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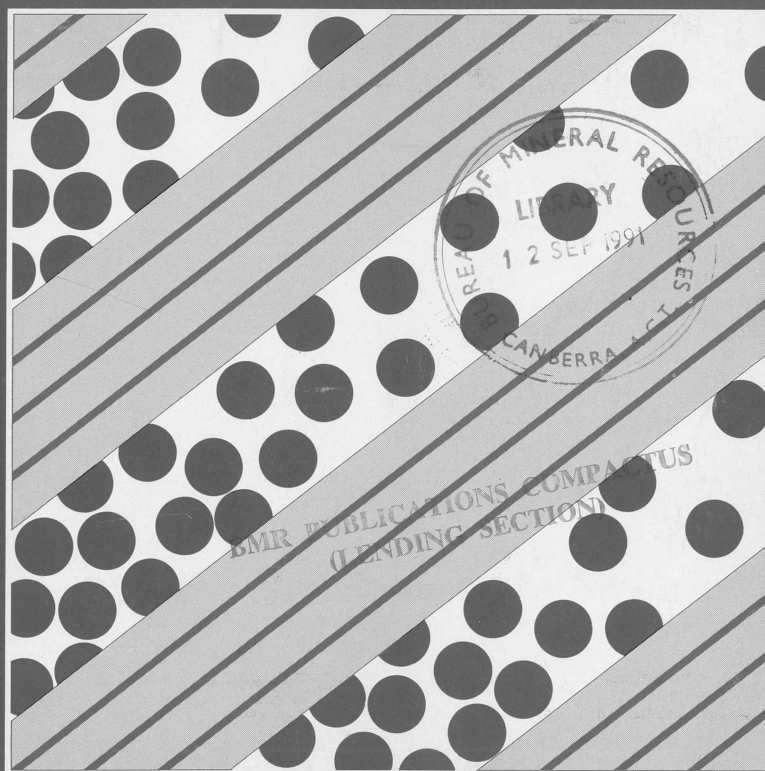
Studies in Fossil Fuels

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CLARENCE-MORETON BASIN WORKSHOP: ABSTRACTS

EDITED BY P.E. O'BRIEN & A.T. WELLS



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BUREAU OF MINERAL RESOURCES
GEOLOGY & GEOPHYSICS

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BUREAU OF MINERAL RESOURCES
GEOLOGICAL SURVEY OF NEW SOUTH WALES
GEOLOGICAL SURVEY OF QUEENSLAND

**CLARENCE-MORETON BASIN
WORKSHOP**

JUNE 1990

ABSTRACTS

Edited by P.E. O'Brien and A.T. Wells
Bureau of Mineral Resources, Canberra.

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INTRODUCTION

The Clarence-Moreton Basin was originally targeted by BMR and the Geological Surveys of Queensland and New South Wales because it was a basin for which no up to date geological synthesis existed. In particular, it contained a similar sequence to the petroleum-bearing Surat and Eromanga Basins to the west which suggested a re-examination of its petroleum potential was warranted. The work program incorporated:

- a. An extensive study of basin stratigraphy and sedimentology in outcrop and the subsurface, including the drilling of four stratigraphic holes.
- b. Aquisition of regional seismic data across the northern part of the basin.
- c. Extensive sampling of potential hydrocarbon source rocks for organic geochemical work in BMR and petrological and maturation studies by CSIRO Division of Exploration Geoscience.
- d. A review of existing palynological data and the examination of new material to improve the biostratigraphic subdivision of the basin.
- e. A collaborative study by Melbourne University School of Earth Sciences and BMR of basin thermal history using Apatite Fission track thermochronology.
- f. Re-interpretation of company seismic to produce a series of structure contour and isopach maps of the basin.
- g. Gravity and aeromagnetic data have been updated for the basin by flying aeromagnetic and radiometric surveys to complete coverage and by compilation of recent gravity data into a single data base. These data have been interpreted in terms of the latest understanding of basin and basement geology.

At the same time, Dr. Chris Fielding of the University of Queensland commenced studies of the sedimentology of the Walloon Coal Measures and a number of companies undertook exploration programs in permits in both New South Wales and Queensland.

The results of these studies are being compiled into a BMR Bulletin and Map Folio. This workshop aims to summarise the major components of the Clarence-Moreton Project and to provide a forum for discussion of the basin's resource potential.

THE LITHOSTRATIGRAPHIC FRAMEWORK OF THE CLARENCE-MORETON BASIN AND THE DISTRIBUTION AND CHARACTER OF POTENTIAL RESERVOIR UNITS

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The existing lithostratigraphic schemes in the Clarence-Moreton Basin have been established for several decades. Their major problems are that nomenclatures have been erected independently for specific parts of the basin, and in some cases local names have been used for small areas of investigation. Hence it was not until a regional study and synthesis of the geology of the basin, by the BMR and collaborating agencies, that a lithostratigraphic framework could be constructed that was compatible and workable basinwide.

Two main approaches were employed to achieve this result:-

1. Upgrading the existing lithostratigraphic names of the Bundamba Group.
2. Rationalising the existing nomenclatures.

Revision of the stratigraphic nomenclature and elimination of the existing confusion in names of units in the basin was considered to be an essential first step in understanding basin evolution and assessing petroleum potential.

In the past different criteria have been employed to define formation boundaries with varying and usually limited success. The most useful criteria found to distinguish most of these formations are sandstone composition and sandstone/mudrock ratios. For example the quartz-feldspar-lithic arenites of the Marburg Subgroup are overlain by the Walloon Coal Measures which contain volcanic litharenites. The Marburg Subgroup lower boundary is marked by a change to clean quartz sandstone in the underlying Ripley Road Sandstone of the Woogaroo Subgroup.

We redefine the Marburg Formation as the Marburg Subgroup of the Bundamba Group

and divide the Subgroup into two formations, the uniform sandstone of the Gatton Sandstone and the mixed sandstone and mud rocks of the younger Koukandowie Formation. The formations are upgraded, pre-existing, members. The Gatton Sandstone contains two members. Along the western basin margin, the Koreelah Conglomerate Member forms the base of the Gatton Sandstone where it overlaps basement rocks, and the Calamia Member of mixed mudrocks and sandstone composes a basal unit in the Gatton Sandstone in more basinward sections.

The Heifer Creek Sandstone Member is a prominent quartzose sandstone unit in the Koukandowie Formation throughout most of the basin. The mixed mudrocks and sandstone of the Ma Ma Creek Member of the Koukandowie Formation are older than the Heifer Creek Sandstone Member and are mainly known from the northern and central parts of the basin but probably also extend to its southern extremities.

The nomenclature of the Woogaroo Subgroup, which comprises the Aberdare Conglomerate (and equivalent Layton's Range Conglomerate) at the base, overlain by the Raceview Formation and the Ripley Road Sandstone at the top has remained unchanged. This terminology has been applied to the pre-Marburg Subgroup rocks over the whole Clarence-Moreton Basin. Other names that have been used for this part of the succession elsewhere are abandoned to avoid unnecessary duplication and consequent confusion of names.

The name 'Helidon Sandstone' is discarded as a stratigraphic term principally because the part of the succession it referred to can mostly be divided into the formations that constitute the Woogaroo Subgroup.

This new nomenclature preserves the integrity of existing stratigraphic names and is applicable basin wide. Only one new stratigraphic name the Koreelah Conglomerate Member is introduced in the new nomenclature.

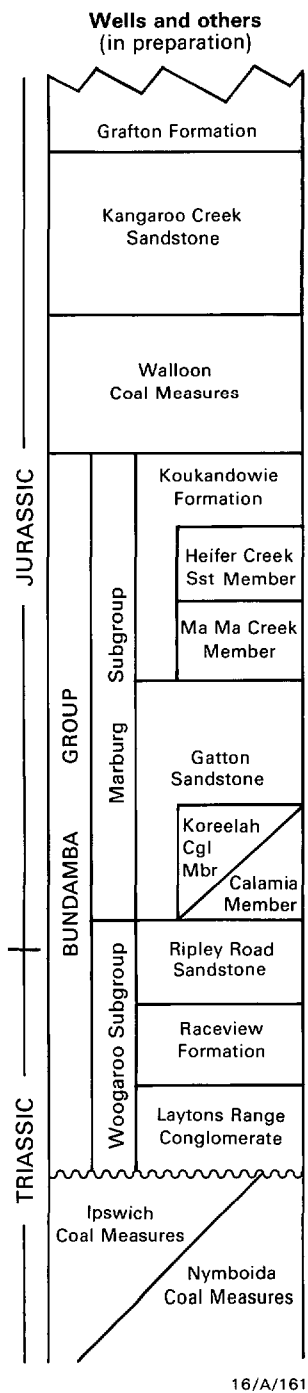
The new nomenclature allows easier recognition of the more porous and permeable units in the stratigraphic succession and indicates their correlation and distribution throughout

the basin. Two important reservoir units defined are the Heifer Creek Sandstone Member of the Koukandowie Formation, and what was commonly known as the 'mid Bundamba Sand'. This latter term corresponds with the Ripley Road Sandstone which is now known to have a wide distribution. Many other units show porous and permeable sands but for the most part they are thinner and restricted in extent.

