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**LINEAMENT ASSOCIATIONS IN THE
COOPER BASIN REGION,
SOUTH AUSTRALIA:
BASEMENT CONTROLS ON
HYDROCARBON DISTRIBUTION.**

by

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LINEAMENT ASSOCIATIONS IN THE COOPER BASIN REGION, SOUTH AUSTRALIA: BASEMENT CONTROLS ON HYDROCARBON DISTRIBUTION.

R K Boucher

ABSTRACT

Detailed lineament analysis of the Cooper Basin area has established the presence of two lineament networks: NW and NE trending lineaments comprise a gas lineament network and show strong correlation with the presence of gas in alternating blocks but contain no gas on or near the lineaments themselves; WNW and NNE trending lineaments comprise a Tethyan primary and orthogonal network that contains no hydrocarbons at the lineament intersections. Some significant oil fields lie on 300° trending lineaments, however, 290° trending lineaments are unprospective along their entire length.

It proved difficult to correlate the lineaments with DST results and CO₂ content of Cooper Basin gas fields primarily because of the difficulties encountered with working with these data. Some of the abandoned wells show good correlation with certain lineaments.

INTRODUCTION

This report follows PIRSA Report Book 97/39, which provided background information, details of the acquired data and a brief overview of the interpretation techniques. Data were acquired over eastern South Australia. It is essential to understand the earlier report before the data within this report are considered because terms, definitions and details of the data described in the earlier report will not be repeated herein.

This report discusses the relationship of the major lineaments with the petroleum distribution in the Cooper Basin area. In particular:

- Any correlation of mapped lineaments greater than 100 km in strike length to the distribution of petroleum fields.
- Whether or not HFPL derived targets that locate mineralisation were similarly suitable for finding petroleum.

- The integration of geological, geophysical and morphological data to determine whether:
 - Lineament controls on the structural evolution of the basin are evident.
 - The presence of favourable host rocks which, when combined with the lineament data, can be used as a predictive targeting tool.
- Any correlation of lineaments with reservoir data, including:
 - Regional permeability variation in the Toolachee and Patchawarra Formation gas reservoirs.
 - Distribution of CO₂ content of Cooper Basin gas fields.

The study focussed on the main area of interest, the Cooper Basin (STRZELECKI and INNAMINCKA 1:250 000 sheets), although it extended over a much larger area. No digital detailed geological or gravity data were made available for the INNAMINCKA sheet and the

aeromagnetic data were very sparse. As a result, the STRZELECKI sheet received the most attention and provided most of the examples.

A location map of the Cooper Basin and major fields is provided in figure 1. The stratigraphy of the Warburton (Cambrian-Ordovician), Cooper (Carboniferous-Triassic), Eromanga (Jurassic-Cretaceous) and Lake Eyre (Tertiary-Recent) Basins are provided in figure 2.

Previous work used in this study includes Boucher (1995) which outlined orthogonal lineaments influencing the distribution of gas in the Cooper Basin. O'Driscoll (1982, 1983) and Campbell and O'Driscoll (1989) described basin forming lineaments for the Cooper Basin area (fig. 3).

COOPER BASIN LINEAMENTS

The lineaments discussed in this study are shown in figure 24. The data in this figure is provided at the back of the report and folds out to be used as a reference. Most of these lineaments combine to represent two differing systems, referred to as:

1. The gas lineament network (NE and NW trending lineaments, figs 5 to 10) and
2. The Tethyan Primary and Orthogonal network (WNW and NNE trending lineaments, figs 11 to 14).

THE GAS LINEAMENT NETWORK

Boucher (1995) described an orthogonal lineament network within the Cooper Basin that influences the known distribution of gas within the basin. The network comprises NW and NE trending lineaments (figs 5 & 6). Lineaments have been added to those previously published. These lineaments are referred to as the gas lineament network.

Both the Fly Lake-Burrunga (FL-BU) and Nulla-Moolion (NU-MO) lineaments were described earlier by Boucher (1995) and remain for this study. Orthogonal trends, Merrimelia-Bookabourdie (ME-BO) and Della-Wancoocha (DE-WA), were published as lineaments (x) and (y) respectively in Boucher (1995). The Dullingari-Bookabourdie lineament (DU-BO) has been recognised in this study and the

Wonominta Block lineament added from O'Driscoll (1982).

The Wonominta block lineament (WBL, figs 3 & 7) is expressed strongly in geological ingredient data in western New South Wales, however not as strongly in the Cooper Basin area. The Wonominta Block lineament is a northwest trending corridor that, along with G8, encloses most of the gas accumulations in the southern Cooper Basin (Figure 3).

A series of abandoned (wet) gas wells occur along the Fly Lake-Burrunga lineament in the Toolachee area. They appear mainly within 1 km of the lineament (figs 5 & 6), despite containing valid structural traps (figs 8 & 9) and despite generating hydrocarbons that migrated through the traps (Dunlop *et al.*, 1992). The gas depleted zone (fig. 10) lies in a structurally controlled block defined by the Fly Lake-Burrunga lineament.

The location of most of the gas fields within the basin occurs in alternating blocks situated on either side of the lineaments that comprise the gas network. The gas accumulates in 'shadow zones', at least one kilometre away from the lineaments. The larger gas fields in particular tend to lie within 10 km of the lineaments. It would therefore appear that the most prospective areas for gas within the Cooper Basin are the 'shadow zones', 1-10 km from lineaments and in alternating blocks (fig. 5).

Age of the gas network

The gas network is rarely seen in HFPL data, implying it has not been active recently. The gas network does not appear to be relevant to oil distribution yet is very significant to the gas distribution (fig. 5). The gas network was either:

- Active/influential during the Permian, influencing:
 - Reservoir facies and/or
 - Source facies
- Active/influential post Cooper Basin time, influencing:
 - Hydrocarbon generation and/or
 - Migration.

Unlike continental trends G8 or G2 that transect Australia and influence geological environments from the Proterozoic to Recent, the gas network

might represent a failed or sporadically active lineament system restricted to certain times in geologic history. It is possible that the system is:

- A rotated imprint of a Tethyan primary and orthogonal system when the continent was in a differing orientation or
- A lineament system developed within G8.

Application of the gas network to exploration

Figure 5a is designed to assist exploration target definition by combining lineament data with other exploration data. The data used in the analysis are:

- The gas network.
- Prospective 'shadow zones' within the gas network (at least one and up to ten kilometres from the gas network) that lies within the Permian Cooper Basin area.
- Anticlinal closures that do not coincide with:
 - Existing fields.
 - Abandoned wells.

When these data are combined, prospective areas for drilling can be defined (fig. 5b). This process can be replicated to consider the prospectivity of stratigraphic plays that may occur within the 'shadow zones'.

It is uncertain, however, how applicable the data is in areas near the basin edges where the network has not been well identified, in particular outside WBL. Boucher (1995) explained that the influence of FL-BU outside G8 was diminished. It remains uncertain if the network is active outside of the G8 corridor.

THE TETHYAN PRIMARY AND ORTHOGONAL LINEAMENT NETWORK

The Tethyan primary and orthogonal lineaments mapped for the Cooper Basin area are shown in figure 11.

'Mineral target' areas

Tethyan primary (WNW) lineaments are the principal global lineaments (O'Driscoll 1980)

and with their associated NNE orthogonal lineaments, are fundamental to the mineral-targeting paradigm established by O'Driscoll (1972). The WNW and NNE lineaments provide favourable sites for mineralisation up to 4 km from their intersection. Theoretical 'mineral targets' of 4 km radius are shown at the intersections of the Tethyan primary and orthogonal network (fig. 11). The actual target areas are the portions of the WNW lineaments enclosed within the tectonic target. These data assume all intersections would be granted 'mineral target' status. Despite being prospective hosts for mineralisation, these target areas yield no hydrocarbons. These zones effectively contain no hydrocarbons in the Cooper Basin area (fig. 11). Infact, almost the entire target areas in most instances contain no hydrocarbons and in some examples, gas fields seem to lie on the periphery of the target circles (eg along WNW4, 9 and 10; fig. 11). The only exception where significant hydrocarbons occur within a tectonic target is the northern part of the Merrimelia field. In particular, almost all of the Merrimelia oil wells lie within this target area (fig. 12). However, the Toolachee, Patchawarra and Tirrawarra gas reservoirs occur outside the target area (these formations do not occur on top of the Merrimelia structure). Only the small Nappamerri Group gas reservoir extends within the target circle.

WNW9 intersects NNE6 at the top of a basement high that forms part of the Toolachee structure (fig. 13). The four wells drilled on this structure were abandoned despite being located on a four way dip closure in a proven prospective area. This provides an excellent example where no hydrocarbons occur in what should be a valid trap that coincides with a 'mineral target' at the intersection of WNW and NNE lineaments.

WNW9

The most significant Tethyan primary lineament is WNW 9 (fig. 11). This lineament provides an important example explaining the distribution of hydrocarbons along the lineament and demonstrates that:

- A thorough understanding of the geology of an area is important before lineament data can be successfully integrated.
- Lineaments and seismic mapping combine to identify and prioritise targets for drilling.

A cross section along WNW9 (fig. 14) shows the hydrocarbon traps and fields along the lineament. Brittle deformation of the Big Lake Suite granodiorite along the lineament which intruded the Warburton Basin during the Carboniferous seems to have occurred, resulting in a valley between the Moomba central and Moomba north palaeohighs (refer figs 1, 11; the outline of the Moomba field approximates the palaeohighs). Erosion produced this valley prior to and during early Permian Cooper Basin development. Elsewhere, deformation of the Cambro-Ordovician Warburton Basin sediments and volcanics has produced a series of basement highs and lows. Some structures have been subsequently rejuvenated at varying times in the overlying basin's history (eg. at Gidgealpa and Namur). Some apparent structures, however, are pre-existing basement highs which sediments have overlapped and finally draped (eg. at Toolachee).

Large oil fields occur at Strzelecki and Gidgealpa that also contain gas. No orthogonal lineament occurs at these locations unlike at Toolachee northeast (fig. 13). It is therefore concluded that structures along this lineament are prospective except where:

- An intersecting orthogonal occurs
- The geology is unfavourable (in this case, brittle deformation of the Big Lake Suite granodiorite does not provide significant topographic highs and therefore traps).

No stratigraphic plays have been tested along WNW9. These may prove to be prospective in the future.

WNW13

Unlike WNW9, WNW13 has no petroleum along its entire length (fig. 11) despite having intersecting NNE trends. Like the lineaments that comprise the gas network, WNW13 is notable by the number of abandoned wells along the lineament (fig. 17) despite the presence of numerous valid structural and stratigraphic traps amongst some otherwise productive areas. WNW13 does have some oil fields adjacent to the lineament at Taloola and Tantanna. WNW13 transects the south-western edges of the Big Lake and Toolachee fields. The Toolachee field at this point appears to be deflected along the lineament representing a

Tethyan twist. The Strzelecki Creek similarly is deflected across WNW13.

WNW14 and 11

WNW14 (fig. 11) contains no known hydrocarbons along its length. However, hydrocarbons occur adjacent to the trend. These include the oil and gas fields at Tirrawarra, Merrimelia and Fly Lake. Similarly, WNW11 trends between oil and gas fields at Meranji and Kanowana.

WNW4, 7 and 10

WNW4, 7, and 10 contain oil fields but no gas fields (fig. 11). However, these are some of the basins smaller fields and there are no more than two fields per lineament. Indeed it is difficult to relate the oil fields to these lineaments, especially given that a significant number of oil wells do not lie on the lineaments.

Strike trends of the WNW lineaments

WNW13, 14 and 11 are all true Tethyan (ie approximately 290° azimuth) lineaments whereas WNW9, 4, 7 and 10 are of approximately 300° azimuth. The former is non-hydrocarbon bearing whereas the latter are occasional oil bearing. Further investigations are required to determine the factors why some WNW trends are unprospective whilst others are highly prospective or indifferent.

Application of both lineament networks to exploration

The gas network was used to establish regions of high prospectivity by combining lineament data with depth structure maps and well information (fig. 5). In the same manner, anticlinal traps that have little or no prospectivity can be determined by combining:

- Lineaments with no hydrocarbon associations, which include:
 - Lineaments forming part of the gas network
 - Tethyan (290°) lineaments
 - WNW lineaments within 4km of an intersecting NNE orthogonal lineament

- Anticlinal closures that do not coincide with:
 - Existing fields.
 - Abandoned wells.

These data are provided in figure 15.

Many of the oil fields in the region occur in the Eromanga Basin at the eroded Cooper Basin margin (fig. 1). This edge would not necessarily be expected to be lineament controlled (c.f. figure 8 in Boucher 1997). The migration pathways might prove to be influenced by the lineaments, however, the location of the traps at the Cooper Basin margin may not be. These data could be useful for prioritising oil exploration along the Cooper Basin edge where:

- 300° trends occur (eg. at the basin margin where WNW4 passes)
- No intersecting orthogonal occurs (eg. at the basin margin where WNW10 intersects NNE4).

Exploration for oil inside and outside the basin margins can be focussed along the 300° lineaments.

LINEAMENTS AND RESERVOIR PROPERTIES

LINEAMENTS AND CO₂ DISTRIBUTION

The analysis of CO₂ data and correlation with lineaments was hindered by a lack of data. CO₂ data in the PEPS-SA database does not have unique well information, instead averages are applied across entire fields. It is therefore not possible to determine what influence lineaments have on CO₂ as they pass through fields.

Figure 16 shows CO₂ data and low frequency lineaments. The most notable feature of this relationship is that the fields with the highest CO₂ (>40%) occurs in a block not favourable to gas occurrences to the southwest of FL-BU and between ME-BO and NU-MO.

LINEAMENTS AND ABANDONED GAS WELLS

The PEPS-SA database classifies all abandoned wells together. Each well was therefore

investigated individually to determine why it was abandoned before comparisons with lineaments were made. The analysis included abandoned wells that were:

- Wet
- Tight
- Contained no reservoir

Wells excluded because they were abandoned for non-productive reservoir reasons include:

- Junked wells
- Wells abandoned because the reservoir was depleted
- Wells drilled off structure (despite then possibly being classed as a failed stratigraphic test)
- Wells drilled for oil and not gas that:
 - Were drilled outside the Permian Cooper Basin
 - Did not drill through the Eromanga Basin and into the Cooper Basin

Figure 17 shows the wells that were either wet, tight or contained no reservoir and the gas network. It has already been established that the southern part of FL-BU relates to a series of abandoned (wet) wells (fig. 6). Numerous wet and tight wells occur along WNW13.

LINEAMENTS AND DST RESULTS

Numerous biases occur in drill stem test (DST) data including:

- When no DST is run because nearby reservoirs are known to be good.
- When no DST is run because log anomalies indicate a good reservoir.
- Test accidentally was not run over the reservoir section targeted.
- Marginal looking reservoirs will all be tested whereas poor or good ones may not be. Presumably the number of wells with poor or no flows is relatively increased due to this.
- No DST is run because of bad hole conditions.
- DST results need to be overlooked where 'basement' is tested that was mistaken for non-'basement'
- The amount of water cushion.
- A highly deviated or horizontal well exposes more of the reservoir to the test tool

than a vertical or near vertical well (NB. very few such examples occur in the Cooper Basin).

- Several DSTs are run in a single hole or formation. This is particularly relevant where an RTSTM result from 'basement' occurs in a hole that contained a significantly high flow from a test within the Permian section.
- The level within a formation being tested (ie. comparing differing reservoirs, even though they may be in the same formation, will not provide uniform data).
- The age of the well which may reflect differing quality testing tools.
- When the choke size is decreased from 1/2" to 1/4", boosting the flow from RTSTM to something measurable.

These biases meant correlation with lineaments proved difficult.

Several figures are included to relate DST results to LFL (figs 18 to 23). Figure 18 shows DST results from all wells that flowed greater than 3 million cubic feet per day (MMCFD) and the gas network. These data emphasise that the gas occurrences occur within the gas network regardless of the flow rate. Differing criteria were experimented with in an attempt to determine a better correlation, however none was forthcoming. Otherwise, the data are random and do not define any trends or emphasise any particular lineaments.

Patchawarra Formation

Figure 19 provides all the DST results where flows were achieved from the Patchawarra Formation. Like figure 18, these data emphasise that the gas distribution occurs within the gas network.

Patchawarra Formation DSTs which did not flow gas or at a rate too small to measure (RTSTM) is more indicative of the number of wells drilled within the gas network rather than the basinwide quality of the Patchawarra Formation reservoir (fig. 20). To overcome this bias somewhat, wells drilled within existing fields were excluded from the data (fig. 21). A significant number of the remaining wells with poor DST results occur on WNW13 and 10. A number of wells with poor DST results occur in the Tantanna area where a thin Patchawarra Formation overlapped basement and was

subsequently partly eroded. However, this block within the gas network should be productive based on the 'checker-board' distribution of the other fields.

It would be advantageous to further investigate the reasons why poor DST results occur within the fields (fig. 20). Alignments do occur within these data (arrowed in fig. 20). Some do not correlate with existing trends whereas others do. It would be necessary to study these trends within the fields in detail to ascertain the reasons for these poor results.

Toolachee Formation

Toolachee Formation DSTs which did not flow gas or at RTSTM were considered in the same manner as those from the Patchawarra Formation (figs 22 & 23). WNW9 correlates with the poor DST results especially near intersecting orthogonal lineaments. NW5 transects the Moomba and Gidgealpa South fields and correlates especially well with poor DST results in the Toolachee Formation despite being in the middle of producing fields.

CONCLUSIONS AND RECOMMENDATIONS FOR FURTHER WORK

This report is the first known in the world to comprehensively analyse multiple data sets and to present a detailed lineament analysis of a petroleum basin. The lineament relationships observed in this study can be used as a predictive tool in relatively unexplored portions of the Cooper Basin area and analogous basins elsewhere.

Two lineament networks occur within the Cooper Basin area:

1. The gas lineament network comprises NW and NE trending lineaments. Gas occurs in alternating blocks within the network, especially within G8, but not along the lineaments themselves despite the existence of valid structural traps. Most of the larger gas fields occur in 'shadow zones', 1-10 km from the lineaments. Modelling of dip closure within these zones identified areas for future exploration.

2. The Tethyan primary and orthogonal lineament network comprises WNW and NNE lineaments. Intersections of the WNW and NNE lineaments that provide prospective mineral targets elsewhere, are not prospective for petroleum. 290° trending lineaments are non-hydrocarbon bearing whereas 300° trending lineaments contain some of the large oil fields when no intersecting orthogonal lineament occurs. Further work is required to determine why this occurs.

Attempts to correlate the lineaments identified in this study with DST results and CO₂ content of Cooper Basin gas fields proved to be difficult because of the bias of the data. A great deal more work is required to fully understand these criteria before correlation can be made with lineaments. The Fly Lake-Burrunga lineament and WNW13 provide good examples where abandoned wells occur along a lineament. Elsewhere, however, more understanding of the well data is required to relate it to the lineaments. Overall, the density of DST, CO₂ and abandoned well data reflects the density of drilling in and around existing fields.

