,945 m
- estimated net-to-gross: 30 %
- average net pay thickness: 94 m
- average porosity: 10 %
- equilibrium CO_2 density: 550 kg/m³
- residual gas saturation: 0.1;
- storage efficiency factor: 0.17.

The resulting CO_2 storage capacity is 286 Mt (5 TCF) of CO_2.

This estimate is considered to be grossly larger than the actual CO_2 storage capacity, since it does not consider the expected large variations in reservoir quality in terms of thickness, net-to-gross, porosity and permeability.

Potential storage area map for the Lissoy Sandstone (after Paten 1977). Other reservoir units may exist along the eastern and western margins

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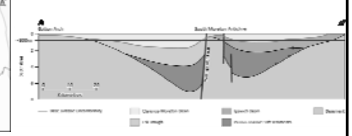
LOW PROSPECTIVITY

Clarence-Moreton Basin

Clarence-Moreton Basin location map showing wells and cross section locations.

- Mesozoic basin in SE QLD
- Mostly too shallow
- Insufficient data to determine reservoir quality and extent
- Insufficient data to determine seal quality



Regional schematic cross-section showing the relationship of the Clarence-Moreton Basin to other older basins (modified from Korsh et al. 1989)

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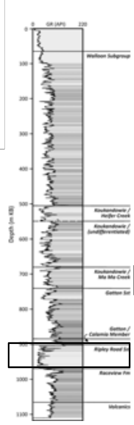
LOW PROSPECTIVITY

Clarence-Moreton Basin



Unit	Location	Maximum Thickness (m)	Porosity %	Permeability (mD)	Regional/Sub Regional Seal(s)	Potential Trap Mechanisms	Footnotes	Seal Type	Bulk Seal Effectiveness	Faults through Seal	Porosity	Permeability	Depth at Base Seal Adequate	Total Score
Grafton Formation	Insufficient data	Insufficient data	Insufficient data	Insufficient data	Insufficient data	Insufficient data		None	1	2	2	2	1	Fail
Kangaroo Creek Sandstone	Insufficient data	Insufficient data	Insufficient data	Insufficient data	Insufficient data	Insufficient data		None	1	2	2	2	1	Fail
Walloon Subgroup	Interbedded siltstone, claystone, sandstone and coal up to 811 m thick where drilled													
Koukandowie Fm (Heifer Creek Sandstone Member)	Logan Sub-basin	244 (gross)	15–24; Med 19.5; n=8	1–27; Med 1.9; n=8	Walloon	Residual gas saturation	1, 4	C	2	2	2	2	2	10
Koukandowie Fm (undifferentiated)	Logan Sub-basin	325 (gross)	Insufficient data	Insufficient data	Walloon & Intraformational	Residual gas saturation	4	U	2	2	2	2	2	10
Koukandowie Fm (Ma Ma Creek Member)	Interbedded siltstone, claystone and fine sandstone 30—65 m thick where drilled													
Gatton Sandstone	Logan Sub-basin	484 (gross)	8.3–20; Med 16; n=33	0.11–19; Med 1.7; n=33	Ma Ma Creek	Residual gas saturation	2, 4	C	2	2	2	2	2	10
Gatton Sst (Calamia Member)	Interbedded mudstone, siltstone and fine sandstone > 50m thick where drilled													
Ripley Road Sandstone	Basinwide	510 (gross)	10–30; Med 17, n=104	0.11–8925; Med 65; n=104	Calamia	Structural & Residual gas	3, 4	C	2	2	3	3	2	12
Raceview Formation	Basinwide	192 (gross)	<10	Insufficient data	Calamia & Intraformational	Structural & Residual gas	4	U	2	2	2	2	2	10
Aberdare/ Laytons Range Conglomerate	Logan & Cecil Plains	75 (gross)	Insufficient data	Insufficient data	Calamia	Residual gas saturation	4	U	2	2	2	2	2	10

- Good-excellent reservoir sandstones recorded. Due to limited data the extent of these is unknown.

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LOW PROSPECTIVITY

Clarence-Moreton Basin

There is insufficient data to accurately calculate the CO_2 storage capacity in the Clarence-Moreton Basin. However, an estimate has been made using the following inputs:

- area 2,772
- injection depth ~ 800-1,000 mBGL;
- gross thickness: 200 m;
- estimated net: gross 70 %;
- equilibrium CO_2 density ~ 275 Kg/m³;
- average porosity 22.5 %;
- residual gas saturation 0.1; and
- storage efficiency factor: 0.08.

Estimated storage volume of approximately 192 Mt CO2

Maximum potential storage areas in the Clarence-Moreton basin. There is not enough information to map reservoir fairways.