Some observations from the available measured porosities and permeabilities are:

1. Maximum recorded porosities and permeabilities occur in the Ripley Road Sandstone in the area of the Toowoomba Strait, and Cecil Plains Sub-basin.
2. Values for maximum permeability decrease markedly east and southeast of the Toowoomba Strait.
3. Values for maximum porosity do not show marked gradients but on average are slightly higher in the central and western areas.
4. The Ripley Road Sandstone shows consistently higher porosity and permeability in comparison to other formations.
5. The Koukandowie Formation shows a number of porous and permeable sands, chiefly in the Heifer Creek Sandstone Member.
6. Both the Gatton Sandstone and Walloon Coal Measures show isolated porous sandstone interbeds but they are infrequent.
7. The porosity and permeability recorded in the Aberdare Conglomerate, Raceview Formation, Calamia Member, Ma Ma Creek Member, and over the greater proportion of the Gatton Sandstone and Walloon Coal Measures, are on the average relatively low. The notable exceptions are isolated sandstone bodies in the Raceview Formation, (Ropeley 1, Sextonville 1), Gatton Sandstone (GSQ Ipswich 19-21 R, BMR Warwick 6, 7, Clifden 3), and Walloon Coal Measures (GSQ Ipswich 7, Rappville 1).

The general decrease in permeability and porosity in most units towards the southeastern part of the basin is most likely caused by greater depths of burial, and consequent high heat flows experienced by the sediments in this area.



16/A/161

Figure 1. Lithostratigraphy of the Clarence-Moreton Basin.

THE SOUTHERN CLARENCE-MORETON BASIN IN NEW SOUTH WALES: A TALE OF TWO MARGINS.

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Fair to excellent exposures of the main Clarence-Moreton Basin (CMB) sequence occur on the eastern and western basin margins in N.S.W. The sequences at both margins have their own characteristics which have been observed in reconnaissance mapping and traversing. However, the essential elements and complexities of the Bundamba Group to Kangaroo Creek Sandstone sequence are well laid out at both margins.

Middle Triassic rift sequence coal measures (western margin) and Late Triassic Ipswich Coal Measures equivalents (eastern margin), underlie the CMB. Initial CMB deposition at both basin margins comprised Late Triassic coarse alluvial-fan facies containing local and New England Fold Belt detritus (Corindi, Layton Range Conglomerates). At the eastern margin, these rudites comprise the basal part of the well-exposed Woogaroo Subgroup facies trio: conglomerate (Corindi Conglomerate), interbedded sandstone-mudstones (Raceview Formation) and the distinctive, very coarse grained, quartzose Ripley Road Sandstone. At the western margin, however, the Woogaroo Subgroup is much more restricted, consisting of the well-developed Laytons Range Conglomerate, overlain in some areas by probably Raceview Formation; the Ripley Road Sandstone is absent in all adequately continuous sections.

On both basin margins, a complex sequence of sandstones, and sandstone-mudstone facies (the Marburg Subgroup) occurs between the Woogaroo Subgroup and the distinctive Middle-Late Jurassic Walloon Coal Measures. Thick-bedded quartz-lithic sandstones occur as stacked channel sands (Gatton Sandstone) at the base of the subgroup. At the western basin margin, the Gatton Sandstone is a more heterogeneous immature sequence than at the eastern basin margin (abundant fossil wood logs and fragments, mudstone-sandstone overbank deposits, and abundant conglomerate lenses (e.g. Koreelah Conglomerate Member). The thinly interbedded sandstones-mudstones

of the Calamia Member, at the base of the Gatton Sandstone at the eastern margin, are readily mapped in the Coast Range area.

A complex unit of interbedded sandstone, siltstone and claystone is present at the top of the Marburg Subgroup at both basin margins (Koukandowie Formation). The base of the formation on the western margin comprises a distinctive coarse-grained cross-bedded, quartzose sandstone (Heifer Creek Sandstone Member). This member is also present on the eastern margin, at least in the Coast Range area, where it is also present in DDH Pillar Valley 2. A thin unit of basaltic volcanoclastics and lavas (Towallum Basalt) occurs beneath the Heifer Creek Sandstone Member at the southern to south-western margin.

Two aspects of the geology of the Walloon Coal Measures have been modified in the study:

(a) The top-Bundamba/base-Walloons boundary has been shifted upwards in the section by recognising it as a change from quartz-lithic (Marburg) to quartz-poor volcanolithic (Walloons) sandstones. This has decreased the mapped extent and thickness of Walloon Coal Measures.

(b) The feldspathic Maclean Sandstone Member has been shown to occur more widely than previously realized along both margins.

The Kangaroo Creek Sandstone and Grafton Formation have been adequately mapped in previous reconnaissance studies although the extent of the Grafton Formation has probably been underestimated. A significant field of Tertiary magnetic, trachytic-basaltic volcanics (flows, volcanoclastics, intrusives) occurs east of Baryulgil which is more extensive than previously realised.

WEST
MARGIN

EAST
MARGIN

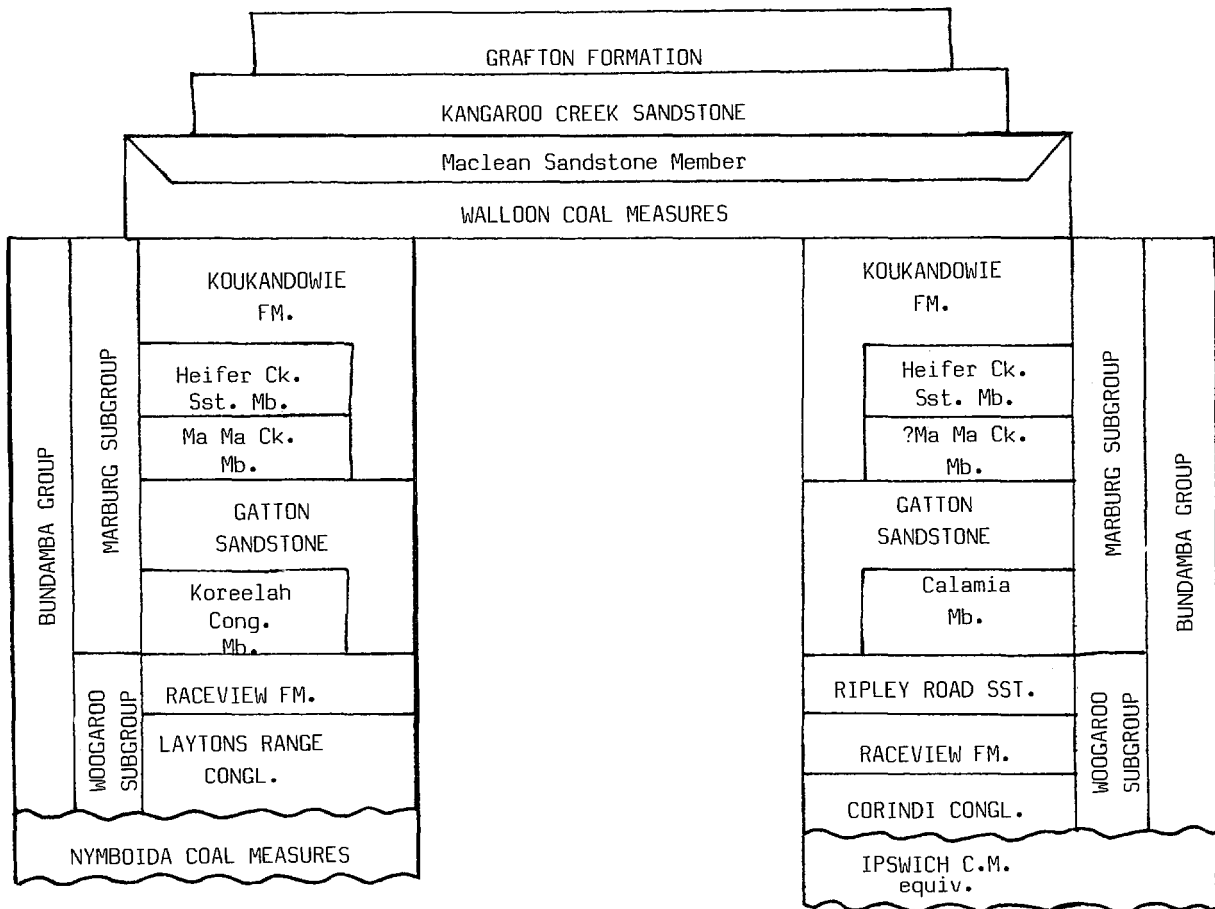


Figure 1. Schematic outline of the lithostratigraphy at the east and west basin margins, southern Clarence-Moreton Basin, N.S.W.

