BMR
COMP
1994/42
c. 2

ORIGIN OF PETROLEUM IN THE BOWEN AND SURAT BASINS: IMPLICATIONS FOR SOURCE, MATURATION AND MIGRATION

BMR PUBLICATIONS COMPACTUS
(NON—LENDING—SECTION)

BY CHRISTOPHER J BOREHAM

RECORD 1994/42

AUSTRALIAN GEOLOGICAL SURVEY ORGANISATION
LIBRARY
- 6 FEB 1995

AGSO

BMR
COMP
1994/42
C.2

Restricted

AGSO RECORD 1994/42

ORIGIN OF PETROLEUM IN THE BOWEN AND SURAT BASINS: IMPLICATIONS FOR SOURCE, MATURATION AND MIGRATION

By

Christopher J. Boreham

Marine, Petroleum and Sedimentary Geology Division
Australian Geological Survey Organisation, Canberra

A CONTRIBUTION TO THE
NATIONAL GEOSCIENCE MAPPING ACCORD PROJECT:
SEDIMENTARY BASINS OF EASTERN AUSTRALIA

© Australian Geological Survey Organisation 1994

R9404201

DEPARTMENT OF PRIMARY INDUSTRIES AND ENERGY

Minister for Resources: Hon. David Beddall, MP
Secretary: Greg Taylor

AUSTRALIAN GEOLOGICAL SURVEY ORGANISATION

Executive Director: Harvey Jacka

© Commonwealth of Australia 1994

ISSN: 1039-0073
ISBN: 0 642 21254 6

This work is copyright. Apart from any fair dealings for the purposes of study, research, criticism or review, as permitted under the *Copyright Act 1968*, no part may be reproduced by any process without written permission. Copyright is the responsibility of the Executive Director, Australian Geological Survey Organisation. Requests and inquiries concerning reproduction and rights should be directed to the **Principal Information Officer, Australian Geological Survey Organisation, GPO Box 378, Canberra City, ACT, 2601.**

Table of Contents

© Australian Geological Survey Organisation 1994

List of Figures

© Australian Geological Survey Organisation 1994

© Australian Geological Survey Organisation 1994

© Australian Geological Survey Organisation 1994

List of Tables

List of Appendices

© Australian Geological Survey Organisation 1994

ABSTRACT

A detailed regional geochemical study of over 70 oils and condensates, 11 natural gases and 130 core samples from potential source rocks enable resolution of the generation and migration history of petroleum in the Bowen and Surat basins. Biomarker analysis confirmed a pre-Jurassic source for the petroleum. Stable carbon-isotope analysis further indicated a Permian-sourced petroleum and was able to differentiate a very minor and localised Triassic source contribution. The dominant source for the petroleum is terrestrial land plants as well as a minor marine source influence. Lower delta plain and alluvial Permian coals show the higher liquid potential compared with upper delta plain facies. Initial liquid expulsion from the source rock occurred at vitrinite reflectance 0.65-0.7% and continued to Ro of 1.05%. This was followed by the main phase of gas generation between 1.05%<Ro<1.4%. The gas generation enabled remobilisation of liquid petroleum for further migration. Biodegradation occurred throughout the basins' petroleum migration history, resulting in an initial regional phase of heavy palaeobiodegradation followed by a second phase of more localised and less intense in-reservoir alteration.

INTRODUCTION

Regional Geology

The Bowen and overlying Surat Basins are situated in east-central Queensland and extend south into northern New South Wales. The Permo-Triassic Bowen Basin is an elongate basin, recognised as the northern continuation of the Bowen-Gunnedah-Sydney basin system, with a length of 900km extending from Collinsville in Queensland to Moree in New South Wales. It covers a total area of just over 200000km^2.

The Bowen Basin consists of two main depocentres, the Taroom and Denison Troughs although a smaller depocentre, the Arbroath Trough, occurs to the southwest of Roma. The largest of the troughs, the north trending Taroom Trough in the east contains up to 9000m of Permian and Triassic sediments (Figs. 1 and 2) and covers an area of approximately 50000km^2 (Hawkins et al., 1992). It is bounded to the west by the Wunger Ridge, Roma and Collinsville Shelves and the Comet Ridge. Its eastern limit is the structural eastern margin of the basin. To the west and separated from the Taroom Trough by the Comet Ridge, the north-northwest trending Denison Trough is 320km long and 60km wide. It is bound on the west by the Nebine Ridge and Springsure Shelf and on the north and south by the Capella and Roma Shelves, respectively. Deposition within the Denison Trough was most active during the Early Permian where sedimentation overlaid the Comet Ridge in the Early Permian and the Springsure Shelf in the Late Permian, providing continuity with the Taroom Trough and the Galilee Basin, respectively. The trough contains up to 6500m of non-marine and marine clastic rocks with the maximum thickness occurring in the southwest. More than 2700m of this is basal rift-fill which has not been penetrated fully by drilling (Gray, 1989).

© Australian Geological Survey Organisation 1994

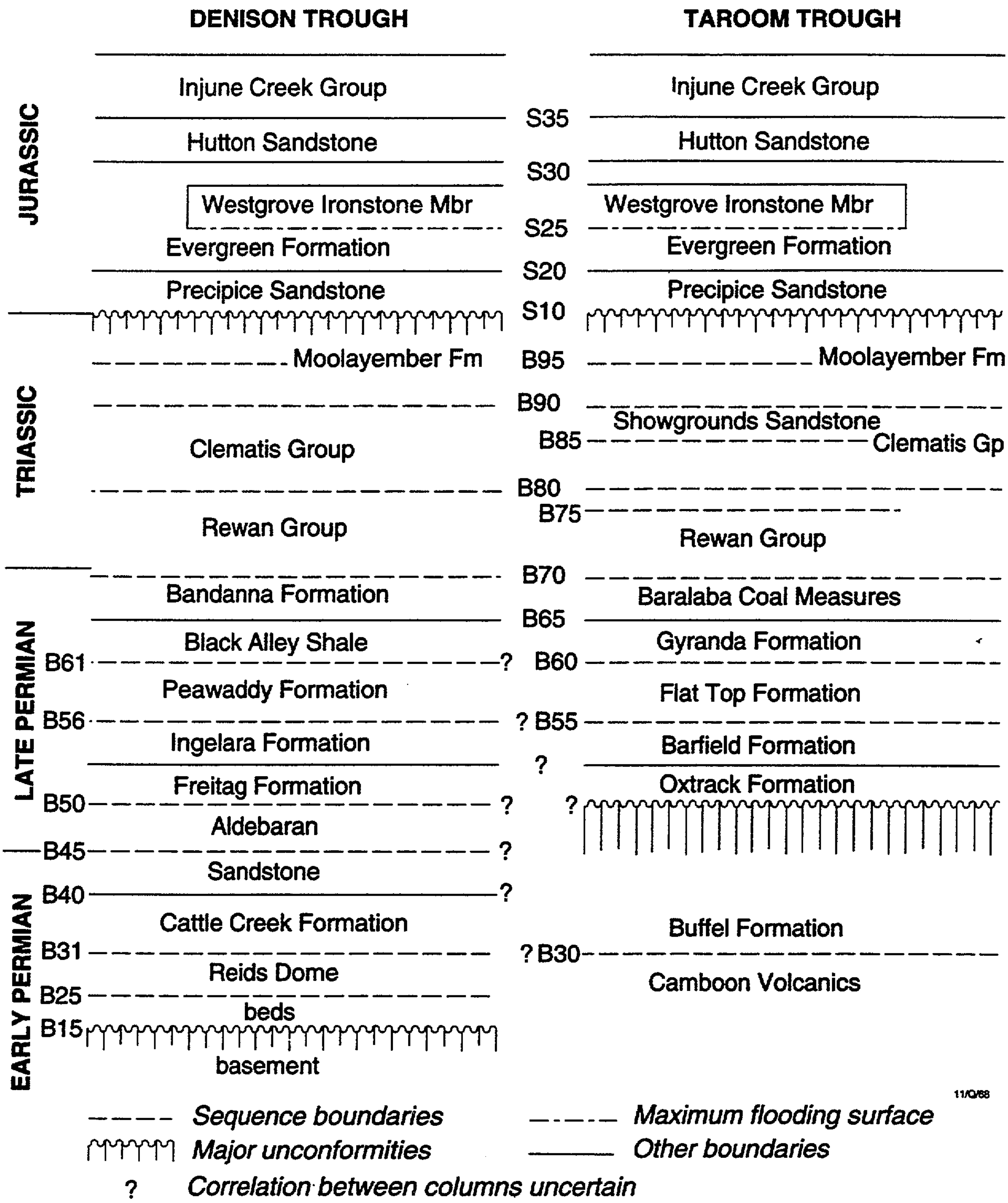


Figure 1. Stratigraphic column and sequence boundaries in the Bowen (Triassic and Permian) and Surat (Jurassic) basins (after Totterdell et al., 1991). In the Taroom Trough region the Blackwater Group is synonymous with the Baralaba Coal Measures whereas the Back Creek Group covers Gyranda Formation through to Buffel Formation.

© Australian Geological Survey Organisation 1994

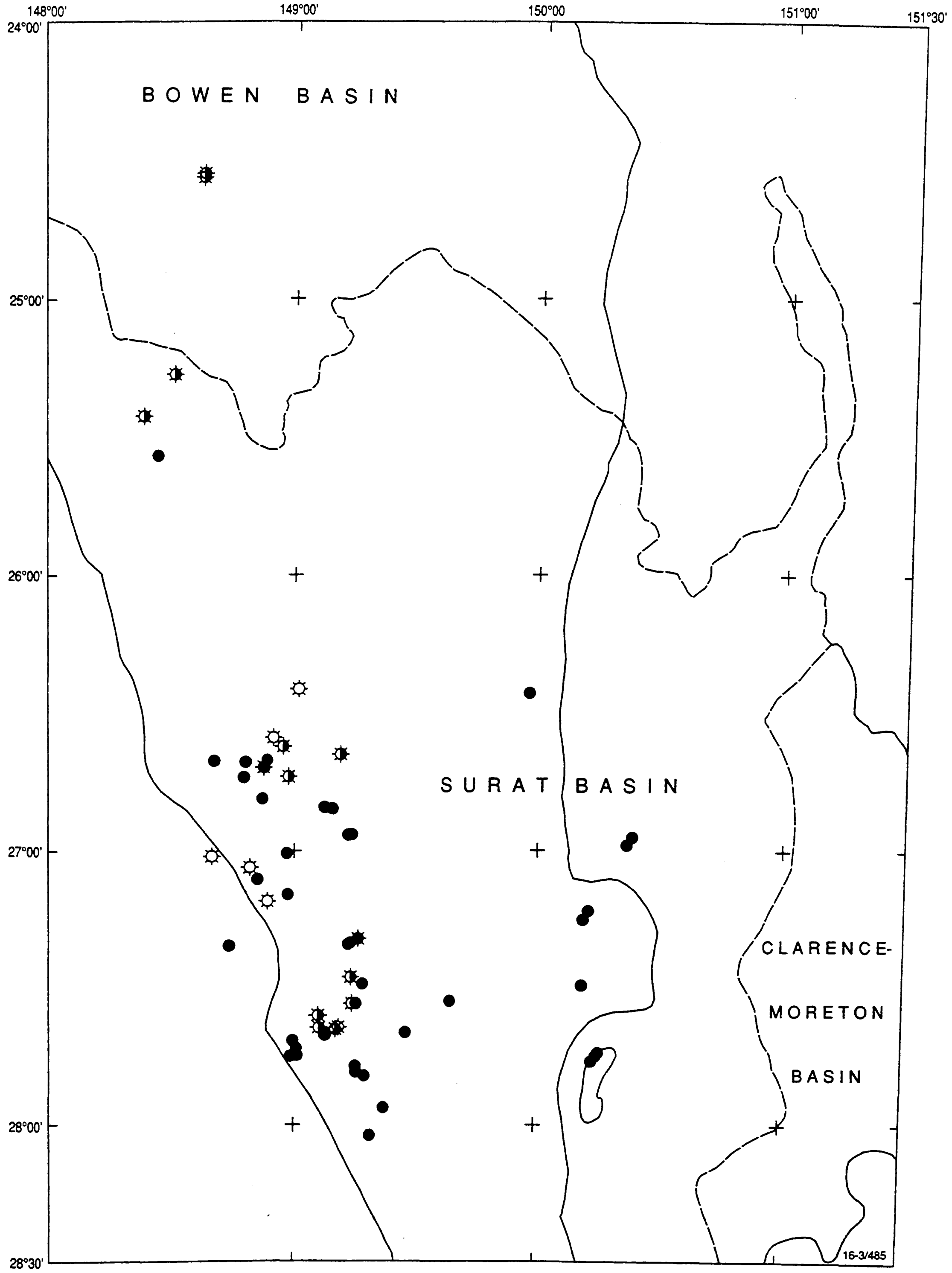


Figure 2. Location map showing the area and the extent of the Bowen and Surat basin. Symbols show the location of the petroleum samples (Tables 1 and 3) analysed in this study.

© Australian Geological Survey Organisation 1994

To the south the Bowen Basin is overlaid by the younger Surat Basin (Figs. 1 and 2) for about half the total area of each basin. It is an eastern arm of the more extensive East Australian Jurassic to Cretaceous depositional system. The Surat Basin is broadly meridional, extending for 800km between Taroom in the north and Dubbo in the south. At its widest it is about 450km and has a total area of 270000km^2 (Allen, 1976). The maximum section of about 2300m occurs in the Mimosa Syncline over the site of the Taroom Trough. The succession thins relatively gently by deposition and onlap onto the western shelves, to 1250m at Roma and 1520m at Riverslea on the Wunger Ridge. On the crest of the Nebine Ridge to the west of Roma, it is 600m. A similar relationship is shown with the eastern shelves where the section is 1800m at Moonie, thinning to 1150m on the Kumbarilla Shelf. The present northern limits are clearly erosional, and it is uncertain as to how far the sediments originally extended to the north, although it is assumed that sediment thickness decreased in a northerly direction (Mallett et al., 1990)

Basin Development and Depositional History

Bowen Basin

The stratigraphic sequences in the Bowen basin are summarised in Figure 1. The evolution of the Bowen Basin commenced in the Late Carboniferous or Early Permian through initial rift forming by back-arc extension, followed by a mid-Permian sag phase and then to a Late Permian-Middle Triassic foreland basin stage (Korsch et al., 1990; Murray, 1990).

Extension of the crust at the western margin resulted in rapid subsidence of the Denison Trough and the development of a series of tilted fault block, half grabens. The initial thick rift-fill was deposited in a complex alluvial fan, fluvial and marsh environment and resulted in the coal-bearing Reids Dome beds on the western shelf. Coal seams occur locally up to 25m thick (Gray, 1989). Contemporaneous volcaniclastic and associated sediments of the Camboon Volcanics were deposited along the eastern margin (Fig. 1).

The sag phase (post-extension thermal subsidence) associated mainly with the mid Permian, resulted in widespread marine transgression and regression cycles for the remainder of the Early Permian and for much of the Late Permian. The basin which was probably closed to the north and south saw the influx of the sea from the east over the subsiding and inactive volcanic arc (Fielding et al., 1990). Deposition of the marine Cattle Creek Formation was strongly diachronous because contact in the west between it and the terrestrial Reids Dome beds ranges from sharp to the development of marginal marine 'transition beds'. On the slowly subsiding eastern margin, the Buffel Formation represents a condensed sequence of carbonate and clastic facies. On the western margin, craton-derived sediment of the Staircase Member of the Cattle Creek Formation was deposited in restricted deltas. The emergent highlands to the west and a relatively stable basin geometry provided the deltaic sediments of the Aldebaran Sandstone (Fielding et al., 1990). Sandstone associated with this regressive event form many of the known reservoirs

© Australian Geological Survey Organisation 1994

in the Denison Trough. The Taroom Trough generally lacked these high energy sand influxes along its margins and the fill is generally poorly sorted and clay choked. To the north at this time, localised extensional activity resulted in subsidence of the small Blair Athol Basin and resultant coal-bearing sediment fill. The northern margin was composed of coastal plain environments wherein the Collinsville Coal Measures (Ingelara Formation equivalent?) were deposited. Deltaic facies along the western margins continued into the Late Permian to deposit the (lower) German Creek Formation. In the east, continued subsidence of the inactive volcanic arc saw the coastal carbonate/siliciclastic sediments of the Oxtrack Formation pass into the thick shelf mud succession of the Barfield Formation (Fielding et al., 1990).

At this stage in the Late Permian, reactivation of the volcanic arc (uplift of the New England Orogen) and westward thrusting in the New England Orogen transformed the Bowen Basin into a foreland basin. The Flat Top Formation in the east is a consequence of the shedding of volcanic lithic sediment from the emerging volcanic arc. In the northern half, eastward prograding deltas combined with major axial fluvial systems to deposit the lower delta plain German Creek and upper delta plain Moranbah Coal Measures (Falkner and Fielding, 1990). Marine environments at this time were limited to the central-western region wherein deposition of the Peawaddy Formation occurred via southward prograding deltas which also covered the Springsure Shelf. Transgression over the southern half deposited the lacustrine or quasi-marine Black Alley Shale while non-marine deposition of the Fort Cooper Coal Measures occurred in the north. Deltaic sediment supply from the still active arc system in the east resulted in the Gyranda Formation. Subsequent subdued volcanic activity in the east may have precipitated the basin wide peat forming environments of the prograding delta and alluvial systems of Late Permian Bandanna Formation (southwest), Baralaba Coal Measures (southeast) and the Rangal Coal Measures (central and northern). The Permian section may be over 4000m in the north near Taroom.

Intensifying uplift and thrusting in the east, coupled with an inferred climatic change involving hot, humid conditions with pronounced wet and dry periods, saw the Permian swamps replaced by a fluvial environment during the Triassic (Elliott, 1989). The first of these was the red-bed sediments of the Early Triassic Rewan Group. These volcanic lithic sediments which are devoid of coal conformably overlie the Permian Blackwater Group in the basin centre while they are unconformable at the basin edges. In the Denison Trough, quartz sandstone is common in the basal section of the Rewan Group. Reservoirs are sealed regionally by subsequent transgressive marine units although intra-formational seals are common throughout. In the Taroom Trough, reservoir sands are developed locally within the Rewan Group but are of poor quality.

Uplift in the west resulted in the alluvial quartzose deposits of the Clematis Group around the Early-Middle Triassic boundary. The fluvial system of the Clematis Group extended over the Denison Trough and into the Taroom Trough where it is represented along the southwest margin by the principal petroleum reservoir, the Showgrounds Sandstone. This succession in the Taroom Trough is

© Australian Geological Survey Organisation 1994

significantly thinner in the southern part of the trough than its maximum development in the north. The fluvial style of deposition was terminated in the southern and western regions of the basin by a transgression which deposited the fine-grained sediments of the Snake Creek Mudstone Member of the Lower Moolayember Formation. A return to dominantly alluvial systems in the Middle Triassic saw the deposition of the youngest Bowen Basin sequence, the Moolayember Formation. Sandstone reservoirs occur in some areas of the Roma Shelf and Wunger Ridge but are generally inferior in quality to that of the Showgrounds Sandstone. Up to 5000m of Triassic sediments are preserved in the northern Taroom Trough.

Surat Basin

The stratigraphic sequences in the Surat basin are summarised in Figure 1. Uplift at the end of Middle Triassic time, in some parts up to 3000m (Elliott, 1989), ended Bowen Basin deposition. The throws of many of the normal faults associated with the half grabens were reversed at this time, to become major thrust faults (Elliott, 1989).

Erosion and peneplanation, in localised areas down to Permian sediments, resulted in a general smooth, low relief topography (Elliott, 1989). At a time of subdued tectonic activity, the Surat Basin was initiated in the Early Jurassic by regional subsidence of the older rocks and saw fluvial-lacustrine-coal swamps being deposited in a broad, gentle subsiding, intracratonic basin. From this time, continuity was established with the Eromanga Basin to the west and the Clarence-Moreton Basin to the east. The thickest accumulation, up to 1700m, of Jurassic sediments occurs within the Mimosa Syncline. This structural feature closely parallels the depositional axis of the underlying Taroom Trough. The non-marine history was characterised by alternation of low and high energy sedimentary cycles of fine and coarse grained sediments, respectively and provide favourable reservoir/seal associations at successive levels. The initial blanket sandstone, the Precipice Sandstone, provides the principal reservoir in the Surat Basin. High energy quartzose sandstones are associated also with low energy complexes as exemplified by the Boxvale Sandstone Member within the Evergreen Formation. This facies and other strongly stratigraphically controlled sand distributions provide the other main reservoir within the Surat Basin (Gray, 1989). Non-marine deposition (Precipice Sandstone to Injune Creek Group) culminated in Cretaceous mudstones and siltstones deposited in response to the worldwide Aptian marine transgression. By mid-Albian times, sedimentation was again non-marine. The Lower Cretaceous section in the central Surat Basin is over 1000m thick.

Structures within the Surat Basin were generally formed by compaction and drape over basement topography and by rejuvenation of structural trends within the underlying Bowen Basin and basement although they have much less vertical relief. The Late Cretaceous saw the basin tilted to the south and the withdrawal of the sea. Through to the Early Tertiary, periods of erosion saw loss of Surat Basin section north of 25°S (Fig. 2), peneplanation, deep weathering and probable meteoric water invasion. Mid Tertiary tilting to the southwest was accompanied by

© Australian Geological Survey Organisation 1994

widespread volcanic extrusion to the north and east of the Surat Basin. Erosion and meteoric water invasion of the Surat basin succession has occurred from Late Tertiary to Recent times, particularly in the northeastern part of the basin, and Cainozoic sediments are limited to an irregular veneer less than 200m thick (Elliott, 1989).

Petroleum Reserves and Reservoirs

Since the discovery of commercial oil at Moonie in 1961, the development of the Bowen and Surat Basin's oil and gas reserves has been intimately tied to market forces. This is partly due to the small to moderate volume of the overall accumulations. Current accumulated reserves (1960-1988) consists of approximately 17000Mm^3 of gas and 5000$x10^3m^3$ of total liquids (oil, condensate and LPG). Of these approximately 70% of the gas reserves remain in place, with the rate of successful discovery more than compensating for depletion due to production (Gray, 1989). However, the liquid reserves are now almost depleted and new technologies and concepts are required to maintain future liquid reserves.

<u>Bowen Basin</u>

The Taroom Trough has initial recoverable reserves (remaining recoverable reserves are in brackets) of 9655 (7200)xMm^3 of gas, 694 (463)$x10^3m^3$ of LPG, 673 (347)$x10^3m^3$ of condensate and 410 (180)$x10^3m^3$ of oil (Gray, 1989). Gas discovered on the Roma Shelf is relatively dry, becoming progressively wetter to the south, where it contains significant condensate reserves and is commonly associated with light oil. The Showground Sandstone is the main reservoir of the Roma Shelf and Wunger Ridge with the latter location having the larger field size. The remaining gas and gas/condensate fields were discovered in the Moolayember Formation, the Rewan Formation and several levels within the Permian succession. Oil discoveries lie along the eastern flank of the Wunger Ridge and in the southern part of the Roma Shelf. The Showground Sandstone contains most of these small-size discoveries whereas oil has also been found in the Moolayember Formation and the Rewan Group. Empirical evidence suggests that reservoir charge was controlled by the progressive updip overlap of regional seals, the Rewan Group and Snake Creek Mudstone Member. The regional pattern, therefore, is for the Showgrounds Sandstone to be charged updip of the Rewan Group pinchout and for the younger reservoirs, beyond that of the Snake Creek Mudstone.

In the Denison Trough, the least explored region, recoverable gas reserves on a CO_2-free basis are projected to be 4100Mm^3 (Gray, 1989). The fields are large by comparison with those of the Taroom Trough. Gas from known fields is dry, ranging from 85% to 99% methane on a CO_2-free basis. Minor amounts of condensate are associated with the gas and a non-commercial light leg is present in the Merivale gasfield. Southern fields contain variable CO_2 content, up to 33%, while there is negligible CO_2 in the northern Denison Trough gas fields (Elliott, 1989). Known petroleum reservoirs are mainly fluvial to marginal marine sandstone, of Early to Late Permian with the Aldebaran Sandstone being the principal reservoir in the southern part of the Trough. Other reservoirs lie in the upper Reids Dome

© Australian Geological Survey Organisation 1994

beds and the basal Rewan Group. Reservoir distribution is stratigraphically controlled. Unfortunately, porosity and permeability are generally less than with fluvial sands of the Surat Basin due to the cementation by pore water after deposition.

Surat Basin

For the Surat Basin initial recoverable reserves were estimated at 5820 (1623) Mm^3 of gas, 297 (139)$x10^3m^3$ of LPG, 103 (70)$x10^3m^3$ of condensate and 3984 (124)$x10^3m^3$ of oil (Gray, 1989). Over forty gas fields have been discovered on the western Roma Shelf and Wunger Ridge. Dry gas with more than 90% methane occurs in the northern fields. It becomes progressively wetter towards the south with increased condensate and LPG content. Fifteen oil fields have been discovered in the Surat Basin. By far the largest is Moonie ($3631x10^3m^3$) on the structurally-complex eastern margin, followed by Alton ($334x10^3m^3$) in the Central area, which, between them contain 97% of the Surat Basin oil reserves. Reservoirs for all the fields consist of quartzose sandstone, principally from the Precipice Sandstone and from multiple levels in the Evergreen Formation. In general, the reservoir sands are relatively thin and erratic in width and direction. While reservoir sands are difficult to pinpoint because of their nature, they are numerous. Along the northeastern eroded margin of the basin, the Precipice sandstone is massive, reaching a thickness of 100m. It becomes a thin and restricted basal sandstone, thinning to 9m on the Roma Shelf. At Moonie, the reservoir is relatively thick, massive and some 33m thick. The Evergreen Formation shows similar variability where strong stratigraphic controls have influenced sand distribution. Apart from the Moonie oil field where trapping is essentially structural, most hydrocarbon accumulations in the Surat/Bowen Basin occur in combination with structural/stratigraphic traps which commonly involve up-dip pinchouts or draping of laterally restricted channel sands over the flanks of structural highs and noses (Thomas et al., 1982). In the Surat Basin, entrapment seems to have occurred generally in the oldest sealed reservoir above the basal unconformity. The presence of several stratigraphic levels within a field implies imperfect stratigraphic seals, or the presence of fault conduits feeding successive reservoirs. Indeed, this probably accounts for minor petroleum accumulations in the younger reservoirs in the Hutton and Springbok Sandstones.