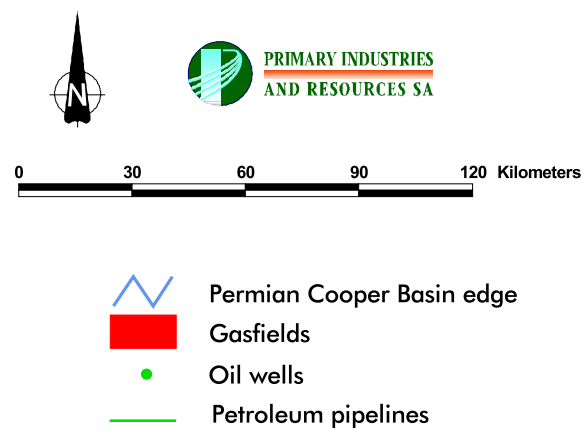
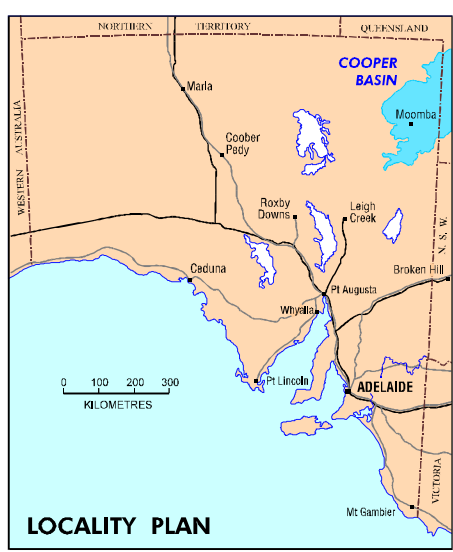
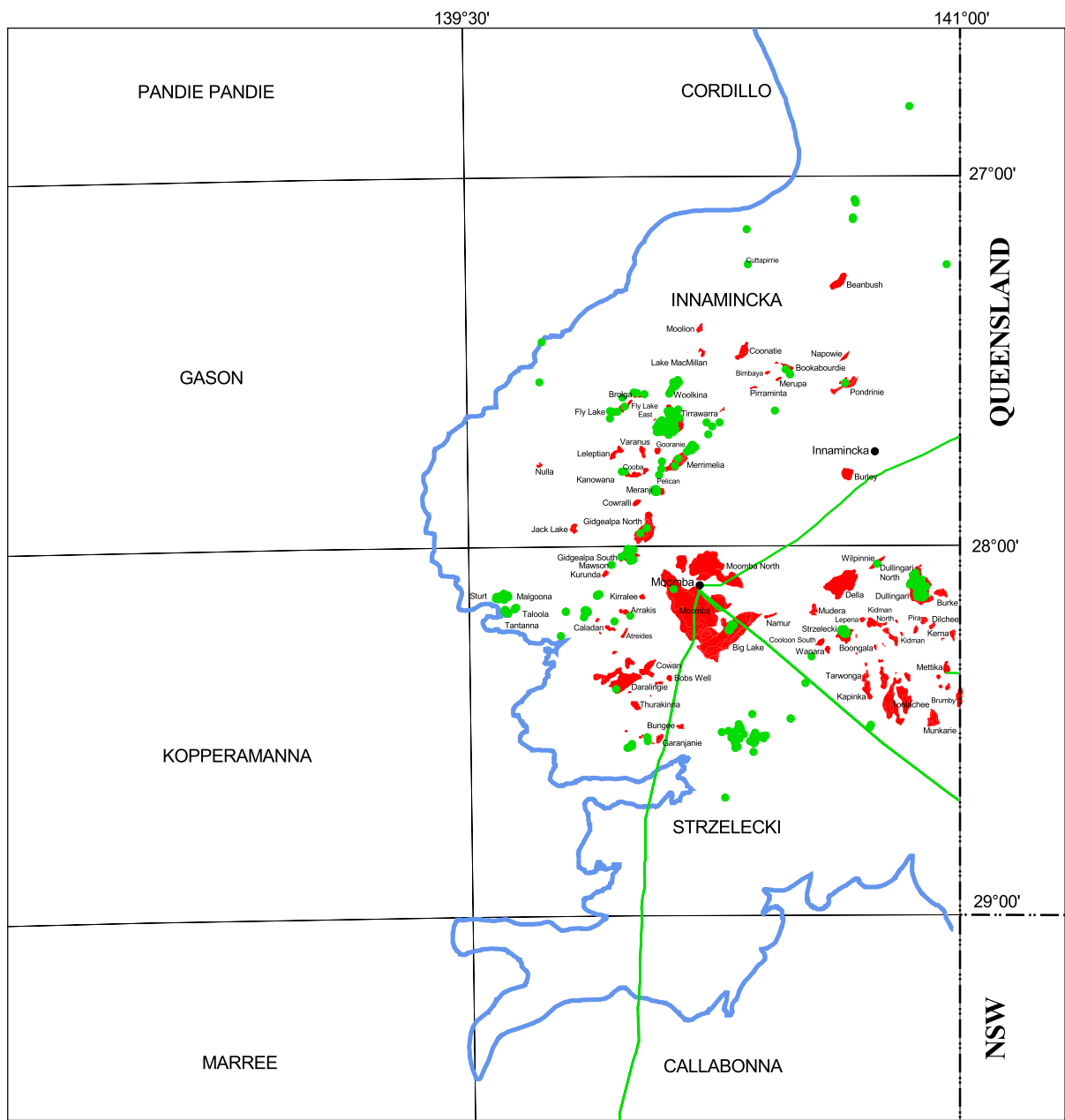
Geological qualification of lithologies and structures along WNW9 assisted to determine the petroleum prospectivity along this trend. Such analysis along other lineaments will provide a better understanding of the petroleum prospectivity elsewhere in the basin.

ACKNOWLEDGMENTS

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Cooper Basin oil and gas occurrences

Figure 1
98-0256

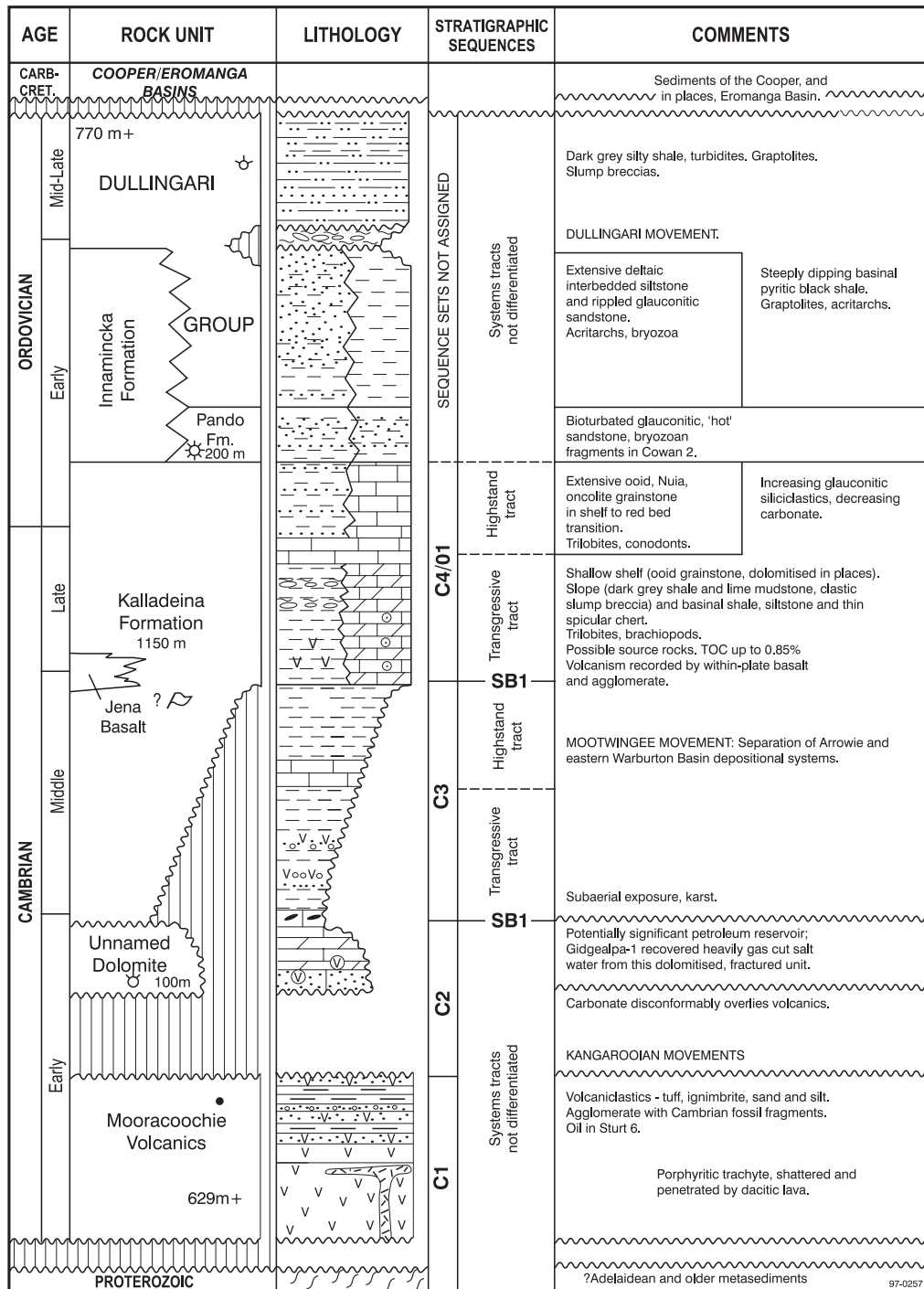


Figure 2a Stratigraphic summary of the Warburton Basin

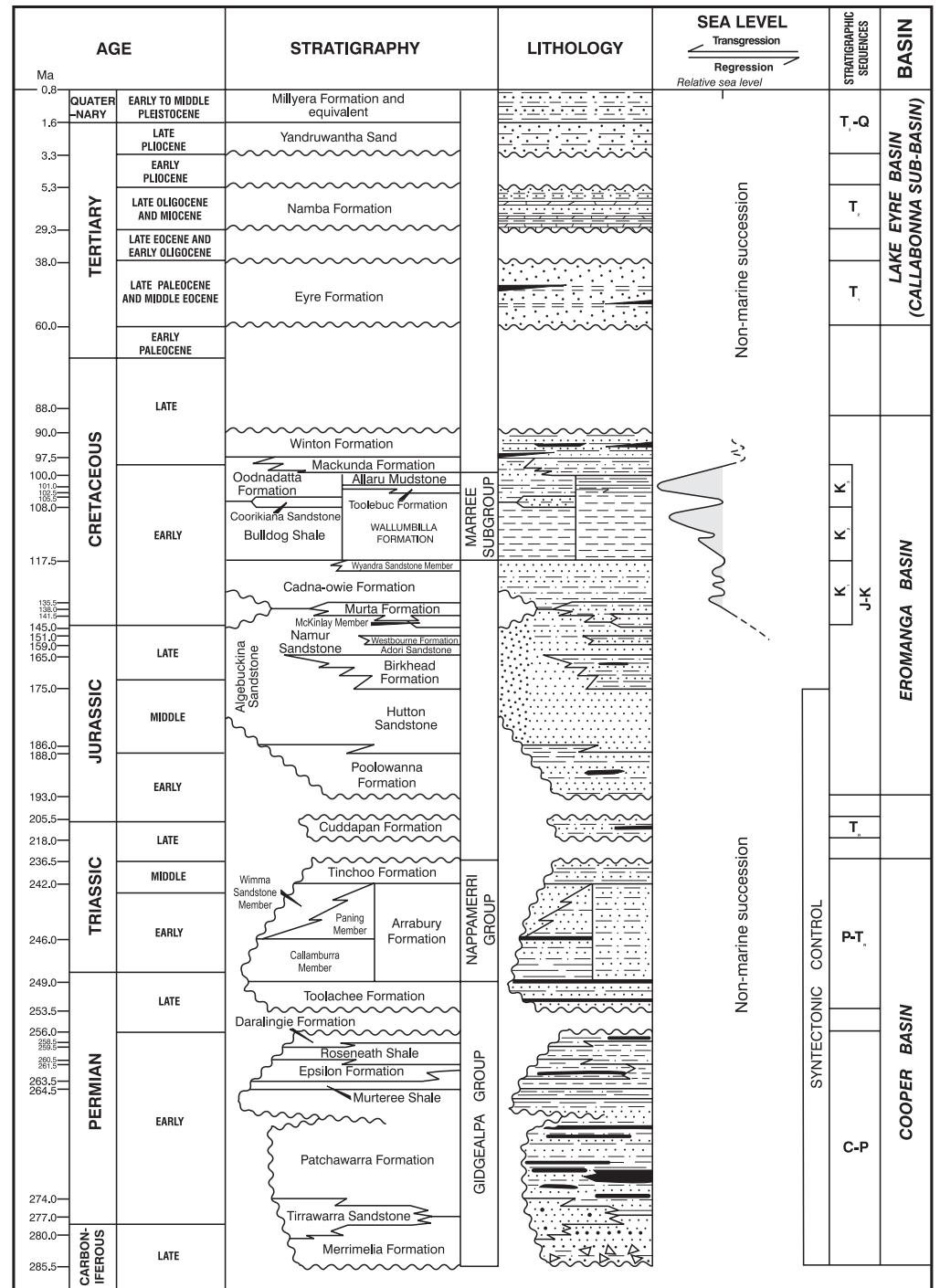


Figure 2b Stratigraphic summary of the Cooper, Eromanga and Lake Eyre Basins

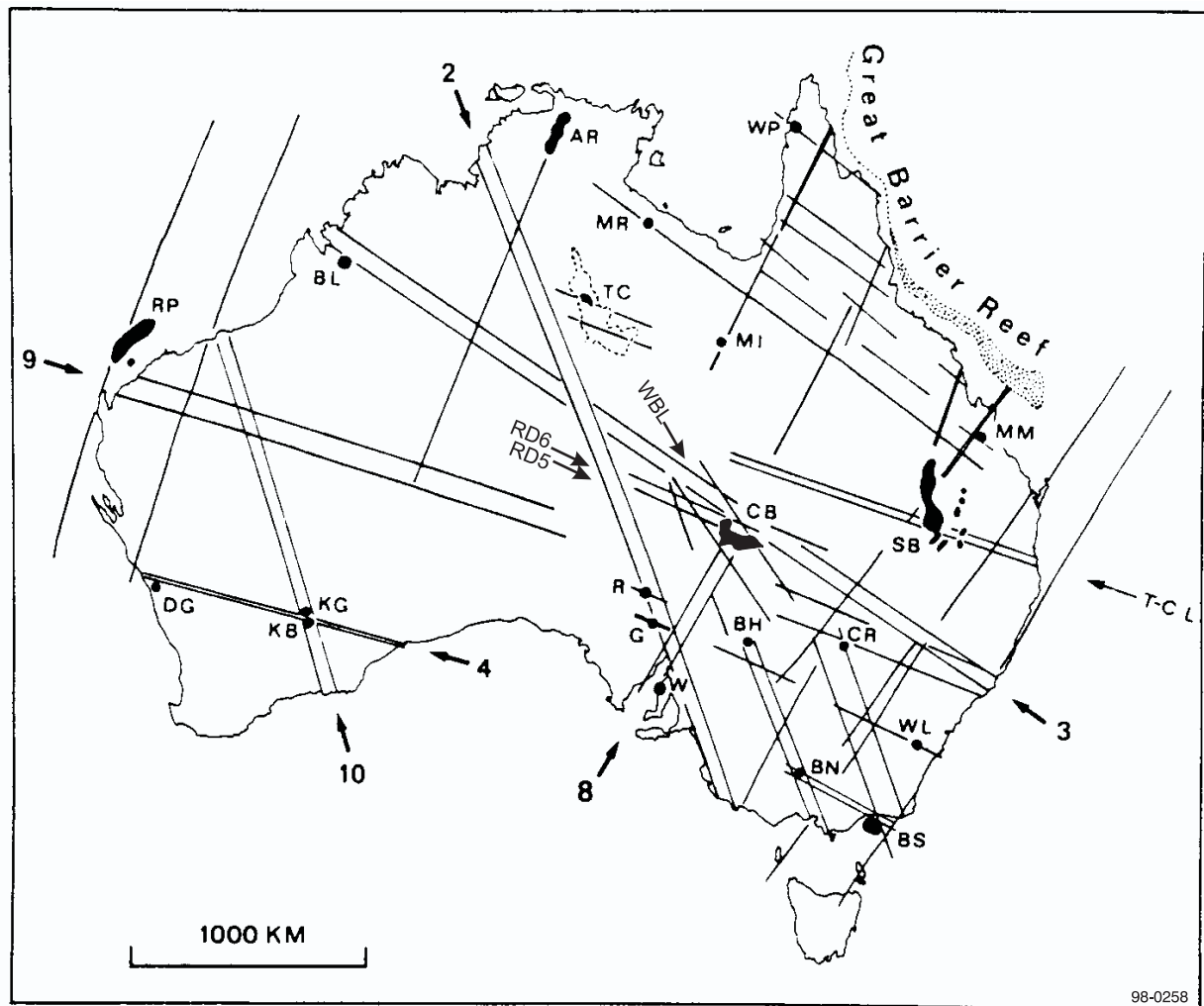
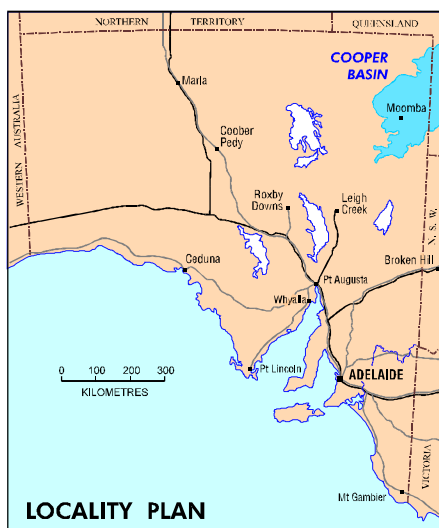
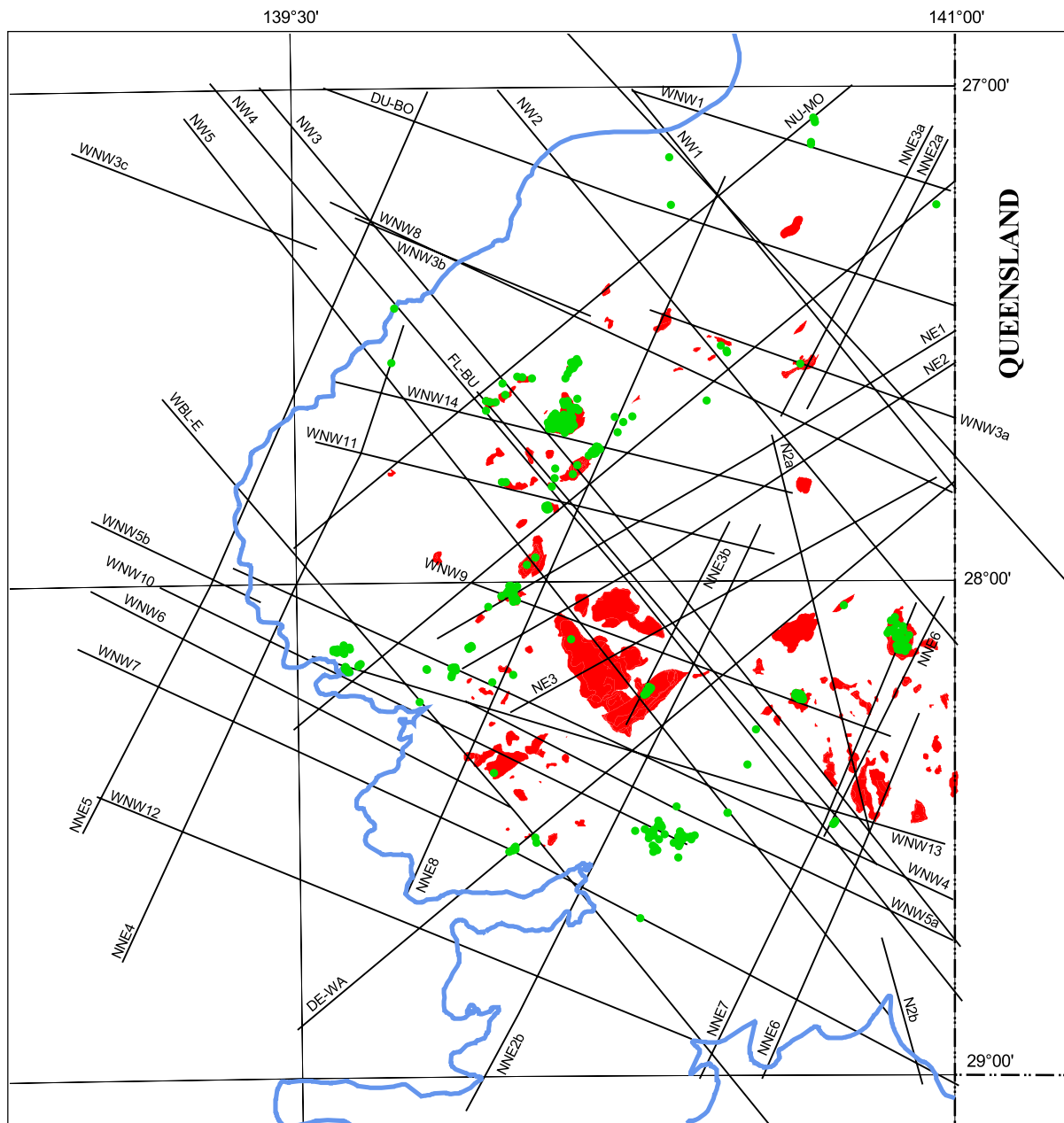