SEDIMENTATION STYLES IN THE CLARENCE-MORETON BASIN

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The non-marine sediments of the Bundamba Group in the Clarence-Moreton Basin are divided into units that reflect their detrital composition and sedimentation style. The major units are:

1. The Raceview Formation and Aberdare and Layton's Range Conglomerates which represent deposition in highland valleys and basin margin braidplains that pass out into low-gradient suspended load streams in the sub-basin axes.
2. The Ripley Road Sandstone which is a sheet of quartzose sandstone deposited by braided streams.
3. The Gatton Sandstone replaces the Ripley Road Sandstone with a change to labile detritus and some rearrangement of palaeocurrents although braided streams persisted. The transition between the two units takes place in the Calamia Member of the Gatton Sandstone which contains a higher proportion of floodplain mudstone than the Ripley Road or Gatton Sandstones.
4. The Ma Ma Creek Member of the Koukandowie Formation represents a change from sandy braided streams to deposition in a flood plain with extensive lakes and swamps and sinuous and vertically aggrading streams.
5. These muddy environments were then replaced by braided streams carrying quartzose sand that deposited the Heifer Creek Sandstone Member of the Koukandowie Formation.
6. In the eastern half of the basin, the Heifer Creek braided streams were replaced by

sinuous channels carrying labile detritus and more extensive floodplains.

7. The change from the Bundamba Group to the Walloon Coal Measures is marked by a major influx of volcanolithic detritus. The alluvial plain consisted of meandering channel belts flanked by levees and crevasse splays and separated by shallow floodbasins and peat-forming wetlands.

The Walloon Coal Measures depositional system was then replaced by braided streams that deposited the Kangaroo Creek Sandstone. It forms a sheet of cross bedded quartzose sandstone. In places, the Walloon Coal Measures were partly eroded prior to Kangaroo Creek deposition. The Kangaroo Creek Sandstone is overlain by the Grafton Formation which is composed of labile sandstones and abundant floodplain mudstone.

Some changes in both composition and depositional style can be related to tectonic uplift of the hinterland and basin subsidence variations. The replacement of the Ripley Road Sandstone by the Gatton Sandstone and the change in the eastern part of the basin to the upper Koukandowie Formation fall into this category. A rise in eustatic base level was the probable cause of the Gatton Sandstone - Ma Ma Creek Member transition and the Raceview Formation - Ripley Road and Ma Ma Creek - Heifer Creek changes probably reflect cyclic adjustments of the fluvial systems to accommodate the tectonic and base level changes.

Potential source rocks and seals are most common in the finer-grained units such as the Calamia Member, which may provide a seal for the Ripley Road Sandstone, the Ma Ma Creek Member, which may seal some porous and permeable channel sandstones in the top of the Gatton Sandstone and in the Koukandowie Formation, in which interbedded mudstones may seal and source sandstone bodies making up the Heifer Creek Member. The Walloon Coal Measures abundant coal and organic-rich floodplain mudstone but have little reservoir potential. The Kangaroo Creek Sandstone and Grafton Formations are probably too widely exposed to have trapped hydrocarbons.

ORIGIN AND SIGNIFICANCE FOR REGIONAL CORRELATION OF EARLY JURASSIC IRON-RICH OOLITE IN THE BUNDAMBA GROUP

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Iron-rich oolitic sequences are present in the rock record from the Proterozoic to the Holocene. The depositional environments of these sequences are marine and continental. In Europe, ferruginous oolite is known from rocks of Devonian, Ordovician, Carboniferous, Late Triassic and Jurassic age. The greatest volume of literature is on oolites of Jurassic age. Jurassic oolites are coincident with high sea levels. It is also likely that the Early Jurassic oolite deposition in southeastern Queensland and New South Wales is coincident with a high sea level.

Iron-rich oolite beds are present in the Surat, Mulgildie, Clarence-Moreton, Nambour and Maryborough Basins in southeast Queensland. Beds of oolite are of variable thickness are present in the different basins. The most persistent iron-rich oolite bed forms a basin-wide Early Jurassic marker. This marker has been determined by palynological evidence as isochronous. In the Clarence-Moreton Basin the oolite occurs within the Ma Ma Creek Member of the Koukandowie Formation, Marburg Subgroup.

In the Clarence-Moreton Basin, oolite intervals stratigraphically higher than the isochronous marker bed have been found in GSQ Ipswich 18 and 24. Three beds of oolite are present in GSQ Ipswich 18 (74.93 m, 176.48 m and 378.26 m). In GSQ Ipswich 24, beds of oolite are present at 1018 and 1034.79 m. The upper beds in GSQ Ipswich 18 (176.48 and 74.93 m) and the upper bed in GSQ Ipswich 24 (1018 m) are much thinner (<10 cm) than the isochronous marker bed and have a similar mineralogy. They represent a similar depositional environment later in the Jurassic.

Representative samples from selected areas in the basins were analysed using the following techniques in order to define their mineralogy and environment of deposition.

The methods of investigation of surface and subsurface oolite samples included:

- (1) Detailed core logging of sections containing the oolite unit;
- (2) Thin section petrology of surface and subsurface oolite;
- (3) X-ray power diffraction of individual ooids and whole rock oolite samples;
- (4) Scanning electron microscopy of subsurface oolite samples;
- (5) Qualitative elemental analysis on ooids and cement using the Energy Dispersive Spectrometer.

Subsurface iron-rich oolites are composed dominantly of quartz-rich ooids bound together by a siderite cement. Surface oxidation of the oolite has produced a rock dominated by quartz, goethite and haematite; hence this band is described as a ferruginous oolite. Table 1 compares the mineralogy of oolite and ooids from coreholes and surface samples.

Formation of oolite involved a complex multistage process which included primary ooid formation under oxidising conditions. Burial and changes of Eh and pH from oxidising acidic to reducing, alkaline conditions produced pyrite and siderite during the early stages of diagenesis. In the subsurface the ooids are dominantly quartz-rich and set in a siderite cement. Authigenic berthierine may have been produced during these early stages or later following deeper burial. The presence of berthierine in the oolite interval in GSQ Ipswich 24 is similar to occurrences in Triassic coal measures in Japan. The occurrence of berthierine in samples from the Clarence-Moreton Basin is due to authigenic processes and does not infer a marine origin. Surface oxidation converts siderite to goethite and haematite. Periodic emergence and the formation of palaeosols are recognised.

The oolites formed in a lacustrine environment in a broad flood plain with interspersed marshes. Sporadic flooding events occur above and below the oolite marker bed. A Lake Chad-style model is favoured for the formation of the oolites. The Ma Ma Creek Member above and below the oolite represents a continental flood-plain deposit.