Previous Geochemical Studies on the Origin of Petroleum

Denison Trough

In the Denison Trough, gas-prone Type III source rocks of considerable potential exist throughout the Permian succession with the Cattle Creek Formation and the Reids Dome beds constituting the most favourable source facies (Jackson et al., 1980). The significant gas reserves in the region are consistent with the hydrocarbon potential of the rocks although a small oil leg in the Merivale field also implies some liquid potential. The fluvial and lacustrine sediments within the Triassic section constitute poor source rocks (Jackson et al., 1980). Within the interval covered by the Cattle Creek Formation and Aldebaran Sandstone, juxtaposition of the source and reservoir has been recognised and could present favourable stratigraphic traps. Marginal marine sandstones at the top of the Reids Dome Beds form the productive reservoir zone in the Merivale field. In the northern part of the Denison Trough, the Freitag Formation forms the reservoir for the Rolleston gas field while the areally limited nearshore Catherine Sandstone supports the Arcturus gasfield. For the two gasfields, favourable juxtaposition of Permian source and reservoir may account for the gas reserves in the stratigrahically higher Mantuan Formation (Ingelara Formation equivalent?). Alternatively, they may be charged from the lower imperfect seals. A similar leakage may account for the Yellowbank gasfield in the Triassic Rewan Group.

In the north, the Reids Dome beds are overmature while in the southeast around Taroom 11, the upper section of the Reids Dome Beds has not entered the oil window, considered to be between 0.7%<Ro<1.3% (Jackson et al., 1980). Since most traps are full to mapped closure it suggests that there is sufficient source rock volume (Elliott, 1989). The trend to increasing CO_2 content in a southerly direction, closely follows the direction to lower maturation levels. This has been used to suggest that gas generation has not yet peaked in the south and that there still remains oxygen-rich Type III humic kerogen giving rise to a CO_2-rich gas (see alternative origin in Results and Discussion).

Taroom Trough and Surat Basin

The Taroom Trough and the Surat Basin can be classified as a more oil-prone region, based on known discoveries, compared to the Denison Trough. Although the entire Permian to Triassic succession of the Taroom Trough is dominated by Type III kerogen, the Blackwater Group, particularly along the eastern and southern margins, contains significant amounts of oil-prone Type II kerogen (Hawkins et al., 1992). Restricted potential also exists in the Back Creek Group (Fig. 1). In a limited study of 12 oils and 5 potential source rocks Philp and Gilbert (1986) found biomarkers attributable to marine organic matter in the Cabawin oil suggesting a source contribution from the marine Back Creek Group. All other oils were dominated by land plant source materials. The Moolayember Formation also has potential oil-prone source rocks although these have not as yet reached sufficient maturity for significant hydrocarbon generation. From regional vitrinite reflectance studies (Thomas et al., 1982), the Permian succession in the southernmost part of the Taroom Trough and along the southwest margin is in the oil generative zone, 0.7%<Ro<1.3%, whereas in the deeper parts to the north, it is in the gas generative zone, or is overmature (Figs. 3a and b). The change in gas composition from essentially dry gas on the Roma Shelf to progressively wetter in the south (Thomas et al., 1982) has been strongly associated with this maturity gradient following the axis of the Taroom Trough. Thomas et al. (1982) has interpreted the Blackwater Group to be within the oil window throughout much of the Taroom Trough (Fig. 3a), whereas the Back Creek Group is overmature for gas over much of the northern part of the Taroom Trough (Fig. 3b). The Moolayember Formation is mostly immature for oil generation. Although no significant hydrocarbon discoveries have been made in the central portion of the southern Taroom Trough, gas,

© Australian Geological Survey Organisation 1994

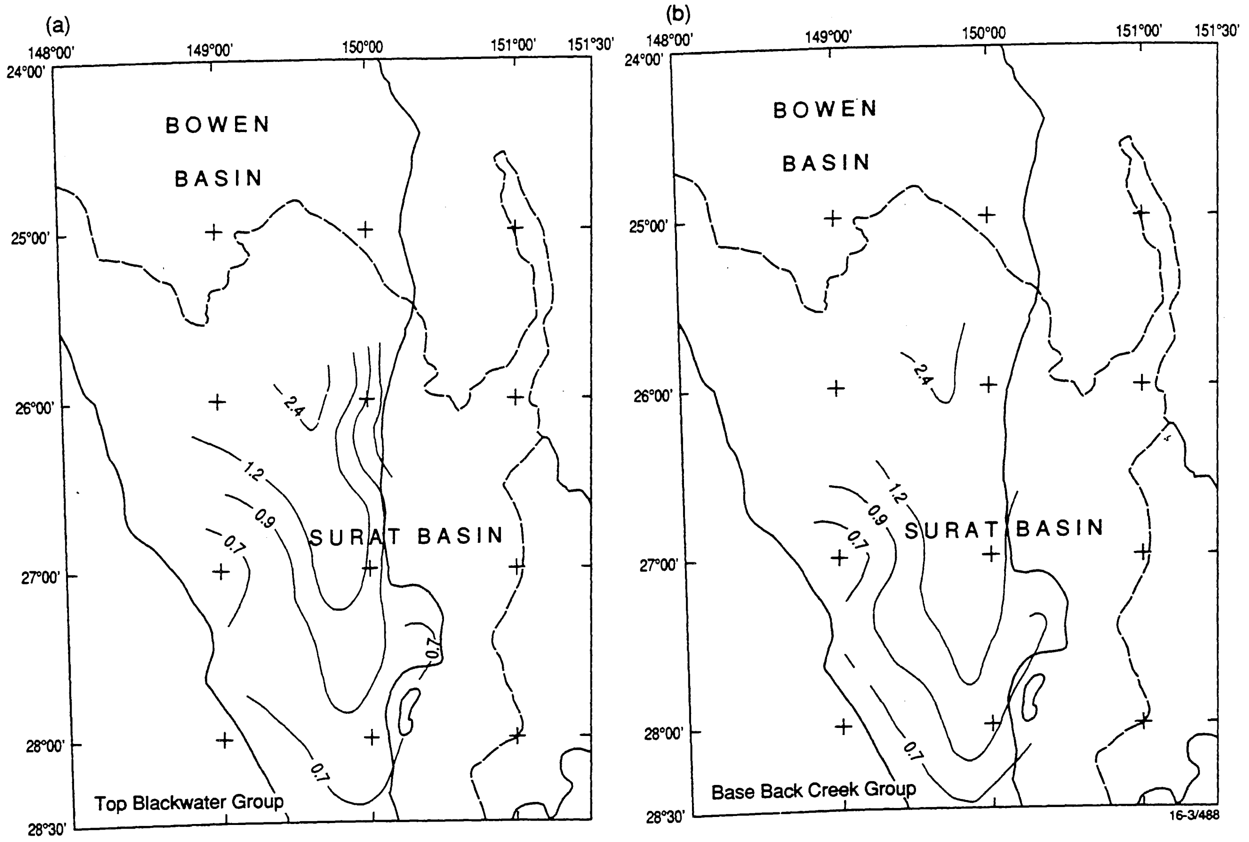


Figure 3. Vitrinite reflectance isopachs for (a) the top of the Blackwater Group (b) base of the Back Creek Group (after Thomas et al., 1982).

© Australian Geological Survey Organisation 1994

gas/condensate and the oil discoveries on the Roma Shelf and Wunger Ridge to the west, and the eastern margin have appropriate reservoir/source relationships for both local and regional migration. Philp and Gilbert (1986) have used ratios of sterane diastereoisomers to suggest that migration pathways are longer for Triassic and Surat Basin reservoired oils along the western margin, compared to the Permian oils in that region and those in the east. Moonie oil also appeared to have a long migration pathway. However, sensitivities of these biomarkers to geochromatographic effects have little current acceptance amongst organic geochemists.

Within the Surat Basin, the Walloon Coal Measures (Injune Creek Group) and parts of the Evergreen Formation have significant source potential. The Walloon Coal Measures are immature over the region and only in the deeper parts of the basin would the underlying Evergreen Formation approach the initial stages of oil generation (Thomas et al., 1982; Philp and Gilbert, 1986). Whether the Jurassic section ever achieves oil generation in sufficient quantity to sustain expulsion from the source is the subject of considerable debate (Hawkins et al., 1992). Initially it was suggested that the local Jurassic Evergreen Formation was the source for the Jurassic Precipice Sandstone oil of Moonie (Moran and Gussow, 1963) based on Jurassic spores in the oil. At that time Traves (1965) favoured a Permian source since oil and gas were also found in Triassic and Permian reservoirs. Others held the popular opinion of a marine source (eg Permian Back Creek Group) discounting any non-marine rocks. Today, opinions are still divided. It has been suggested that the Evergreen Formation must be considered as a possible contributor to petroleum in Jurassic reservoirs (Elliott, 1989). This concept is attractive if petroleum is to be discovered away from the interpreted pathways from the older sediments (Gray, 1989). Specifically, both the Bennett and Conloi fields, reservoired at the top of the Precipice Sandstone, are thought to have been sourced from the overlying Evergreen Formation (Elliott, 1989). Furthermore, the source of the Moonie accumulation is thought to be a combination of Jurassic and Permian source rocks with the latter supplying the bulk of the hydrocarbons (Elliott, 1989). On the other hand, geochemical analysis of a small dataset of Bowen and Surat Basin oils points solely to a Permian source (Thomas et al., 1982; Philp and Gilbert, 1986).

Scope of Present Work

The question of the source for, and timing of generation of, the petroleum liquids in the Bowen and Surat Basins is addressed here through a comprehensive geochemical analysis of a large set of petroleum liquids, gases and potential source rocks. The samples cover all of the productive areas in the two basins. Bulk hydrocarbon composition and detailed biomarker examination are used to reveal oils and condensates related to a common source(s) and reservoir conditions. The lateral and vertical distribution of petroleum is discussed in terms of regional migration pathways, maturity levels and source rock distributions. Age-specific biomarkers are used to critically examine the contribution of Jurassic source rocks to petroleum in the region. Carbon-13 isotopic composition of sediments and petroleum components allows for further delineation of gas-source rock and liquid-

© Australian Geological Survey Organisation 1994

source rock associations and the timing of petroleum generation.

EXPERIMENTAL

Samples

Petroleum

Table 1 lists the liquid petroleum samples used in the study. Oils and condensates with AGSO Nos. < 500 were obtained from AGSO's National Petroleum Collection. These were supplemented by donations from industry (AGL Petroleum (now Santos Ltd.); Bridge Petroleum Ltd., Central Queensland Natural Gas, Command Petroleum Holdings NL, Crusader Ltd.). Natural gases from current production wells were supplied by industry (AGL Petroleum, Bridge Petroleum Ltd., Oil Company of Australia NL).

Sediments

Cores from the Bowen and Surat Basins were collected in two phases. The first sampling closely followed those well sections analysed during the previous investigations in our laboratories from the Taroom Trough (Hawkins et al., 1992) and Denison Trough (Jackson et al., 1980). These samples correspond to AGSO Nos. 18xx, 36xx and 50xx in the Taroom Trough and 36xx and 50xx in the Denison Trough (Table 2b). Additional outcrop material was collected during a 1992 AGSO/GSQ field excursion in the study area (AGSO Nos. 52xx) and various Permian coals were supplied by Ray Smith of Geological Survey of Queensland (GSQ) and have AGSO Nos. 53xx. Jurassic sediments from the neighbouring Eromanga and Clarence-Moreton Basins were obtained from Dr. Peter Hawkins (deceased) of the Geological Survey of Queensland (GSQ; Hawkins et al., 1991) and AGSO's previous study (Boreham and Powell, 1991), respectively. The second sampling phase of core material (AGSO Nos. 6xxx; Table 2b) occurred during 1993 to coincide with a detailed AGSO/GSQ geochemical investigation involving cuttings selected using a regional well grid. Analytical procedures for Rock Eval/TOC and solvent extraction were as previously described (Boreham and Powell, 1987; Powell et al., 1991)

Isolation of hydrocarbon fractions

Bitumens isolated via soxhlet extraction of the crushed sediments (Boreham and Powell, 1987) or whole oil/condensate (100mg) were added directly to the top of a silica column (12g in petroleum ether) and the saturated hydrocarbons, aromatic hydrocarbon and polars were successively eluted with petroleum ether (40-60°C; 40ml), petroleum ether/dichloromethane (1:1; 50ml) and dichloromethane/methanol (1:1, 50ml), respectively. The solvent was reduced in volume by rotary evaporator at 30°C to 1ml, transfered to weighed vials and excess solvent removed under a stream of nitrogen until a constant weight was maintained.

The saturated hydrocarbons were further separated into two fractions on silicalite

(West et al, 1990). To a pasteur pipette, plugged with glass wool, was added silicalite powder (1gm). The saturated hydrocarbon fraction (10mg) dissolved in pentane (50 µl) was transfered to the top of the column, allowed to stand for 10 minutes, before a silicalite non-adduct fraction (SNA) containing branched and cyclic hydrocarbons was eluted in pentane (4ml). The silicalite adducted fraction (SA) containing straight-chained, iso- and antiiso-alkanes, was isolated, after dissolution of the zeolite in 30% HF, by liquid-liquid extraction into hexane.

Gas chromatography

Gas chromatographic traces of the saturated hydrocarbon fraction and the whole oil (1:100 dilution; wt:vol of hexane) were developed on a HP 5890 Series II gas chromatograph equipped with a HP programmable on-column injector, HP 7673 autosampler and fitted with a 25 m methylsilicone fused silica narrow-bore capillary column (HP Ultra-1). After injection the oven was programmed from 30°C to 310°C at 4°C/min and held for a further 20 min while the injector was programmed at 150°C/min to 310°C. Hydrogen was used as the carrier gas and maintained under static pressure control (15 psi). The gas chromatograph, autosampler and data reduction were controlled by DAPA Scientific chromatography software.

Gas chromatography-mass spectrometry

Gas chromatography-mass spectrometry (GC-MS) analysis was carried out using a VG 70E instrument fitted with a HP 5790 GC and controlled by a VG 11-250 data system. The GC was equipped with either an Ultra-1 fused silica capillary column (50mx0.2mm I.D., 0.33µm film thickness) for saturated hydrocarbons or a DB-5 fused silica column (30mx0.25mm I.D., 0.2µm film thickness and a retention gap of uncoated fused silica (1.0mx0.33mm). The samples (in hexane) were injected on-column (SGE OCI-3 injector) at 50°C and the oven programmed to 150°C at 10°C/min then to 300°C at 3°C/min with a hold period of 30min for the saturated hydrocarbons or at 60°C and oven programmed to 300°C at 4°C/min. for the aromatic hydrocarbons. The carrier gas was hydrogen at a linear flow of 30cm/sec. The mass spectrometer was operated with a source temperature of 240°C, ionisation energy of 70eV and interface line and re-entrant at 310°C. In the full scan mode the mass spectrometer was scanned from m/z 650 to m/z 50 at 1.8 sec/decade and an interscan delay of 0.2 sec. The aromatic hydrocarbons were analysed in the SIR mode and the ions were selected according to Alexander et al. (1987, 1988). In the multiple reaction monitoring (MRM) mode for analysis of the saturated hydrocarbons, the magnet current and ESA voltage were switched to sequentially sample for 26 selected parent-daughter pairs including one pair (m/z 404 -> 221) for the deuterated sterane internal standard (Chiron Laboratories, Norway). The sampling time was 40ms per reaction with 10ms delay giving a total cycle time of 1.3s. Under these GC-MS (MRM) conditions, increased selectivity and sensitivity of the biomarker traces is obtained and it allows deconvolution of coeluting peaks which could otherwise lead to ambiguities under standard GC-MS (SIR) conditions.

© Australian Geological Survey Organisation 1994

Gas Chromatography-Isotope-Ratio-Mass Spectrometry

The carbon isotopic compositions of individual gas components were determined using isotope-ratio-monitoring gas chromatography-mass spectrometry. The instrument consists of a Varian 3400 gas chromatograph connected to a Finnigan MAT 252 isotope-ratio mass spectrometer via a micro-volume combustion system. The GC was equipped with a PoraPlot Q fused silica column (10mx0.53mm I.D.). The gas was injected (50µl) using a gas-tight syringe into a heated split injector (split ratio 1:50). The column temperature was maintained at 30°C for 2 min then temperature programmed to 200°C at 10°C/min and held at the final temperature for 20 minutes. The individual gaseous hydrocarbons were quantitatively converted to CO_2 and H_2O in the combustion reactor (CuO, 850°C), and following removal of water, the isotopic composition of CO_2 was measured. $\delta^{13}C$ values were determined using the manufacturer's software which corrected for background contributions, partial separation of isotopic species on the chromatographic column, and contributions of ^{17}O.

Stable Carbon Isotopes

For the stable carbon isotope analysis on kerogens, whole liquids, distillation cuts and saturated and aromatic hydrocarbon sub-fractions, typically 2mg was sealed in a quartz tube and oxidised over CuO at 950°C. The liberated CO_2 was analysed using a VG Sira-12 isotope-ratio mass spectrometer. All $\delta^{13}C$ values are calculated relative to the Pee Dee Belemnite standard (PDB).

RESULTS AND DISCUSSION

The correlation process linking oil to oil, oil to gas, gas to gas, oil to source, and gas to source requires information that can distinguish source differences as well as allowing for secondary processes such as maturation and alteration. The parameters used in this study involve bulk or major compositional components, gas chromatographic "fingerprints", biomarkers, and carbon stable isotope ratios of compound classes or in the case of gases, individual hydrocarbons. These parameters are used to define genetic relationships allowing similar groups or families to be defined. In order to process such a large data set and to gain an overview on a regional scale, the oils, condensates and gases have been sorted into subsets based on stratigraphic position of the reservoir and region of occurrence. Further subdivisions, where appropriate, are based on their geochemical signatures within the bulk parameters. Biomarker analysis and carbon isotopic composition of the saturated and aromatic hydrocarbons have been used to enhance petroleum to source rock correlations based on the bulk parameters by providing more detailed information on the source type and age, depositional environment and thermal maturation.

© Australian Geological Survey Organisation 1994

Gross Petroleum Composition

Liquid Hydrocarbons

The proportions of the hydrocarbon compound classes within the oils (Table 2a and Fig. 4) reveal a wide classification ranging from paraffinic, through paraffinic-naphthenic to naphthenic crudes. The variation is independent of stratigraphic horizon and basin position (Fig. 4 and Tables 1 and 2a). However, use of these compositional characteristics does not represent a particularly informative criteria for sub-division as the differences are not directly related to variations in source organic matter but reflect alteration within the reservoir of an initial paraffinic petroleum (see below under the sub-heading 'In-reservoir Alteration'). This is best illustrated in the capillary gas chromatograph-FID traces (Fig. 5) which groups the petroleum according to the relative abundances of *n*-alkanes and isoprenoids, pristane and phytane. The 'unaltered' group of oils (Group O0) show a regular

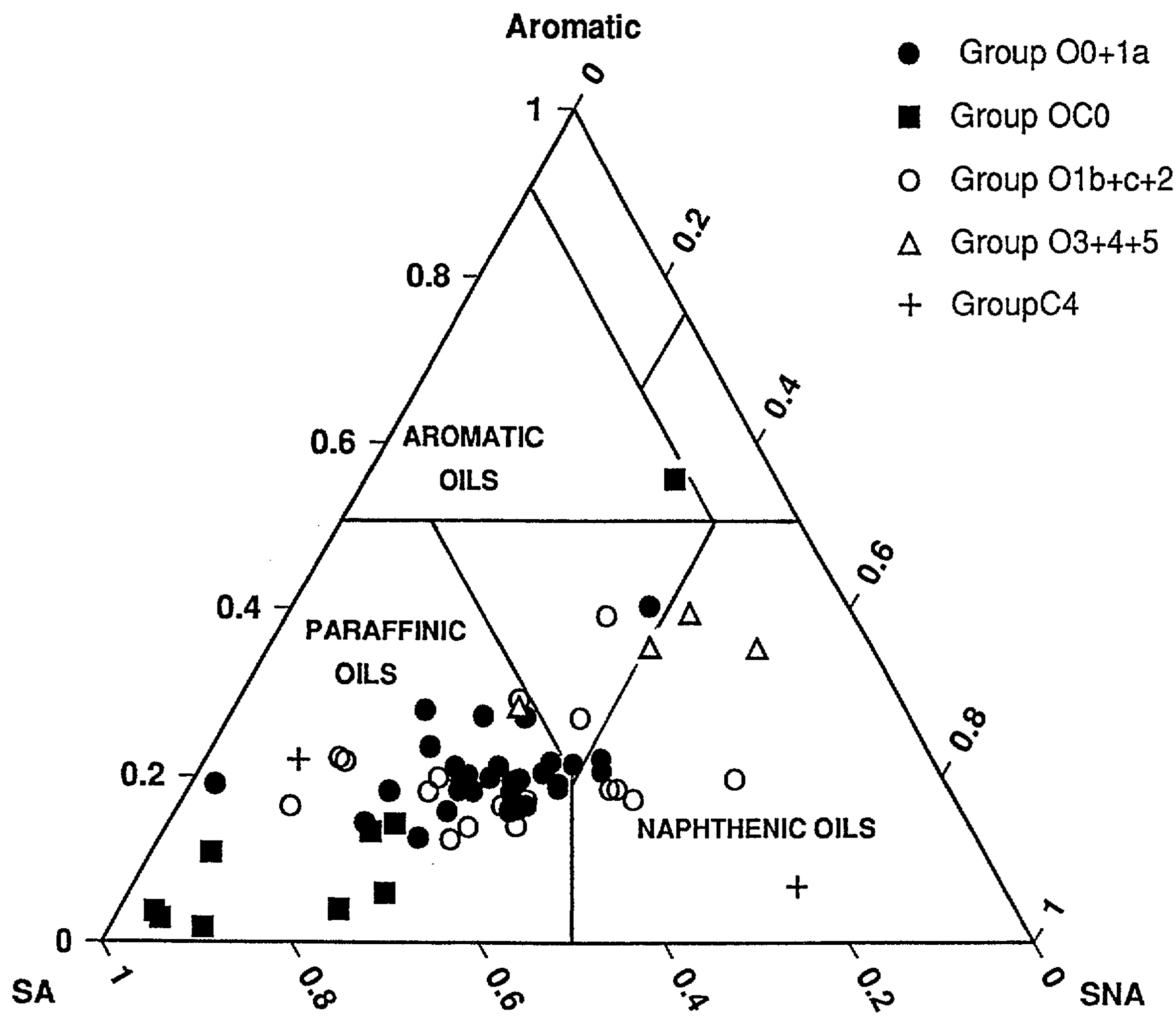


Figure 4. Triangular plot of the relative percentages of *n*-alkanes (SA), branched and cyclic hydrocarbons (SNA) and aromatic hydrocarbons (symbols are based on the biodegradation grouping).

© Australian Geological Survey Organisation 1994

decrease in relative concentration of individual *n*-alkanes with increasing molecular weight. The rate of decrease becomes more pronounced on progression to a 'heavy' condensate (Group OC0) and 'light' condensate (Group C0). In the latter case, the bulk of the volatile organic material has carbon numbers < C_{10}. The 'altered' group of oils is characterised by a progressive loss of light *n*-alkanes (Groups O1a-c), centred around C_{12}-C_{14}, followed by loss of the higher molecular weight *n*-alkanes (Groups O2-O4) and finally the loss of the isoprenoid hydrocarbons, pristane and phytane (Group O5). Similarly, the condensates (Groups OC0 and C0) also show loss of straight-chained hydrocarbons (Groups OC1 and C4). The sample from Rockwood 1 (#97) is considered to be an altered heavy condensate (Group OC1) where the loss of the light hydrocarbons has lead to the selective enhancement of the >C_{15} *n*-alkanes. Furthermore, the Rolleston condensate (Group C4) shows a lack of *n*-alkanes. These characteristics based on similar gas chromatographic composition have been used as an alternate criteria for grouping the liquid petroleum (Table 2a, column 4).