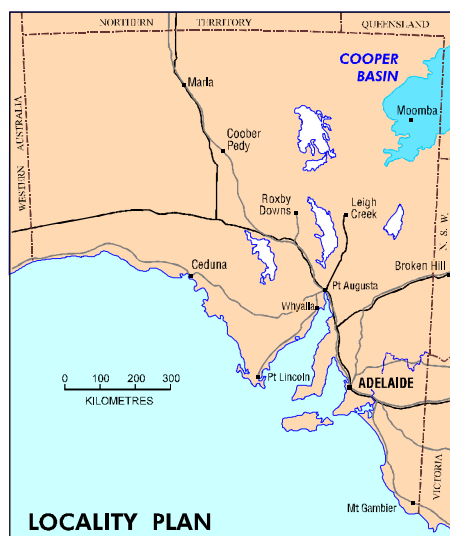
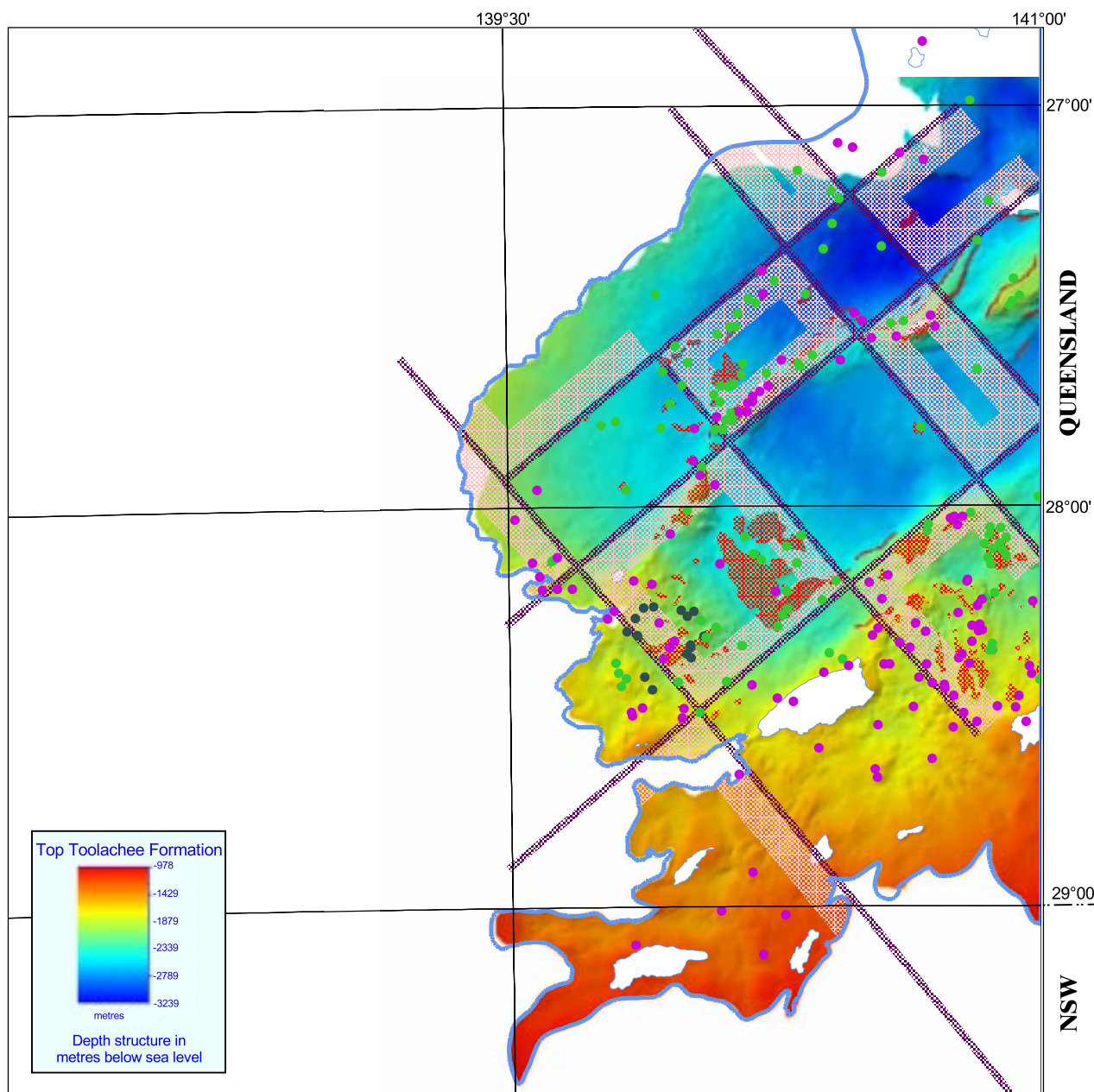
Figure 3 Continental lineaments (after O'Driscoll 1982). The petroleum envelope within the Cooper Basin (CB) occurs at the intersection of G8 and Wonominta Block Lineament (WBL)



- Low frequency lineament
- Gas fields
- Oil wells

Low frequency lineaments (LFL) for the Cooper Basin area

Figure 4
98-0272



PRIMARY INDUSTRIES
AND RESOURCES SA

0 20 40 60 80 100 Kilometers

ABANDONED WELLS

- Wet
- Tight
- No reservoir
- Permian absent
- Fault zone

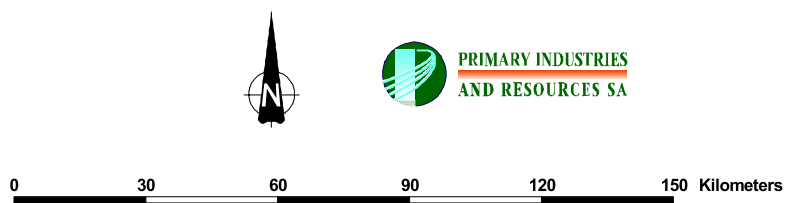
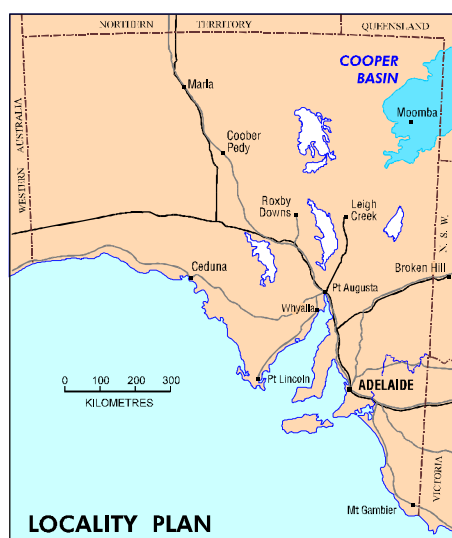
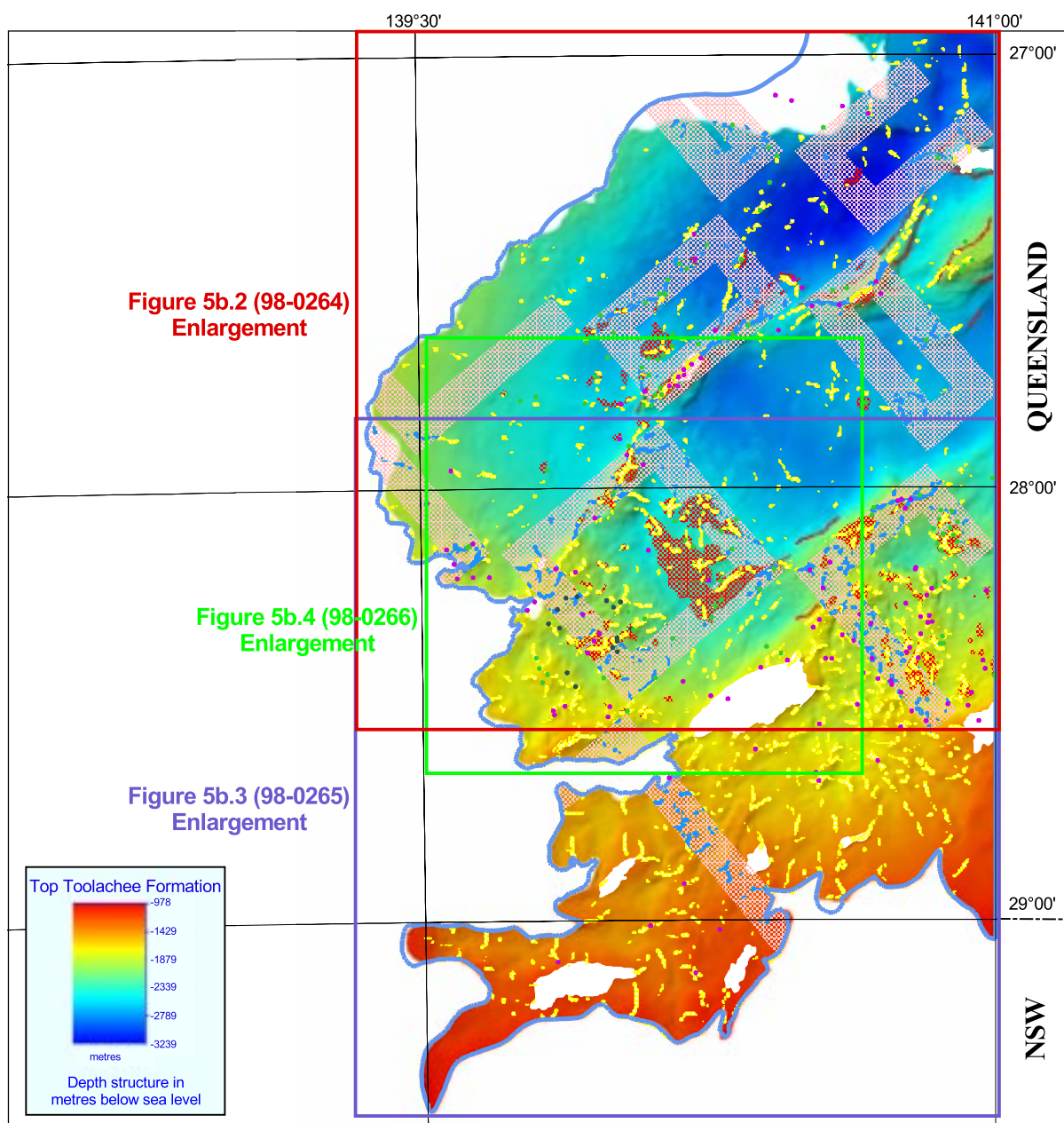
Gas fields

- Gas fields
- Unprospective areas surrounding the gas lineaments (1km buffer)
- Prospective gas network zones ('shadow zones')

The gas network, top Toolachee Formation depth structure map and abandoned wells within the Cooper Basin showing the lineaments of the gas network (purple) buffered to 1 km representing the unprospective areas surrounding the lineaments (refer Figure 6). Most of the larger gas fields are located 1-10 km of the lineaments in alternating blocks (pink).

Figure 5a

98-0262



ABANDONED WELLS

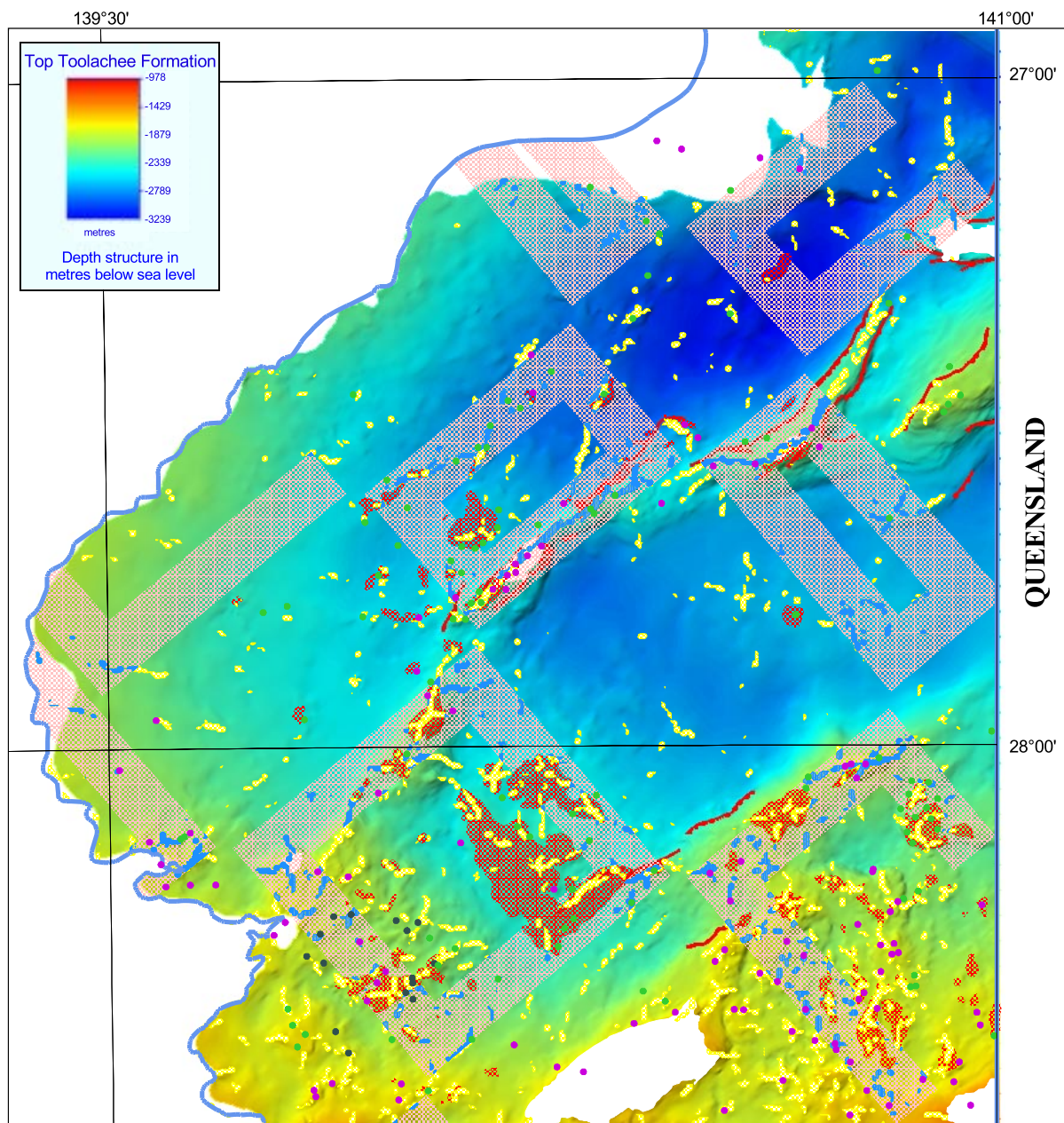
- Wet
- Tight
- No reservoir
- Fault zone

- Areas of high potential for future exploration
- Structural highs (anticlinal closures)
- Gas fields
- Prospective gas network zones ('shadow zones')

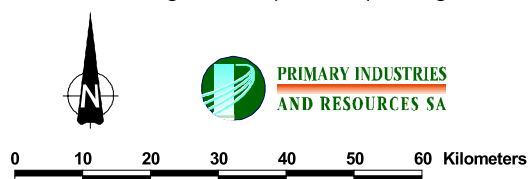
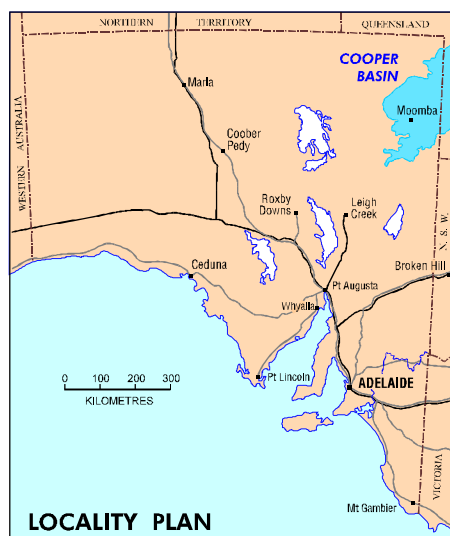
Regional view of structural highs (yellow) which are combined with the 'shadow zones' (pink) to highlight untested areas of potential for future exploration (blue)