Table 1. Mineralogy of oolites and ooids, Clarence-Moreton Basin (+ + = dominant; + = minor, tr = trace)

WELL	DEPTH (m)	SAMPLE	QUAR TZ	SIDER ITE	SMECT- ITE	KAOLI- NITE	CHLOR- ITE	BERTHI ERINE	PYRITE	FELDS PAR	HEMA TITE	GOETH ITE	CALCITE	NATRO- JAROSITE
GSQ Ipswich 18	74.93	oolite	++	++	-	+	+	-	tr	-	-	-	-	-
GSQ Ipswich 18	"	ooids	++	-	-	-	+	-	-	-	-	-	-	-
GSQ Ipswich 18	176.48	oolite	++	++	tr	-	tr	-	-	+	-	-	-	-
GSQ Ipswich 18 (marker bed)	378.26	"	+	++	+	-	tr	-	tr	-	-	-	tr	tr
GSQ Ipswich 24 (marker bed)	1034.79	ooids	++	tr	++	-	?++	-	-	-	-	-	-	-
Ma Ma Creek outcrop	surface	oolite	++	-	-	++	-	-	-	-	+	++	-	-
Outcrop	surface	oolite	++	-	-	-	-	-	-	-	tr	++	-	-

THE MIDDLE JURASSIC WALLOON COAL MEASURES IN THE TYPE AREA, THE ROSEWOOD-WALLOON COALFIELD, SE QUEENSLAND

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In the Rosewood-Walloon Coalfield, the Middle Jurassic Walloon Coal Measures are represented by an erosionally truncated sequence of interbedded clastic sedimentary rocks and coals totalling up to 250 m in thickness. Coal has been mined by mostly underground methods since 1881, although more recent mining has utilised open cut/open pit methods. Natural exposures are rare, but excellent exposure has been created by open pit mining, and a substantial amount of borehole core is available from the area.

Using data from open pit mines and boreholes, a facies analysis of the Walloon Coal Measures has been undertaken. Three facies associations have been recognised; A, comprising major channel sandstone bodies, B, comprising four facies of interpreted floodplain origin, and C, comprising organic-rich and bentonite facies representing mire environments. Bentonites are interpreted as diagenetically altered ash falls which accumulated in peat swamp environments. Coal seams, which are of high-volatile bituminous rank, are mostly up to 2 m thick and display complex regional geometry in three dimensions.

The sequence is interpreted as the deposits of an extensive alluvial plain which was crossed by meandering channels of variable dimensions. Between major channels were shallow floodbasin environments and on inactive parts of the plain were peat-forming wetlands (mires). Periodic volcanic eruptions showered ash across the area, which was preferentially preserved in mire environments. The described sequence forms part of a vast alluvial drainage system which occupied the Great Artesian Basin during Middle Jurassic times.

THE PALYNOLOGICAL RECORD OF THE CLARENCE-MORETON BASIN

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The sedimentary sequence of the Clarence-Moreton Basin is dated on evidence accumulated by regional palynological studies by several workers dating back 30 years, and on possible eustatic evidence (Fig. 1). The following biostratigraphic relations and geological ages are proposed for individual formations.

Woogaroo Subgroup

The Aberdare and Laytons Range Conglomerates and Raceview Formation are associated with Assemblages A and B, and dated latest Triassic (Rhaetian). The Ripley Road Sandstone (incorporating the 'Helidon Sandstone') is associated with Assemblages A, B, C, and D, and is dated latest Triassic (Rhaetian) to earliest Jurassic (?Pliensbachian).

Marburg Subgroup

The Gatton Sandstone is associated with Assemblages C and D, and Unit J2-3, and is dated Early Jurassic (?Sinemurian-?Toarcian). The Koukandowie Formation is associated with Assemblage D, Unit J2-3, and Unit J4, and dated Early Jurassic (?Pliensbachian) to basal Middle Jurassic (Aalenian).

Youngest Sequence

The Walloon Coal Measures is associated with Unit J4 and basal Unit J5-6, and dated Middle Jurassic. The Kangaroo Creek Sandstone is associated with Unit J5-6, and the Grafton Formation with Unit J5-6 and the lower *Cicatricosisporites australiensis* Zone. The fossil evidence is very tenuous and suggests a Middle to Late Jurassic age for the two formations.

Evidence of eustasy as an independent means of age determination is scarce, and is thought to have been masked by tectonism during the final phase of the New England Orogeny. Possible indications of movements of local pre-Mesozoic structural units,

and along the West Ipswich Fault are suggested by the apparently time-discordant character of several strata units, such as the Gatton and Koukandowie Formations, and the presence of hiatuses within the Ripley Road Sandstone.

However, it is suggested that the post-orogenic mudstone/sandstone/siltstone cycle of the Walloon/Kangaroo Creek/Grafton sequence may have been eustatically induced. By linking that sequence with global Jurassic sea level movements the Walloon Coal Measures and Kangaroo Creek Sandstone are tentatively dated Middle Jurassic (Bajocian-Bathonian and Bathonian-Callovian), and the Grafton Formation Middle to Late Jurassic (Callovian-Tithonian). These ages fall within the present palynological estimates but need to be verified.

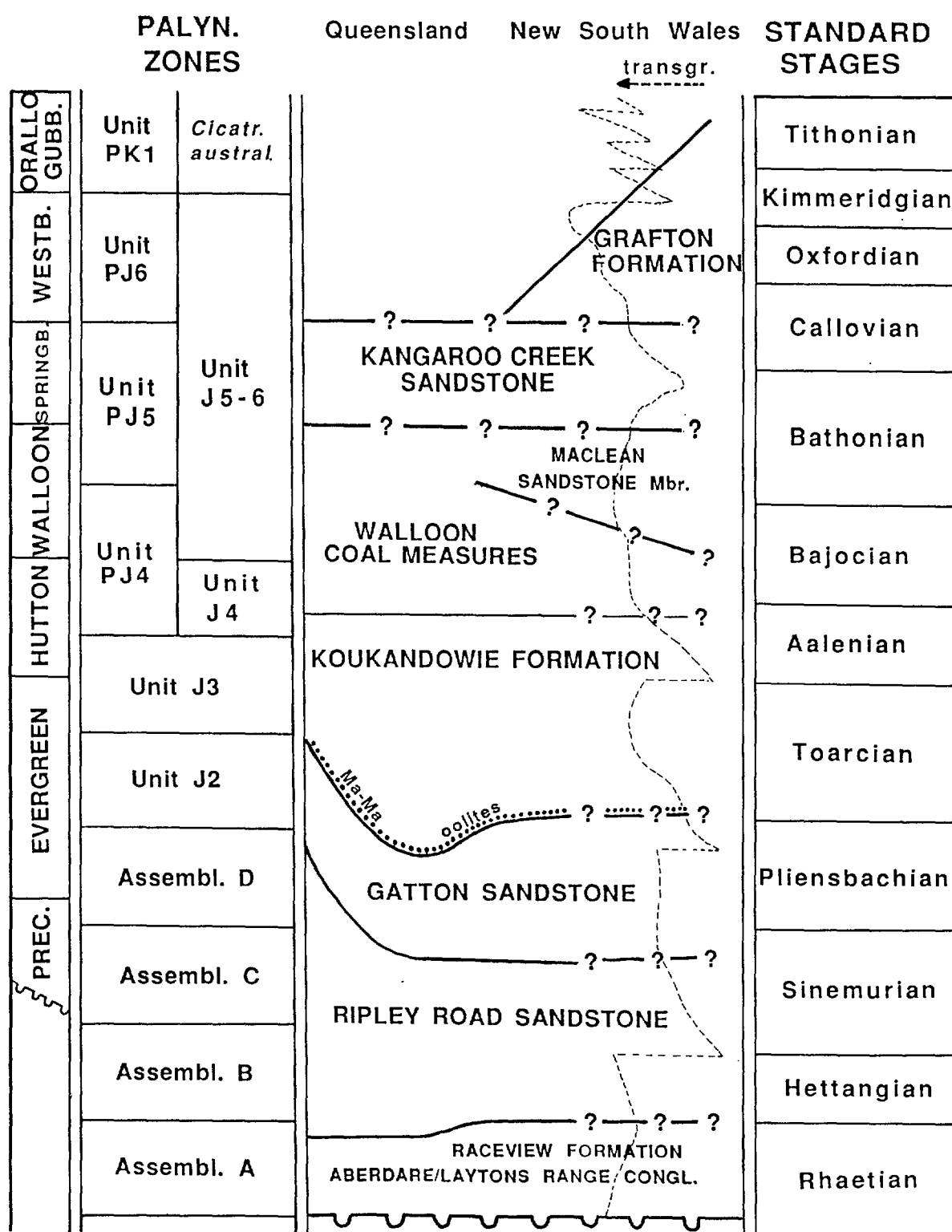


Figure 1. Proposed zonal relationships and geological ages of Clarence-Moreton Basin formations, based on palynology and eustasy (global sea level curve of Haq & others, 1989).