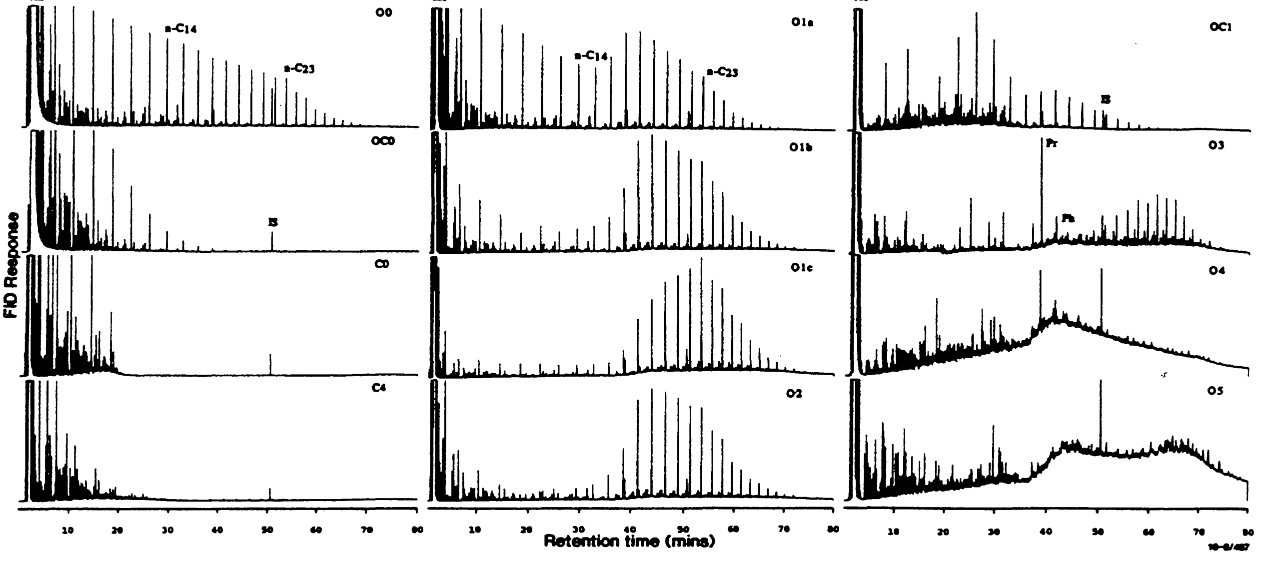


Figure 5. Gas chromatography traces of liquid petroleum for representative alteration groups (a) O0, OC0, C0, C4 (b) O1a, O1b, O1c, O2 c) OC1, O3, O4, O5.

© Australian Geological Survey Organisation 1994

Gaseous Hydrocarbons

The gas compositions are presented in Table 3 and range from dry gas, dominated by methane, to an extremely wet gas with a high proportion of C_{2+} hydrocarbons. In the Taroom Trough, there is a strong northerly trend to increasing dryness (Thomas et al., 1982). Thus, the southern-most wells on the Wunger Ridge are wetter than the northern wells on the Roma Shelf. Within the latter region, the gases become progressively drier to the north (Table 3). In the Denison Trough the situation is similar, gas wetness increases in a southerly direction although the C_{2+} hydrocarbon content is less than the gases on the Wunger Ridge. The carbon dioxide increases with the wet gas content in the Denison Trough with Yellowbank 3 having 30% CO_2. However, no simple relationship exists between the carbon dioxide and hydrocarbon composition for the Taroom Trough wells where CO_2 is a minor component.

These compositional changes in the region have been documented previously and attributed to a maturation effect (Thomas et al., 1982); the drier gas being generated from the higher maturity source rocks. The vitrinite reflectance isopachs in Figure 3 show an northerly increase in maturation along the axis of the Taroom Trough. Although this maturation profile can undoubtedly influence the composition of the evolved hydrocarbons, it is by no means the sole process. As will be shown below in the Maturation Section, the carbon-13 isotopic composition of the individual hydrocarbons show only a weak maturity trend; the maturation level at which the gases were generated slightly decreases, or remains constant, as the dryness increases.

In-reservoir Alteration: Biodegradation and/or Water Washing

Liquid Hydrocarbons

The oils and condensates in the Bowen and Surat basins have been subjected to varying degrees of in-reservoir alteration. It is a simple matter to determine the degree of alteration from an examination of the overall characteristics of the gas chromatographic trace (Fig. 5) as was discussed above. A mechanism involving 'evaporative fractionation' (Thompson, 1988) can explain changes in composition. Here, a gas/condensate phase separates from the mother liquid leaving an oil depleted in light hydrocarbons. However, the predicted compositional changes ie. paraffin-enriched condensate and aromatic-enriched residual oil (Thompson, 1988; Dzou and Hughes, 1993) does not appear to be prevalent among the Bowen and Surat liquids. Thus 'evaporative fractionation', although it may be locally important, does not appear to be of regional significance. On the other hand, the compositional changes in the liquid petroleum parallel those observed in response to biodegradation and/or water washing (Peters and Moldowan, 1993 and references therein). Indeed, both biodegradation (Philp and Gilbert, 1986) and water washing (Thomas et al., 1982) have been proposed individually as responsible for oil alteration at Moonie. This alteration is also expressed in slight changes in the isotopic composition of the C_{12+} saturated and aromatic

© Australian Geological Survey Organisation 1994

hydrocarbons (Fig. 6a); the absolute isotopic values being primarily source controlled (see below). The loss of *n*-alkanes in the most severely altered samples leads to slight isotopic depletion in the saturated hydrocarbons. These changes are readily explained in terms of biodegradation which initially removes the isotopically ^{13}C-enriched lower *n*-alkane homologues followed by the ^{13}C-depleted waxy *n*-alkanes (Chung et al., 1994; Boreham, unpublished results) leaving an isotopically depleted branched/cyclic saturated hydrocarbon fraction (Boreham, unpublished results). For the aromatic hydrocarbons, isotopic shifts are not always observed in response to biodegradation (Palmer, 1993). For the Moonie oils, the aromatic hydrocarbons show only minor differences in isotopic composition suggesting that biodegradation has had little effect. On the other hand, water washing should show isotope selectivity biased more towards the aromatic hydrocarbons, due to their increased water solubility. The condensates (OC), on average, have a heavier isotopic signature in the saturated hydrocarbons consistent with the observed strong correlation between ^{13}C isotope enrichment and decreasing molecular weight fractions (see below; James, 1983). It must be realised that the $<C_{12}$ light hydrocarbons have been lost in the isolation procedure and the overall isotopic trends could be more pronounced (c.f. large shifts in gas isotopic composition).

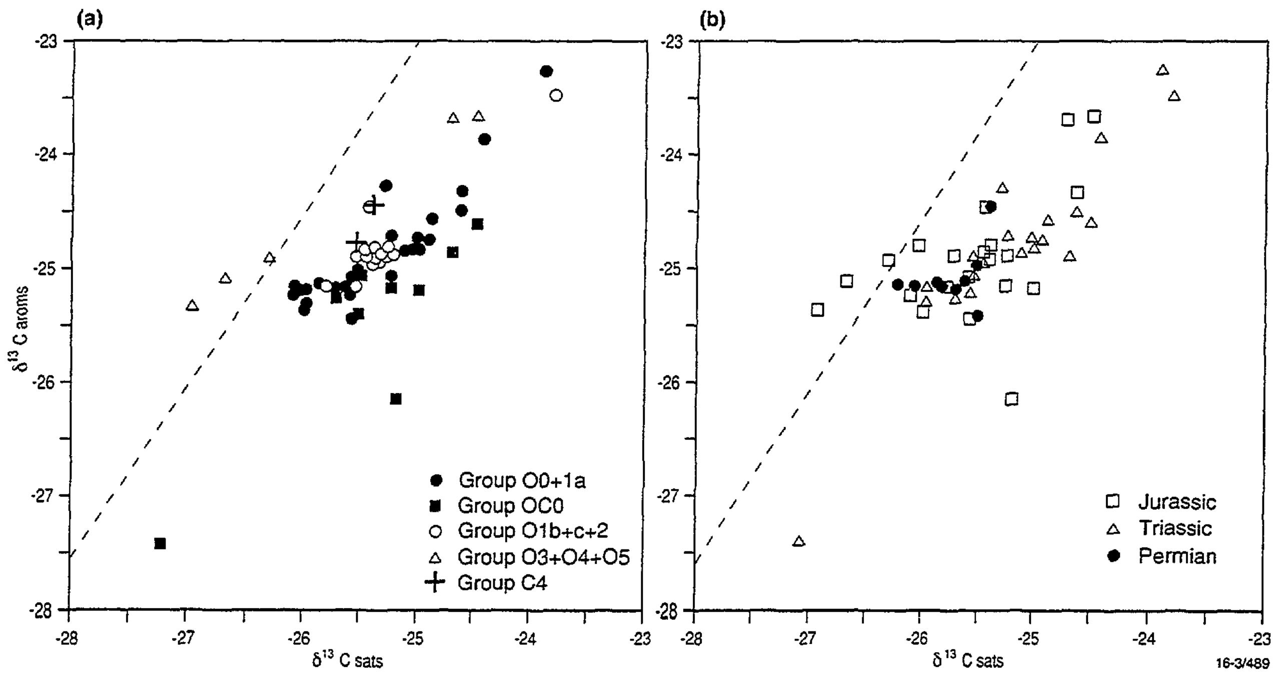


Figure 6. Plot of δ^{13}C of saturated hydrocarbons versus δ^{13}C of aromatic hydrocarbons as a function (a) degree of alteration and b) reservoir age. Dotted line represents Sofer's (1984) discrimination between marine oils (right side) and terrestrial oils (left side).

© Australian Geological Survey Organisation 1994

The effects of in-reservoir biodegradation have been quantified to the extent that various 'scales' of biodegradation have been constructed. The most recent scale of Peters and Moldowan (1993) is reproduced here for comparison (Table 4). Other scales (Volkman et al., 1983; Chosson et al., 1992) have all of the gross characteristics in common but have subtle differences at the molecular biomarker level, primarily associated with heavy biodegradation. Waterwashing can produce similar effects although not as well characterised, reflecting to some extent the difficulty in separating the two processes. Additionally, water washing can selectively remove soluble low molecular weight aromatics and can still operate above the temperature limit (approx. 80-90°C) at which the aerobic microorganisms responsible for biodegradation cease to function (Palmer, 1993). Although the composition of the light aromatics was not determined in this study, both biodegradation and water washing have a role to play in the alteration of the petroleum. Whether one process dominates over the other is difficult to predict. For simplicity it is assumed that the compositional variations are a result of biodegradation unless other experimental evidence is inconsistent with biodegradation, then a water washing mechanism is favoured. The majority of the altered liquids are reservoired in the Jurassic where there is widespread meteoric invasion of oxygenated waters although alteration occurs at all stratigraphic levels (Fig. 6b). Oxygen-rich waters, coupled with suitable reservoir temperatures, yield conditions which can sustain aerobic bacterial biodegradation (Palmer, 1993). However, the strongest supporting evidence for biodegradation is from the carbon isotopic compositions of the associated gases (see below).

From the gas chromatography traces (Fig. 5) it is evident that the most altered petroleum, Riverslea 1, has experienced, at the least, moderate biodegradation (ranking 5, Table 4). Higher levels of biodegradation are difficult to resolve using gas chromatography-FID. Better resolution is provided by the analysis of polycyclic biomarkers, mainly steranes and triterpanes, by gas chromatography-mass spectrometry (GC-MS). Table 4 outlines a 'quasi-stepwise' sequence describing the general order of susceptibility of various biomarker compound classes to biodegradation. It is also clear that biodegradation cannot be described by a truly sequential alteration of compound classes and that the relative rates of degradation of different biomarker classes and homologous series within these classes are influenced to varying, as yet undefined, degrees by different bacterial populations. However, there appears to be a genuine resolvable step between the complete removal of the isoprenoids (ranking 5) and the beginning of alteration of the steranes (ranking 6) (Peters and Moldowan, 1993). Figures 7a and 7b show cross-plots for specific biomarkers where one isomer or homologue is more susceptible to biodegradation compared to another. Thus, the C_{30} hopane and the 20R isomer of $\alpha\alpha\alpha C_{29}$ sterane are more susceptible to biodegradation than C_{30} diahopane and $\alpha\alpha\alpha C_{29}$20S, respectively (Fig. 7a), while the same is true for the relative stabilities of C_{29} diasteranes and C_{27} steranes compared to C_{29} steranes (Fig. 7b; hopane ratios, diasterane to sterane and sterane homologue ratios in Table 5a, and sterane isomer ratios in Table 6a). It is clear from Figure 7 there exists no simple relationship between extent of biodegradation (discerned from the GC-FID) and changes in isomer ratios. Indeed the most altered oil, Riverslea 1, shows no discernible alteration of the steranes and regular hopanes. Using the above

© Australian Geological Survey Organisation 1994

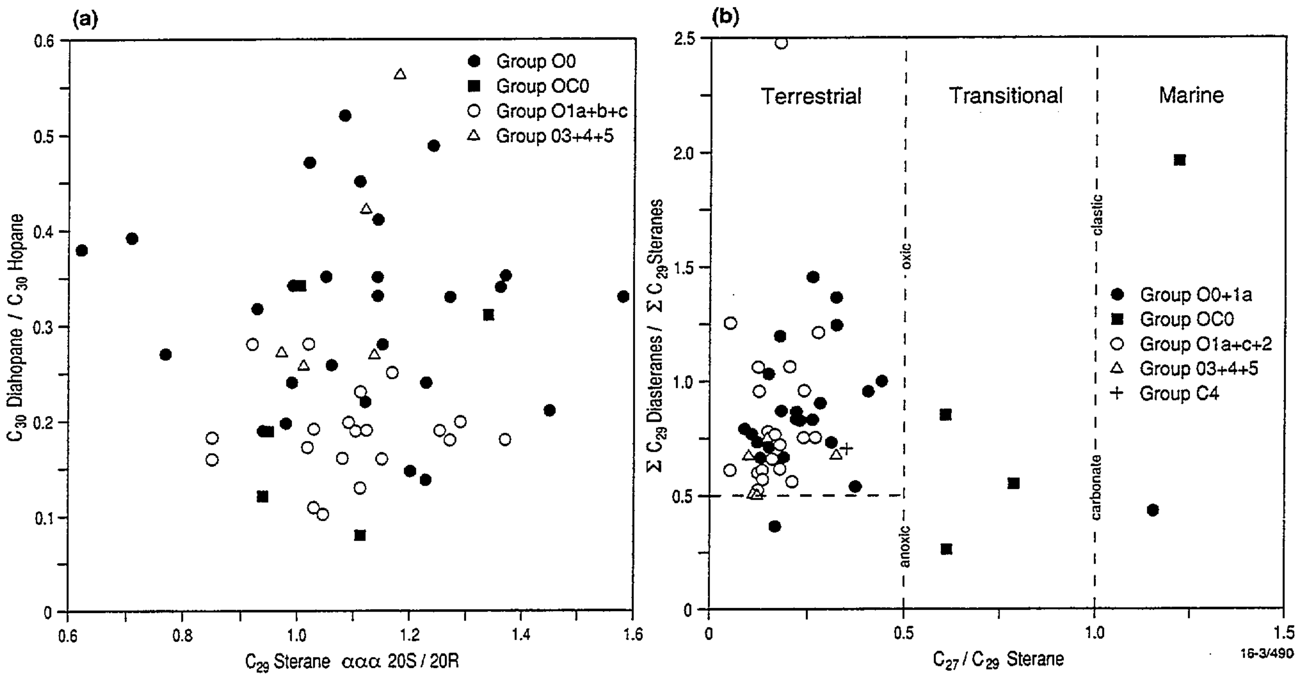


Figure 7. Plot of biodegradation-sensitive ratios a) C_{30} diahopane / hopane versus $\alpha\alpha\alpha C_{29}$ sterane 20S / $\alpha\alpha\alpha C_{29}$ sterane 20R b) $\Sigma\ C_{29}$ diasteranes / $\Sigma\ C_{29}$ steranes versus $\alpha\alpha\alpha C_{27}$ sterane 20R / $\alpha\alpha\alpha C_{29}$ sterane 20R in liquid petroleum.

© Australian Geological Survey Organisation 1994

observations, oils and condensates from the region have experienced, at most, a moderate degree of in-reservoir biodegradation up to ranking 5 (Table 4). As such, the sterane and the hopane parameters used to define maturity and source influences (see below) are, most likely, unaffected by the effects of biodegradation.

Another biomarker indicator of biodegradation is the occurrence of a homologous series of 25-norhopanes (Palmer 1993 and references therein). These compounds are typical of many, but not all, heavily biodegraded oils, it has been suggested that the 25-norhopanes result from the bacterial removal of the 25-methyl group from the regular 17α(H)-hopanes at the later stages of biodegradation. Alternatively, generation of the 25-norhopanes may begin at a much earlier stage of biodegradation and only become detectable when the regular hopanes are removed by heavy biodegradation (Chosson et al., 1992). Furthermore, the occurrence of 25-norhopanes in source rock extracts points to a much earlier process where these biomarkers could form as a consequence of bacterial reworking of organic matter (Noble et al., 1985; Chosson et al., 1992). The results of this study allow us to differentiate between some of these possibilities. Since none of the comprehensive set of potential source rocks contain detectable 25-norhopanes (Table 6b), their presence in the liquid petroleum must be a direct result of biodegradation. The 25-norhopanes have been detected in the majority of oils and condensates in the Bowen and Surat basins (Table 6a). In one case (Borah Creek 5) the 25-norhopanes dominate the regular 17α(H)-hopanes (25-norhopane/hopane = 2.66; Table 6a) and appear together with high *n*-alkane abundance (Group O1a; Table 2a). The occurrence of the former biomarker in unaltered to moderately biodegraded oils (Tables 2a and 6a) can be interpreted as indicating a recharging of the initial biodegraded reservoir by an unaltered oil (Alexander et al., 1983; Volkman et al., 1983; Philp, 1983; Talukdar et al., 1986, 1988; Sofer et al., 1986). Subsequently, a more areally restricted phase of biodegradation would have to occur. This multi-stage process of palaeo- and present-day biodegradation would necessitate dramatic regional changes in the hydrodynamics within the Bowen and Surat basins, not an unrealistic suggestion considering the complex structural history. Alternatively, a pervasive heavy biodegradation occurred along the secondary migration pathway resulting in the generation of the 25-norhopanes and a residual petroleum enriched in the more resistant biomarkers. At the same time, the regular and hopane content must have been depleted to a level so as not to significantly influence their final composition following the second charge. Since contact time between petroleum and oxygenated waters would vary across the basin, hydrocarbons in some areas would experience more intense biodegradation than others. Continual supplementation with unaltered liquid petroleum would dilute the initial biodegradation signature although still retaining detectable concentrations of the more resistant biomarkers (eg. 25-norhopanes and diahopanes). Once emplaced in the reservoir, and conditions being favourable, the petroleum is further biodegraded to its current levels, albeit to levels insufficient to generate additional 25-norhopanes or alter major biomarker classes. A plot of 25-norhopane/hopane against $n\text{-}C_{12}/n\text{-}C_{17}$ (Fig. 8) depicts the consequence of these events where there is an apparent lack of correlation between parameters sensitive to the initial and final

© Australian Geological Survey Organisation 1994

stages of biodegradation, respectively.

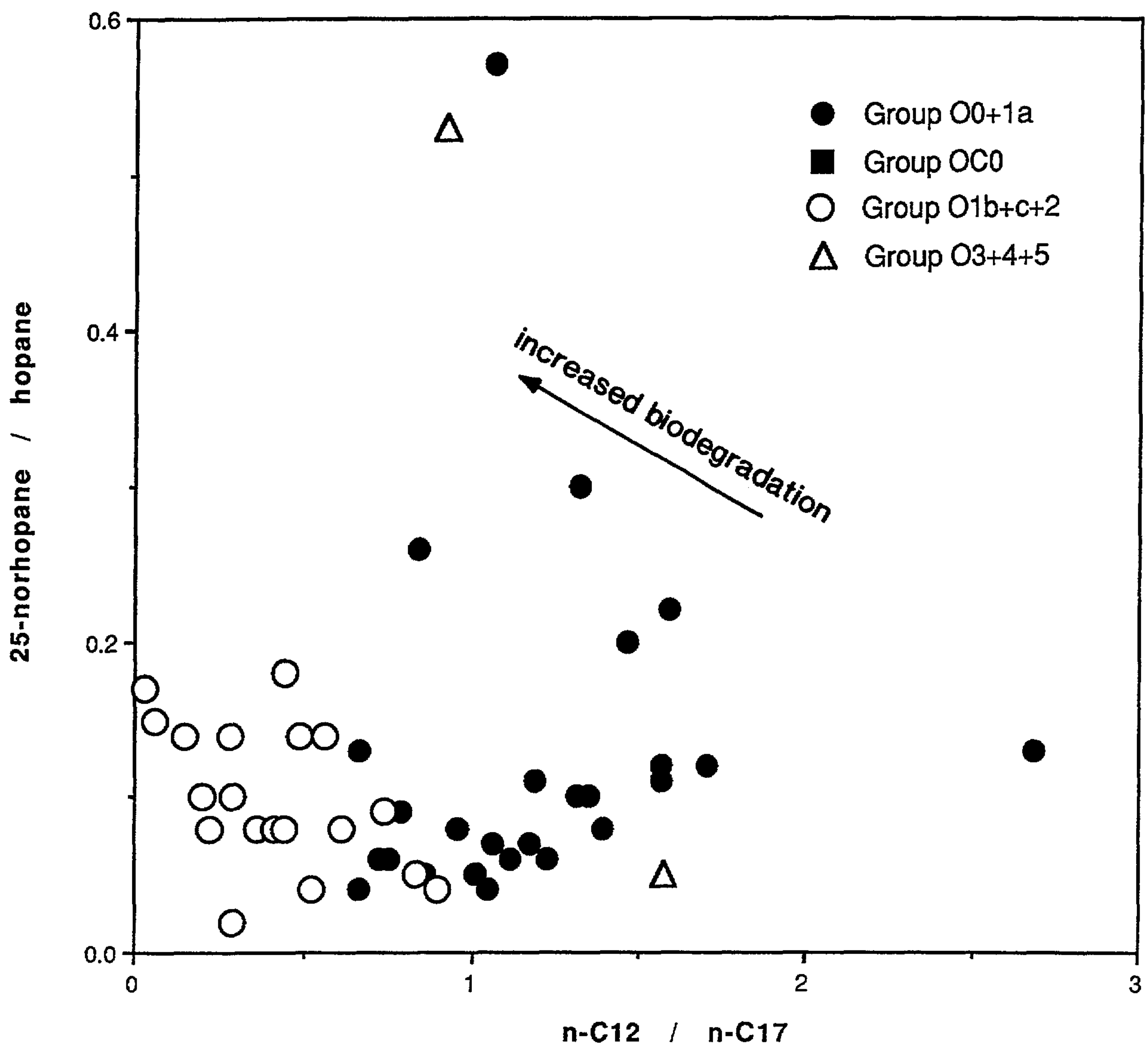


Figure 8. Plot of 25-norhopane versus n-C_{12}/n-C_{17} in liquid petroleum.

© Australian Geological Survey Organisation 1994

Gaseous hydrocarbons

The effects of biodegradation can be seen in the bulk (Table 3) and isotopic composition (Table 7) of the hydrocarbon gases. Selective removal of *n*-alkanes compared with their branched analogues occurs for the gases from Beldene 5, Kincora 7, Merivale 5 and Pleasant Hills 20 which have high iso-butane/*n*-butane and iso-pentane/*n*-pentane ratios compared with ratios around unity for the other gases (Table 3). Furthermore, high iso-alkane/*n*-alkane ratios are associated with low propane contents. Although differences in the terrestrial source rock composition may contribute to the variability in the iso-alkane/*n*-alkane ratios, it is considered more likely that the gases have been effected by in-reservoir alteration. In the case of Beldene 5 and Pleasant Hills 20, the high iso-alkane/*n*-alkane ratios are associated with normal carbon-13 isotopic differences between individual hydrocarbons (Table 7). Here, the alteration may be best attributed to water washing.

In unaltered gases, individual *n*-alkanes show a general trend to isotopic enrichment in carbon-13 with increasing molecular weight (James, 1983, 1990; Schoell, 1983, 1984). However, biodegradation results in selective attack on propane and preferential consumption of the lighter carbon-12 isotope (James and Burns, 1984). This causes the isotopic composition of the residual propane to become progressively heavier depending on the severity of biodegradation and can result in isotopic reversals where propane can become more enriched in the carbon-13 compared with the heavier hydrocarbons. In Kincora 7 and Merivale 5, this has occurred and propane has become the most isotopically enriched component. For the latter well, there is also evidence to suggest that biodegradation has also affected the isotopic composition of *n*-butane, albeit to a lesser extent than propane, as there exists an isotopic reversal between *n*-butane and *n*-pentane. For Rolleston 1, in-reservoir alteration appears to be restricted to the heavier $>C_7$ *n*-alkanes of the condensate (Group C4 in Table 2), with the gas hydrocarbons remaining intact (Tables 3 and 7). Thus, it appears that the biodegradation effects the light liquid *n*-alkanes before the gaseous *n*-alkanes and high molecular weight wax components.

There is an association between the extent of alteration and locality and this may point to different regions having unique hydrodynamics. Petroleum from the southwest on the Wunger Ridge is the least affected by alteration. Here, the oils and condensates show only mild alteration while the gases remain intact. Where higher levels of alteration are evident in the liquids from the Roma Shelf and Denison Trough, the gases also start to show evidence of compositional modification.

Maturation

Maturation is the process whereby sedimentary organic matter is converted into oil and gas under the action of heat. The extent of conversion or maturation level is defined by many physical and chemical parameters. For petroleum, chemical maturity parameters are the only ones available and their usable "maturity window"

© Australian Geological Survey Organisation 1994

depends on the particular biomarkers. The chemical maturity parameters can be used in overview to describe whether the petroleum is immature, mature or overmature or further refined to include sub-divisions, eg. early, peak and late oil generation within the oil window. Furthermore, empirical correlations have been defined which equate a chemical maturity parameter with an equivalent vitrinite reflectance. This can then be used to suggest the maturity level of the source rock when expulsion occurs assuming in-reservoir maturation is negligible. However, it also must be realised that the chemical maturity parameter is an average over the maturity range for which petroleum is being generated in a basin and an average of that petroleum entering the reservoir. For the liquid petroleum, chemical maturity parameters based on the gas chromatographic profile, saturated and aromatic biomarkers and carbon-13 isotopic composition will be compared. For the gases, the isotopic composition of individual hydrocarbons will be examined in order to suggest the history of gas generation.