Figure 5b.1

98-0263



Refer to Figure 5b.1 (98-0263) for regional view



ABANDONED WELLS

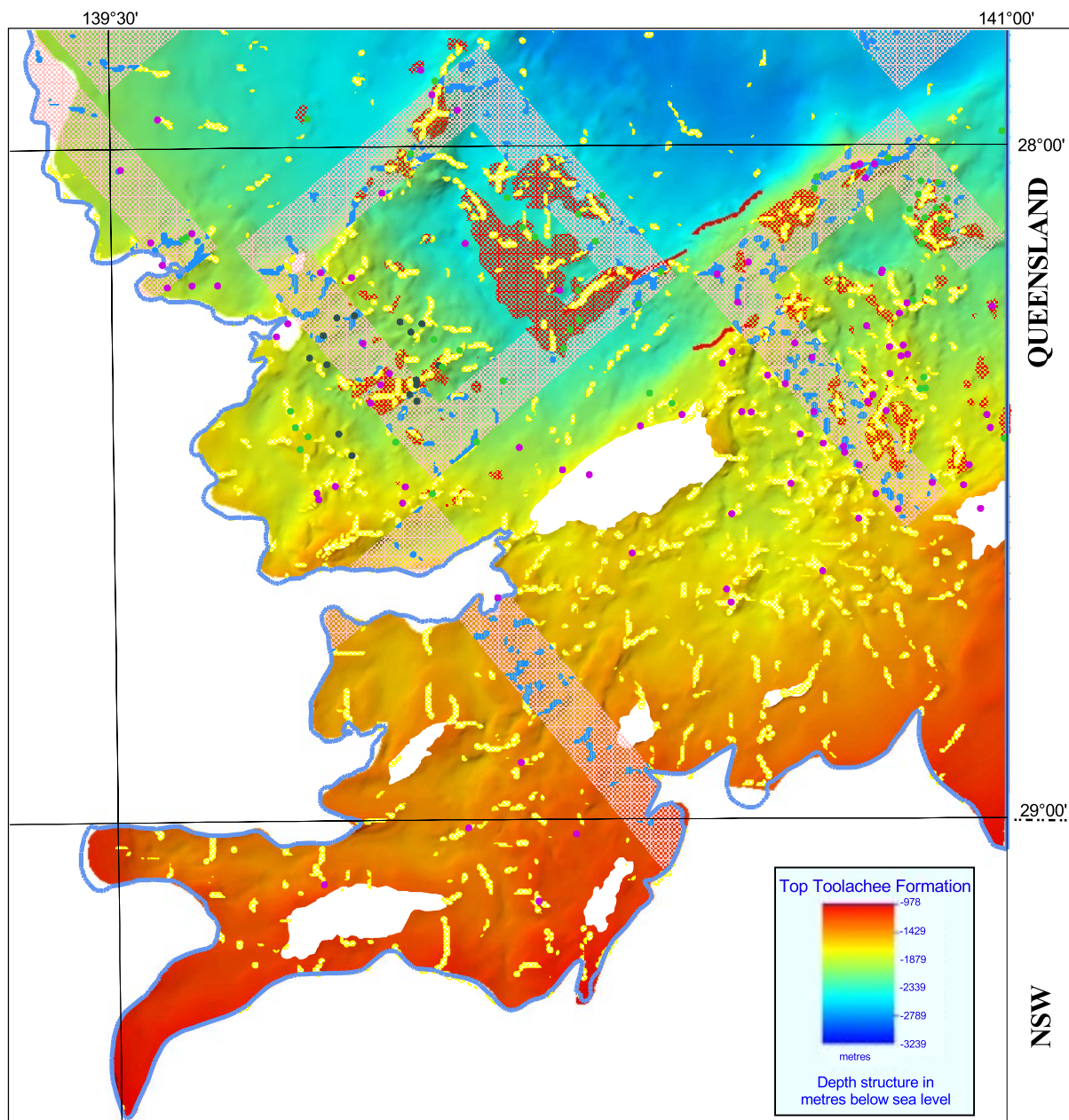
- Wet
- Tight
- No reservoir
- Fault zone

- Areas of high potential for future exploration
- Structural highs (anticlinal closures)
- Gas fields
- Prospective gas network zones ('shadow zones')

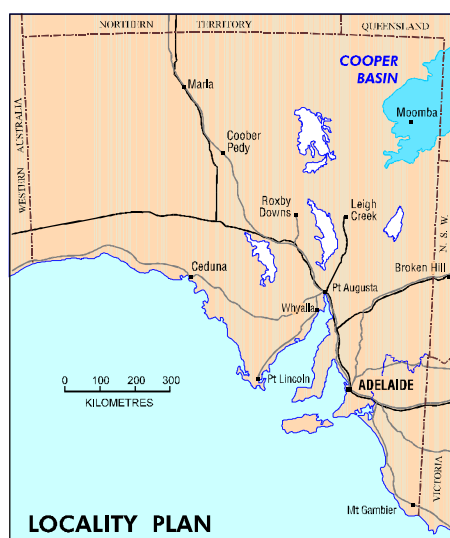
The location of structural highs (yellow) which are combined with the 'shadow zones' (pink) to highlight untested areas of potential for future exploration (blue)

Figure 5b.2

98-0264



Refer to Figure 5b.1 (98-0263) for regional view



PRIMARY INDUSTRIES
AND RESOURCES SA

0 10 20 30 40 50 60 Kilometers

ABANDONED WELLS

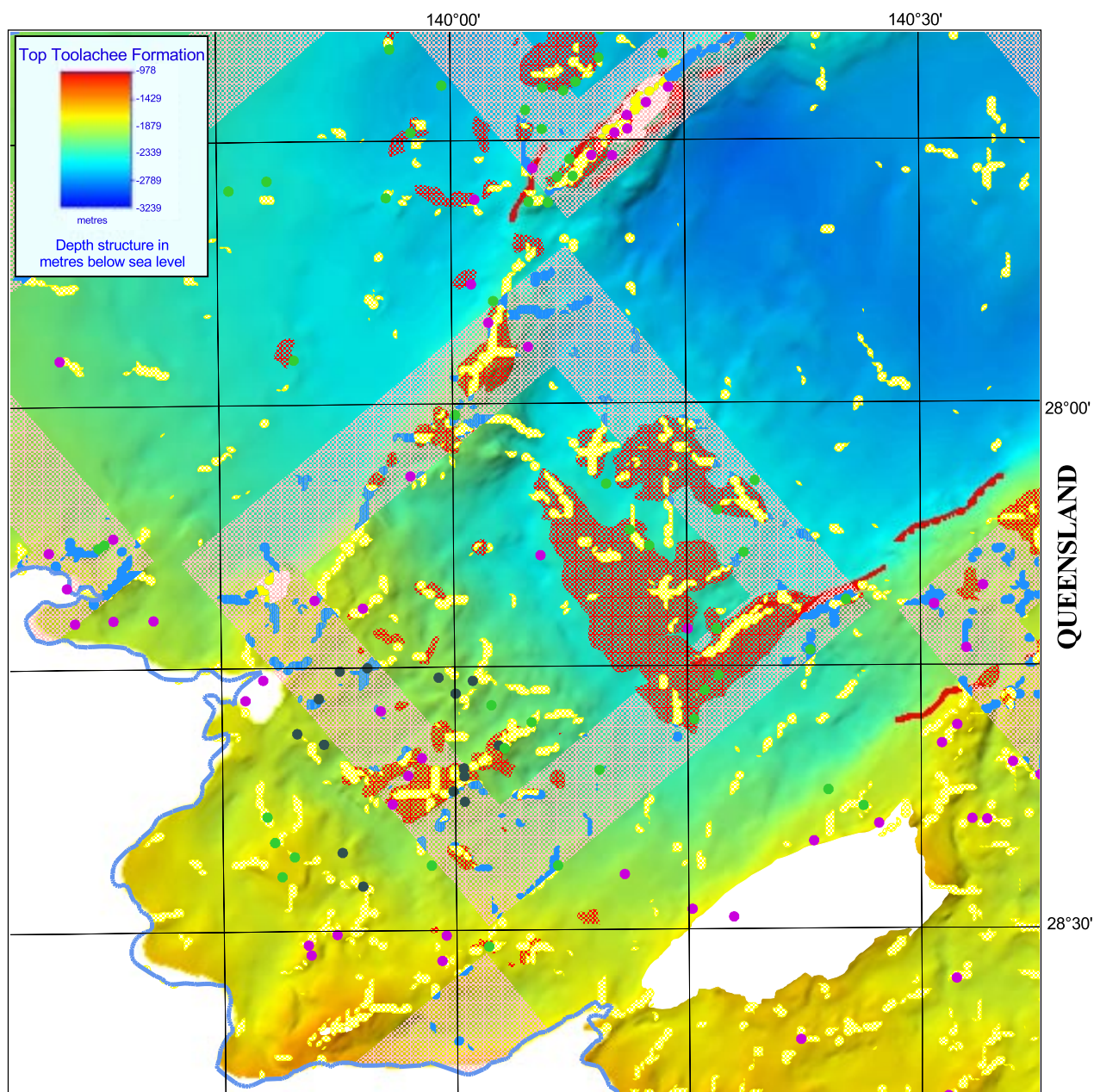
- Wet
- Tight
- No reservoir
- Fault zone

- Areas of high potential for future exploration
- Structural highs (anticlinal closures)
- Gas fields
- Prospective gas network zones ('shadow zones')

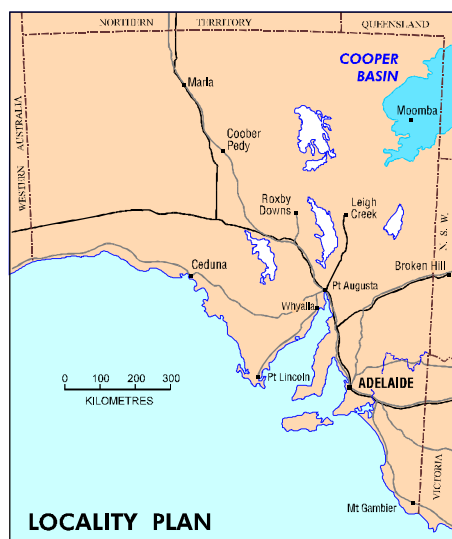
The location of structural highs (yellow) which are combined with the 'shadow zones' (pink) to highlight untested areas of potential for future exploration (blue)

Figure 5b.3

98-0265



Refer to Figure 5b.1 (98-0263) for regional view



PRIMARY INDUSTRIES
AND RESOURCES SA

0 10 20 30 40 Kilometers

ABANDONED WELLS

- Wet
- Tight
- No reservoir
- Fault zone

- Areas of high potential for future exploration
- Structural highs (anticlinal closures)
- Gas fields
- Prospective gas network zones ('shadow zones')

The location of structural highs (yellow) which are combined with the 'shadow zones' (pink) to highlight untested areas of potential for future exploration (blue)

Figure 5b.4

98-0266

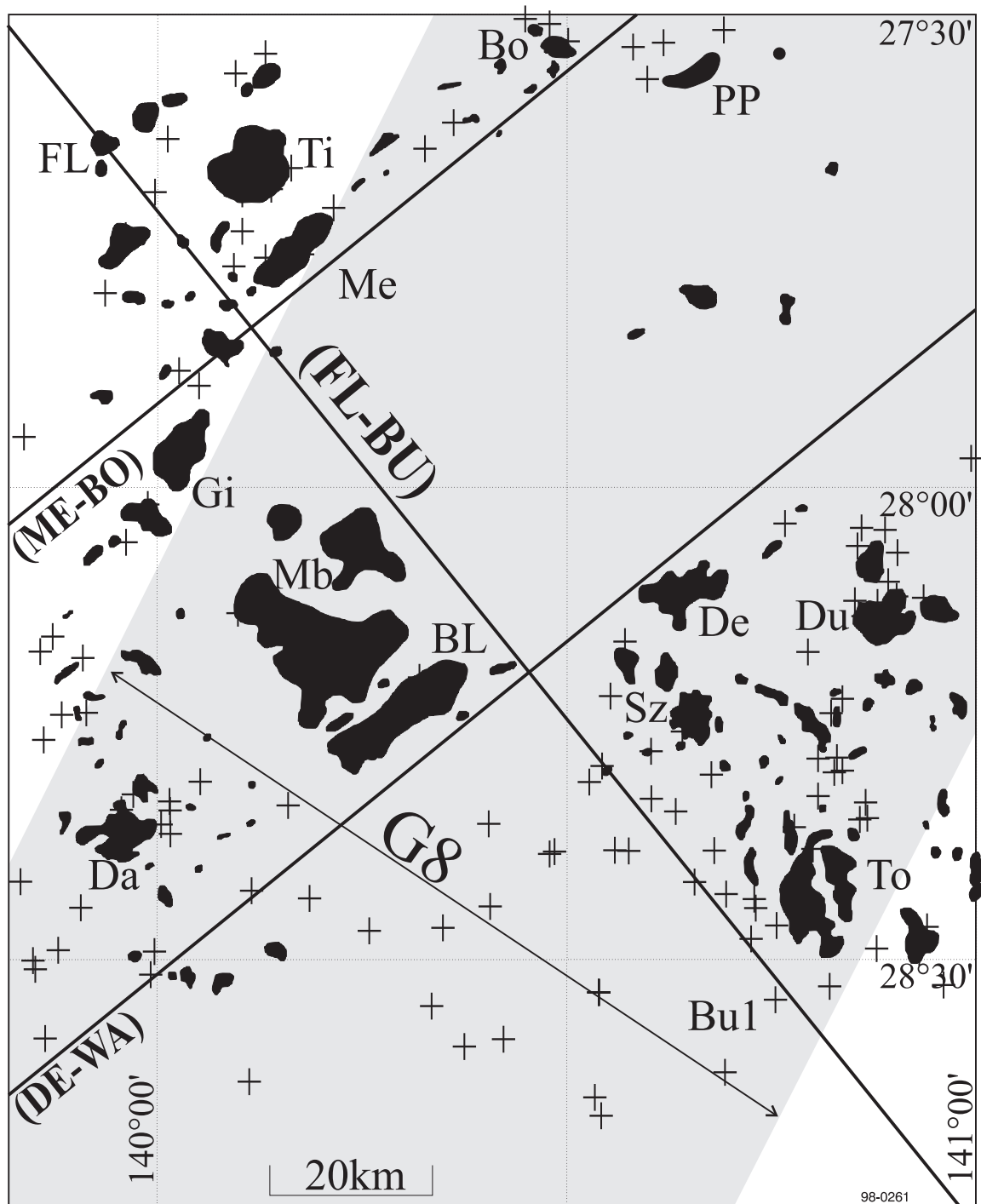


Figure 6 The Fly Lake-Burruna lineament (FL-BU) showing a series of abandoned (wet) wells along the southern part of the lineament (after Boucher 1995)



Figure 7 The Wonominta Block lineament (arrowed)

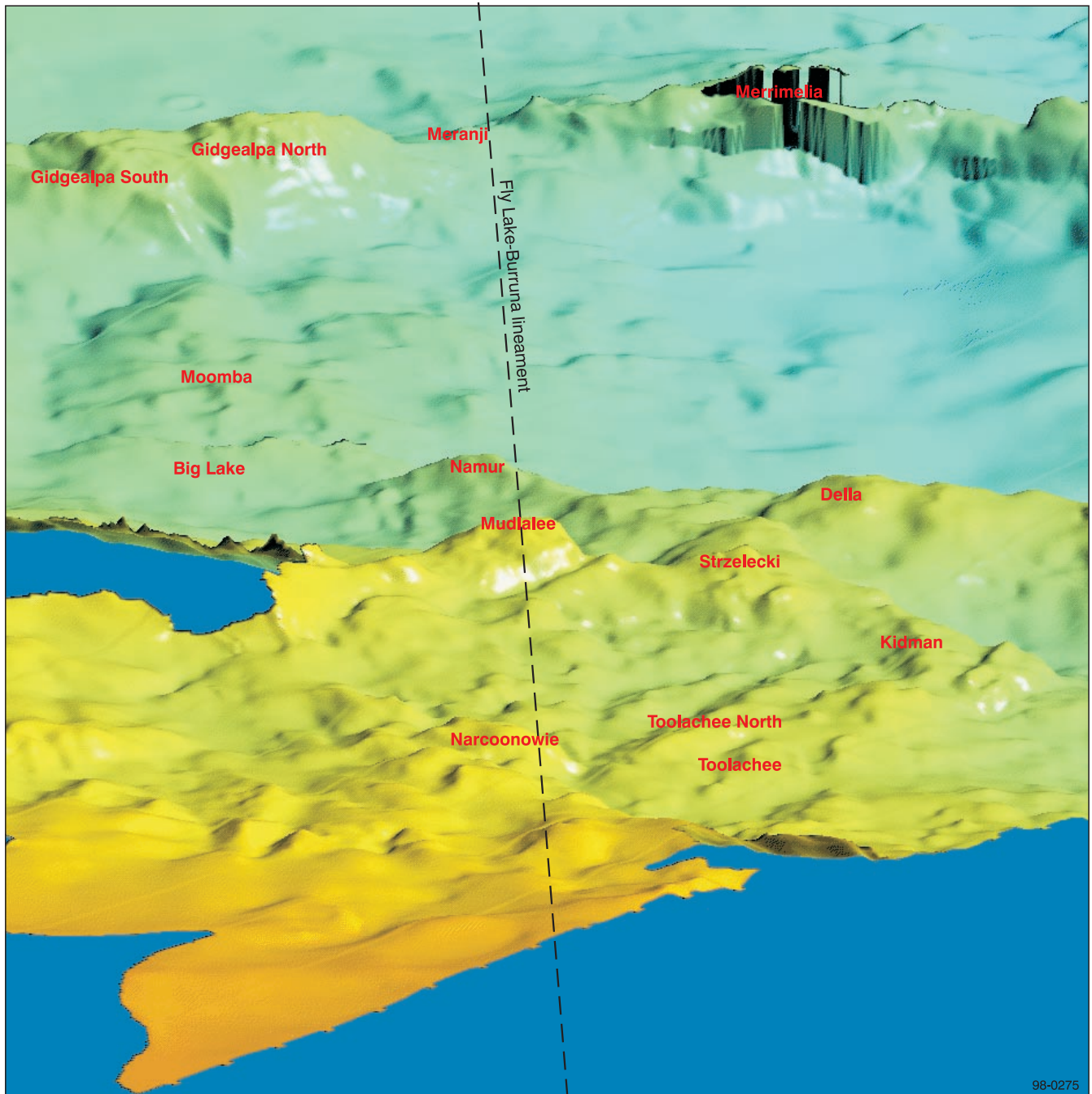


Figure 8 Low angle view looking north-west along the Fly Lake-Burrana lineament showing structural highs along or near the lineament that do not contain petroleum despite being valid traps