ORGANIC PETROLOGY OF SEDIMENTS IN THE CLARENCE-MORETON BASIN

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The organic petrology of sediments in the Triassic-Jurassic Clarence-Moreton Basin has been studied as part of the BMR-CSIRO project to evaluate the petroleum potential of the basin. Both coals and dispersed organic matter (DOM) could be potential sources for oil and the prospectivity of each has been assessed using organic petrography. A total of 220 samples from the Walloon Coal Measures, Marburg Subgroup, Woogaroo Subgroup and Ipswich Coal Measures were examined.

Results of the maceral analyses on coals and DOM were plotted on triangular diagrams and the points were density contoured. The maceral compositions of the concentration centres of these density contours are given below: (Figures in parentheses show number of analyses on which results are based).

Interval	Type of Organic matter	Vitrinite	Liptinite	Inertinite
Walloon Coal Measures (all samples)	(35) Coal	80	20	0
	(66) DOM	90	10	0
Walloon Coal Measures (east omitted)	(35) Coal	80	20	0
	(51) DOM	90	10	0
	DOM	65	30	5
Marburg Subgroup (all samples)	(30) Coal	90	10	0
	(59) DOM	65	30	5
Marburg Subgroup (Ipswich area)	(11) Coal	85	15	0
	(20) DOM	20	70	10
Marburg Subgroup (North, NSW)	(15) Coal	90	5	5
	(22) DOM	65	30	5
Woogaroo Subgroup	(5) Coal	90	0	10
	(19) DOM	55	10	35
Ipswich Coal Measures	(22) Coal	80	0	20
	(28) DOM	50	20	30

The coals from the Triassic-Jurassic sequence are vitrinite-rich, and of a similar composition to coals in the oil-producing Gippsland Basin. DOM throughout the

sequence contains more liptinite and less vitrinite than associated coals (except for some Walloon Coal Measures DOM) (Fig. 1).

The most liptinite-rich DOM occurs in sediments of the Marburg Subgroup from the Ipswich area, where the rank of the organic matter is immature to marginally mature for oil generation.

The liptinite in the coals and DOM is composed of sporinite, liptodetrinite and suberinite with minor cutinite, resinite and alginite.

Coals and DOM are associated in "organic facies" and their compositions are related to their palaeodepositional environments. Unfortunately, the relationships between organic types and environments have not yet been established for these sediments, but relationships between coals and DOM have been. DOM has a higher liptinite content than associated coals by around 20-30%, in general, being more or less in particular areas. Irrespective of maturity, the source potential of the DOM would seem to be greater than that of associated coals, although the major liptinite in DOM, sporinite, has a lower potential than suberinite, which is dominant in the Jurassic coals, in particular. Organic matter in the Ipswich area would appear to have the best source potential, on the basis of type, but not maturity.

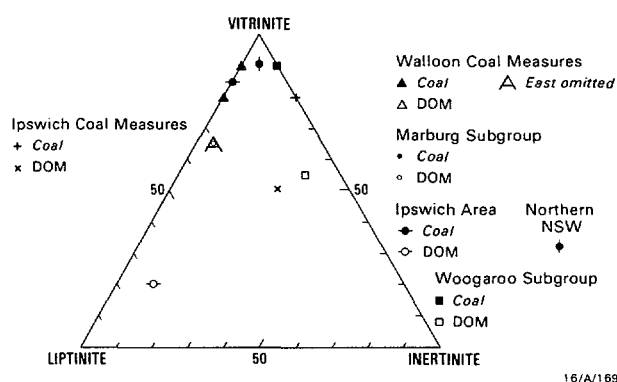


Figure 1. Maceral compositions of centres of density contours.

A PALEOGEOTHERMAL STUDY OF THE CLARENCE-MORETON BASIN

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Acceptance of the concept that mean average reflectivity ($R_{m_0}\%$) of vitrinite constitutes an absolute maximum paleogeothermometer, for a heating duration in excess of 1 Ma (Barker, 1983; Price, 1983; Barker & Pawlewicz, 1986), permits conclusions to be drawn, based on vitrinite depth/ $R_{m_0}\%$ data trends, concerning aspects of the paleogeothermal history of the Clarence-Moreton Basin. Interpolation and extrapolation of the vitrinite depth/ $R_{m_0}\%$ profiles allows estimates to be made of the maximum paleotemperature for a given interval, the thickness of any section lost by uplift and erosion, and the maximum paleogeothermal gradient. The latter can be used to make estimates of the maximum paleoheat flow density, provided that certain assumptions are made in respect of the bulk thermal conductivity of the sedimentary section.

Vitrinite depth/ $R_{m_0}\%$ parameters have been derived for nineteen boreholes by linear least squares regression of depth/ $R_{m_0}\%$ data pairs. The logarithmic depth/ $R_{m_0}\%$ gradient (m) values for these boreholes fall in the 0.18-0.24 range. The extrapolated values for the vitrinite $R_{m_0}\%$ surface intercept (S) range from about 0.3% in the western part of Clarence-Moreton Basin, in Queensland, to values that exceed 1.0% in the southeastern part of the basin in northeastern New South Wales. Clearly, the bulk of the oil window ($R_{m_0} = 0.5-1.3\%$) has been exhumed in the southeastern part of the basin, whereas in the western part of the basin the onset boundary of the oil window is still below the present-day surface. Estimates of the thickness (H) of the section, lost by uplift and erosion, depend on the (m) and (S) values and the value selected for the original surface vitrinite $R_{m_0}\%$; the latter is usually in the 0.18-0.20% range. Assuming an original value of 0.2% for vitrinite $R_{m_0}\%$ at the surface, estimates for (H) range from less than 1 km in the western part of the basin to in excess of 3 km in the southeastern part of the basin.

Estimates of the maximum paleotemperature (T_{mpt}) for a given interval can be made directly from vitrinite $R_{m_0}\%$ using the Price (1983) vitrinite $R_{m_0}\%$ /maximum

paleotemperature relationship. For example, in the western part of the basin T_{mpt} estimates at the top of the Middle Jurassic Walloon Coal Measures fall in the 40-80°C range, whereas in the southeastern part of the basin the corresponding T_{mpt} values are in excess of 125°C. Estimated T_{mpt} values for the top of the Basal Jurassic/Late Triassic Ripley Road Sandstone range from about 100-130°C in the western part of the basin to 210-270°C in the southeastern part of the basin. The top of the Upper Triassic Ipswich Coal Measures yields estimated T_{mpt} values ranging from 135-155°C in the western part of the basin to 270-300°C in the southeastern part of the basin.

Estimates of maximum paleogeothermal gradient (G_{max}) range from 55 to 74°C/km, with higher values, i.e. 64-74°C/km, tending to occur in the southeastern portion of the basin. Assuming that the Clarence-Moreton Basin and any overlying, but now eroded, sedimentary section are dominated by clastic rocks, with a typical clastic rock bulk thermal conductivity 2.09 W/mK, these G_{max} values imply maximum paleoheat flow density (Q_{max}) values of 115-154 mW/m².

T_{max}, and other Rock-Eval pyrolysis parameters, are often used to estimate vitrinite R_{m0}%, and the level of thermal maturity, in those instances where vitrinite R_{m0}% data are not available or are not considered reliable. The relationship between T_{max} and vitrinite R_{m0}% is examined and compared with the IFP trends reported in the literature. The T_{max}/vitrinite R_{m0}% relationships for many of the boreholes approximates the IFP Type III kerogen trend. However, it is clear that, although T_{max} values can be used for estimating the vitrinite R_{m0}%, independent corroboration of the level of thermal maturity is essential.

The results obtained for the Clarence-Moreton Basin are consistent with paleogeothermal studies reported for other sedimentary basins that are located along the eastern margin of Australia, e.g. Sydney Basin, Gunnedah Basin/Coonamble Embayment (Surat Basin), Bowen Basin, etc. thereby providing an insight into the overall paleogeothermal history of eastern Australia.