Liquid Hydrocarbons

The OEP index (Table 2a), a measure of the predominance of odd numbered versus even numbered *n*-alkanes, is in the range 1.05 and 1.09 (one value at 1.12) for unaltered (O0) and slightly altered (O1a) oils. Being close to unity, these OEP values imply that the petroleum is thermally mature. The methyl phenanthrene index (MPI-1), is a widely used chemical maturity parameter based on the relative proportions of phenanthrene and isomers of methylphenanthrene (Radke and Welte, 1983). Various correlations (Radke and Welte, 1983; Boreham et al., 1988; Radke, 1988) have been found between MPI-1 of the bitumen and the observed vitrinite reflectance (Ro) of the sediment. This in turn enables a measured MPI-1 on a oil or rock extract to be translated to a calculated vitrinite reflectance (Rc). Since the chemical transformations are uniquely influenced by time and temperature, it is proper to 'calibrate' for the specific basin and thermal history. When the observed vitrinite reflectance for a series of related Permian coals is plotted against MPI-1 (Fig. 9; Table 8), linear regression analysis gives a correlation similar to that obtained by Radke and Welte (1983); the latter will be used in the subsequent discussion. For the liquid petroleum, a calculated vitrinite reflectance is within the range $0.65\% < Rc < 1.05\%$ (Fig. 10; Table 9a) except for Conloi oil which has a slightly higher value of 1.2% Rc. The latter may indicate generation from more mature source rocks or, alternatively, is a consequence of in-reservoir alteration (a combination of both maturation and biodegradation was favoured by Philp and Gilbert (1986) in explaining the anomalous maturity parameters for Conloi). It is known that moderate levels of biodegradation can effect the phenanthrene distributions. However, it is unclear why Conloi is affected and not the more severely altered oil at Riverslea 1 (Group O5 from GC-FID) which has a MPI-1 value within the range of the other liquids.

The maturity range observed for the liquids is consistent with the generally accepted range for liquid generation from a terrestrial land plant source (Tissot and Welte, 1984). Furthermore, there is little difference between the maturity level of oils and condensates although the latter, on average, show a slightly lower maturity (Fig. 10; Table 9). The same Rc value for all the oils from the Moonie field (Table

© Australian Geological Survey Organisation 1994

9) implies generation at the same maturation level and indirectly same source, and further that mild biodegradation has not affected the phenanthrenes distribution.

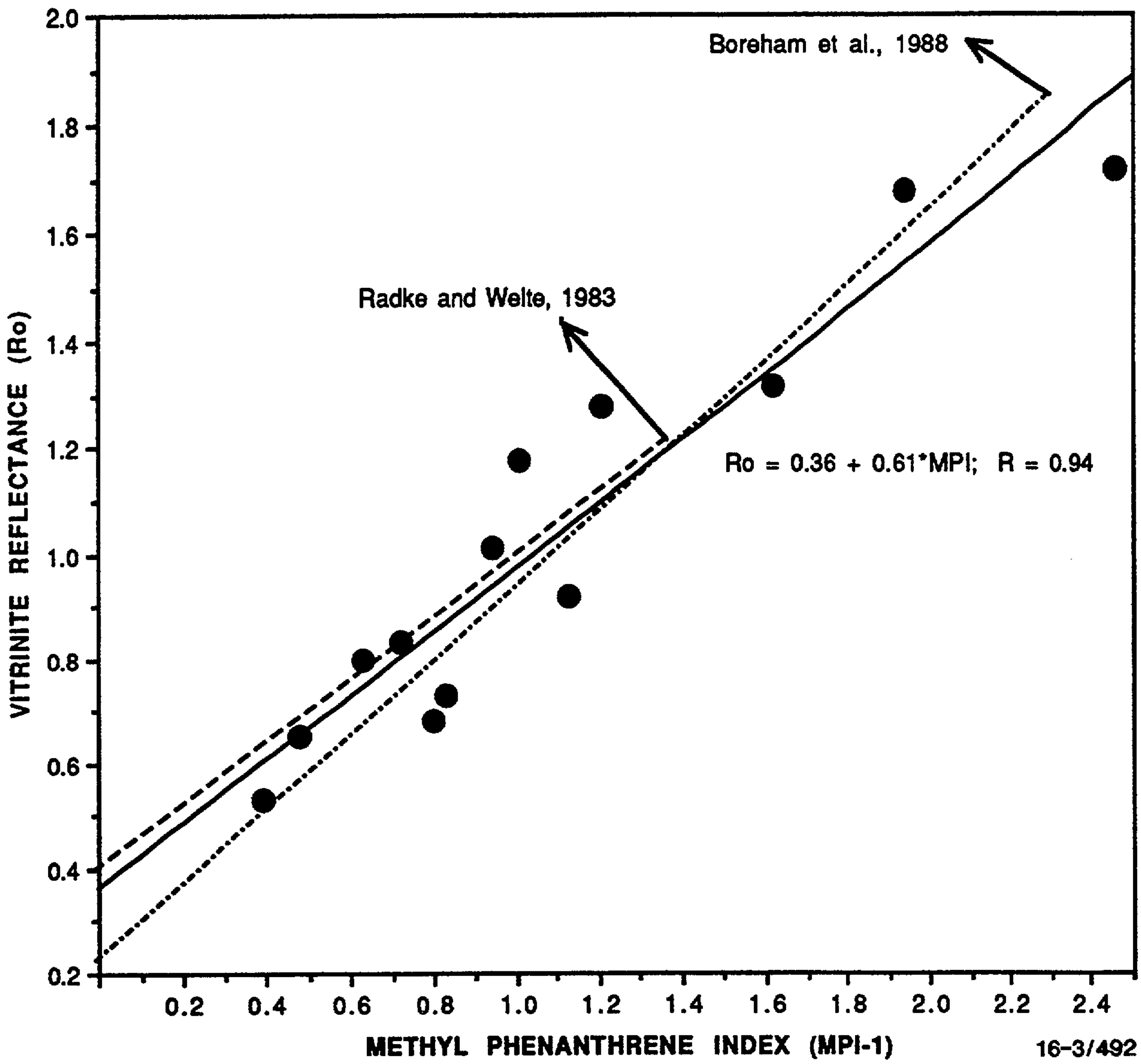


Figure 9. Plot of vitrinite reflectance (% Ro) versus MPI-1 in liquid petroleum.

© Australian Geological Survey Organisation 1994

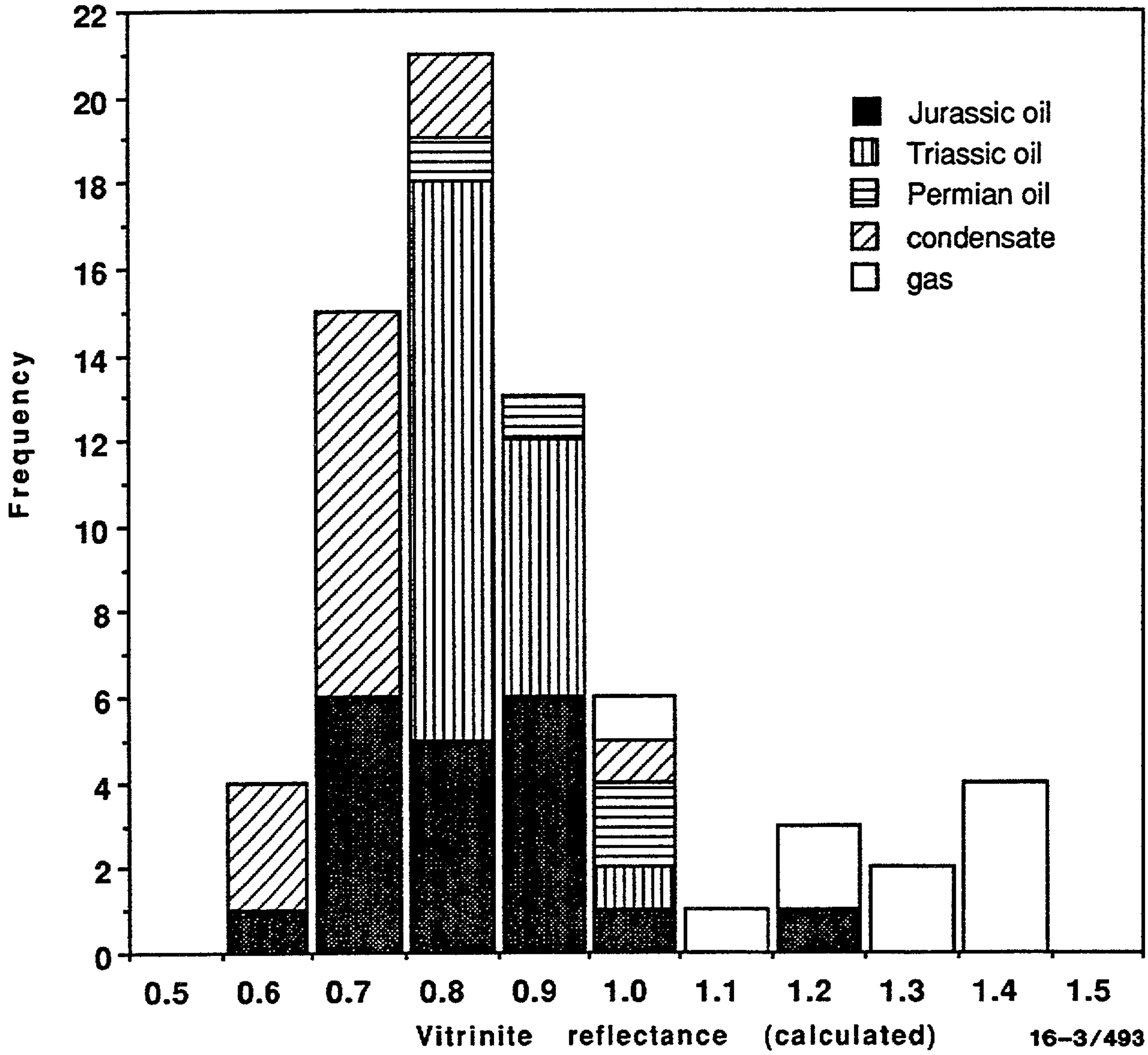


Figure 10. Frequency plot of Rc (calculated vitrinite reflectance) for oils, condensates and gases. Note that only one representative value is used for each alteration group (Table 2a) in the Moonie field.

© Australian Geological Survey Organisation 1994

There can be a complication in the maturity estimates for condensates since a single value for MPI-1 can correspond to two calculated Rc values, one at a maturity level before significant liquid cracking (Ro<1.35%) and the other at higher maturities, Ro>1.35% (Radke and Welte, 1983). More recent work has shown that the effective range can be extended to higher maturity levels (below and above Ro 1.7%; Boreham et al., 1988, Fig. 9) before a decrease in the MPI-1 value. This highlights the danger of using individual maturity parameters in isolation. When chemical maturity parameters based on internal isomer ratios of dimethylnaphthalene (DNR-1) and trimethylnaphthalene (TNR-1) (Alexander et al., 1985) are considered (Fig. 11; Table 9), oils and condensates are indeed shown to be generated at similar maturity levels, the latter before significant liquid petroleum cracking.

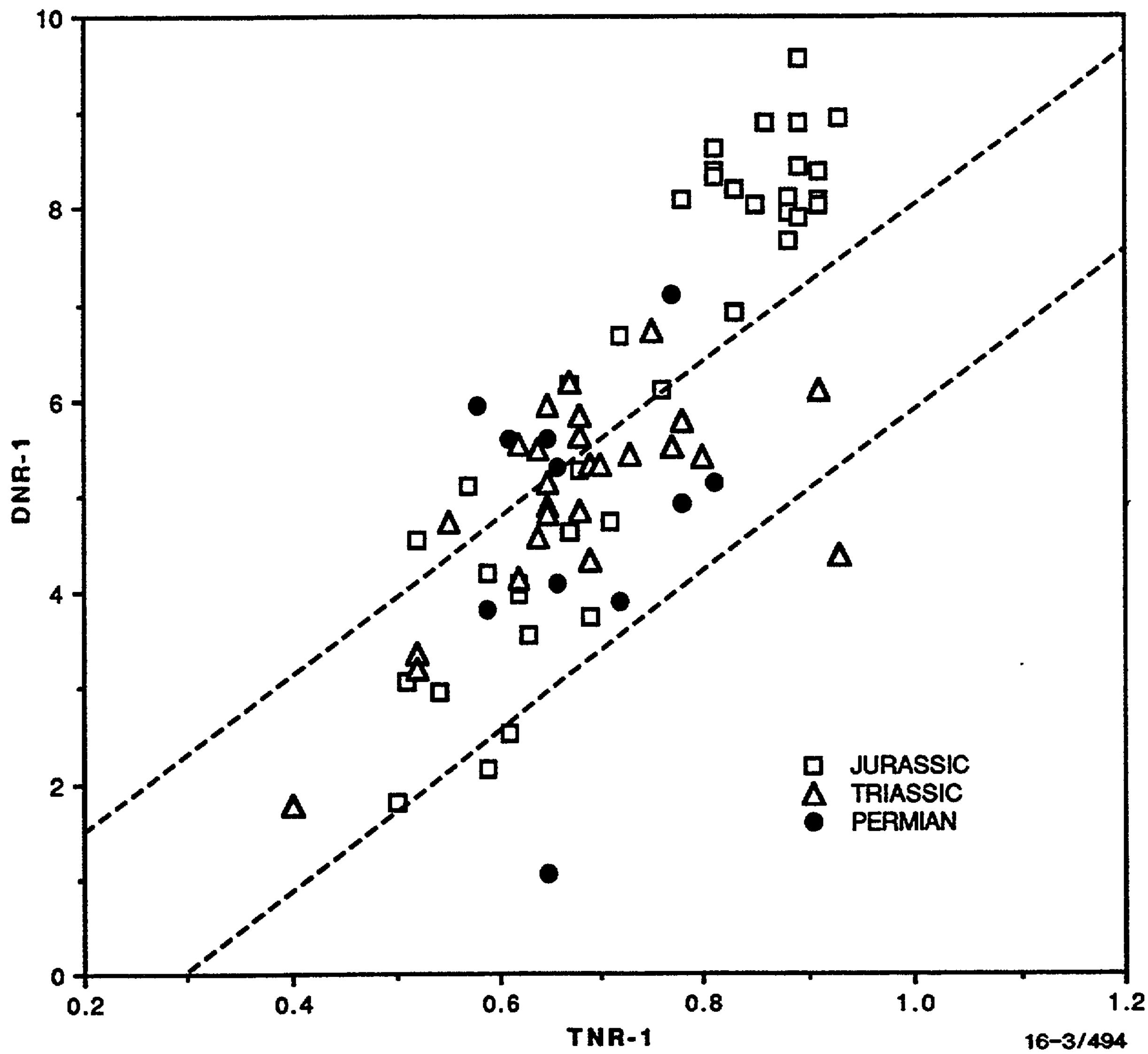


Figure 11. Plot of TNR-1 versus DNR-1 in liquid petroleum.

© Australian Geological Survey Organisation 1994

Saturated hydrocarbon biomarkers provide a complementary set of chemical maturity parameters. However, all these parameters reach their end point values at lower maturation levels than the aromatic hydrocarbons and therefore have a narrower effective range for maturity estimates. The ratio of 22S to 22R C_{32} bishomohopane (Table 5a) is specific for immature to early oil generation and generally shows no further change from 55-60% 22S isomer after approx. Ro 0.6%. (Peters and Moldowan, 1993). All the liquids, with only a few exceptions, have obtained their equilibrium values, consistent with the maturity levels determined from the aromatic hydrocarbons. The Tm/Ts (or Ts/Tm) ratio is another useful maturity indicator and can be used with high maturity oils up to Ro approx. 1.2-1.4%. It also has a strong source control which may partly explain its low correlation with Rc (Fig. 12).

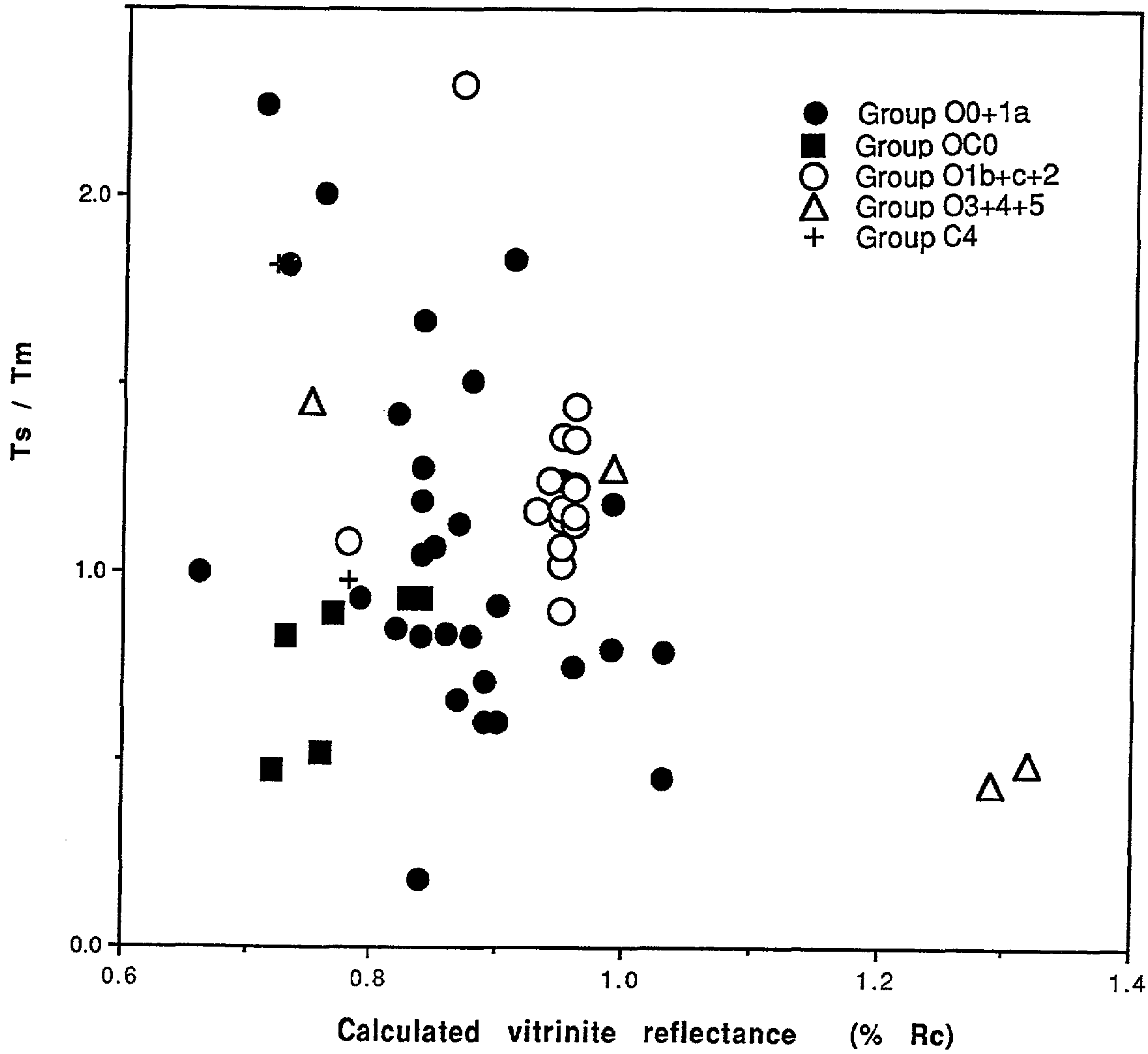


Figure 12. Plot of Ts/Tm versus Rc in liquid petroleum.

© Australian Geological Survey Organisation 1994

For the majority of liquids 0.5<Tm/Ts<1.5 (Fig. 13a) whereas the sediments additionally show higher and lower ratios (Fig. 13b) consistent with their extended maturity range. However, the Permian sediments, when compared to the younger sediments, show the closest match with the oils.

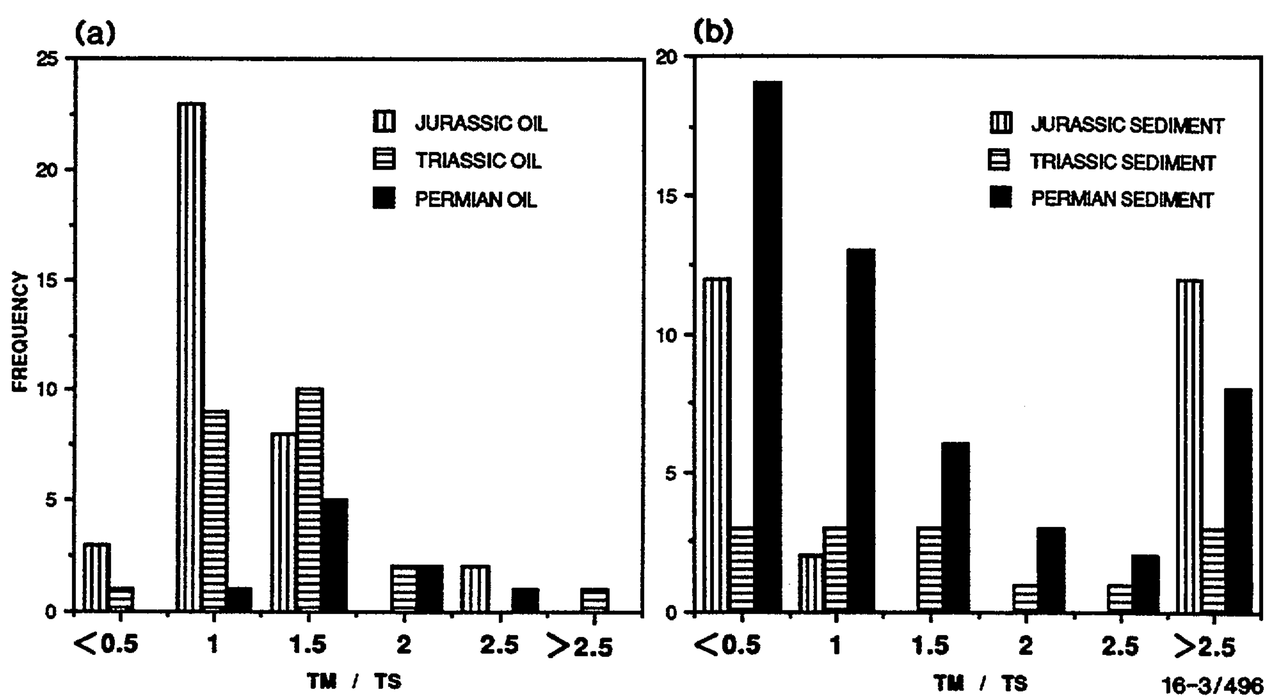


Figure 13. Frequency plot of Tm/Ts in a) liquid petroleum b) sediments.

© Australian Geological Survey Organisation 1994

Isomerisation at C-14, C-17 and C-20 in the C_{29} 5α(H),14α(H),17α(H)-steranes provide another set of widely used chemical maturity parameters. Isomerisation at C-14 and C-20 is considered to be source-independent (Seifert and Moldowan, 1986; Peters and Moldowan, 1993 pp. 240) while isomerisation at C-20 is slightly faster than at the other two carbon centres. All centres reach pseudo-equilibrium by peak oil generation. The plot between sterane maturity and Rc (Fig. 14) shows little correlation between the two.

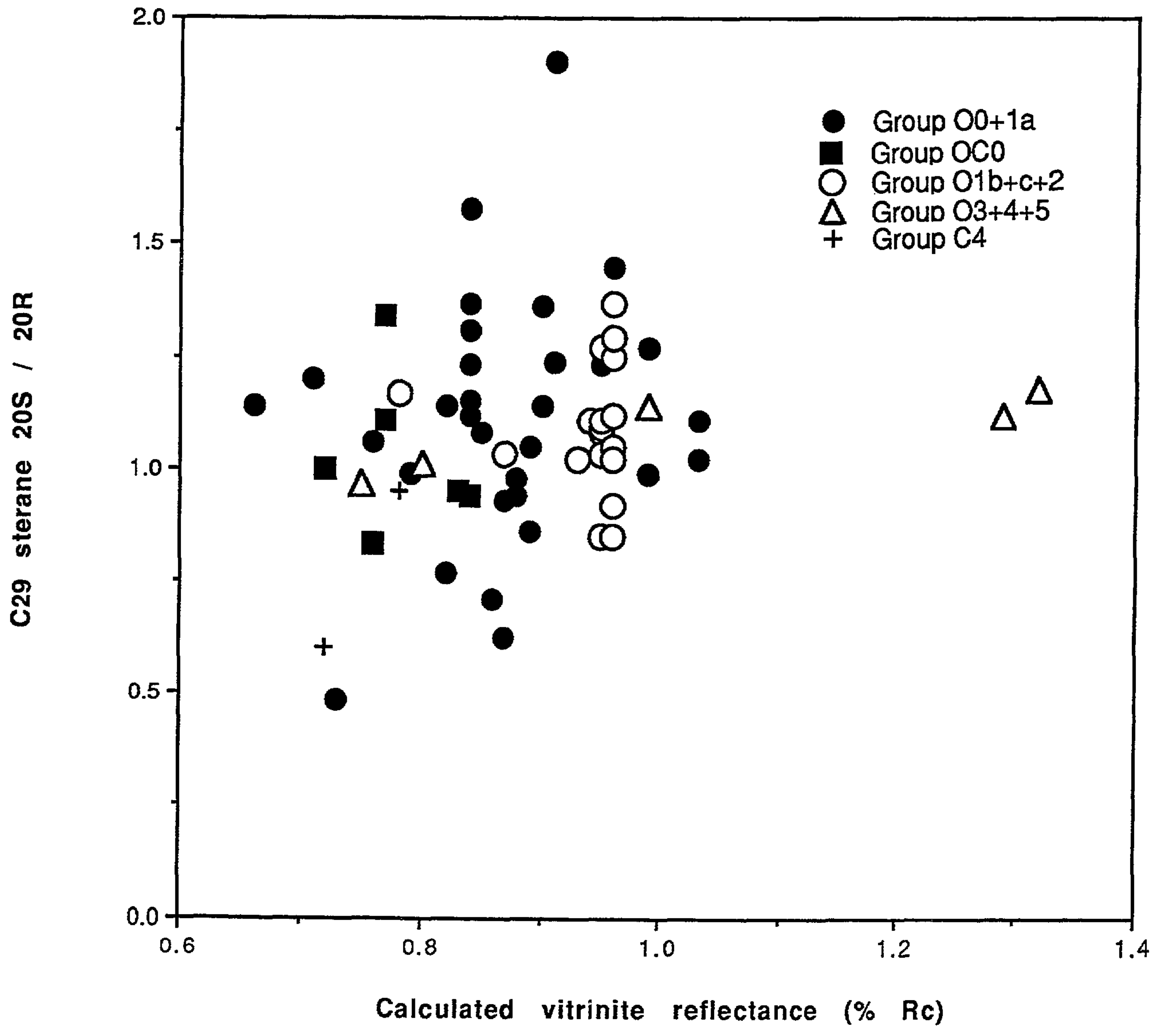


Figure 14. Plot of $\alpha\alpha\alpha C_{29}$ sterane 20S/20R versus Rc in liquid petroleum.