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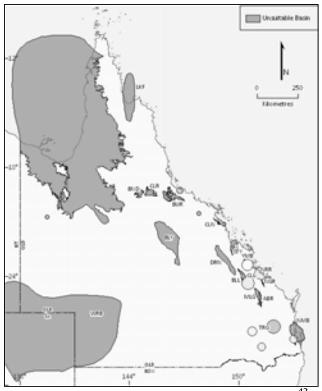
UNSUITABLE

Unsuitable Basins

- 19 unsuitable basins are known to be unprospective as their reservoirs and/or seals are all below the minimum criteria
- Most of these basins are located in eastern and northern Queensland, often in close proximity to major CO_2 emissions nodes.
- Most fail on containment due to highly deformed basin fills that lack regional seals or because they have a shallow basin fill that lacks a regional seal.
- The shallowness of the sedimentary fill in many of the basins prevents the storage of CO_2 in its supercritical state.



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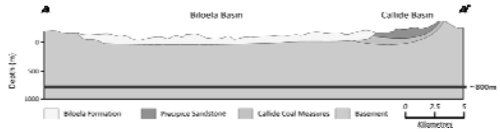
UNSUITABLE

Biloela and Callide Basins



Generalised geological cross-section of the Biloela and Callide basins (modified from Monto 1:250,000 map). Note that the both basins are entirely < 800 m deep.

Unit	Reservoir Summary Information							Seal Ranking			Reservoir Ranking			
	Location	Maximum Thickness (m)	Porosity %	Permeability (mD)	Regional/Sub Regional Seal(s)	Potential Trap Mechanisms	Footnotes	Seal Type	Bulk Seal Effectiveness	Faults through Seal	Porosity	Permeability	Depth at Base Seal Adequate	Total Score
Biloela Formation	Basinwide (Biloela)	350	Insufficient data	Insufficient data	No defined regional	None		None	1	1	2	2	1	Fail
Precipice Sandstone	Basinwide (Callide)	100	Insufficient data	Insufficient data	No defined regional	None		None	1	1	2	2	1	Fail
Callide Coal Measures	Basinwide (Callide)	150	Insufficient data	Insufficient data	No defined regional	None		None	1	1	2	2	1	Fail

Ranking for reservoirs in the Biloela and Callide basins. Reservoirs fail due to lack of regional seal, not depth. Reservoir quality is unknown and is therefore ranked as 2.

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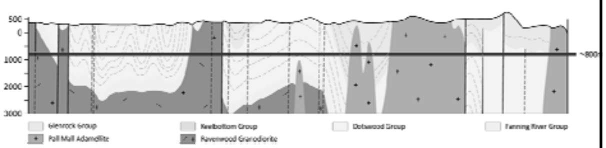
UNSUITABLE

Burdekin Basin

- Example of unsuitable basin failing on seal effectiveness and containment
- Most of these basins are ranked 2 for reservoir effectiveness due to lack of data



Schematic cross-section of the Burdekin Basin (modified from the Townsville 1:250,000 geological map). Section is approximately 65 km long.

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COAL STORAGE

CO_2 Storage in Coal

- Potential storage areas have been defined in major coal basins (Bowen, Surat & Galilee basins)
- Depth structure maps to top of major coal measures generated to define potential storage areas (400 – 1,000 m)
- Storage volumes have not been calculated – know that these will be unrealistically large – injectivity is real issue
- Gross coal thickness maps superimposed on storage area maps to highlight areas with likely greatest capacity
- Results show best potential is in CBM exploration sweet spots – mainly an option for ECBM recovery

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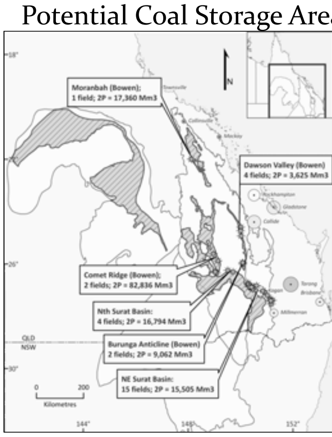
COAL STORAGE

Potential Coal Storage Areas



Location of thick extensive coal measures at depths >400 and <1000m (grey hatched polygons). Also shown are CSG fields and 2P resources (June 2008).

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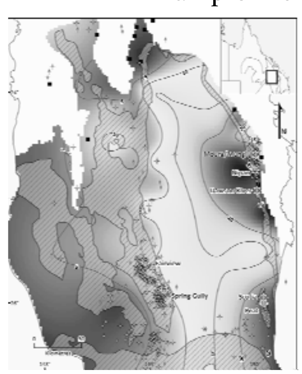
COAL STORAGE

Example- Bowen Basin



Gross coal thickness map (5m contours) for coals in the Bandanna Fm and Baralaba Coal Measures. Coal mines, CSG wells and CSG fields also shown.