STRUCTURE OF THE CLARENCE-MORETON BASIN FROM SEISMIC REFLECTION INTERPRETATION AND FISSION TRACK THERMOCHRONOLOGY

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Structural Model

The Clarence-Moreton Basin is set within the New England Orogen which was dominated by strike-slip faulting from the Early Permian onwards. Seismic reflection profiles across the basin show that transtension along dextral strike slip-faults initiated basin formation beneath the Esk Trough as early as Late Permian (Fig. 2). In the Early Triassic, the strike-slip faulting moved eastward to the site of the present Ipswich Basin and Logan Sub-basin. The geometry of the Esk Trough and Laidley Sub-basin is simple, controlled by transtension along one major fault, the West Ipswich Fault. The Logan Sub-basin, however, formed by the interaction of several intersecting dextral faults with smaller splays so that the basin contains a complex set of basement highs and lows (Fig. 1). After transtension ceased, subsidence because of thermal relaxation led to deposition of the Esk Trough, Ipswich Basin and finally the Clarence-Moreton Basin. Dextral strike-slip continued on the major basin-forming faults producing positive flower structures along the South Moreton Anticline, the Coraki Fault and thrusting along the Coast Range Fault (Figs. 1 & 3).

Fission Track Thermochronology

The apparent apatite fission track ages from outcrops scattered across the basin and surrounding basement fall into three groups (Fig. 4). The northwestern part of the basin shows older ages (about 160 Ma), the east-central part shows ages in the 70 to 90 Ma range and the eastern margin shows ages between 50 and 60 Ma. Superimposed on this regular regional pattern are numerous apparent ages of about 20 Ma with mean track lengths > 14 μ m. These are clearly related to Tertiary volcanism and mostly come from

the areas of maximum Tertiary volcanic activity, though not exclusively. The regional pattern of decreasing apatite age towards the coast is similar to that for southeastern Australia and is probably the result of heating associated with the opening of the Tasman Sea. The Clarence-Moreton samples are younger, probably because of their position on the rift margin, and show different track length distributions, probably because of slower cooling than in southeastern Australia.

Timing of Structural Development

The pattern of apparent apatite fission track ages suggests that maximum heating of the basin took place just prior to and during opening of the Tasman Sea. Shaw (1978) demonstrated sinistral movement along the margin during opening. It is unlikely that the dextral strike-slip movements would continue in the basin concurrent with sinistral, transtensional movement just to the east. Therefore, dextral movement ceased some time in the Cretaceous when the locus of movement shifted east to sinistral faults on the continental margin. This suggests that structures formed by dextral movement pre-date maximum thermal maturity and therefore were in place to receive migrating hydrocarbons.

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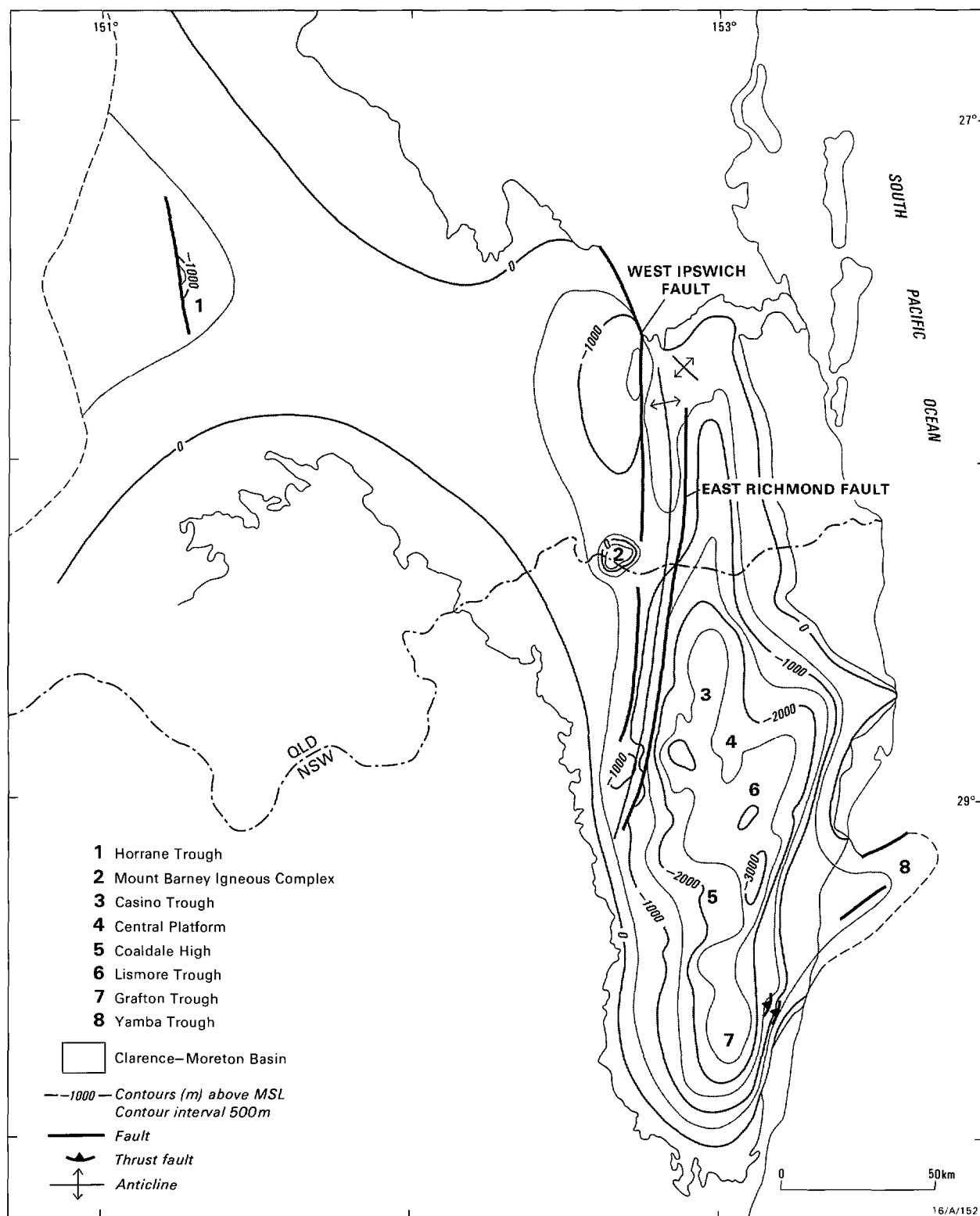


Figure 1. Location and major structures of the Clarence-Moreton Basin. Structures contours show the depth to the base of the basin sequence.