© Australian Geological Survey Organisation 1994

Furthermore, the distribution of the 20S/20R ratio for the oils (Fig. 15a) is best matched by the Permian sediments (Fig. 15b). A biomarker maturity index (BMAI) plot (Seifert and Moldowan, 1981) of sterane ratios of [5α,14α,17α(20S)/5α,14α,17α(20R)] versus [5α,14β,17β(20R)/5α,14α,17α(20R)] is based on similar structural types and shows a strong linearity (Figs. 16a and b).

A uniform feature of all the maturity parameters is the recognition that petroleum was generated over a range of maturation levels. In Figure 15 the modest spread in values may be related to analytical errors associated with determining trace amounts of biomarkers or subtle effects resulting from the initial phase of palaeo-biodegradation, or to differences in thermal histories at different localities influencing isomerisation rates (Peters and Moldowan, 1993). However, on the regional scale, one is struck by the apparent lack of correspondence between the maturity levels determined from the aromatic hydrocarbons and those using the saturated hydrocarbons (Figs. 12 and 14).

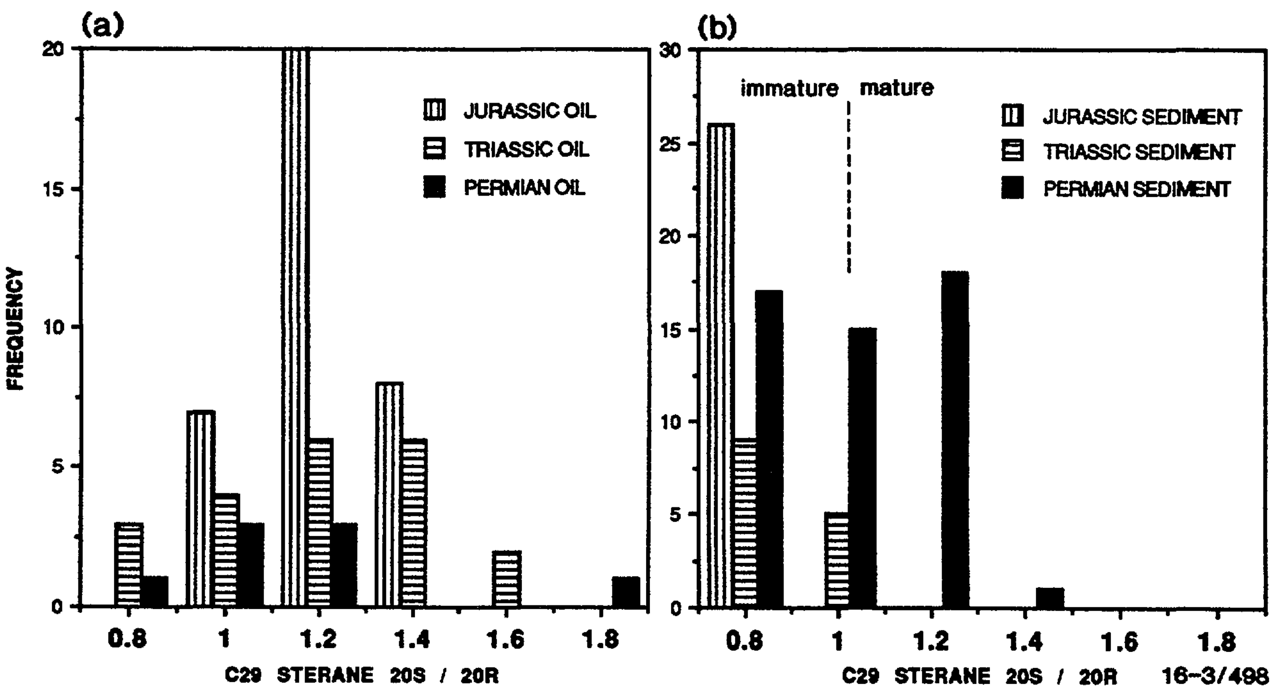


Figure 15. Frequency plot of $\alpha\alpha\alpha C_{29}$ sterane 20S/20R in a) liquid petroleum b) sediments.

© Australian Geological Survey Organisation 1994

In order to reconcile this apparent lack of self consistency, it is concluded that oil accumulations represent a mixture of liquids over a range of maturities (England et al., 1987). Thus, the bulk composition of the oil will represent an average of the trapped liquids. Furthermore, the lower maturity oils have the higher biomarker contents compared with higher maturity oils while the saturated biomarker contents for the condensates are consistently lower than the oils. On the other hand, the relative concentrations of the aromatics in the C_{12+} hydrocarbon fraction increase with maturity (Table 2a). Therefore it can be envisaged that there will be differences in the timing of the release of these unrelated biomarkers classes from kerogen as catagenesis proceeds, while bound and unbound biomarkers can "mature" at different rates (van Grass, 1986). Also, heterogeneity of the predominantly terrestrial source rocks should ensure a strong source control on biomarker release. It is further suggested that the saturated biomarkers in these petroleums reflect a bias towards the initial generated petroleum, while the more abundant di- and triaromatics are the most relevant maturity indicators reflecting the average maturity level of the expelled liquid petroleum (as discussed further under Migration and Expulsion).

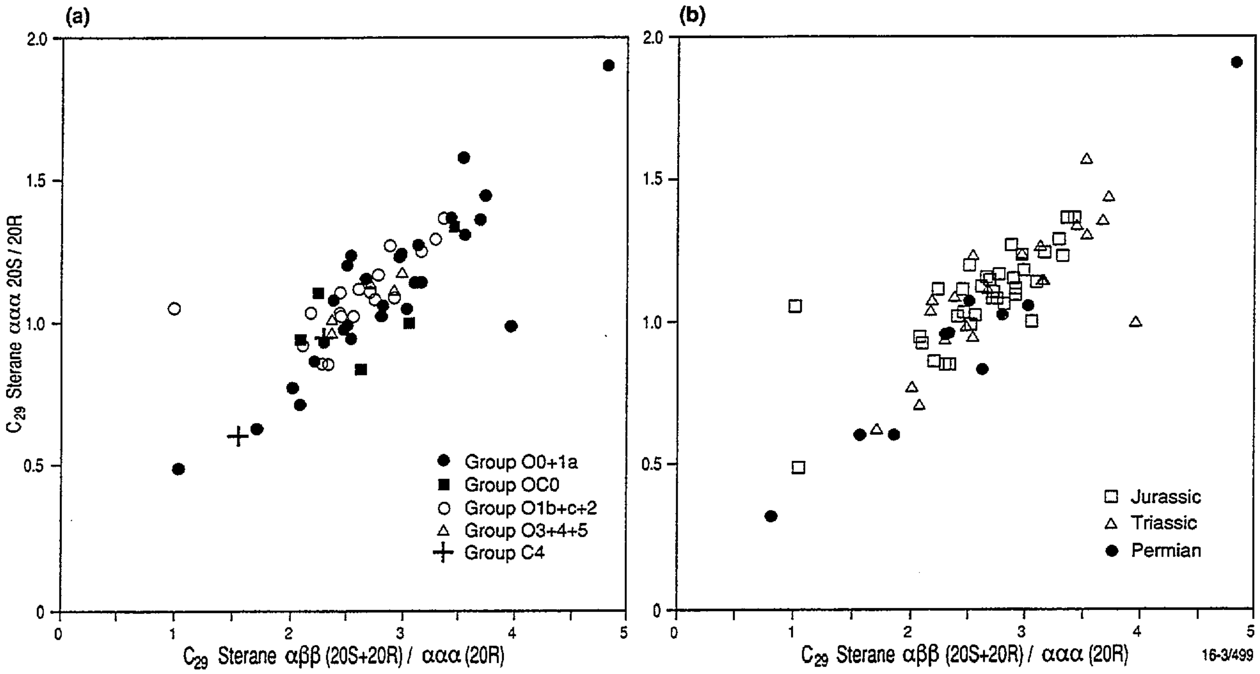


Figure 16. Biomarker Maturity Index in liquid petroleum plotted as a function of a) reservoir age b) level of biodegradation.

© Australian Geological Survey Organisation 1994

The carbon isotope ratios of oils and condensates has been examined to further delineate maturation levels of their generation. The systematic trend in the carbon isotope ratios for discrete distillation cuts (Fig. 17; Table 10) has been utilised by Clayton (1991) to determine maturity relationships within and between liquid petroleums. Since a predominantly terrestrial source has been determined for these petroleums (see also Source section), Clayton's view is that maturity is the main control on the profile of the curves. Low molecular weight components (<200°C; 'condensate-like') from an oil are isotopically lighter by $\delta^{13}C$ of about 1°/$_{oo}$ compared with the residual oil (>200°C fraction) for low maturity oils. Increased maturity levels of generation result in the isotopic ratio of the 'condensate-like' fractions increasing at a faster rate than the heavier oil fractions. This results in the isotopic difference between condensate and oil to be zero at the end of the oil window followed by a reversal in the isotopic trend during oil to gas cracking. Strict adherence to

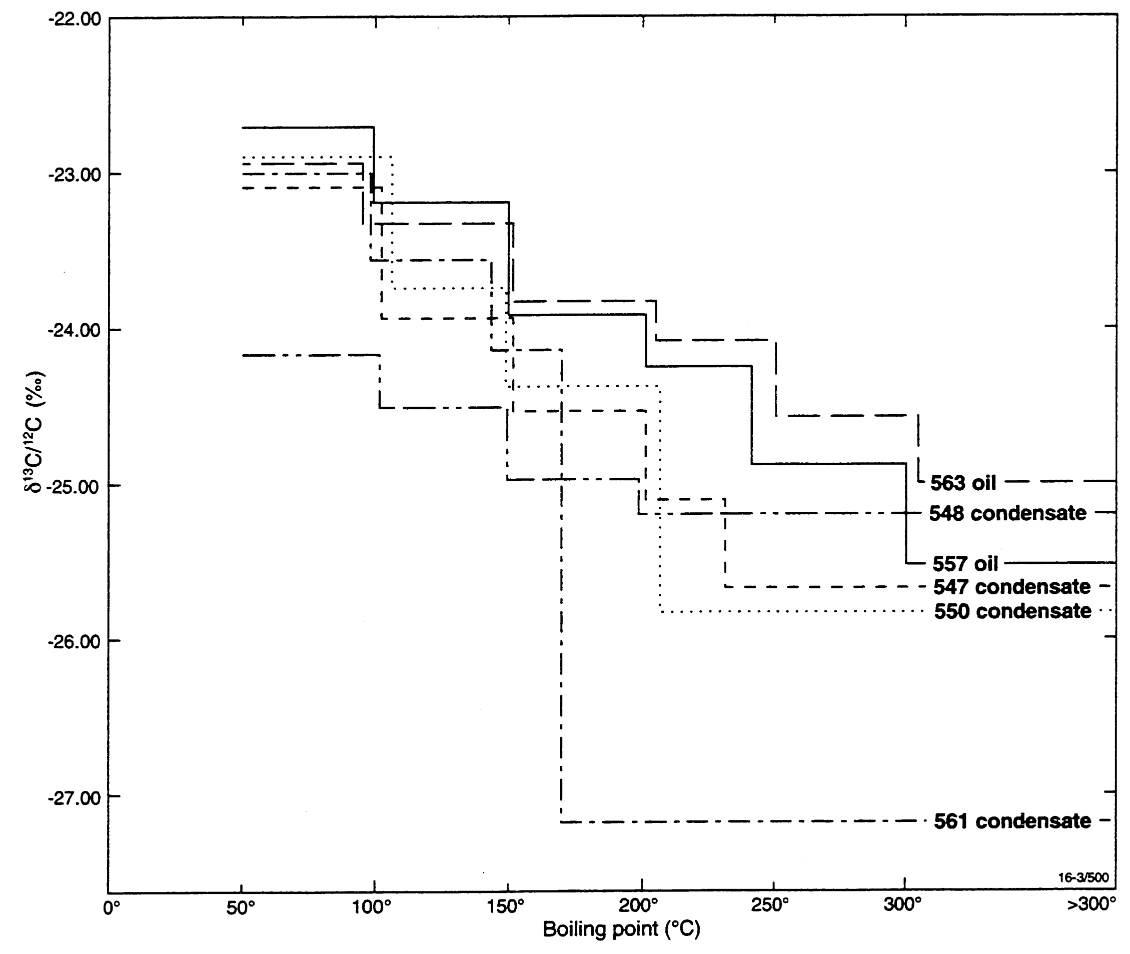


Figure 17. Carbon isotopic composition of distillation cuts for oils and condensates versus distillation cut temperature range.

© Australian Geological Survey Organisation 1994

Clayton's approach ('condensate fraction' is isotopically heavier than oil residue; Fig. 17 and Table 10) implies that the oils were generated at slightly higher maturation levels than those suggested by the biomarker data. However, the usefulness of isotopic data for maturity estimates in this context has to be questioned in the light of recent evidence suggesting a much stronger source control on isotopic composition of different molecular weight liquid petroleum fractions (Chung et al., 1994). Furthermore, the isotopic value for the <200°C fraction of the oil from Rednook (#563, Wunger Ridge) and the condensate from the same well (#561) is identical within experimental error. This infers that both liquids were generated at the same maturity level (Rc difference is 0.1%; within the $\pm$0.05% reliability of this method) and phase separation along the migration pathway may have resulted in a discrete oil and gas/condensate phase, each giving rise to separate accumulations. However, the isotopic match could be fortuitous since the "condensate" component from the oil at Merivale 5 in the Denison Trough also has the same value, and the $\delta^{13}C$ values for Yellowbank Creek 3 (#557, Roma Shelf) and Yellowbank 3 (#547, Denison Trough) are within $\pm 0.4^{\circ}/_{\circ\circ}$. The value for Rolleston 3 is about $1^{\circ}/_{\circ\circ}$ lighter. All the >200°C distillation fractions, except Rednook (#561), are within $1^{\circ}/_{\circ\circ}$ of each other and between 0.6-$2.1^{\circ}/_{\circ\circ}$ isotopically lighter than the <200°C distillation fraction. This degree of variability is the same as is observed in the isotopic ratios of the C_{12+} saturated and aromatic hydrocarbon fractions (Fig. 6). The origin of the light isotopic composition for Rednook (#561) will be discussed below in the Source section.

Gaseous hydrocarbons

The theoretical variation in the separation of carbon isotopes between the individual hydrocarbon components of a natural gas has been used to define the maturity at which the gas was generated (James, 1983). The isotopic separation is independent of the absolute isotopic value, this being a function both of source and maturity. From James' (1990) plot (Fig. 18), the maturity level of the gas (level of organic metamorphism, LOM, or estimated vitrinite reflectance, Rc) is determined using the sliding scale until the isotopic separations (between methane and ethane, ethane and propane etc.) fall on the calculated maturity evolution lines. In the application of this curve-fitting exercise, the following points must also be appreciated: (1) isotopic separations between any two hydrocarbon components, one of which is methane, is considered to be the least reliable (due to the possibility of mixing of the natural gas with isotopically light biogenic methane), whereas the separation between ethane and propane is the most reliable (James, 1990). (2) gases derived from source rocks containing predominantly terrestrial organic matter (coal included) can have isotopic values that indicate a source maturity 1-2 LOM units too high (James, 1983; James and Burns, 1984). Furthermore, for this type of organic matter, *n*-butane may be isotopically lighter than propane which could be confused with biodegradation. (3) biodegradation can lead to isotopic enrichment in propane (James and Burns, 1984) and *n*-butane (this work). Since a predominantly terrestrially-derived source has been assessed for the liquid hydrocarbons (see below), it appears reasonable to assume that the same source exists for the gaseous hydrocarbons, thus point 2 needs to be definitely taken into account in the assessment of the maturity of gas generation.

© Australian Geological Survey Organisation 1994

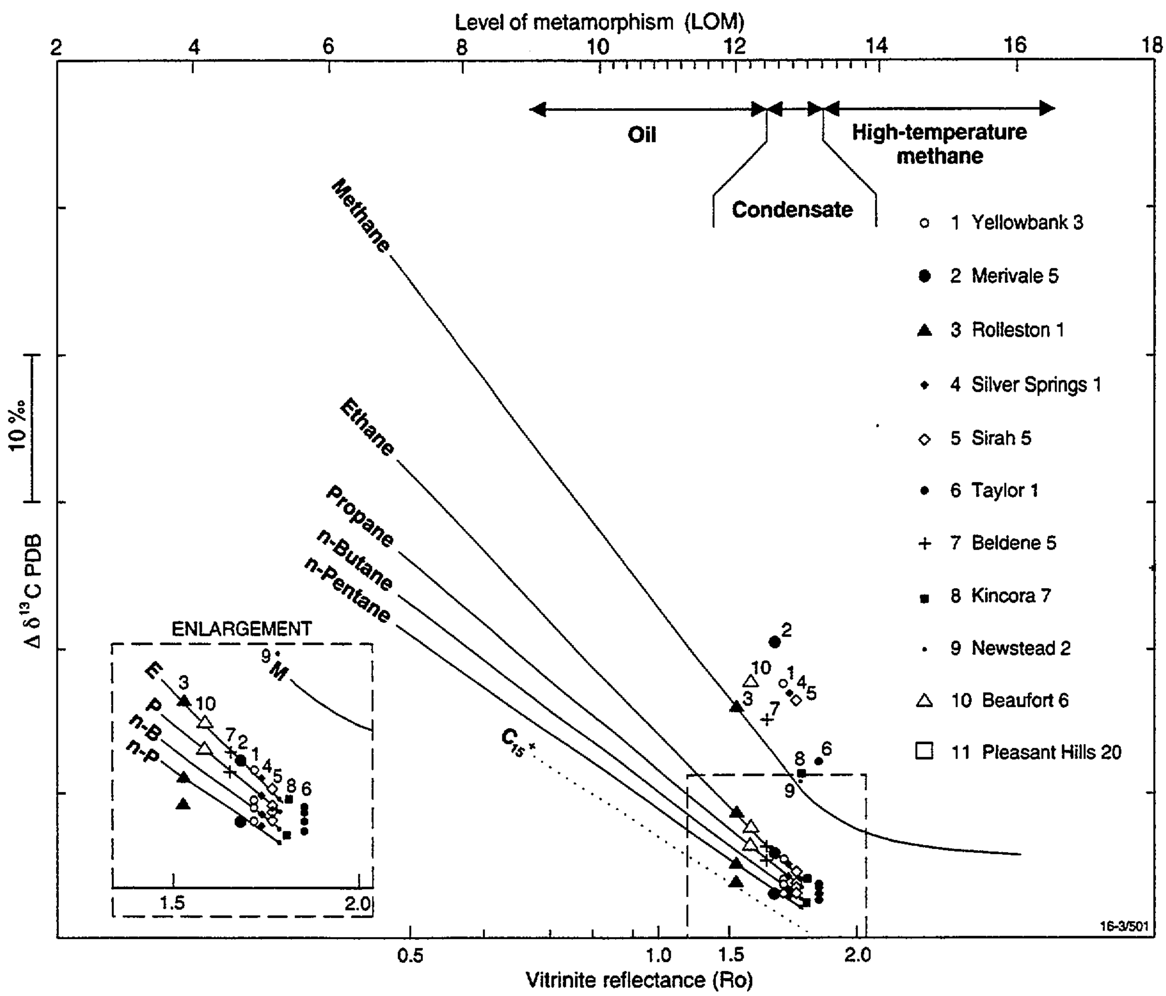


Figure 18. Plot of carbon isotopic separations between individual gaseous hydrocarbons and maturity indicators, level of organic metamorphism (LOM) and % Ro (after James, 1990).

© Australian Geological Survey Organisation 1994

For the Newstead 2 gas, a LOM of 13 provides a good fit between the measured isotopic differences and the theoretical curves for all the *n*-alkanes (Fig. 18). All other gases are assessed to have LOM >12 on the following grounds. When fitting the C_{2+} separations, methane plots above the calculated curve thus requiring an additional source of isotopically light methane. Undoubtedly, this latter source is related to microbiological activity (James, 1983; Schoell, 1983; 1984) either within or outside of the reservoir.

To the north of Newstead, the gases on the Roma Shelf become progressively drier, previously interpreted as a response to a regional northerly increase in source rock maturity (see Bulk Composition section). However, this is not accompanied by a clear isotopic maturity trend. In fact, the drier gases show a slightly lower isotopic maturity. Although this may be real, its also could be due to an inability to gain sufficient resolution of small maturity differences when accompanied by source and biodegradation influences. Thus, Kincora 7, Beldene 5 and Beaufort 6 (C_{2+} hydrocarbons were in too low a concentration to obtain reliable data for Pleasant Hills 20) are assessed to have LOM values of 13 (based on ethane and butane fit, propane was neglected due to isotopic enrichment from biodegradation), 12.5 (ethane and propane) and 12.2 (ethane and propane), respectively.

To the south of Newstead 2 and on the Wunger Ridge, Taylor 1 has the highest maturity with LOM > 13 although this is accompanied by an increase in wet gas content in this region. A LOM of 13 is assessed for Sirah 5 based on ethane and propane, whereas for Silver Springs 1 a slightly lower LOM of 12.8 is obtained from a ethane, propane, and *n*-butane fit.

The three gases from the Denison Trough all appear to be affected by biodegradation to varying degrees. For Yellowbank 3, LOM of 12.2 is obtained from ethane and propane but a slightly higher LOM of 12.7 occurs based on ethane, butane and pentane if it is assumed that propane is mildly affected by biodegradation. Merivale 5 is the most severely affected by biodegradation and not amenable to reliable maturity estimates. However, a LOM of 12.6 can be obtained based on ethane and *n*-pentane; propane and *n*-butane being affected by biodegradation. Rolleston 1 gives a LOM of 10.2 if ethane, propane and *n*-butane are used. However, methane then plots unacceptably below the theoretical line in Figure 18. Based on methane and ethane, a minimum maturity of LOM 12 is derived. Higher LOM values will occur if there is a biogenic component to the methane.

An alternative approach developed by Schoell (1983, 1984) is based on empirical genetic relationships amongst compositional characteristics found in a large database of natural gases. Schoell was able to correlate the isotopic composition of methane and ethane and bulk gas composition to define compositional fields related to biogenic methane, maturation and migration effects. Using two of Schoell's diagrams, a crossplot of the isotopic composition of methane versus C_{2+} hydrocarbons (Fig. 19a) and versus the isotopic composition of ethane (Fig. 19b), it can be seen that (i) methane is produced as a consequence of petroleum

© Australian Geological Survey Organisation 1994

generation and that biogenic methane is only a minor component and (ii) the maturity level for the gas generation is at the end of the oil window (approx. Ro 1.2) for a terrestrial source and before significant wet gas cracking.

When comparing the two approaches, James' maturity levels need to be reduced by approx. 1 LOM to LOM's between 11.2 and 12 (Fig. 18) to bring the maturity estimation in line with that of Schoell (1983). Indeed, this is exactly what is recommended for terrestrially derived gases (James, 1990). The corrected LOM's determined for the gases correspond to a range in effective vitrinite reflectance of 1.05%<Rc<1.4% (Fig. 18). Thus, the main phase of gas generation is separate from and at a higher maturity than the main phase of liquid generation (Fig. 10).