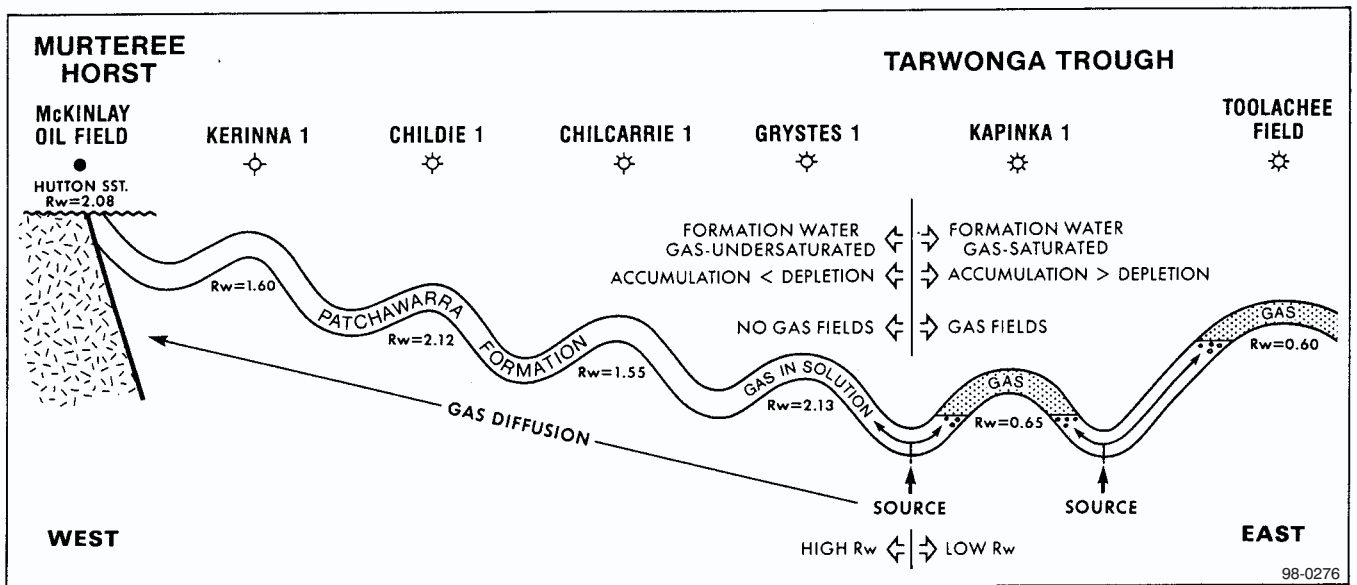


Figure 9 Schematic cross-section through the Tarwonga Trough showing the location of gas depletion or accumulation on either side of the Fly Lake-Burrana lineament (after Dunlop et. al., 1992). The section between Grystes 1 and Childie 1 runs parallel to and along the Fly Lake-Burrana lineament

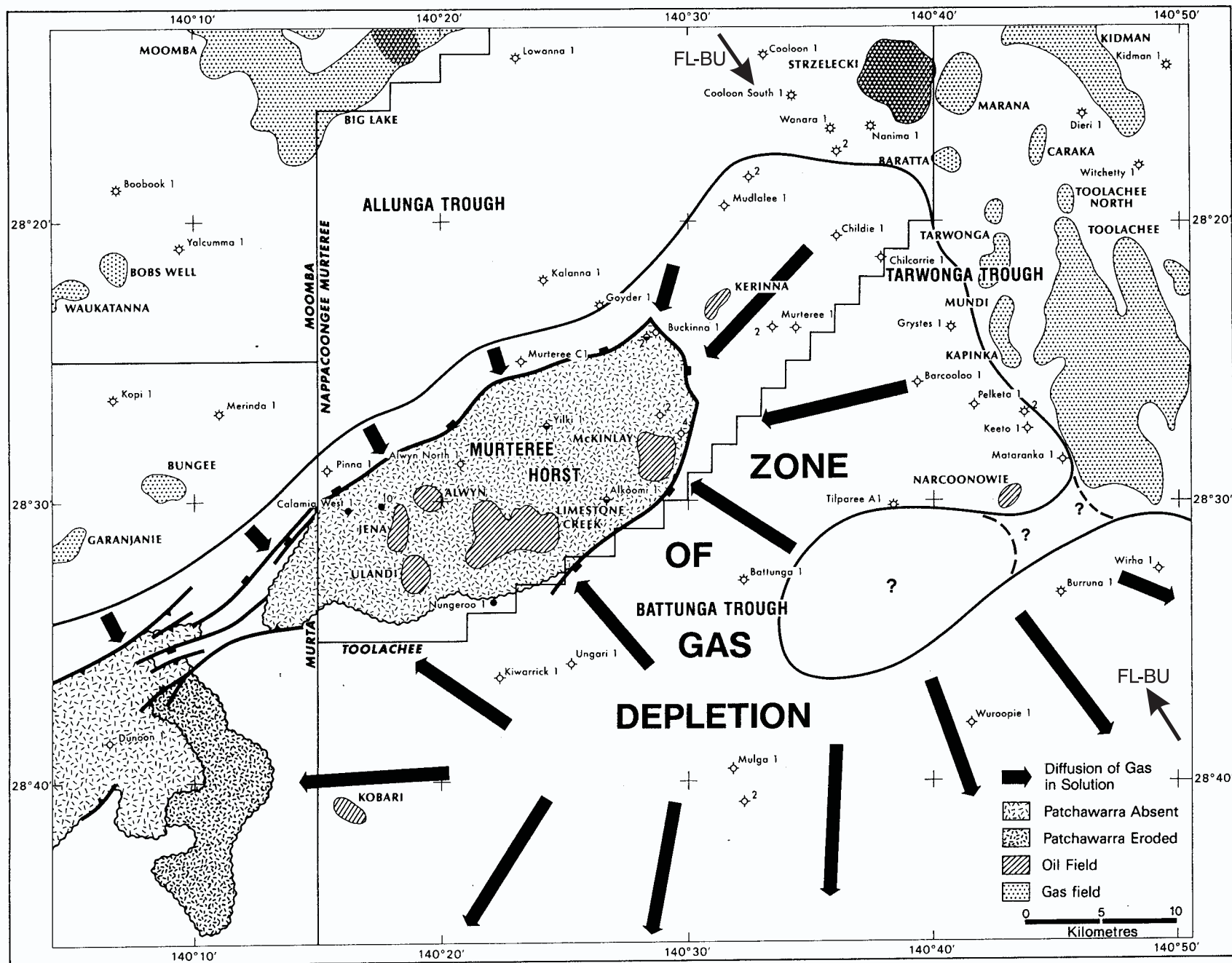
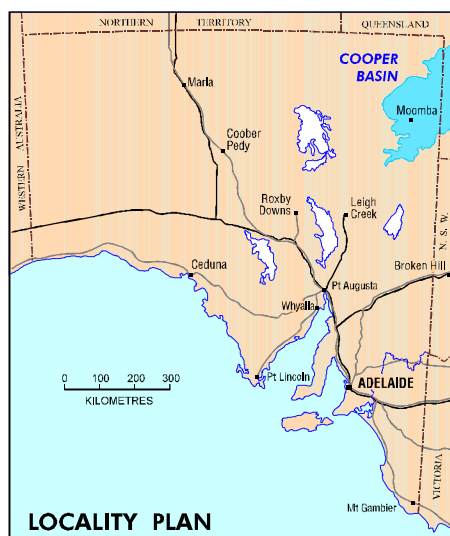
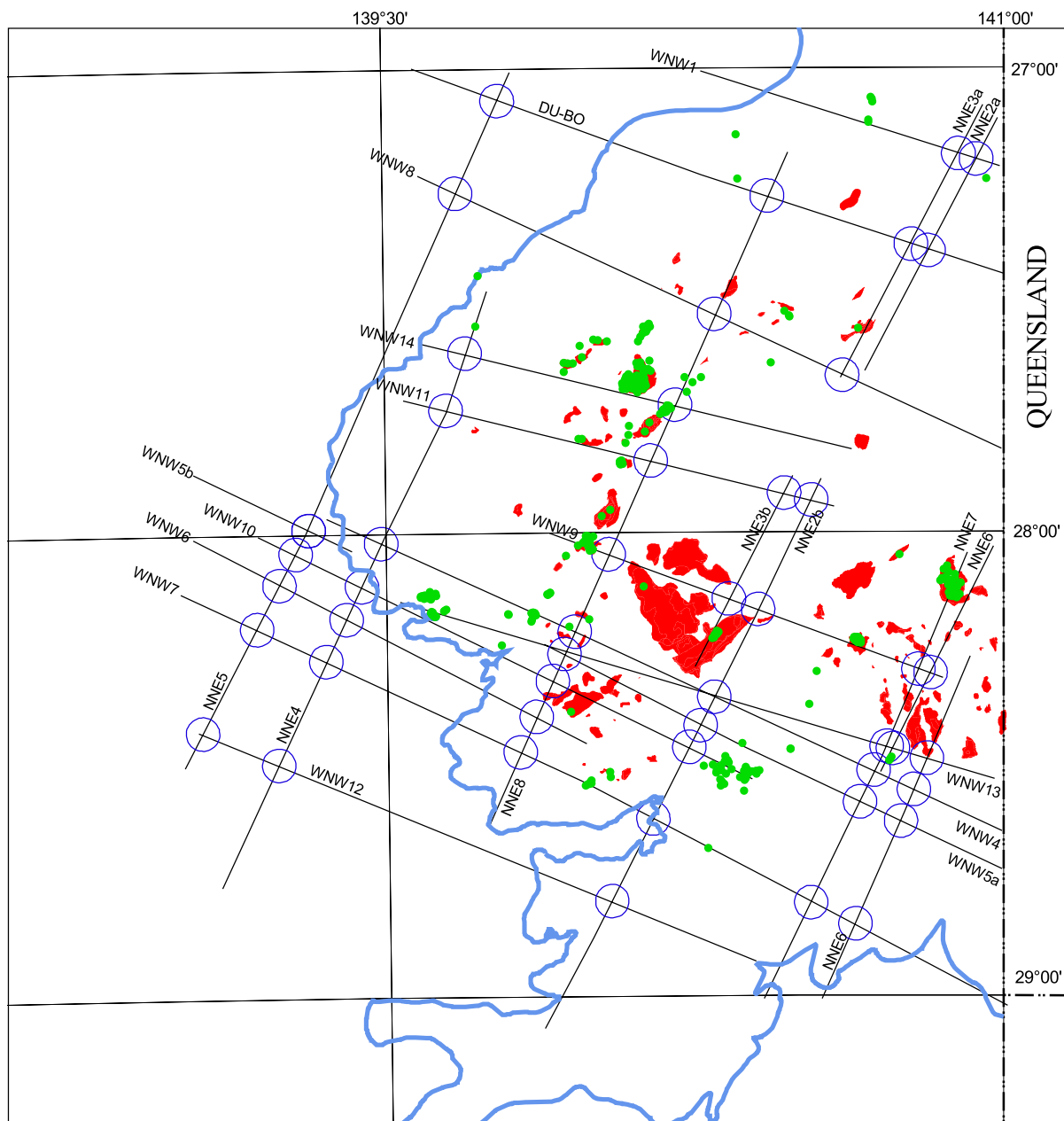


Figure 10 The zone of gas depletion and the location of the Fly Lake-Burruna lineament (after Dunlop et. al., 1992)



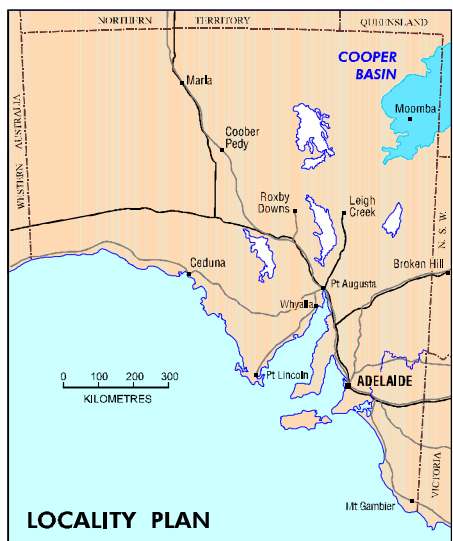
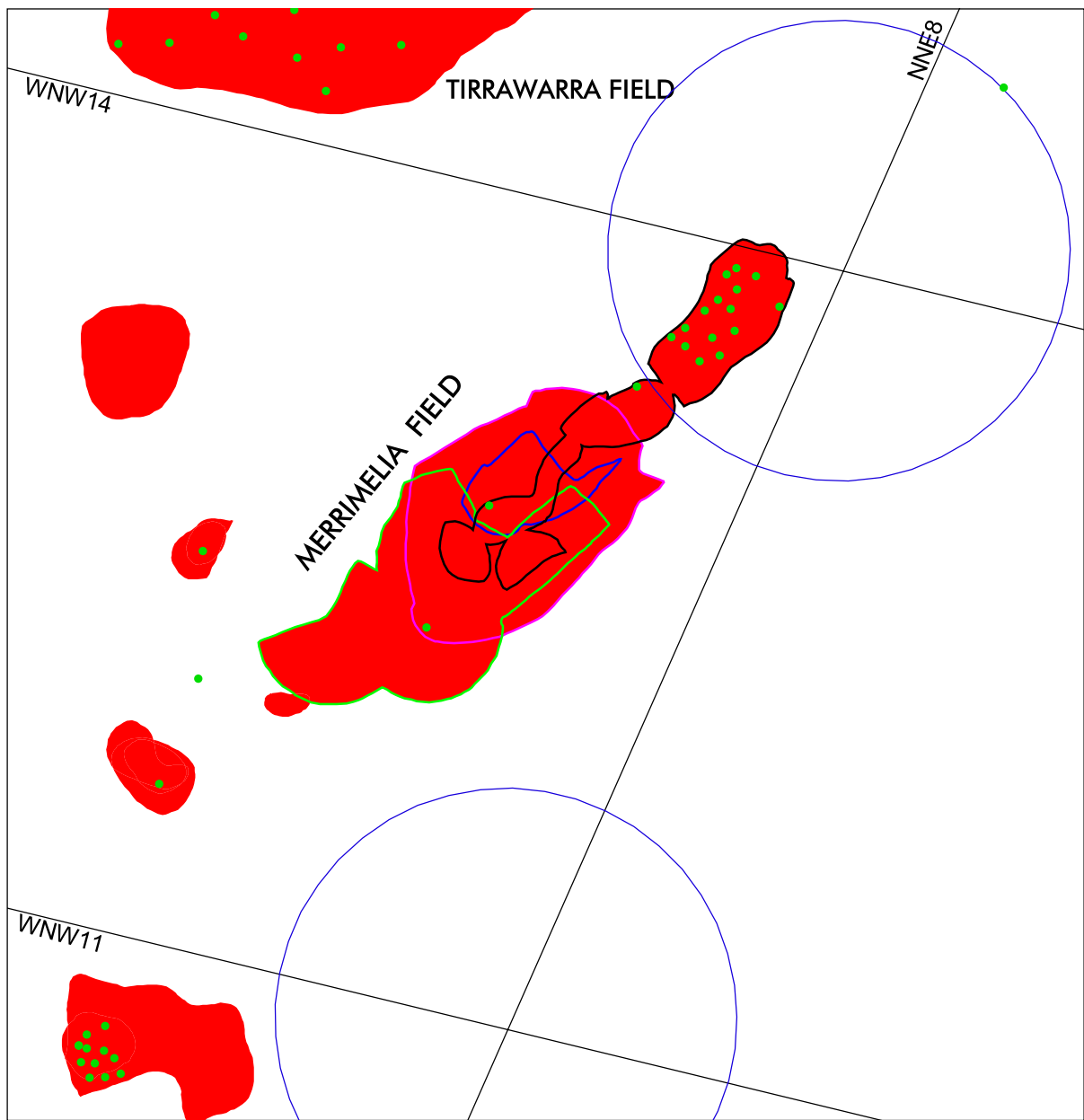
PRIMARY INDUSTRIES
AND RESOURCES SA

0 20 40 60 80 Kilometers

- Gas fields
- Oil wells
- 'Mineral targets'
- Tethyan primary and orthogonal lineaments

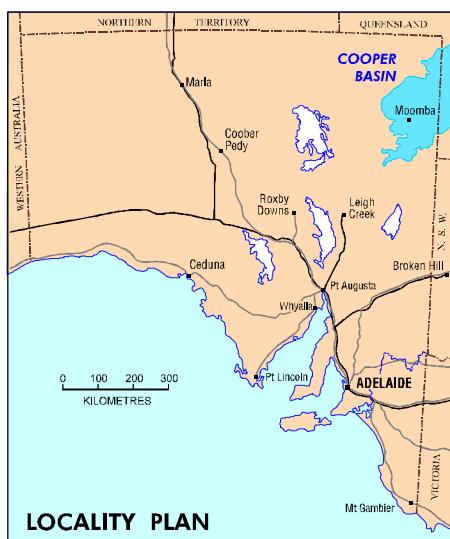
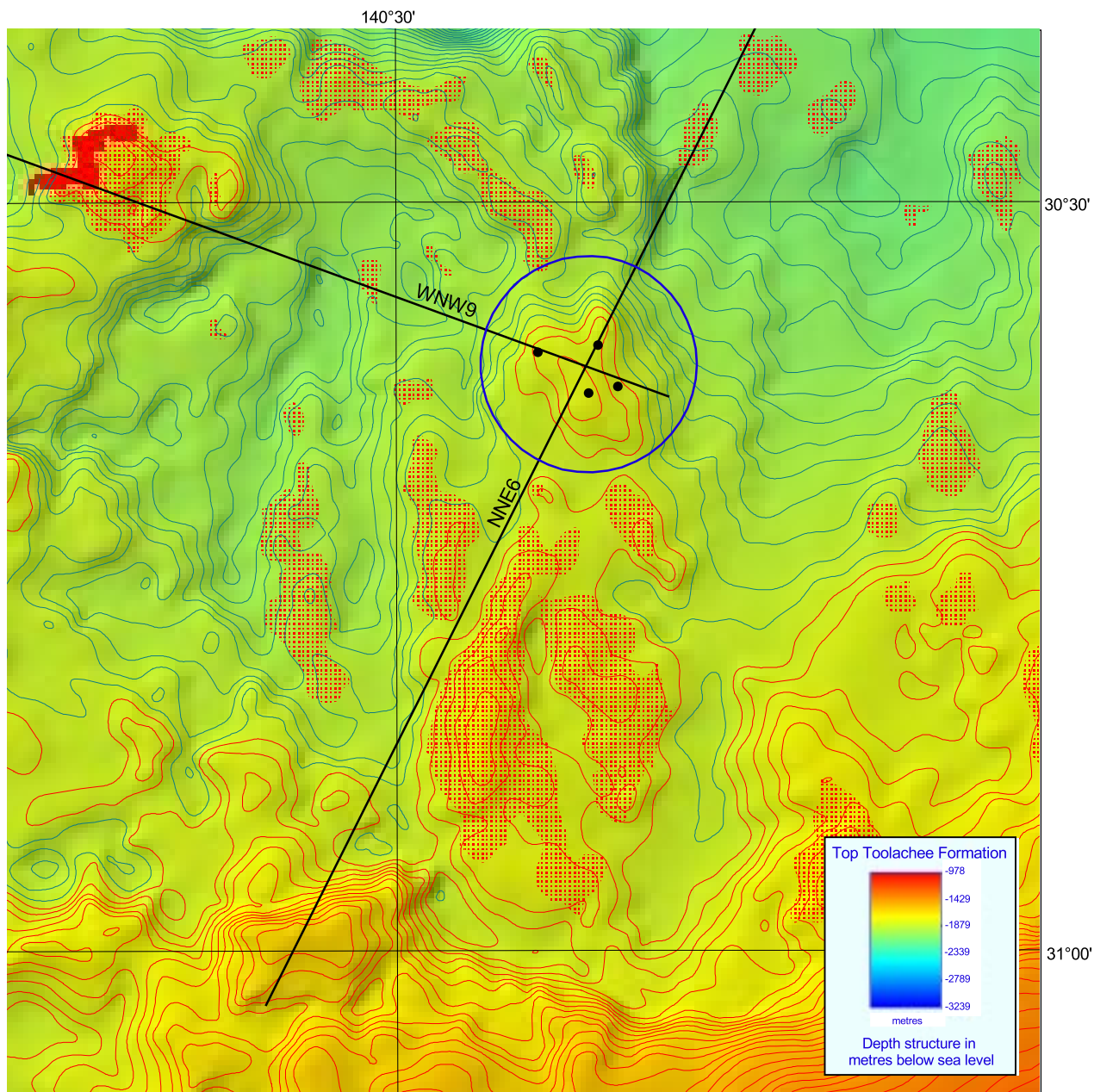
**Tethyan primary and orthogonal lineaments,
mineral targets, gas fields and oil wells**