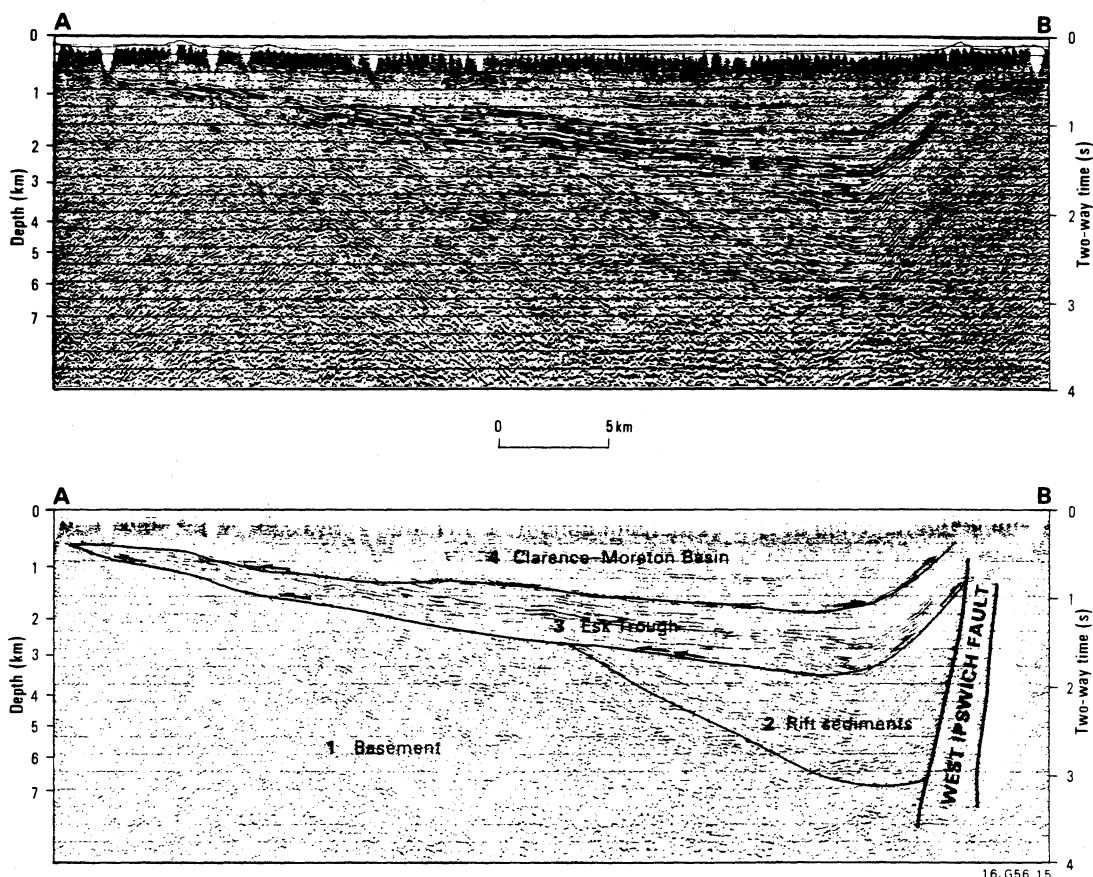


Figure 2. Unmigrated seismic reflection profile across the Esk Trough. Profile shown is a portion of BMR seismic traverse 16 (Fig. 1), a six-fold common depth point, 20 s record length, dynamite source, split spread with 2 km far offset profile. The seismic sequences are: 1. Basement (pre-rift Cressbrook Creek Group), 2. Rift sediments and volcanics, 3. Esk Trough sequence (Toogoolawah Group), and 4. Clarence-Morton Basin sequence (Bundamba Group and Walloon Coal Measures). Arrows indicate direction of onlap. Arbitrary seismic datum is approximately 250 m above sea level. Note that it is above ground elevation which is shown by an irregular profile at the top of the section. Depth scale is from seismic datum.

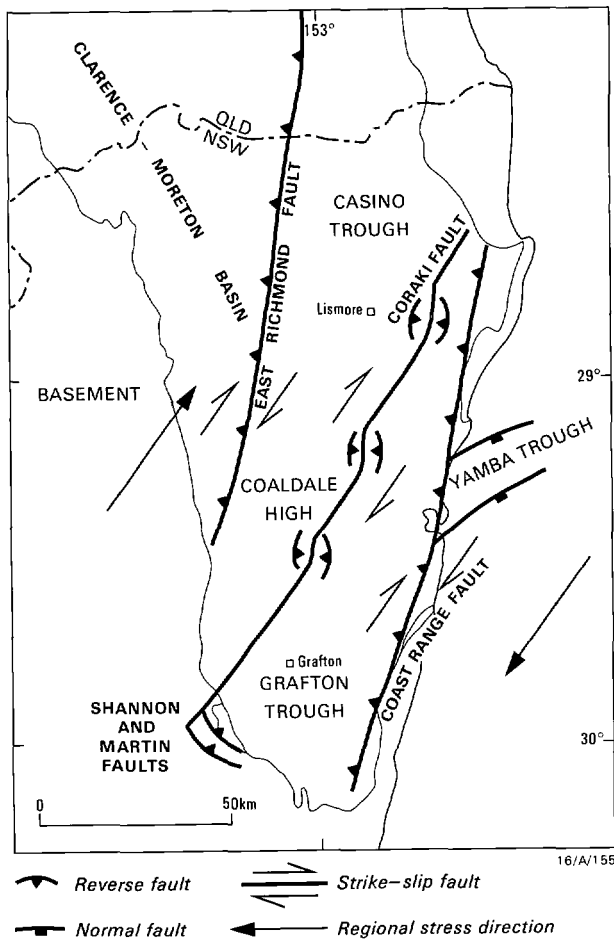


Figure 3. Tectonic model for the southern Logan Sub-basin. West dipping thrust on the East Richmond and Coast Range Faults indicate transpressional movement, the discrete flower structures on the Coraki Fault suggest dextral movement with thrusting and folding on restraining bends or side steps. The regional stress direction is that necessary to produce the sense of movement seen on the major faults. The deeper parts of the Logan Sub-basin occupy zones of diverging faults whereas the Coaldale High occupies the zone where the East Richmond and Coraki Faults converge. In this interpretation, the Yamba Trough is a pull-apart basin formed between splay faults of the Coast Range Fault and the Martin and Shannon Faults are thrust faults splaying from the Coraki Fault.

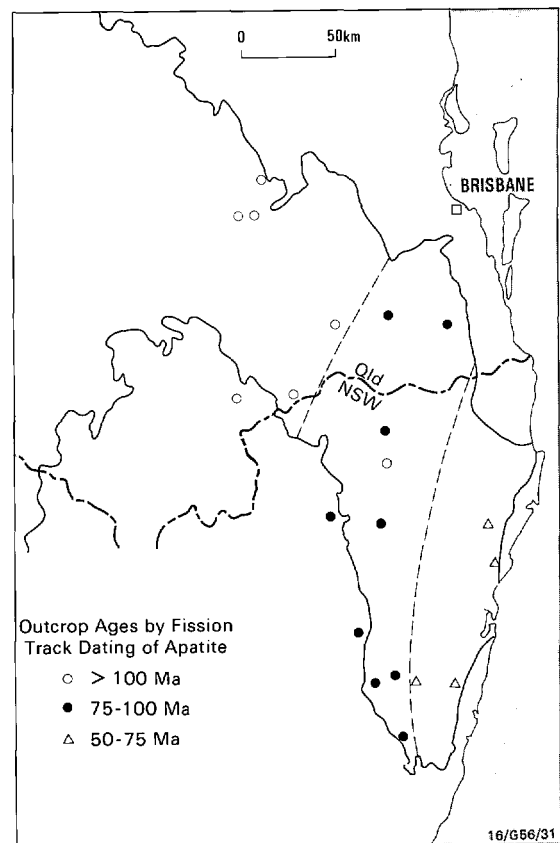


Figure 4. Distribution of apparent apatite fission track ages for samples unaffected by Tertiary intrusions. Samples affected by intrusions are concentrated in the state border region

PETROLEUM PROSPECTIVITY OF THE CLARENCE-MORETON BASIN: A GEOCHEMICAL PERSPECTIVE.

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This re-evaluation of the petroleum source potential of the Clarence-Moreton Basin employs Rock Eval and TOC data from 400 samples from 82 bores and some fresh surface exposures (Figs. 1). Previous work indicated that, of the older sequences beneath the Clarence-Moreton, only the Ipswich Coal Measures seems to have significant hydrocarbon source potential, and then as a gas source. Therefore sampling concentrated on the Walloon Coal Measures and Bundamba Group to investigate the potential for oil generation.

Source rock abundance

The Walloon Coal Measures contain the largest proportion of fine grained facies with the Ripley Road Sandstone being the sandiest unit. Walloon shales and coals have the highest TOC followed by the Koukandowie Formation.

Potential reservoirs

Porous and permeable sandstone is present in the Ripley Road Sandstone, the Heifer Creek Member of the Koukandowie Formation, the top of the Gatton Sandstone and in the Raceview Formation (Fig. 1). The Kangaroo Creek Sandstone also contains porous and permeable sandstone but crops out extensively and is unlikely to have trapped hydrocarbons.

Source rock quality

Rock Eval pyrolysis data show that the coals and carbonaceous shales of the Clarence-Moreton Basin contain oil-prone terrestrial organic matter that are at least as rich as their equivalent sediments of the Eromanga Basin (Fig. 2). The Walloon coals are classified as Type II/III organic matter. These hydrogen-rich coals are not confined to the Walloon Coal Measures but occur throughout the Clarence-Moreton sequence.

Elemental analysis and pyrolysis gas chromatography of kerogens isolated from selected samples confirms the conclusions drawn from Rock Eval analyses.

Evolution of Petroleum Generation Index (PGI) and Petroleum Expulsion Efficiency (PEE)

PGI is the proportion of labile kerogen in a sample that has been converted into petroleum. PEE is the proportion of generated hydrocarbons that have been expelled from the source rock. Both PGI and PEE are calculated by comparing averaged Rock Eval and extract data of a source rock interval of a given maturity with an immature equivalent of the source rock (Cooles & others, 1986).

The Walloon Coal Measures do not begin to generate significant amounts of oil until vitrinite reflectance reaches 0.75% R_o . Hydrocarbon generation is then extremely rapid with most oil generated between 0.8% R_o and 1.0% R_o . Therefore the zone of effective oil generation and migration is very narrow. During the early stages of hydrocarbon generation, expulsion is relatively inefficient. At PGI = 0.16, the PEE is 25% but rises to 75% at PGI = 0.5.