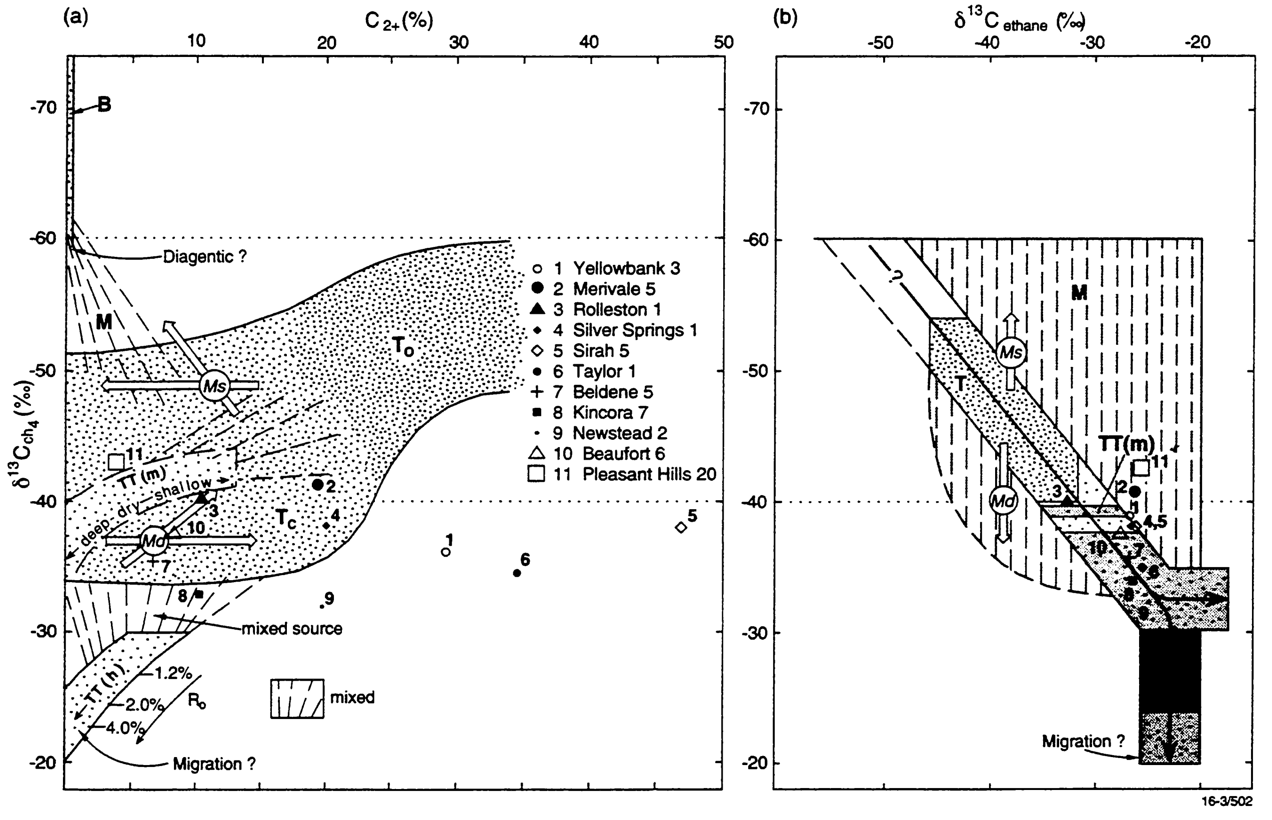


Figure 19. Carbon isotopic composition of methane versus a) percentage of C_{2+} gaseous hydrocarbons b) $\delta^{13}C$ value of ethane (after Schoell, 1983).

Source Parameters

Source Richness

Figure 20 shows the yield of hydrocarbons (ppm) extracted from the sediment cores plotted against TOC. The various fields delineating source richness are empirically derived from examination of bitumen contents of many effective source rocks (Tissot and Welte, 1984; Powell, 1988a). Good gas and liquid source potential exists within sediments of Permian to Jurassic age. In particular, the Permian lower delta plain German Creek coals and the alluvial coals in the Reids Dome beds have similar hydrocarbon potential with HI's of 250mg hydrocarbons/gTOC (Table 8). Both have higher liquid potential than the predominantly gas-prone lower delta plain coals of the Rangal and Bandanna coals (HI <200 mg hydrocarbons/gTOC; Table 8). High HI values (>400 mg hydrocarbons/gTOC) for some Permian sediments (Table 2b) are assumed to indicate a strong contribution from fresh water algae (eg. *Botryococcus*).

In the Taroom Trough, coals and mudrocks of the Blackwater Group have higher liquid potential compared with similar rock types and marine sediments from the Back Creek Group (Carmichael and Boreham, 1994). However, localised liquid potential has been inferred in marine facies in the southern Taroom Trough (Morton et al., 1993).

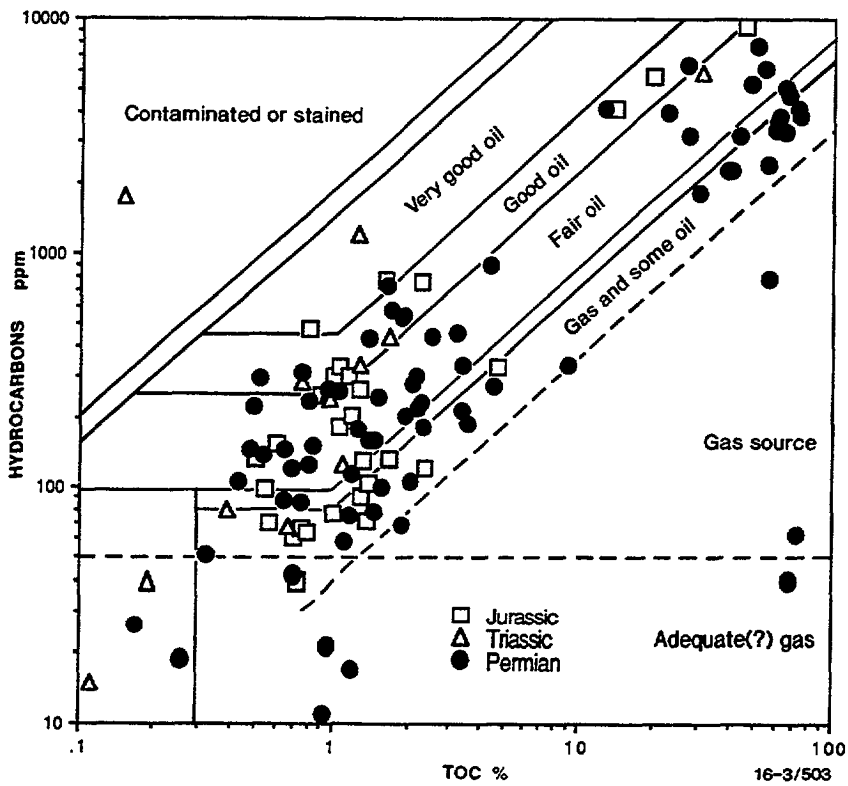


Figure 20. Source richness plot of saturated + aromatic hydrocarbons (ppm) versus TOC.

Gas Chromatographic Parameters

The paraffinic nature and a moderate wax content (C_{22+} *n*-alkanes) support a terrestrial land plant origin (Tissot and Welte, 1984 and references therein) for the unaltered and least altered oils (Figs. 4 and 5). Indeed, the GC-FID fingerprint for saturated hydrocarbons of a Permian potential source rock is very similar to that of the unaltered oil at the same maturity level (Fig. 21). Unfortunately, suitable Triassic and Jurassic potential source rocks were not available at sufficient maturity for a realistic comparison. Pristane (Pr) to phytane (Ph) ratios obtained from gas chromatography have been widely used in determining source affinities and depositional environments (Brooks et al., 1969; Powell and McKirdy, 1973; Volkman and Maxwell, 1986; Powell, 1988b). For the majority of the liquids, Pr/Ph >3.0 indicate terrestrial organic matter source and where the organic matter has been exposed to at least one period of oxic conditions. The bulk of the condensates have Pr/Ph > 6. These high values are susceptible to analytical error associated with trace concentrations as well as fractionation involving phase separation discriminating against the higher molecular weight Ph (Dzou and Hughes, 1993). Conloi (#217) and Westgrove (#391) have Pr/Ph ratios of 1.8 and 2.7 respectively (Fig. 22 and Table 2a). The low ratio for the latter sample is a consequence of using a >250°C distillation cut where there has been selective loss of the lower molecular weight Pr. A simple interpretation of the Pr/Ph ratios can be hindered by sources other than terrestrial land plants for the isoprenoids (Volkman and Maxwell, 1986) and the effects of maturity and biodegradation. Those liquids which have been altered, on average, have lower Pr/Ph ratios than the unaltered liquids (Fig. 22) suggesting that pristane is degraded at a faster rate than phytane. Thus the low Pr/Ph ratio for Conloi most likely results from the alteration in the reservoir and not from any inherent source difference.

Saturated Biomarkers

The low concentration of the biomarkers (with some samples being near the detection limits of the GC-MS instrument) in the reservoired petroleum increases the likelihood of 'contamination' resulting from dissolution of biomarkers from non-source facies along the migration pathway. Although this possibility cannot be entirely eliminated (however see aromatic biomarkers), reliable interpretations can be achieved by the collective use of different classes of molecular fossils. The presence, or absence, or abundance of specific biomarkers or classes of biomarkers enables distinctions to be made between petroleum derived from different source facies and depositional environments.

The presence of C_{30} desmethylsteranes has been universally recognised as a marker for marine organic matter. For example, four oils show the presence of C_{30} desmethylsteranes (Table 6a) indicating an input from marine organic matter. C_{30} desmethylsteranes are common throughout the Bowen and Surat basin sediments (Table 6b) and thus cannot be used to reliably assign a particular source association. However, the highest relative abundance of these biomarkers is found in the marine-dominated sediments of the Permian Back Creek Group. A marine influence has been observed previously in the Cabawin oil by Philp and Gilbert

© Australian Geological Survey Organisation 1994

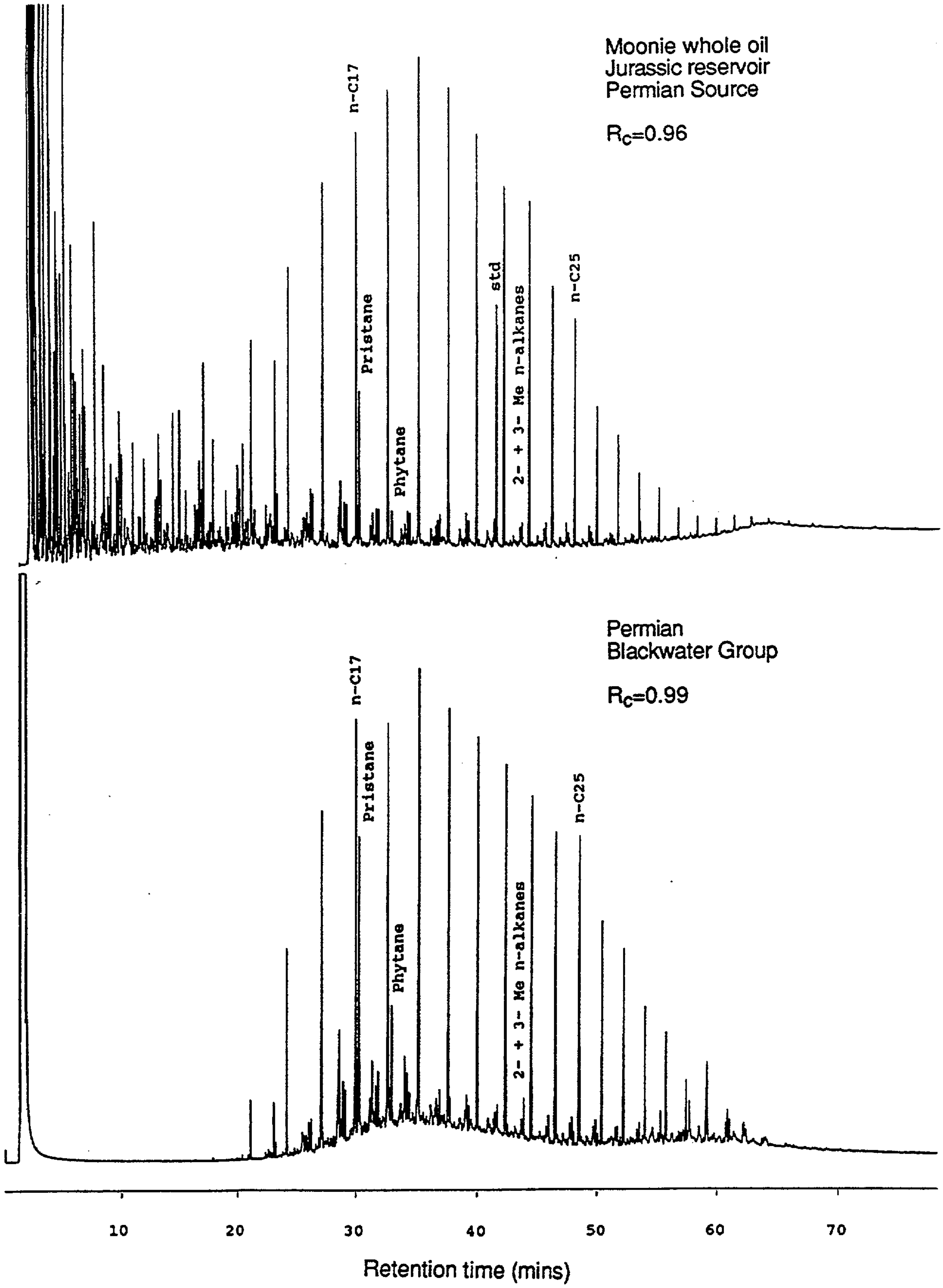


Figure 21. GC-FID trace for a) whole oil and b) saturated hydrocarbons from a Permian potential source rock.

© Australian Geological Survey Organisation 1994

(1986) who used the occurrence of the tricyclic terpanes (Table 6a) to indicate a marine input. However, the analysis of the two Cabawin oils held in the AGSO collection failed to show any signs of the two putative marine biomarkers. In petroleum with demonstrated C_{30} steranes, the C_{30} tricyclic terpane is also present, although the reverse is not the case. A similar, though less rigid, characteristic is seen in the sediments (Table 6b). Thus, a marine contribution is considered definite where the sterane biomarker is present but tentative when only the tricyclic occurs in isolation, since it is recognised that the tricyclic terpanes can have a bacterial source (Peters and Moldowan, 1993), traversing facies boundaries.

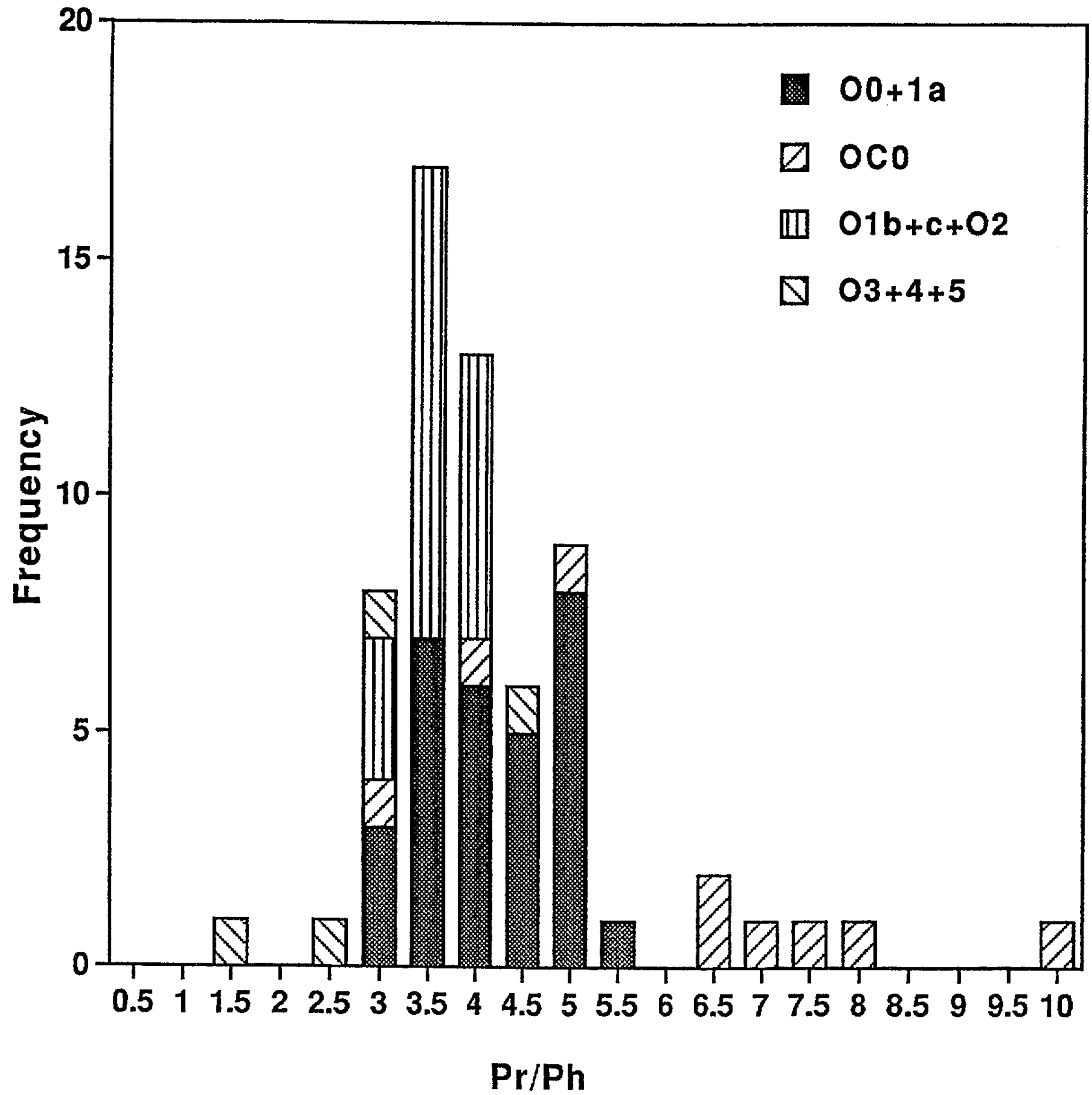


Figure 22. Frequency plot of Pr/Ph ratio in oils and condensates.

© Australian Geological Survey Organisation 1994

The inferred marine influence (definite and tentative) occurs at seven sites (8 oils and condensates in Table 6a) covering all four petroleum provinces and the three stratigraphic levels. Additionally, there appears to be a strong local focus encompassing the Blyth Creek, Wallumbilla and Richmond area. However, for the majority of oils and condensates the cumulative evidence to date reaffirms a dominant terrestrial source.

Terrestrially sourced petroleum has been distinguished from marine sourced oils by a higher hopane/sterane ratio in the former (Hoffmann et al, 1984; Vincent et al., 1985; Philp and Gilbert, 1986). For the Bowen/Surat petroleum, hopane/sterane ratios show a wide range from <0.2 to 20 (Table 6a). The frequency distribution of this ratio (Fig. 23a) for the total liquid set shows a bimodal distribution maximising at 0.5-1.0 and >3.0. The marine-influenced liquids mirror this distribution although there are no values >2.0. Furthermore, the ratio distribution in the Permian sediments (Fig. 23b) is a closer 'fit' with the petroleum although a lower maturity in the Jurassic sediments has, most likely, offset the hopane/sterane ratio to higher values.

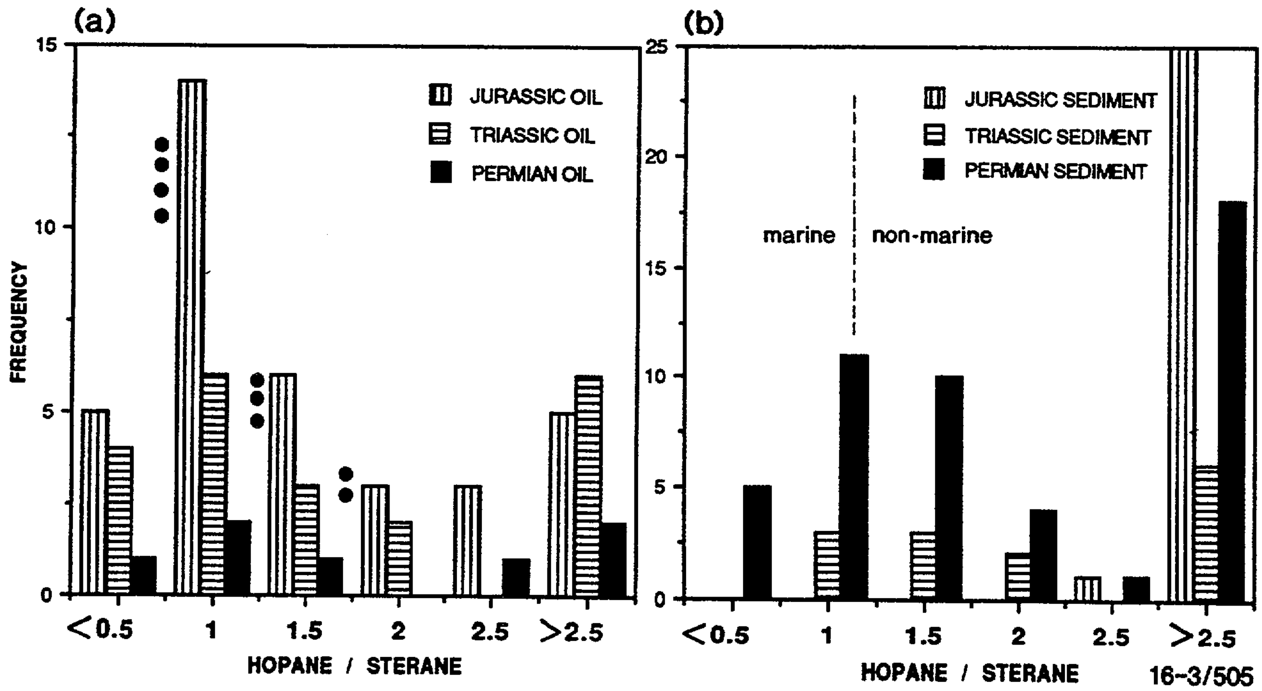


Figure 23. Frequency plots of Σ hopane / Σ sterane in a) liquid petroleum (bars indicate total liquids; circles indicate 'marine-influenced' liquids) b) sediments.

Likewise, the dominance of the C_{29} steranes over the lower carbon numbered C_{27} and C_{28} homologues is a trait of land plant input. Indeed, the majority of the petroleum have low C_{27}/C_{29} sterane ratios (Fig. 24a). However, there are also some samples that show increasing proportions of the C_{27} homologue, albeit with low frequency (Fig. 24a). For the sediments, this source parameter is indiscriminate with respect to age (Fig. 24b) and shows a distribution similar to the liquid petroleum. A terrestrial source dominance for the petroleum is further highlighted in Figure 25.

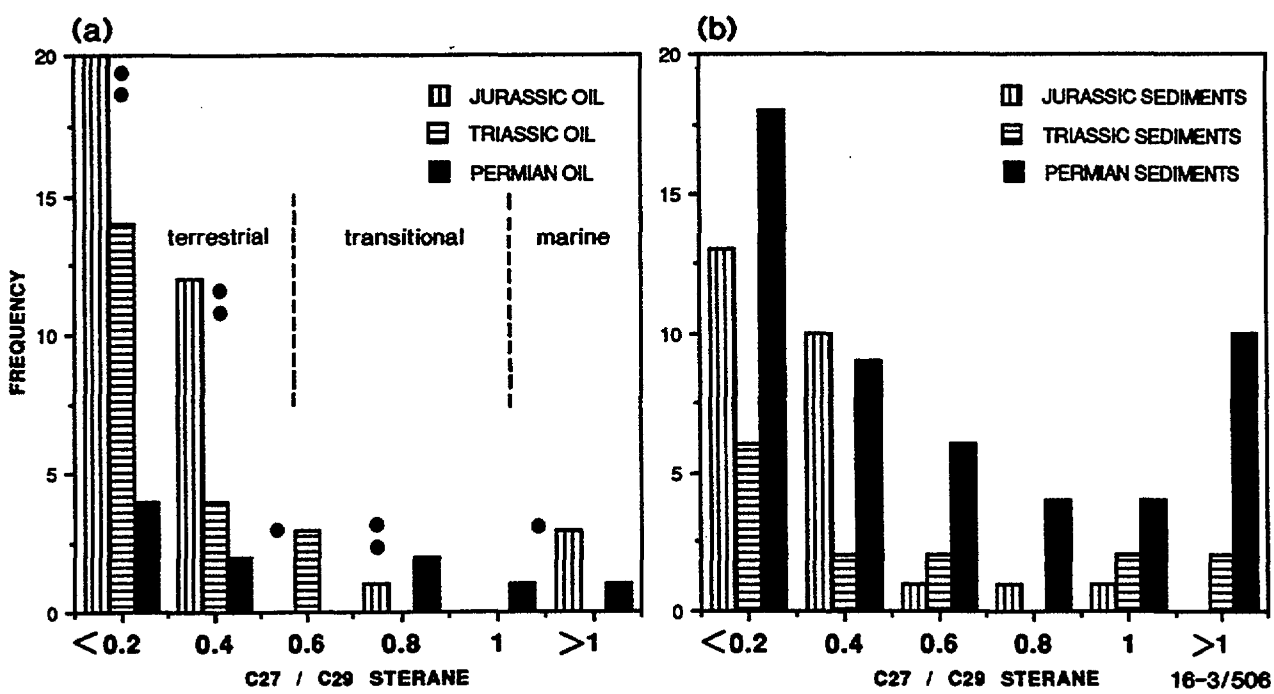


Figure 24. Frequency plot of $\alpha\alpha\alpha C_{27}$ 20R/$\alpha\alpha\alpha C_{29}$ 20R sterane in a) liquid petroleum b) sediments.