Figure 11
98-0278



- MERRIMELIA FIELD**
- Nappamerri Pool
 - Toolachee Pool
 - Patchawara Pool
 - Tirrawarra Pool
 - Oil wells
 - 'Mineral targets'
 - Lineament

The Merrimelia field, lineaments, lineament targets, gas fields and oil wells



**PRIMARY INDUSTRIES
AND RESOURCES SA**

0 5 10 15 Kilometers

DEPTH STRUCTURE CONTOURS

Top Toolachee Formation
(metres below sea level)

- -3240 to -2400
- -2400 to -1840
- -1840 to -980

- Abandoned petroleum wells
- 'Mineral target'
- Tethyan primary and orthogonal lineaments
- Gas fields
- Fault zone

Depth structure map (top Toolachee Formation) of the Toolachee field area. Despite having valid closure, four dry wells exist where the lineament target occurs

Figure 13
98-0280

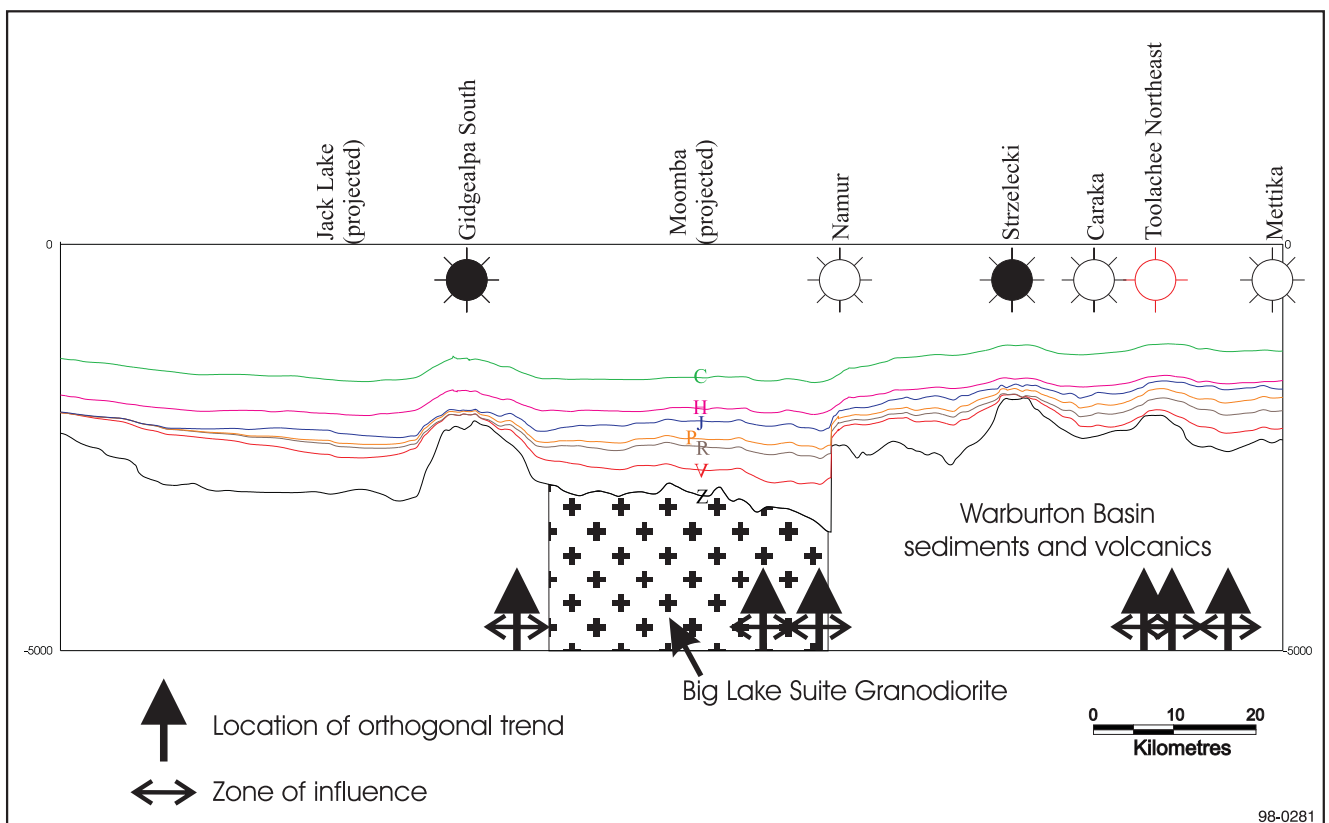
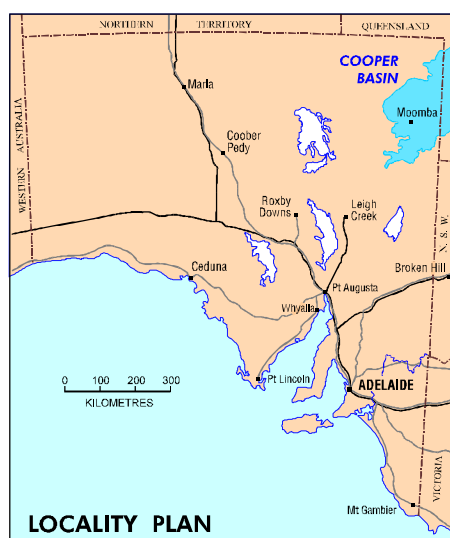
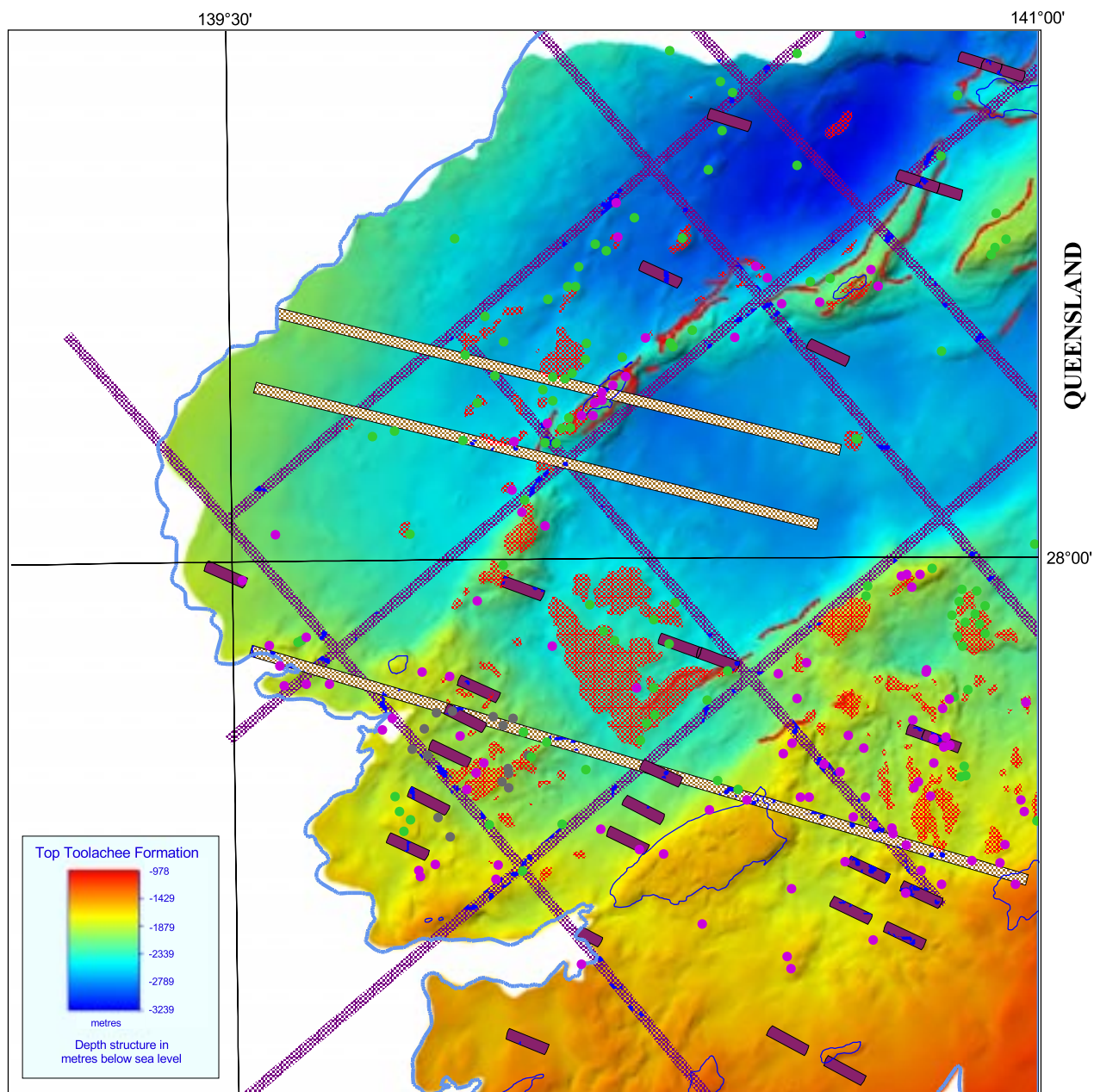


Figure 14 Cross-section along WNW9 showing the petroleum traps which are either filled or dry dependant on the location of intersecting orthogonal lineaments



PRIMARY INDUSTRIES
AND RESOURCES SA

0 20 40 60 Kilometers

ABANDONED WELLS

- Wet
- Tight
- No reservoir
- "Permian Cooper Basin Edge"
- Permian absent
- Gas fields
- Fault zone

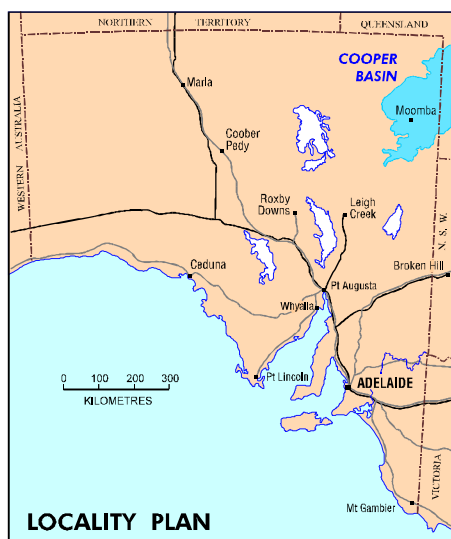
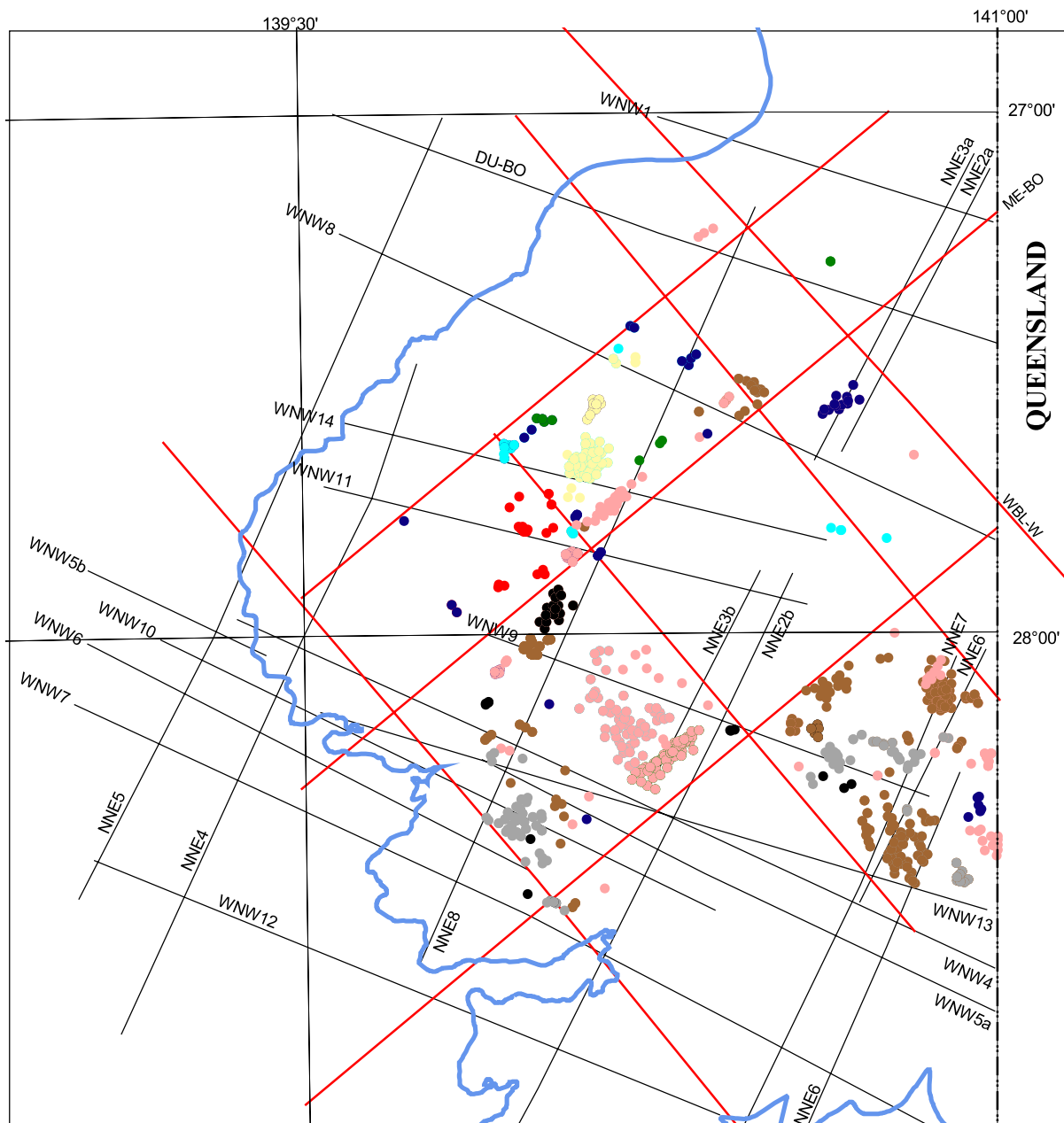
Anticlinal closures - areas of little or no potential for future exploration

UNPROSPECTIVE LINEAMENT ZONES

- 300° lineaments buffered to 1km within 'mineral target' zone
- 290° lineaments buffered to 1km
- Gas lineaments (1km buffer)

Unprospective lineament zones for the Cooper Basin area and structural highs which combine to represent areas of little or no potential for future exploration (blue)

Figure 15
98-0282



PRIMARY INDUSTRIES
AND RESOURCES SA

0 20 40 60 80 Kilometers

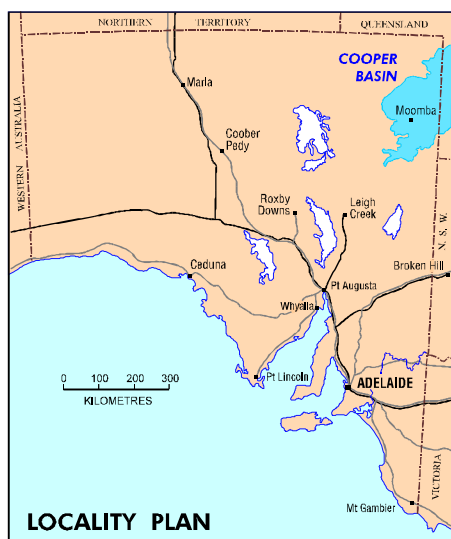
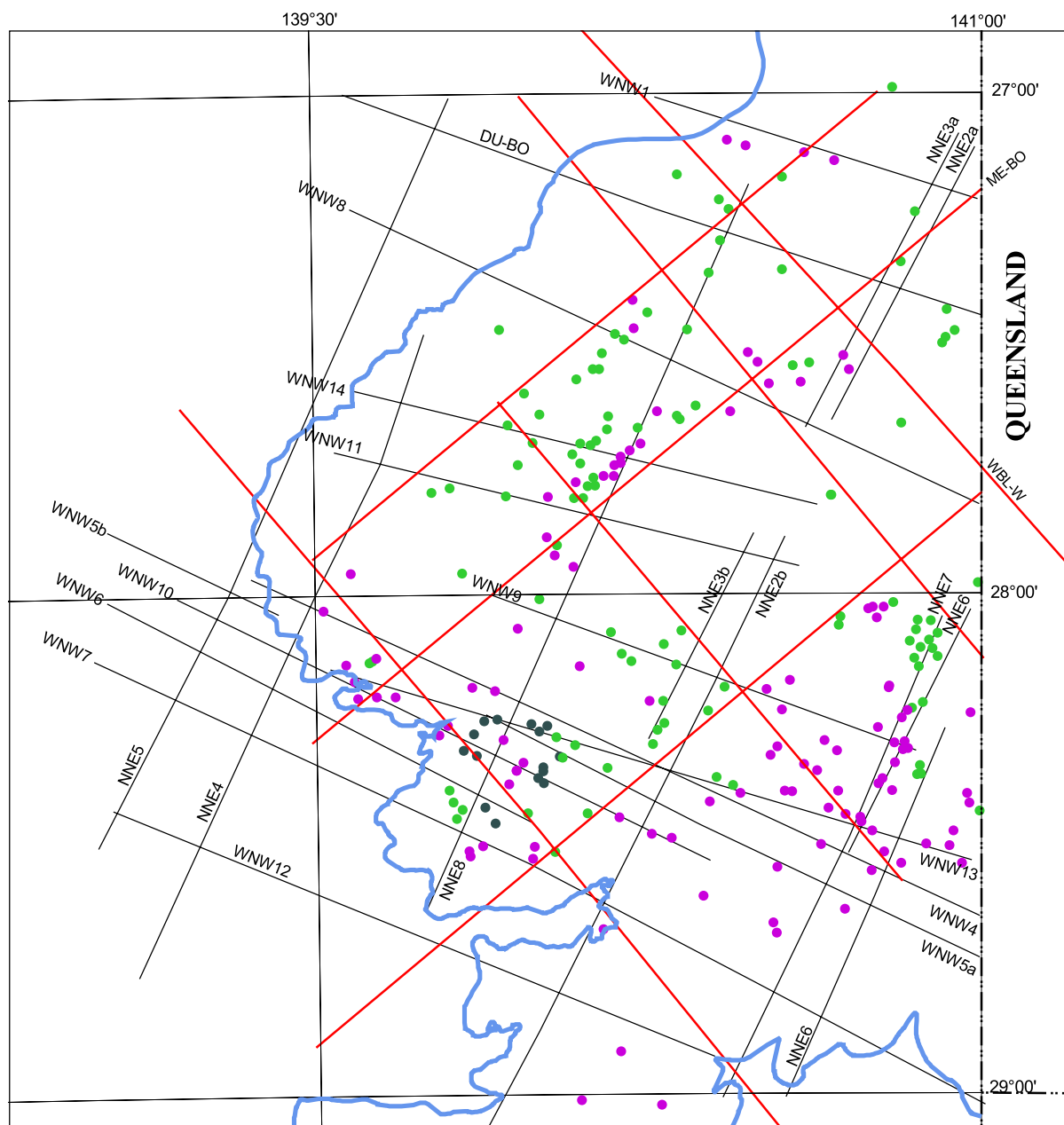
Percentage of CO₂