Source rock maturity

Vitrinite reflectance and Tmax data (from Rock Eval) indicate a progressive increase in source rock maturity from west to east. The Walloon Coal Measures are immature on the western part of the basin but reach oil generating levels in a narrow belt in the east. They are overmature for oil generation along the eastern basin margin (Fig. 3).

Units beneath the Walloon Coal Measures are more mature so that the Raceview Formation is in the oil generating zone where the Walloons are immature.

Fission track ages of apatites from surface samples show higher basin temperatures in the east with original rock ages in the west giving way to progressively younger reset ages in the east. These reset ages in the range of 50 to 100 Ma suggest that maximum temperatures and burial depths were reached in the Late Cretaceous to Palaeocene. Most structural traps were in place by that time.

Burial history

Burial history of the Shannon-1 well was modeled using the program MATOIL. A model consistent with the observed vitrinite reflectance profile requires 10 Ma of elevated heat flow (110 mW/m^2) probably during the late Cretaceous. Differences between model and observed profiles are probably caused by variations in rock conductivity from values assumed in the model.

Prospect evaluation

Major anticlines were evaluated by estimating the volume of source rocks in isorefectance slabs in probable drainage areas using isopach, structure contour and vitrinite reflectance maps. Where the Walloon Coal Measures are in the oil window, the rocks dip east (Fig. 1, O'Brien & others, this volume) whereas iso-reflectance surfaces dip west (Fig. 3). Hence Heifer Creek Sandstone Member reservoirs in most of the well known anticlines in the part of the Logan Sub-basin where the Walloon Coal Measures are in the oil window are fed mostly by over mature source rocks. Deeper reservoirs would have received gas only.

Conclusions

The Clarence-Moreton Basin has potential mainly for natural gas because of the narrow oil window of the abundant oil-prone source rocks and the opposing dips of bedding and iso-reflectance surfaces in the most prospective area.

References

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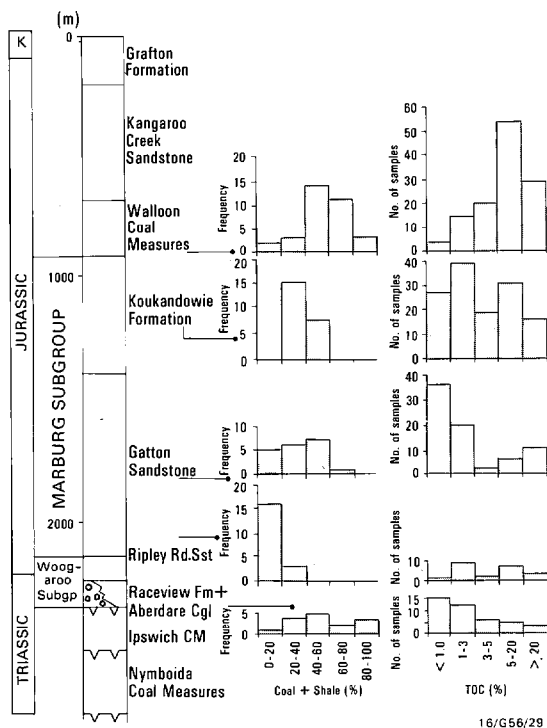


Figure 1. Stratigraphy of the Clarence-Moreton Basin. Oil-prone source rocks are most abundant in the Walloon Coal Measures and Koukandowie Formation. Ipswich Coal Measures contain gas-prone source rocks. Potential reservoir rocks are present in the Heifer Creek Sandstone Member, near the top of the Gatton Sandstone, in the Ripley Road Sandstone and the Raceview Formation.

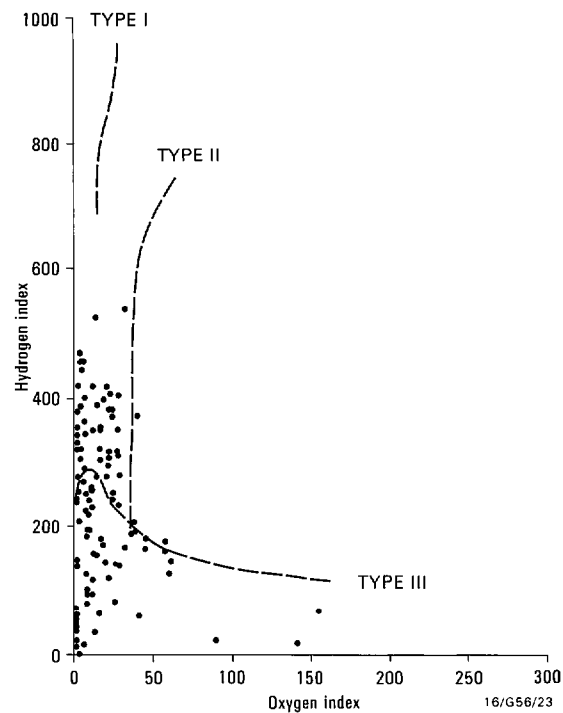


Figure 2. Classification of Walloon Coal Measures kerogen types based on Hydrogen and Oxygen Indices and distribution of Hydrogen Indices according to Tmax.

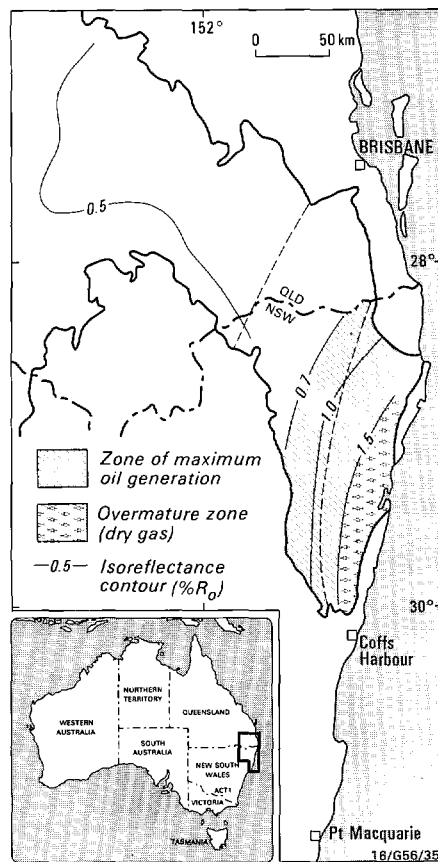


Figure 3. Thermal maturity of the Walloon Coal Measures increases from west to east. Zone of peak oil generation is a narrow belt along the western edge of the conventional oil generation zone.

PETROLEUM EXPLORATION - PEL 258, CLARENCE-MORETON BASIN, NSW

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PEL 258 is located in the central portion of the Clarence-Moreton Basin in northeastern New South Wales. A total of eight oil exploration wells have been drilled in the permit. Hogarth gas field discovered in 1970 and most of the wells drilled in the permit have had significant gas shows and some had minor oil shows.

Although lack of reservoir quality sandstone has been seen historically as the major exploration problem, a number of potential reservoir zones have been identified within the thick (14,000 ft in places) Mesozoic section.

Reservoir quality sandstones occur within the Late Triassic Ipswich Basin sequence (although this is largely untested); minor good reservoir developments occur within the Late Triassic Raceview Formation; the Early to Middle Jurassic Ripley Road Sandstone has thick porous intervals; the Early-Middle Jurassic Koukandowie Formation, specifically its Heifer Creek Sandstone Member, has good porosity and permeability in part; and sporadic reservoir development occurs in the Middle Jurassic Walloon Coal Measures.

Compressive forces in the Early Tertiary resulted in roughly north-south oriented thrust faults evident on seismic data and from surface mapping. A major strike-slip component is evident on a number of these faults (eg. Coraki). Rollover associated with these faults sets up exploration targets, such as Pickabooba and Coraki.

Drape over paleo-highs such as at Rappville also provide structural targets. Stratigraphic/structural plays requiring pinchout of Late Triassic Ipswich Basin reservoirs against Mid-Triassic highs have also been identified (eg. Rappville flanks).

Further seismic (approximately 40 km) is proposed over the Coraki and Pickabooba Prospects to mature to drillable status. The potential exists for development of the Hogarth gas field with seismic reprocessing and remapping required with a view to drilling appraisal wells to further evaluate and test Koukandowie Sandstone reservoirs. Further investigation of the large Rappville structure is also warranted.