© Australian Geological Survey Organisation 1994

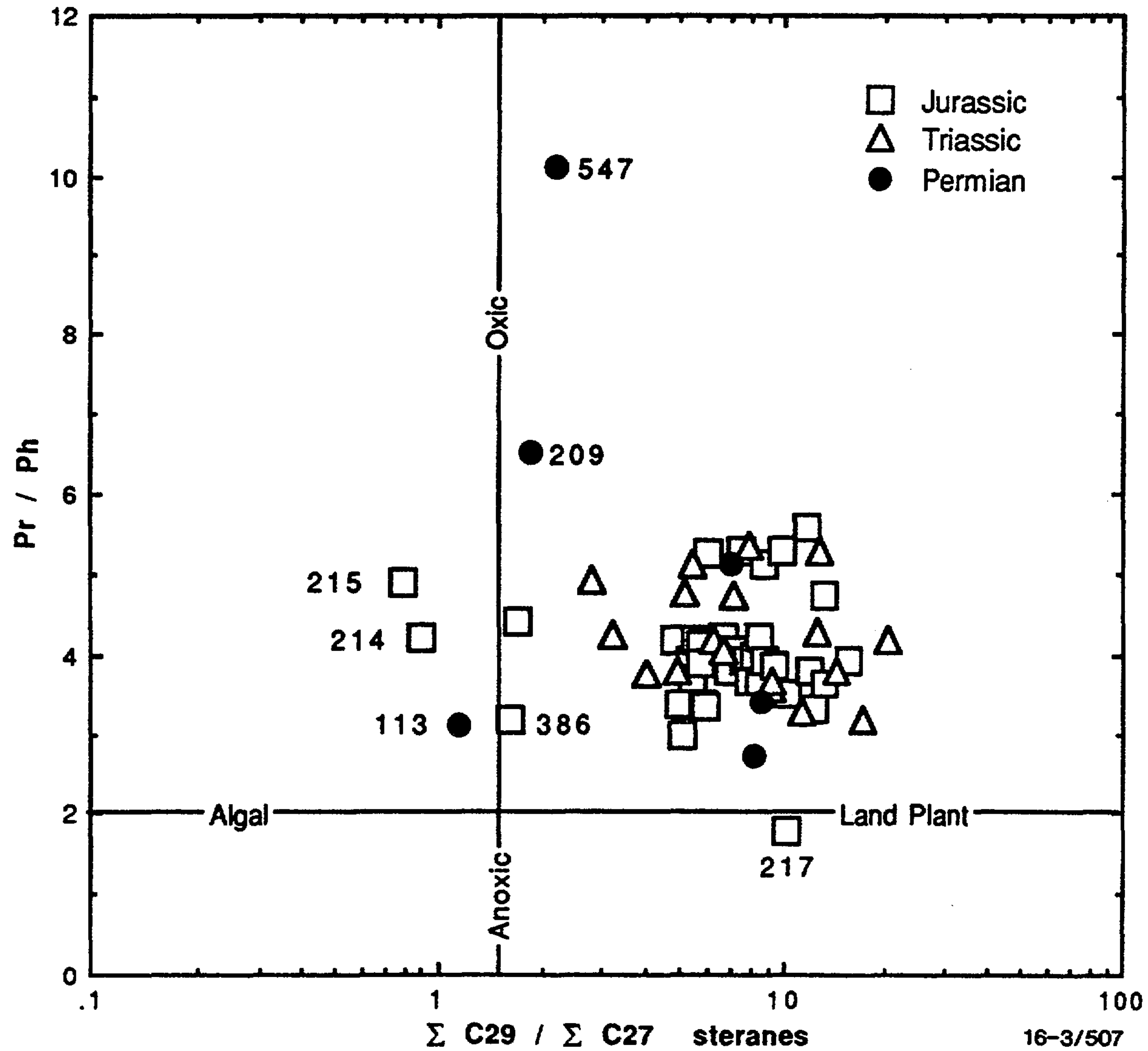


Figure 25. Plot of Pr/Ph versus $\Sigma C_{29} / \Sigma C_{27}$ steranes in liquid petroleum.

© Australian Geological Survey Organisation 1994

From their examination of a limited number of Bowen and Surat Basin oils, Philp and Gilbert (1986) used two other specific biomarkers, 28,30 bisnorhopane (BNH) and Compound X to highlight distinctions between oil samples. Both were used to place the Conloi and Cabawin oils at either end of an inferred source rock compositional spectrum. However, when these two parameters are examined in this expanded sample set the separation into distinct source facies becomes less well defined. Compound X (now known to be the C_{30} 17α(H)-diahopane; Peters and Moldowan, 1993) was detected in the majority of the petroleums and the ratio of 17α(H)-diahopane/17α(H)-hopane was in the range of 0.1 to 0.6 (Fig. 26a). At Kinkabilla both components are in equal concentrations. Its occurrence in the liquids (Table 6a) is best represented as a distribution of values about a mean where an individual value is insensitive to the stratigraphical position and locality. On the contrary, the sediments all show a bias towards lower diahopane/hopane ratios (Fig. 26b). Enrichment of the diahopane (as well as for C_{29} neohopane; Table 6a and b) in the petroleum compared with the sediments has been interpreted to reflect the initial heavy biodegradation selectively concentrating this resistant biomarker (see above).

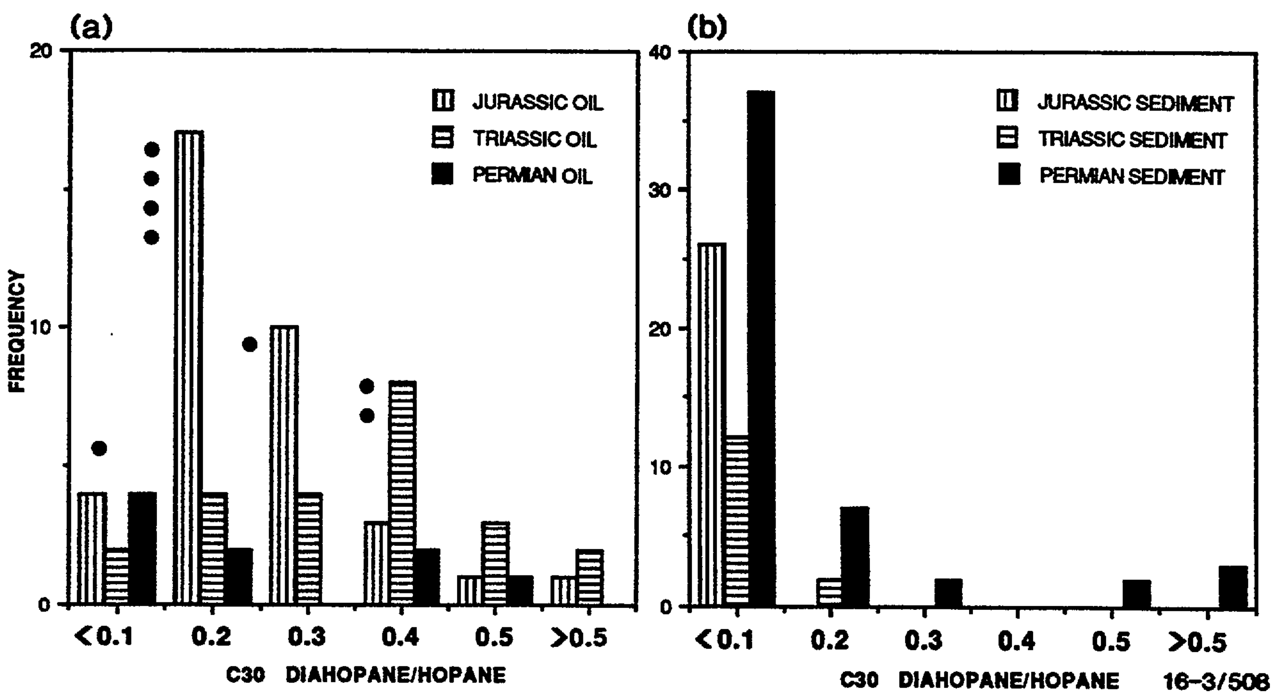


Figure 26. Frequency plot of C_{30} diahopane / hopane in a) liquid petroleum b) sediments.

The C_{28} 28,30-bisnorhopane (BNH) is a minor component and present in a high proportion of the liquid petroleums. The BNH/hopane ratio is < 0.2 except for Borah Creek 5 (#586) with a ratio of 0.4, reflecting an additional source facies. The BNH is thought to have a bacterial origin and high abundances are associated with anoxic depositional environments (Peters and Moldowan, 1993). The variability in the content of BNH may be associated with post depositional bacterial reworking of the terrestrial organic matter in localised anoxic environments. For example, in the coals of the Bandanna Formation, which on bulk chemical parameters are compositionally very similar (Table 2a), BNH ranges from being the dominant hopane to being completely absent (Table 6b).

A parameter that has been quoted to distinguish shale from carbonate source rocks is the ratio of C_{29} norhopane to C_{30} hopane; values >1 indicating the latter source affinity (Peters and Moldowan, 1993). Here, the relationship is less clear as the C_{29} norhopane/C_{30} hopane ratio ranges from 0.3 to 1.9 (majority < 1.2) for both oils and condensates (Fig. 27a) and shows no apparent relationship between a 'marine influenced' petroleum and a higher ratio. The sediments show similar ratio distributions to those for the petroleum liquids independent of sediment age (Fig. 27b). There is a slight positive correlation between the relative amounts of C_{29} hopane and 29,30 bisnorhopane (Table 6a), another biomarker strongly associated with many carbonate-derived oils. Presumably, this inferred source association is not exclusive since the moderate to high diasterane/sterane ratio (Fig. 28a) suggests a strong clastic component to the source rock (Peters and Moldowan,

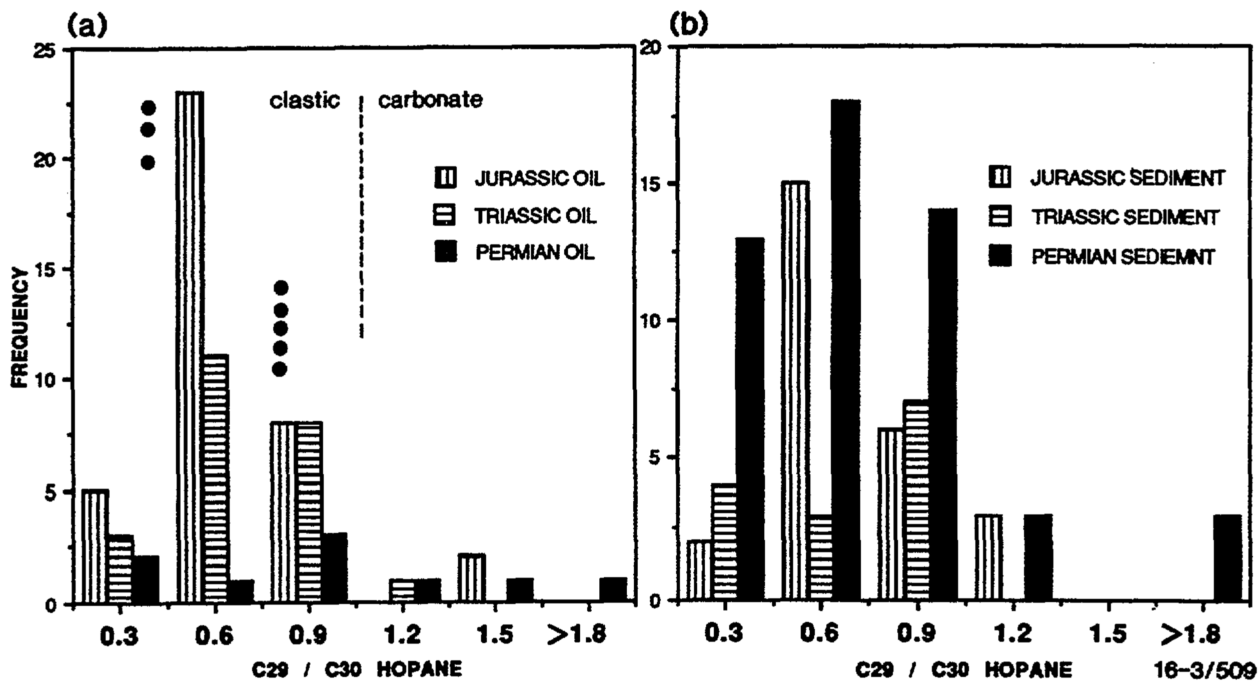


Figure 27. Frequency plot of C_{29} norhopane / hopane in a) liquid petroleum b) sediments.

© Australian Geological Survey Organisation 1994

1993). The Permian sediments exhibit a similar ratio distribution (Fig. 28b) to that of the petroleum although the younger sediments also show the influence on the ratio of their lower maturity (Peters and Moldowan, 1993).

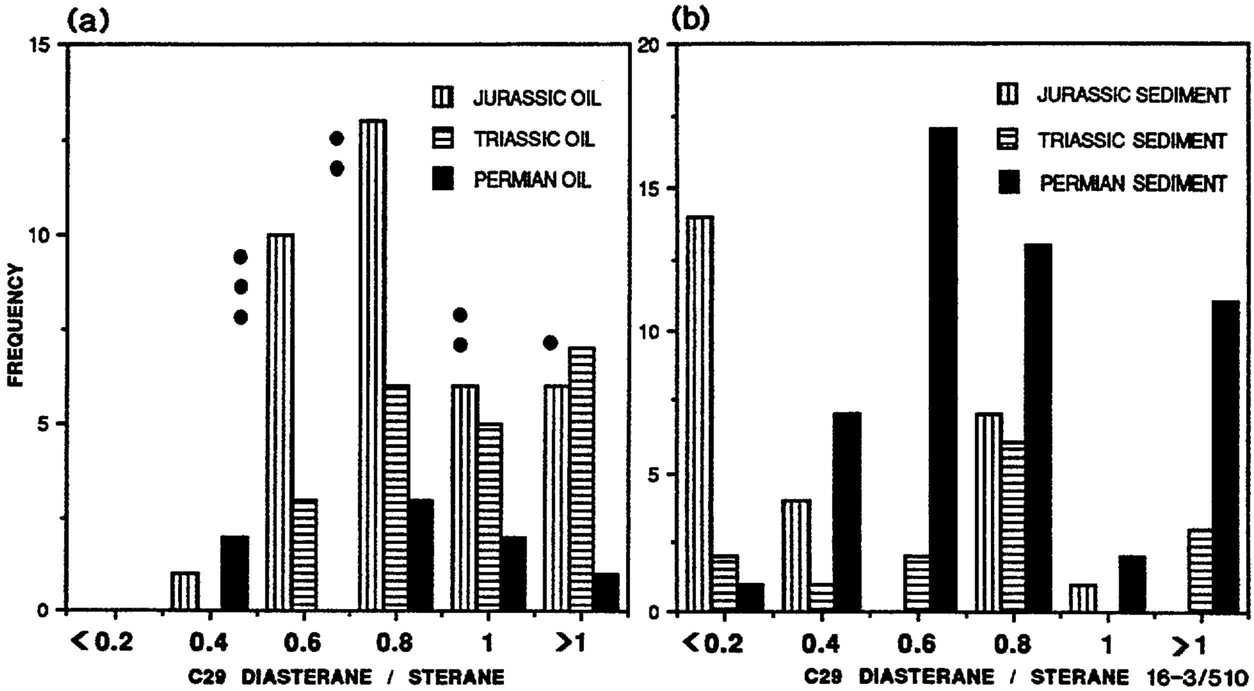


Figure 28. Frequency plot of C_{29} βα diasterane (S+R) / Σ C_{29} steranes in a) liquid petroleum b) sediments.

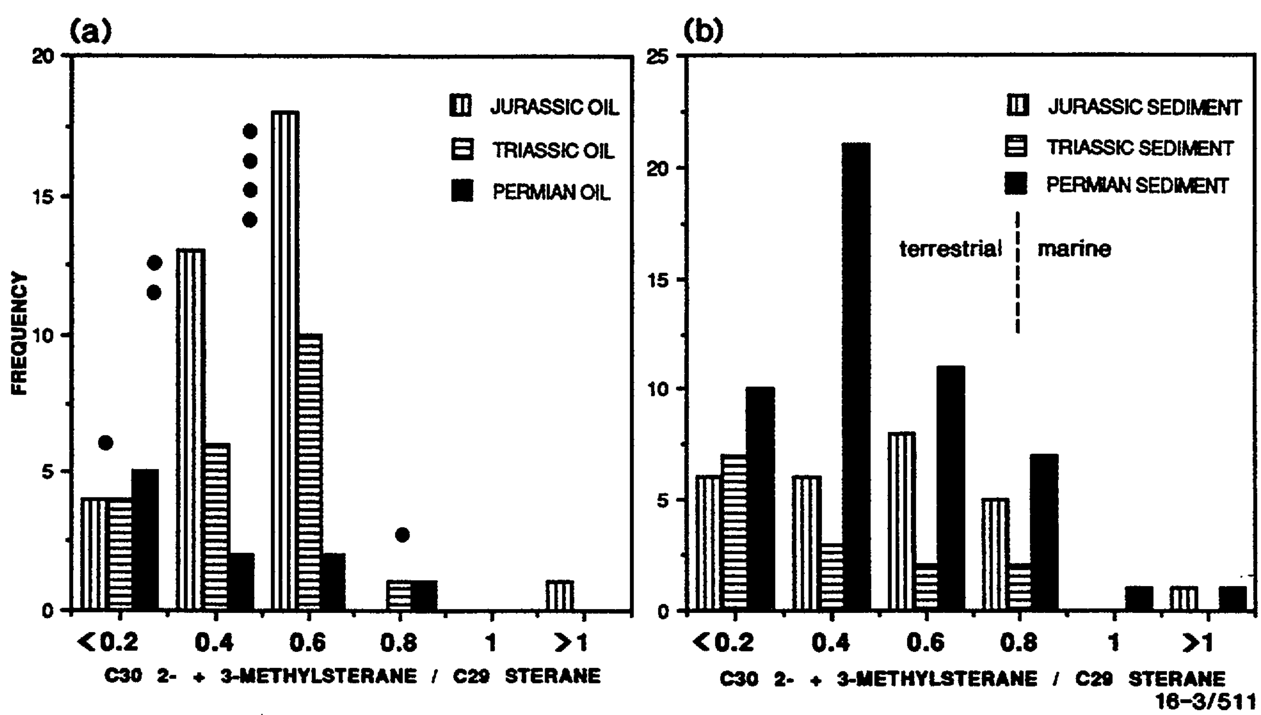


Figure 29. Frequency plot of 2α-methyl- + 3β-methylsterane / C_{29} ααα sterane in a) liquid petroleum and b) sediments.

© Australian Geological Survey Organisation 1994

Methylsteranes can occur in significant proportions relative to their desmethyl counterparts (Figs. 29a and b). The 4α-methylsteranes are subordinate to their 2α- and 3β-methyl isomers in the oils (Fig. 30a) but can exceed them in the sediments (Fig. 30b). It had been proposed that the presence of 4-methylsteranes has the potential to be used as age-specific biomarkers for post-Palaeozoic petroleums (Summons et al., 1987, 1992) particularly since the 4α,23,24-trimethylcholestane (dinosterane) stereochemistry has only been reported in petroleums younger than Triassic (Summons et al., 1987, 1992). However, in light of the presence of 4-methylsteranes (including dinosterane) in these petroleums (Fig. 30a) and their occurrence in the Permian sediments of the Bowen Basin (Fig. 30b) caution should be used in using these biomarkers as age discriminators.

The identification of 2α- and 3β-methylhopanes (Summons and Jahnke, 1992) in the oils and sediments (Tables 6a and 6b) points to a likely input from aerobic methylotrophic bacterial lipids to the source organic matter.

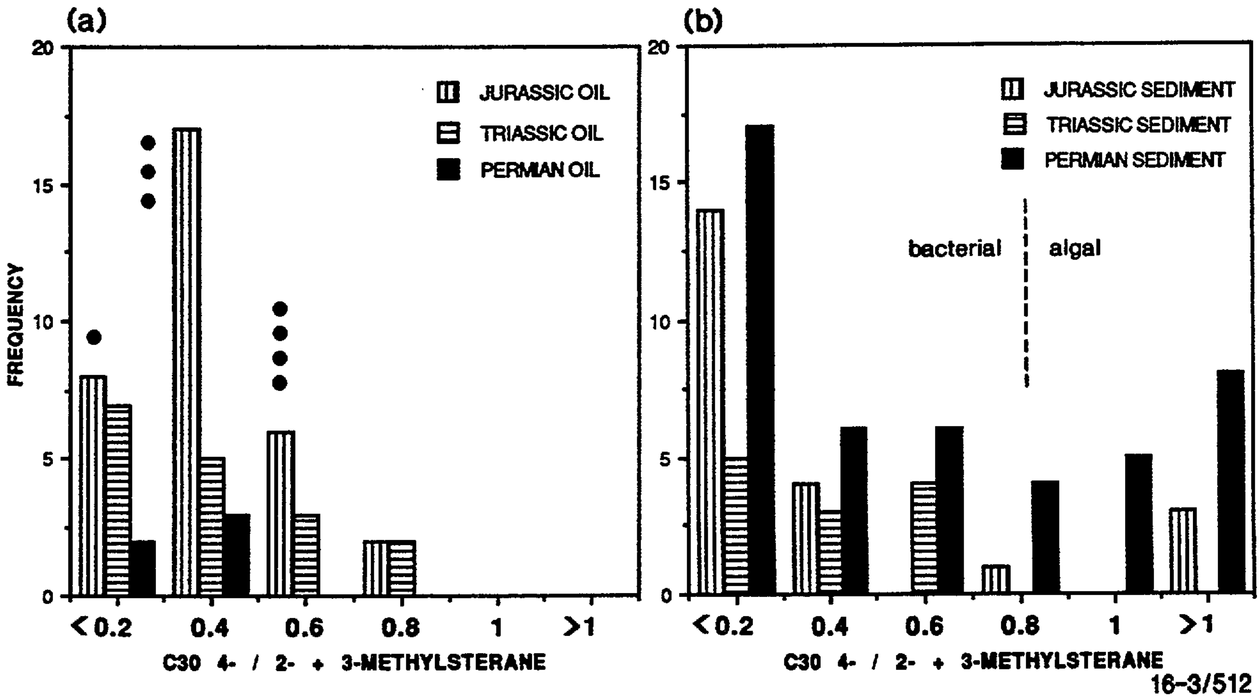


Figure 30. Frequency plot of C_{30} 4α-methyl- / (2α-methyl + 3β-methyl) sterane in a) liquid petroleum b) sediments.

Aromatic Biomarkers

The source parameters used here are those associated with the di- and triaromatic hydrocarbons. Specific source indicators, 1,2,5-trimethylnaphthalene, 1-methylphenanthrene, 1,7-dimethylphenanthrene and retene have been shown to indicate the contribution of Araucaria conifer remains in oils and sediments (Alexander et al., 1988). Since this family of conifers proliferate during Jurassic time and palaeobotanical remains are common in sediments of eastern Australia, the occurrence of these specific aromatics has been used as an age-specific marker for Jurassic and younger sediments and their inferred oils. Although there are also other sources for these compounds, it is the collective enrichment in these specific aromatics above certain "background levels" which identifies the conifer input (Alexander et al., 1988. Figures 31 and 32 (Table 9b) show the ubiquitous enrichment of these biomarkers in Jurassic sediments and extending across basin boundaries into the Jurassic of the adjacent Clarence-Moreton and Eromanga basins (Fig. 31; Table 11; note that the discriminating line for the 1-methylphenanthrene/9-methylphenanthrene ratio is considered to be 1.25 compared with 1 used by Alexander et al., 1988). Triassic and Permian sediments are characterised by their lack of conifer-specific enrichment. Similar plots for the petroleum (Fig. 33) reveal no enrichment and so indicate a pre-Jurassic source for all oils and condensates.

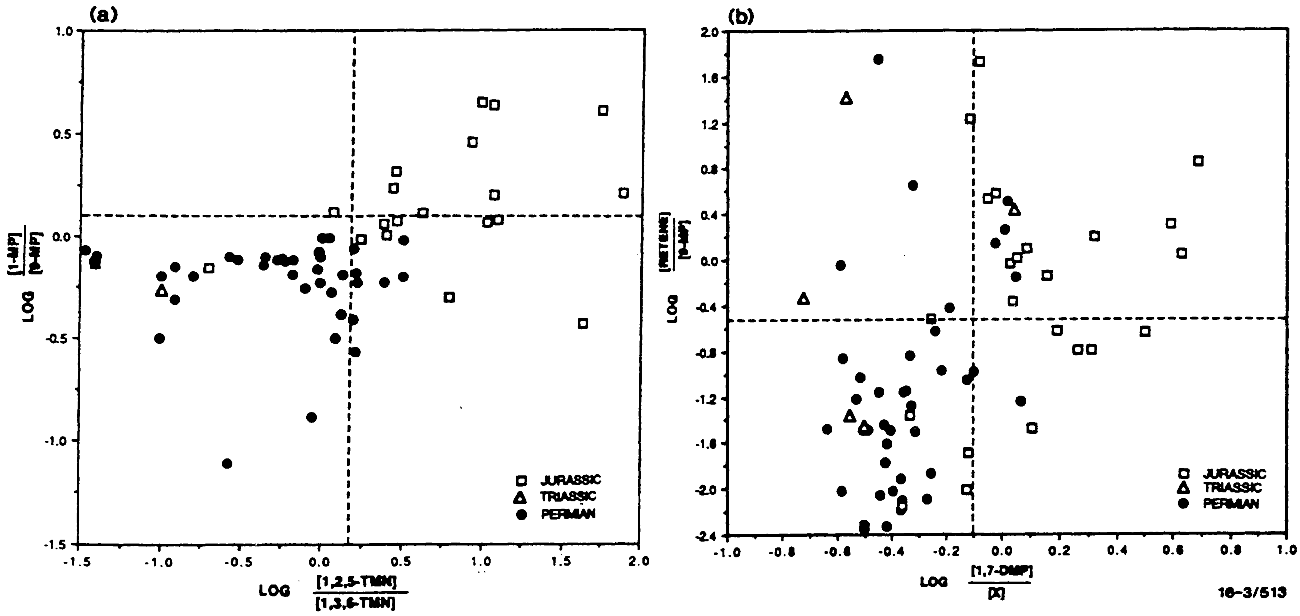


Figure 31. Aromatic hydrocarbon source plots of a) 1- / 9-methylphenanthrene versus 1,2,5- / 1,3,6-trimethylnaphthalene b) retene / 9-methylphenanthrene versus

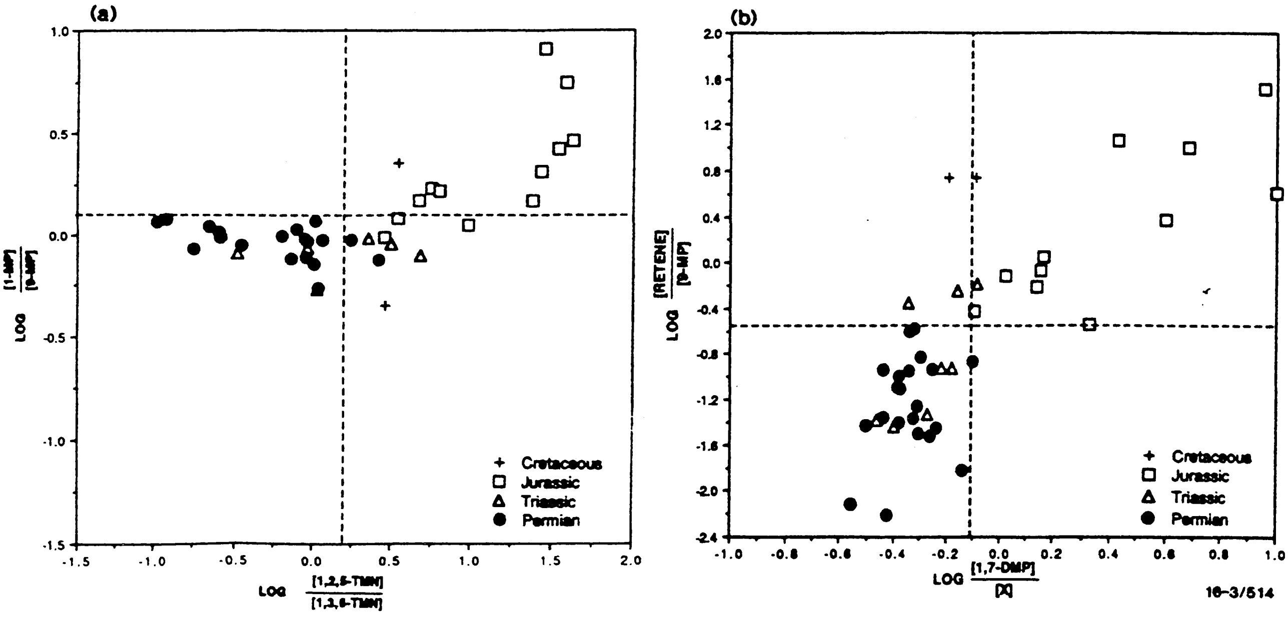


Figure 32. Aromatic hydrocarbon source plots of a) 1- / 9-methylphenanthrene versus 1,2,5- / 1,3,6-trimethylnaphthalene b) retene / 9-methylphenanthrene versus 1,7 dimethylphenanthrene/ X for samples collected from phase 2 sampling with AGSO Nos. >6000.