- 0 - 5
- 5 - 10
- 10 - 15
- 15 - 20
- 20 - 25
- 25 - 30
- 30 - 35
- 35 - 40
- Greater than 40

- Gas lineaments
- Tethyan primary and orthogonal lineaments

Carbon dioxide and low frequency lineaments

Figure 16
98-0283



PRIMARY INDUSTRIES
AND RESOURCES SA

0 20 40 60 80 Kilometers

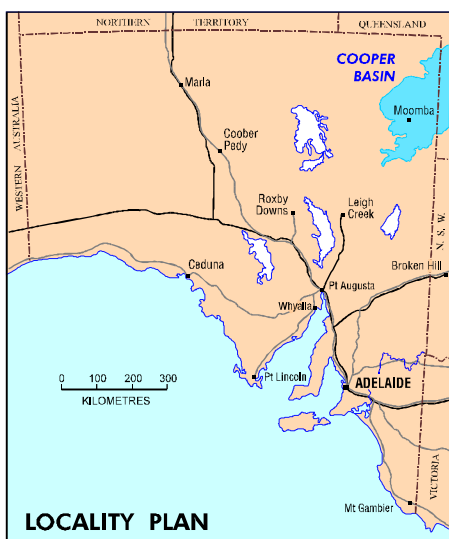
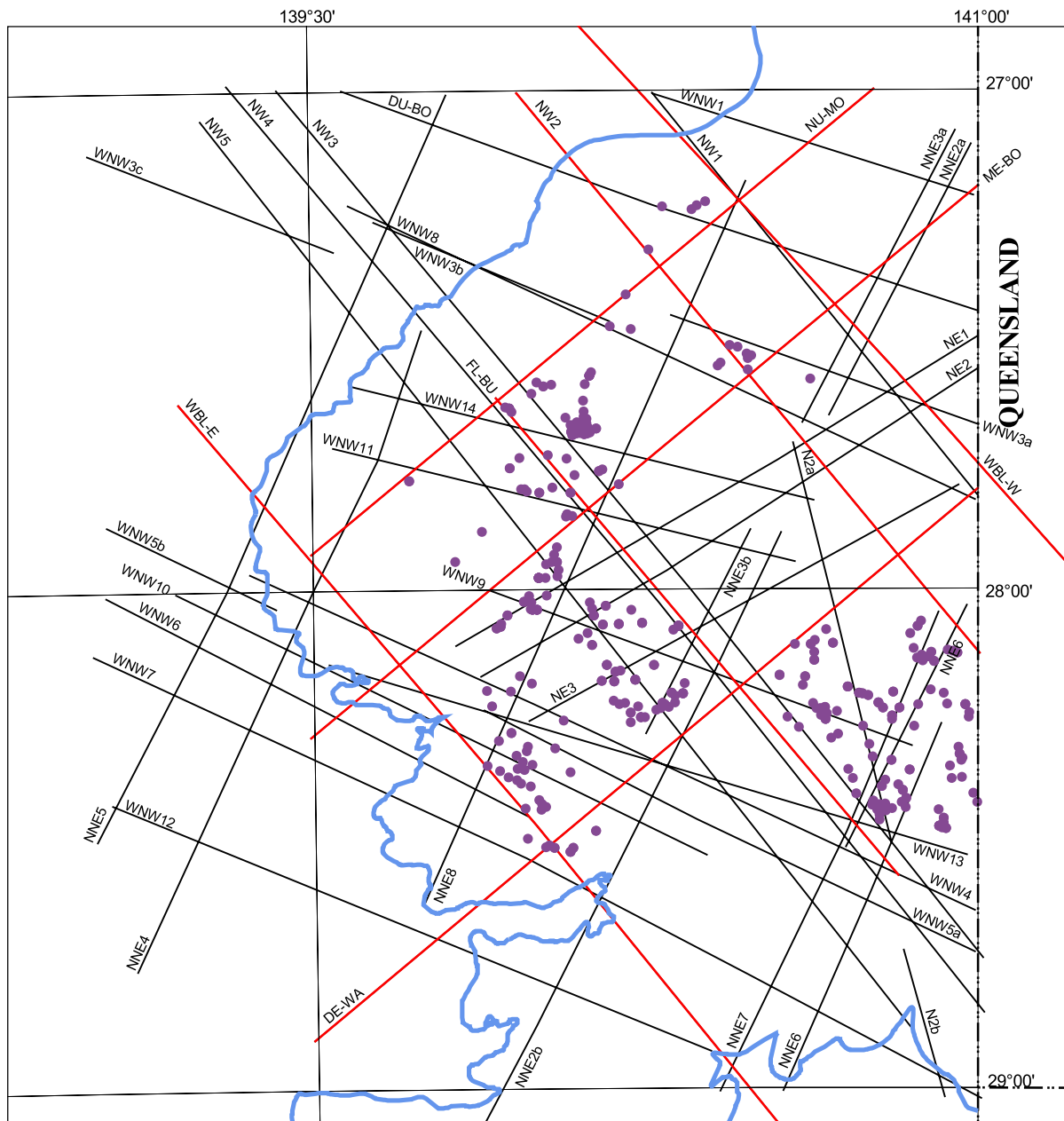
ABANDONED WELLS

- Wet
- Tight
- No reservoir

- Gas lineaments
- Tethyan primary and orthogonal lineaments

**Wet, tight and wells with no reservoir
and low frequency lineaments**

Figure 17
98-0284



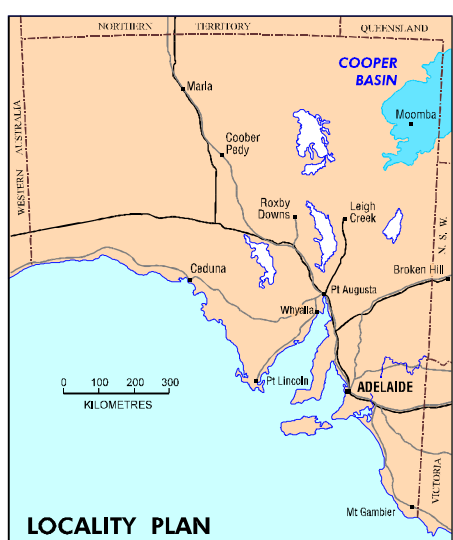
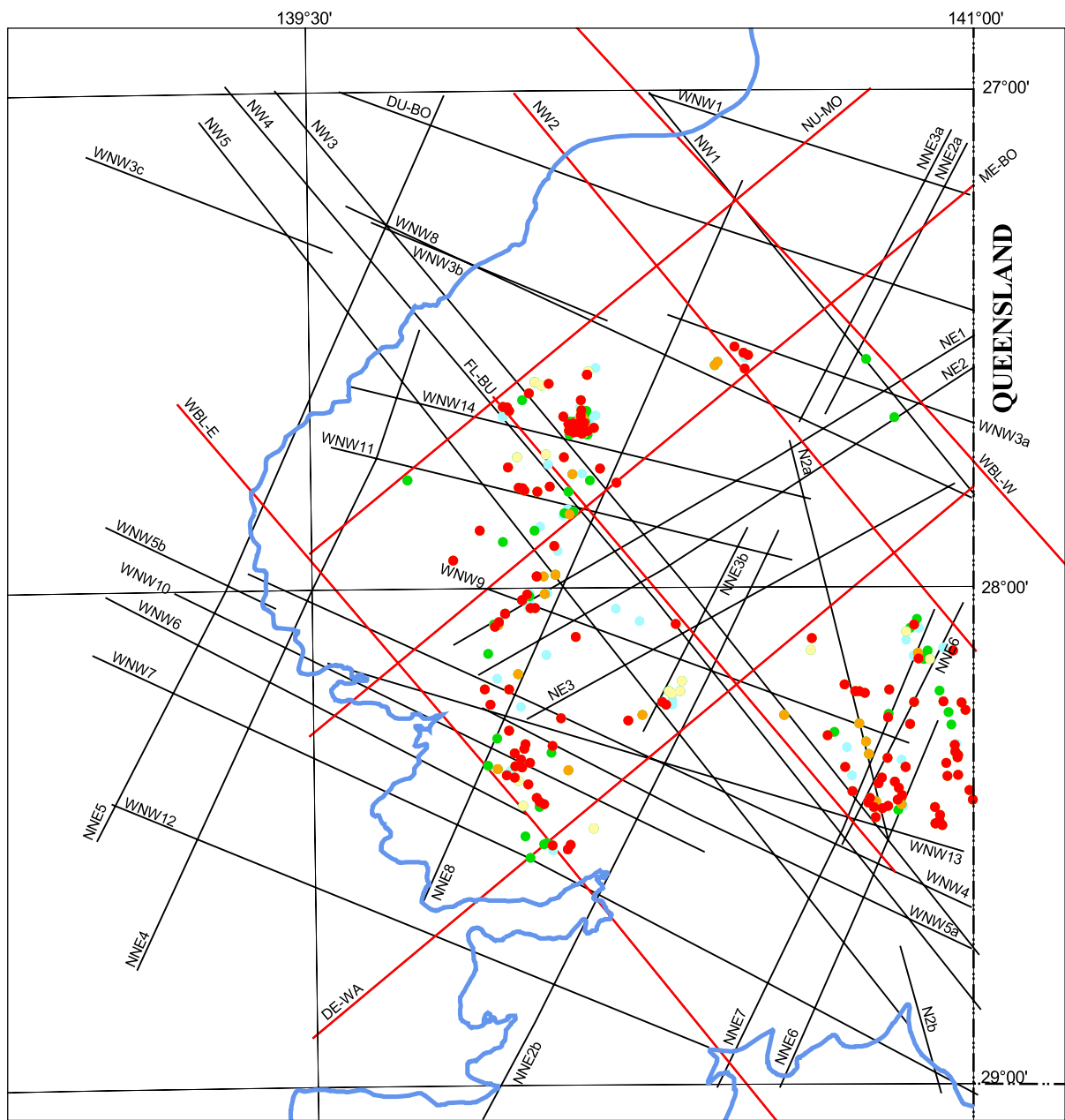
PRIMARY INDUSTRIES
AND RESOURCES SA

0 20 40 60 80 Kilometers

- Wells with gas flow greater than 3 million cubic feet per day
- Gas lineament
- Low frequency lineament

Low frequency lineaments (LFL) and drill stem test (DST) results for all formations where Q is greater than 3 million cubic feet of gas per day (MMCFD)

Figure 18
98-0285



PRIMARY INDUSTRIES
AND RESOURCES SA

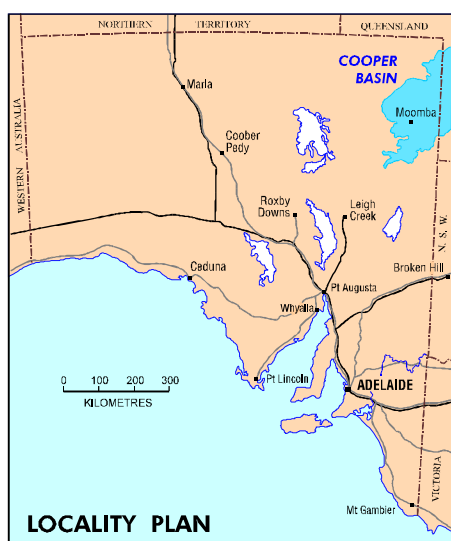
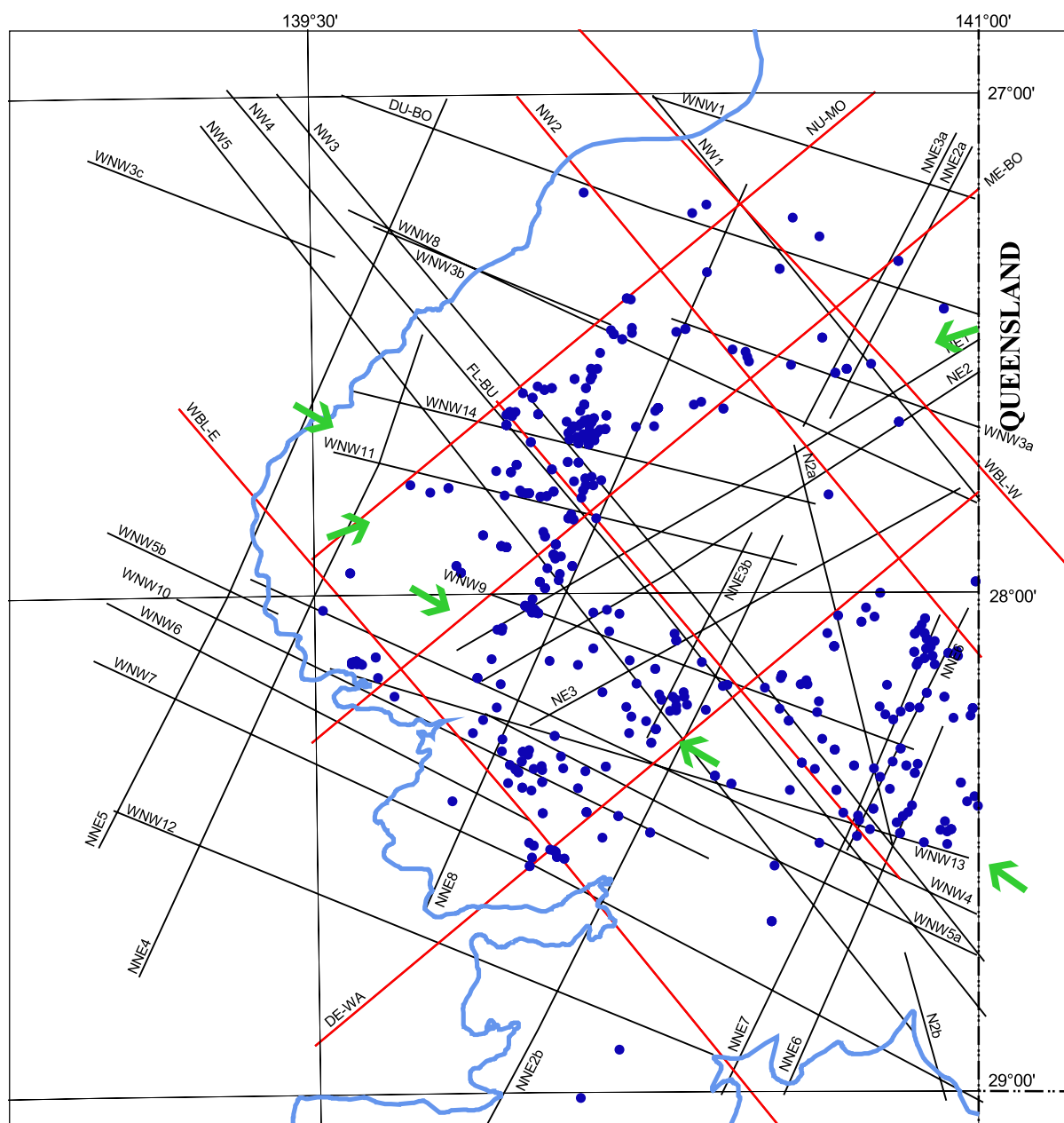
0 20 40 60 80 Kilometers

Q = gas flow in million
of cubic feet per day
(mmcf/d)