Comet Ridge

- Contains world-class CSG resources (Fairview and Spring Gully fields).
- Contains large southeast- plunging anticlines with enhanced permeability (generally > 50 mD) at the crest of structures.
- These fields occur at depths of 500–800 m.

Dawson Valley (Eastern Taroom Trough)

- Depths from 300–1000 m but is mainly at depths <400 m downdip of coal
- CSG production occurs within the Baralaba Coal Measures.
- Low permeabilities (<10 mD)

Burunga Anticline (Eastern Taroom Trough)

- CSG production in occurs in the Scotia and Peat fields
- Depths 500–900 m.
- Loss of permeability with depth, with seams below 900 m are considered sub-economic.

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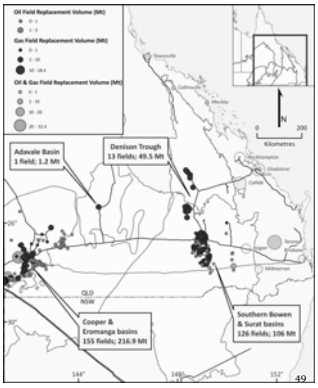
DEPLETED FIELDS

CO_2 Storage in Depleted fields

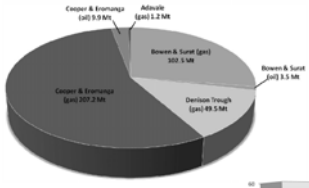
- A maximum theoretical replacement volume (MTRV) calculated on original in place resources as reported by QDEDDI 2008
- A MTRV of 374 Mt CO_2 is estimated for 295 gas and/or oil fields and ~485 reported producing reservoir pools in Queensland
- However, most large fields are still producing and are unlikely to be available for CO_2 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 CO_2.



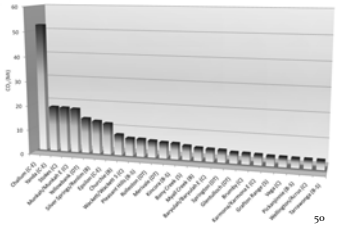
Location of oil, gas and oil and gas fields scaled by MTRV. Also shown are major emissions nodes and gas (red lines) and oil (green lines) pipelines

DEPLETED FIELDS

CO_2 Storage in Depleted fields



Pie chart showing total CO2 MTRV for oil and gas pools in major hydrocarbon basin areas. Chart highlights limitations of oil pools in all basin areas.

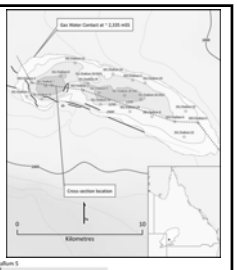


Graph showing the CO2 MTRV for the 25 largest fields (B=Southern Bowen Basin, S=Surat Basin, S-B = fields in the Bowen and Surat basins, D=Denison Trough, C= Cooper Basin, C-E = Cooper and Eromanga basins.

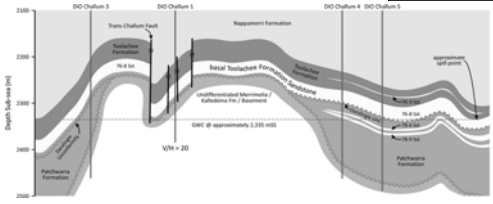
DEPLETED FIELDS

Challum field

- Has the largest potential CO_2 storage of all the Queensland oil and gas fields, with a combined 52.4 Mt
- 5.8 Megatonnes in the Hutton Sandstone, 43.2 Megatonnes in the Toolachee Formation and 3.4 Megatonnes in the Patchawarra Formation.



Above: Depth-structure map of top Toolachee Fm 76.8 sandstone.



Left: Schematic cross-section of Gidgealpa Gp reservoirs (modified from Dehli Petroleum 1989)

Summary

- This atlas is the first step in targeting basins or parts of basins in onshore Queensland where more detailed studies will help evaluate and characterise future storage sites.
- Good opportunities for geological storage are most evident in the Bowen, Cooper, Eromanga, 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.

Summary

- The greatest potential for storage is in regionally extensive reservoir-seal intervals rather than depleted fields.
- Queensland Government have legislation (*Greenhouse Gas Storage Act 2009*) that will come into effect Feb 2010
  - Soon to have gazettal rounds in place for permits to:
    - Explore for underground storage reservoirs
    - Storage of greenhouse gases to take place

Basin prospectivity based on ranking methodology

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- Kat Norman
- James Woodger

Plus QDEEDI team: John Draper, Jonathan Hodgkinson, Mike McKillop, Micaela Preda and Owen Dixon.

Contact

Dr John Bradshaw
Chief Executive Officer
CO2 Geological Storage Solutions
www.cgss.com.au
John.Bradshaw@cgss.com.au
+61 (0)418 624 804

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