- Q > 5
- Q = 4-5
- Q = 3-4
- Q = 2-3
- Q = 1-2

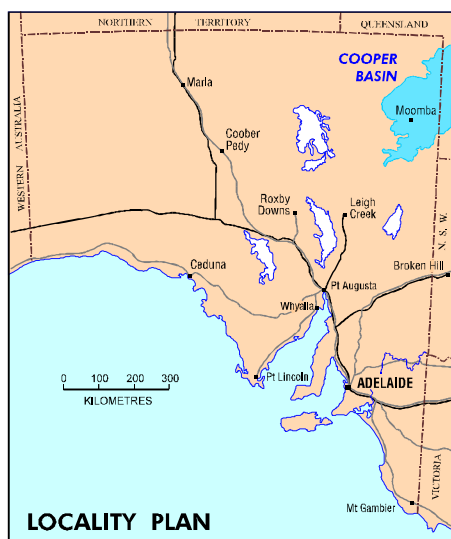
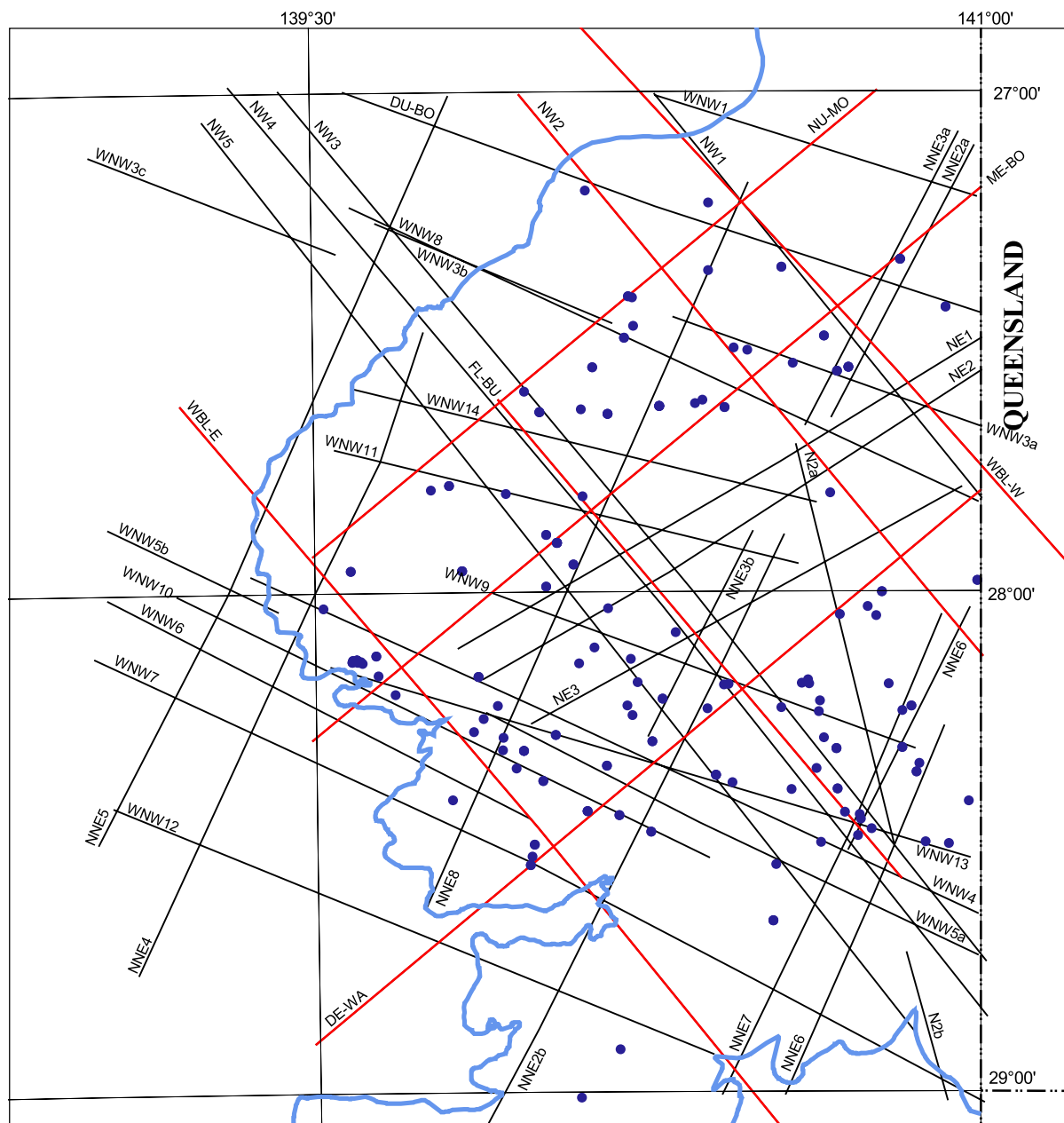
- Gas lineaments
- Low frequency lineaments

Low frequency lineaments (LFL) and drill stem test (DST) results for the Patchawarrra Formation where Q is greater than 1 million of cubic feet per day (MMCFD)



- Wells where gas flow is too small to measure or no flow to surface
- Gas lineaments
- Low frequency lineaments
- ➔ Alignments observed within the well data

Low frequency lineaments (LFL) and drill stem test (DST) results for the Patchawarra Formation that did not flow gas to surface or at a rate too small to measure (RTSTM)



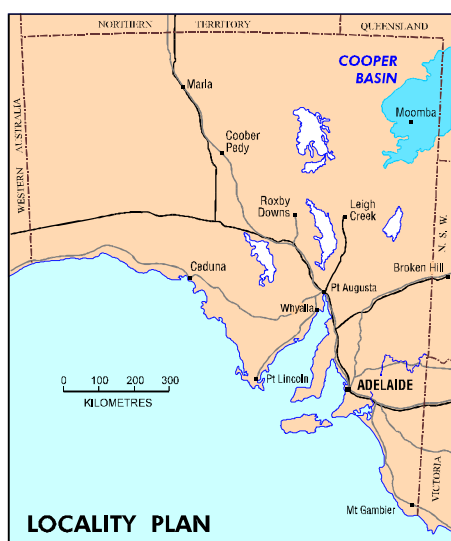
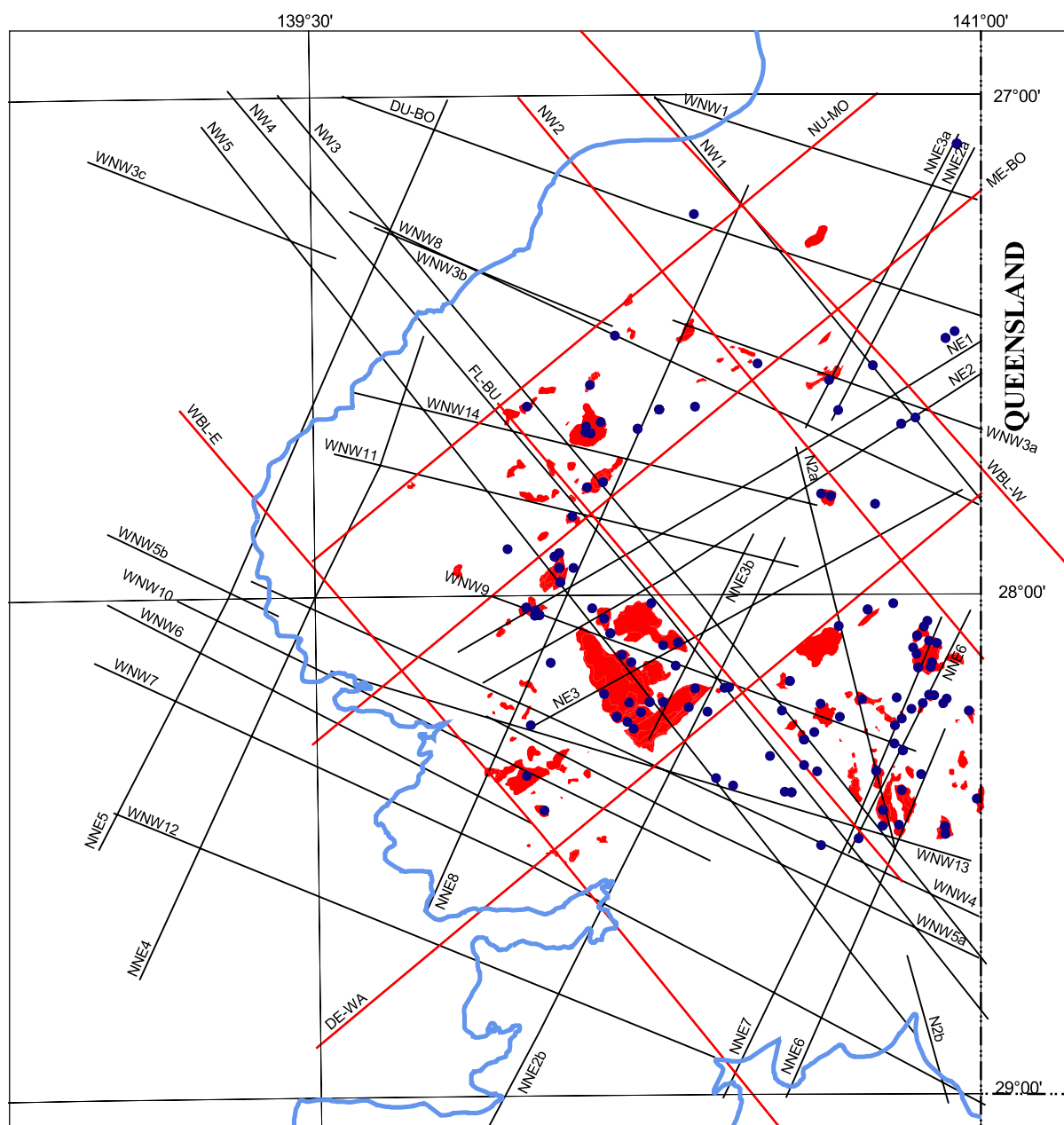
PRIMARY INDUSTRIES
AND RESOURCES SA

0 20 40 60 80 Kilometers

- Wells where gas flow rate is too small to measure or no flow to surface
- Gas lineament
- Low frequency lineament

Low frequency lineaments (LFL) and drill stem test (DST) results for the Patchawarra Formation where Q is a rate too small to measure (RTSTM) but excludes wells within existing fields

Figure 21
98-0288



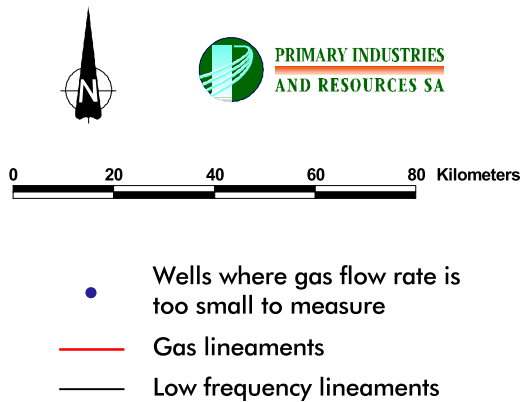
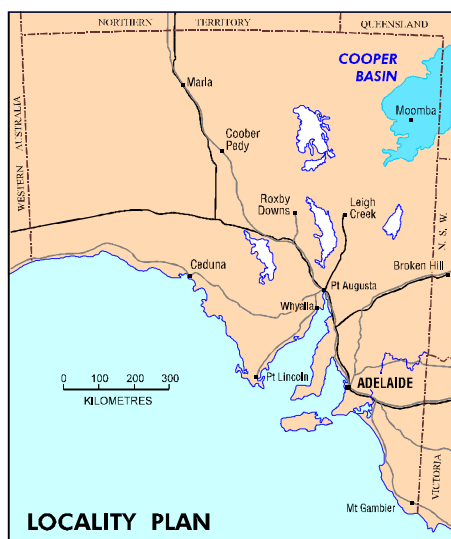
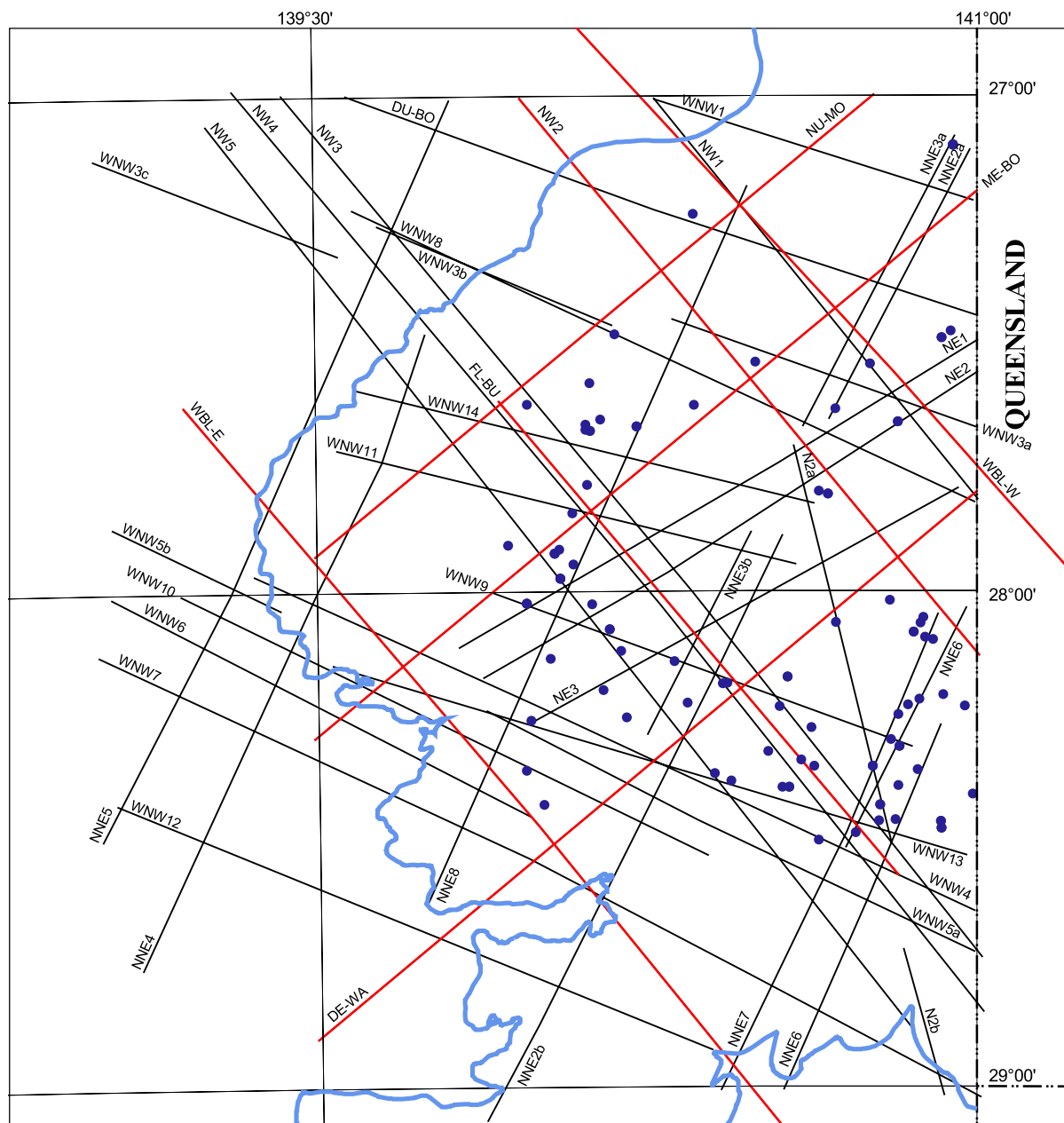
PRIMARY INDUSTRIES
AND RESOURCES SA

0 20 40 60 80 Kilometers

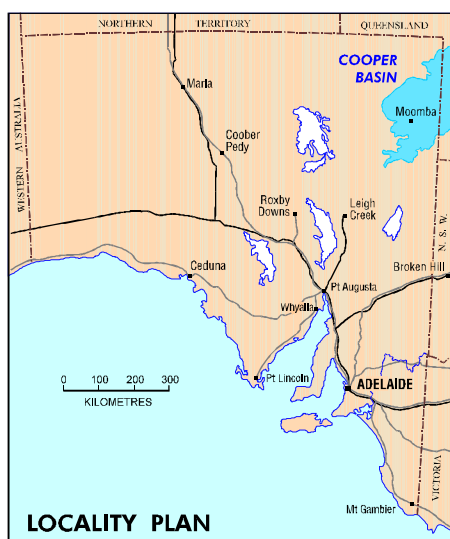
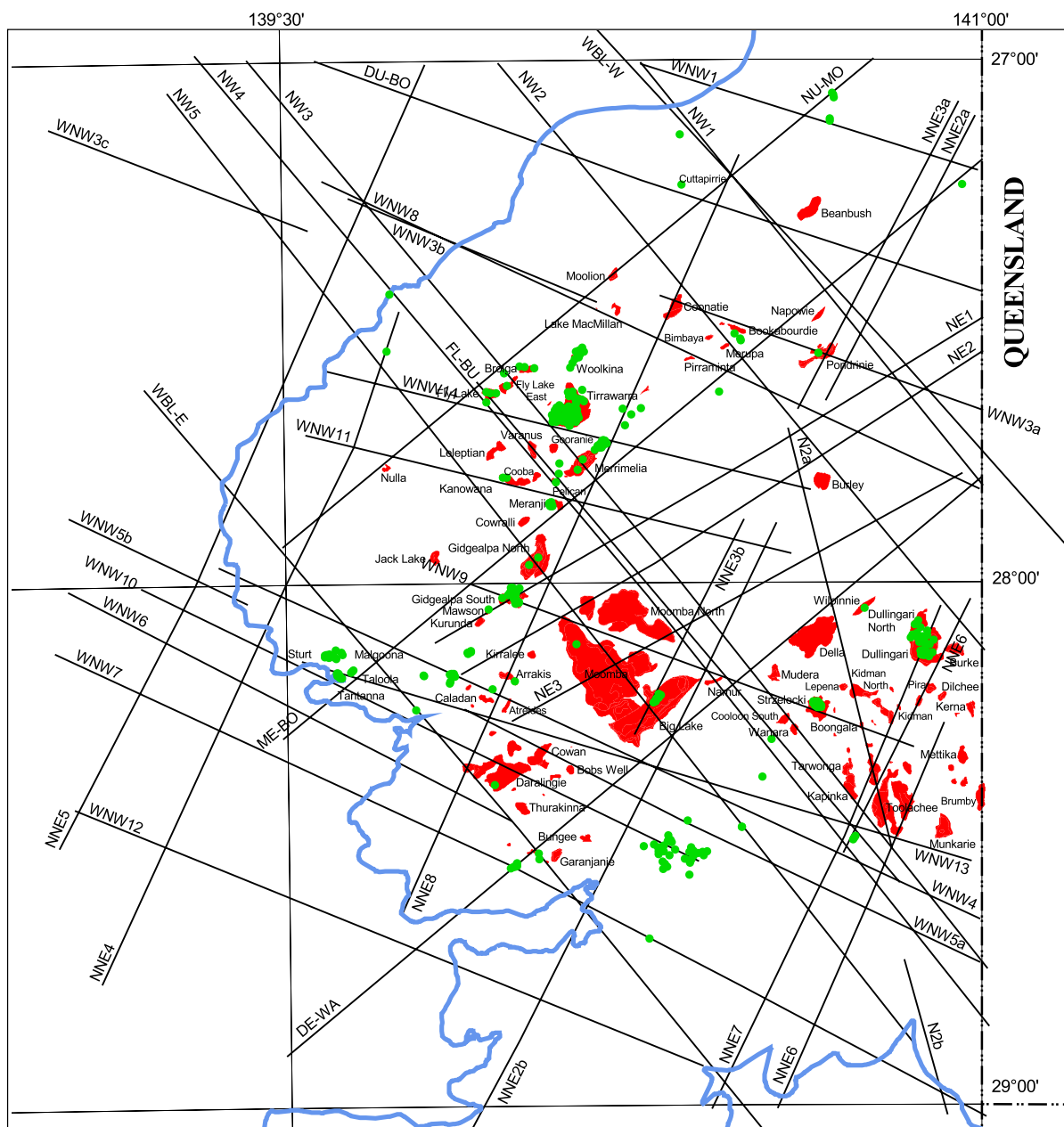
- Wells where gas flow rate is too small to measure
- Gas fields
- Gas lineaments
- Low frequency lineaments

Low frequency lineaments (LFL) and drill stem test (DST) results for the Toolachee Formation where Q is a rate too small to measure (RTSTM). Of particular interest is NW5 that is aligned with a series of wells with poor results despite occurring within the Moomba and Gidgealpa South fields

Figure 22
98-0289



Low frequency lineaments (LFL) and drill stem test (DST) results for the Toolachee Formation where Q is a rate too small to measure (RTSTM) but excludes wells within existing fields



PRIMARY INDUSTRIES
AND RESOURCES SA

0 20 40 60 80 Kilometers



"Permian Cooper
Basin edge"



Low frequency lineaments



Gasfields



Oil wells

**Oil and gas occurrences with low frequency
lineaments (LFL) for the Cooper Basin area**