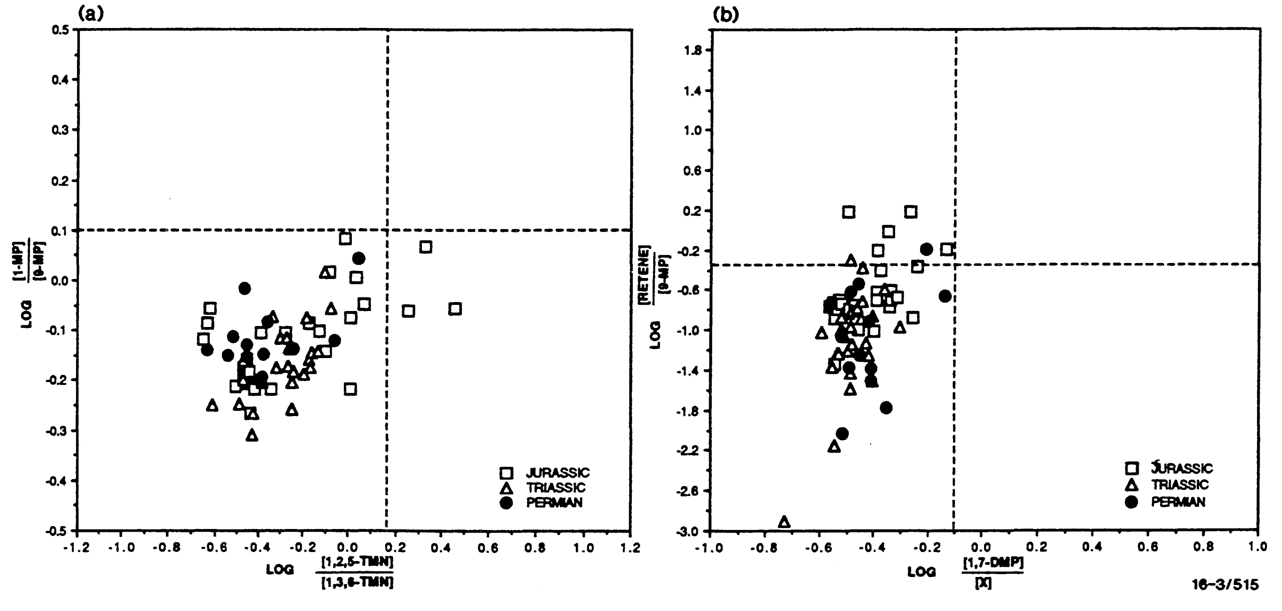


Figure 33. Aromatic hydrocarbon source plots of a) 1- / 9-methylphenanthrene versus 1,2,5- / 1,3,6-trimethylnaphthalene b) retene / 9-methylphenanthrene versus 1,7 dimethylphenanthrene/ X for liquid petroleum.

Stable Carbon Isotopes

Stable carbon isotopes offer another useful tool to correlate petroleum with its source. The $^{13}C/^{12}C$ ratio ($^{o}/_{oo}$) for selected Jurassic, Triassic and Permian sediments are given in Table 12. The Jurassic and Permian sediments show similar isotopic enrichments whereas the Triassic Moolayember Formation is isotopically distinct, being isotopically lighter than the former two by approximately $3^{o}/_{oo}$. Morante et al. (1994) have suggested that the Permo-Triassic boundary across Australia is associated with a distinct isotopic anomaly. However, there appears to be a less well defined boundary in this sample set since the Triassic Rewan Formation is isotopically similar to the Permian (Table 12). Therefore, the lowermost Rewan Formation is most likely of Permian age or that reworked Permian sediments may have provided the fill for a Triassic Rewan Formation.

The carbon isotopic composition of CO_2 has been determined for both Yellowbank 3 and Merivale 5 natural gas (Table 7). For the former, the abundant CO_2 in the gas has an isotopic composition of $-8.1^{o}/_{oo}$ consistent with an inorganic or mantle origin (Rigby and Smith, 1981). In the latter, the minor content of CO_2 is isotopically enriched in ^{13}C at $4.9^{o}/_{oo}$ compared with Yellowbank 3. Although both gases show the effects of biodegradation, the gaseous hydrocarbons were more severely effected in Merivale 5 (see above). Thus, biological activity would also have the ability to deplete a high carbon dioxide content in the gas to leave an increasingly-isotopically heavy residual CO_2 (Whiticar et al., 1986; Smith and Pallasser, 1994). Alternatively, ^{13}C-enriched CO_2 can be generated via aerobic or anaerobic bacterial activity (Gelwicks et al., 1989; 1994).

For the hydrocarbon gases, the isotopic composition of individual components (Table 7) shows the generally observed trend to heavier isotopic compositions with increasing molecular weight (James 1983) although this can be significantly perturbed by maturation and biodegradation (see above). Furthermore, with increasing molecular weight the carbon isotopic composition of the heavier hydrocarbons approaches that of the source (James, 1990). Isotopically iso-butane at an average δ of $-24.3^{o}/_{oo}$ (range -24.8 to $-23.8^{o}/_{oo}$, Table 7) is very similar to the Permian sediments at an average $\delta^{13}C$ of $-23.8^{o}/_{oo}$ from which the C_4 gas has largely inherited its isotopic composition. Therefore, a Permian source is implied for the natural gases. A contribution from the Rewan Formation cannot be eliminated on isotopic grounds, however its low source potential (Fig. 20; Table 2b) precludes it being an effective source rock.

Similarly, the average $\delta^{13}C$ of $-25.1^{o}/_{oo}$ (range -25.6 to $-24.7^{o}/_{oo}$, Table 10) for the whole oil and condensate is considerably enriched in ^{13}C compared to the Moolayember Formation, and therefore incongruent with a source from this rock unit. On the other hand, the average δ value for the petroleum is slightly depleted in ^{13}C compared with the Permian, consistent with a source from this interval. The narrow range in the isotopic values of $<1^{o}/_{oo}$, albeit only on 6 samples, for the whole oils and condensates increases to approx $3^{o}/_{oo}$ for the C_{12+} saturated and aromatic hydrocarbons when the total sample set is involved (Fig. 6). Some of this variability can be accounted for by maturity and biodegradation effects (see above)

© Australian Geological Survey Organisation 1994

which, for related oils, can involve isotopic variations of up to 2 to 3‰ (Peters and Moldowan, 1993) whereas the remaining variability is associated with differing proportions of $<C_{12+}$ lost in the isolation procedure and slight facies variations in the heterogeneous terrestrial source rocks (cf. isotopic range found in the Permian sediments, Table 12). The isotopic values outside these limits indicates a significant change in source rock composition. For Blyth Creek 1 (#386) there is a noticeable contribution from marine organic matter (see saturated biomarkers above) while the anomalous isotopic depletion in the C_{12+} fraction from Rednook condensate (Table 2a), as well as the corresponding >200°C distillation cut (Table 10) suggests either a Triassic source or, less likely, an early generated fraction sourced from isotopically light bacterial lipids. However, this C_{12+} fraction (>200°C) represents <10% of the total condensate and is not representative of the bulk condensate or <200°C distillation cuts which are isotopically similar to and have the same Permian source as the other oils and condensates. Differences in the isotopic composition between the saturated and aromatic hydrocarbons has been used to distinguish between "marine or algal" and "non-marine" oils (Sofer, 1984; Sofer et al., 1986). In Figure 6, application of Sofer's mean distinguishing line (Sofer et al., 1986) places all petroleum within the "marine oils" field, inconsistent with the other data, and further illustrates the limitations of its general applicability (Peters and Moldowan, 1993).

The carbon-13 isotopic composition of the saturated and aromatic hydrocarbons from the Bowen/Surat Basins (Fig. 6 and Table 2a) are comparable with petroleums to the west from the Cooper/Eromanga Basins (Vincent et al., 1985). These petroleums have similar reservoir ages and are also derived from terrestrial organic matter (Vincent et al., 1985). The isotopic composition of the saturated and aromatic hydrocarbons show no correlation with the region of petroleum occurrence, a limited relationship with degree of alteration and some connection with stratigraphic position. With the latter, the petroleum from the Permian reservoirs show a much narrower range in isotopic composition compared with the younger reservoirs (see next section).

Expulsion and Migration

Within the Taroom Trough region, the spatial distribution of the petroleum reservoirs gives an indication as to their mode of migration. Permian reservoirs are located closest to the depositional axis whereas Triassic followed by Jurassic reservoirs are progressively filled updip towards the basin edges (Fig. 34). Although simplistic in outlook, the geochemical parameters further support the concept of medium to long range migration. The aromatic maturity parameter, MPI-1 shows a definite maturity profile, with the less mature, lower Rc, on the basinal flanks while the higher Rc values are closest to the main axial depocentre (Fig. 34). This progression is best explained by a migrating "front" containing an initially generated liquid having migrated the furthest as the front is displaced from behind by liquid petroleum of a progressively more mature signature. The maturity parameters determined on the petroleum also record the wide maturity range, 0.65%<Rc<1.05%, over which petroleum has been expelled from the source rock. This range is entirely consistent with that determined separately for the sediments.

© Australian Geological Survey Organisation 1994

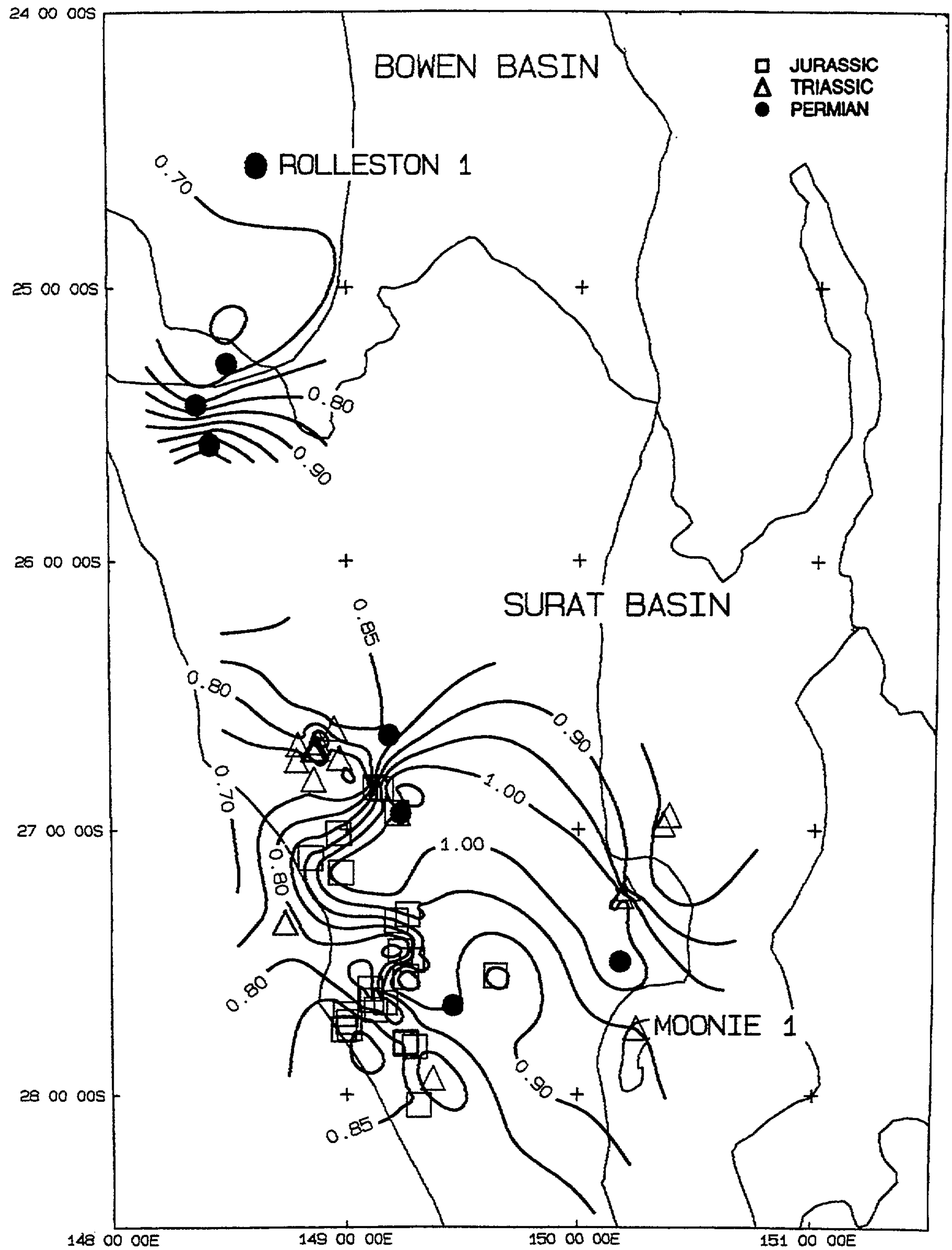


Figure 34. Contour map of Rc in oils and condensates.

© Australian Geological Survey Organisation 1994

Figure 35 depicts the plot of Tmax versus yield of extractable hydrocarbons from the sediments (Table 2b). Using a value of 30mg extractable hydrocarbons/gTOC as a cut-off above which the level of petroleum generation is sufficient to support expulsion from the source rock (Powell, 1988a), the effective 'oil window' for the Permian occurs between 440°C<Tmax<470°C and correlates to 0.7%<Ro<1.3% (from a linear regression analysis on Ro and Tmax data in Table 8). Above Ro of 1.3% cracking occurs leading to a decrease in the yield of extractable hydrocarbons (Fig. 35). The discrepancy between immature local sediments (Fig. 3) and higher oil maturity necessitates a source remote from the reservoir.

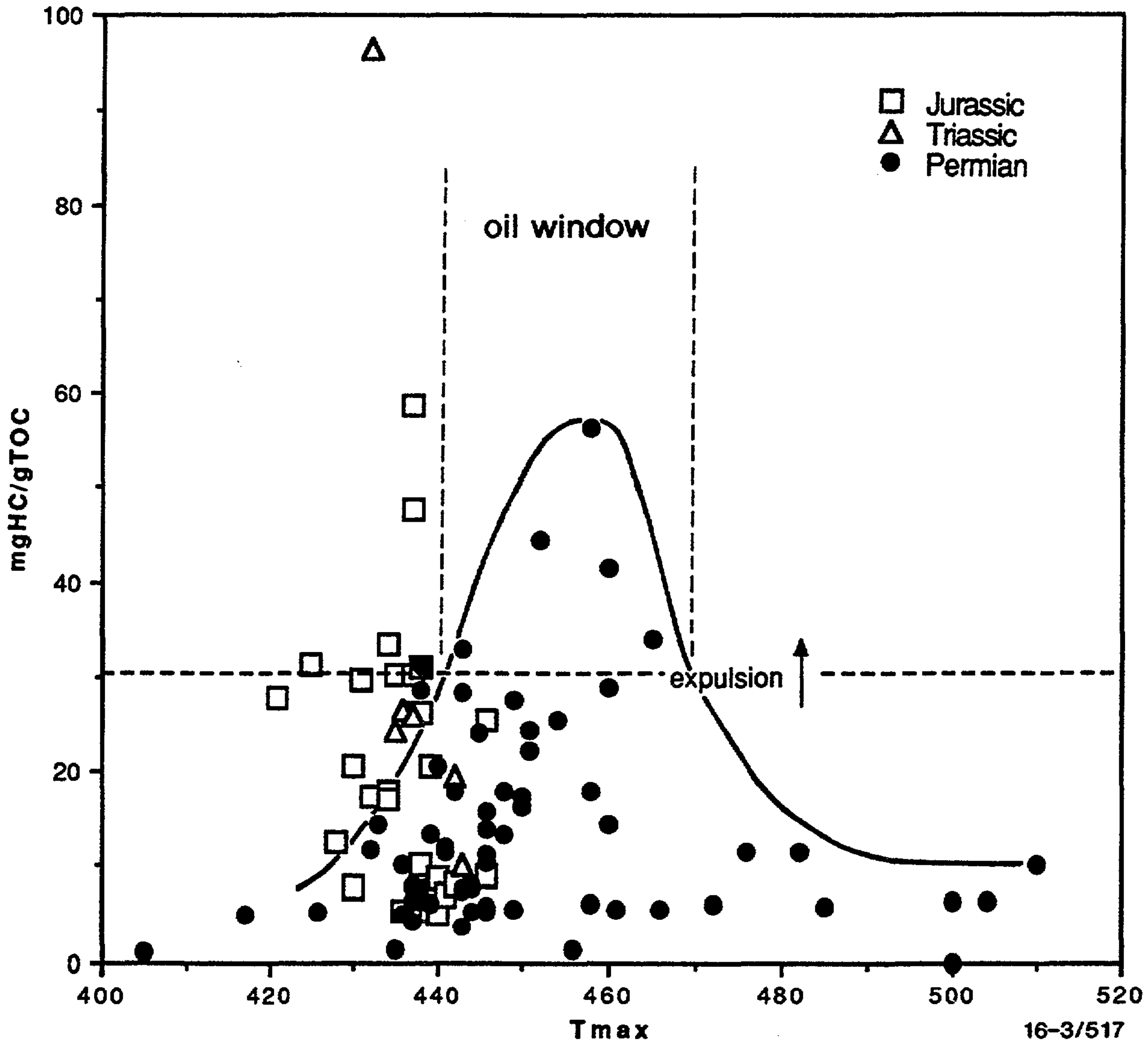


Figure 35. Plot of sediment extract yield (mg saturated + aromatic hydrocarbons/gTOC) versus Tmax (°C).

© Australian Geological Survey Organisation 1994

The maturity levels of the coexisting gaseous hydrocarbons are consistently higher than those observed for the liquid hydrocarbons. Thus, liquid and gas generation and expulsion represent two distinct stages of petroleum development. The initial charge by liquid petroleum, generated from source rocks at maturity levels between 0.65-0.7%<Ro<1.05%, is followed by gas generated from source rocks between 1.05%<Ro<1.4% (peak 1.2% Ro). The liquid potential of the Permian coals and related sediments is only moderate with HI ≤250 mg hydrocarbons/g TOC (Tables 2b and 8). As such a continuous liquid phase probably could not be supported from source to reservoir in all cases. The quantities of liquid petroleum would only support limited migration depending on the "richness" of the source rock. This may be reflected in the biomarker maturity ratios. The earlier generated liquids would have biomarker stereochemistries consistent with a lower average maturity. As generation continues the liquid petroleum is supplemented with biomarkers with increased maturity fingerprints. The richer source rocks could sustain a migrating liquid phase and have a lower effective maturation level for expulsion. Upward migration of liquid to a lower temperature region would freeze the chemical maturity parameters at this maturity level. For the source rocks with lower liquid potential, the petroleum would be retained close to the site of generation. As the source rocks continue to experience higher temperatures, the "free" chemical maturity indicators within the liquid petroleum would continue to "mature" in tandem and probably at a different rate than, and be supplemented by, those reflecting "bound" chemical maturity parameters as they are progressively released from the kerogen. Thus, the average value of a chemical maturity parameter will be governed by the timing of expulsion from the source rock and degree of secondary migration. This may, in part, explain why there is a poor correlation between chemical maturity parameters derived from vastly different chemical structures and where the relative timing of release for the aromatic biomarkers and saturated biomarkers may be slightly different. The liquids could be effectively 'smeared' over the secondary migration pathway. Consequently, the longer residence times would increase the exposure to fluids capable of altering the petroleum. At higher maturities, a large increase in gas generation from the terrestrial organic matter occurs, peaking between Ro of 1.1-1.3%, would create an effective media (oil dissolved in gas) to remobilise the liquid hydrocarbons and support long migration distances to the reservoir.

It is important to consider whether gas generation is from the same Permian source rock that had previously liberated its liquids or from a different Permian source. Preliminary data from a joint AGSO/GSQ regional source quality study on the Permian coals and mudstones suggests that the upper Permian continental sediments are more liquid-prone compared with the mainly marine lower Permian sediments; the latter having considerable gas potential. Therefore, the possibility exists for synchronous generation of oil from the upper Permian and gas from the lower Permian source units leading to mixing to produce a more efficient migrating fluid.

CONCLUSIONS

1. Oils and condensates from the Bowen and Surat basins are paraffinic when

© Australian Geological Survey Organisation 1994

unaltered becoming naphthenic after in-reservoir biodegradation.

2. Biodegradation has had a major impact on the composition of the petroleum. At least two phases of biodegradation are recognised. An initial and widespread phase resulted in heavy biodegradation leading to the generation of 25-norhopanes. Replenishment of the altered petroleum by a volumetrically superior pristine liquid was followed by a more restricted final stage of biodegradation. The latter has a gas chromatographic signature showing a progressive loss of light *n*-alkanes closely followed by the waxy *n*-alkanes and finally depletion of the isoprenoids pristane and phytane. Biodegradation is also recognised in the condensates by a loss of *n*-alkanes and in the gases by anomalously heavy isotopic compositions of propane and to a lesser extent *n*-butane.

3. Potential source rocks for liquids occur at various stratigraphic levels in the Surat (Jurassic) and Bowen (Triassic and Permian) basins based on bulk geochemical parameters of TOC, Rock Eval and bitumen yield. Lower delta plain coals show a higher hydrocarbon potential compared with upper delta plain coals while some liquid potential is recognised in the alluvial coals from the Denison Trough. Oil-to-source correlations involving gas chromatographic features are hampered by the effects of widespread biodegradation and the general immaturity of the sampled Triassic and Jurassic section. Saturated tetra- and pentacyclic biomarkers do not show the resolution required to differentiate terrestrially-dominated source rocks of Jurassic to Permian age. On the other hand, aromatic biomarkers having strong conifer affinities can distinguish Jurassic sediments from those of older age. This constrains the age for the source of the liquid petroleum to pre-Jurassic. Stable carbon isotopes are effective in further distinguishing the terrestrial Permian sediments from the richest Triassic potential source (Moolayember Formation). The effective source rocks for the liquid petroleum in the Bowen and Surat basins are the Permian terrestrial sediments with minor contributions from the marine-influenced source rocks. Some evidence exists for a localised, and very minor Triassic source contribution. Natural gas is also sourced from catagenesis of Permian organic matter. Carbon dioxide, which can occur in significant amounts, has a dual origin: inorganic and microbiological. Inorganic carbon dioxide presumably generated in the mantle or from decomposition of carbonates at depth is isotopically depleted in ^{13}C compared with that derived from microbial biodegradation.

4. For sediments in the Bowen and Surat basins, correlations have been developed between the common maturity parameters Tmax, extract yields and MPI and the optically measured vitrinite reflectance. Combined with measurements of MPI on the liquid petroleum and $^{13}C/^{12}C$ ratio on individual gaseous hydrocarbons, it has allowed source rock and petroleum maturity to be compared using a common 'calculated vitrinite reflectance' (Rc) scale. Liquid petroleum (oils and condensates) is expelled over a maturity range of $0.65\% < Rc < 1.05\%$. There is a distinct maturity separation between the timing of liquid and gas generation with the latter occurring between $1.05\% < Rc < 1.4\%$. The petroleum maturity corresponds well with the observed 'oil window' for the Permian sediments between $0.7\% < Ro < 1.3\%$ and peak generation at 0.9-1.0% Ro. For the liquid petroleum, maturity parameters

© Australian Geological Survey Organisation 1994

based on saturated tetra- and pentacyclic maturity parameters lack clear relationships with aromatic maturity indicators. Similarly, poor correlations exist between maturity parameters based on different structural types (eg. hopanes and steranes) while stronger relationships occur for closely related structural isomers (eg. $\alpha\alpha\alpha$S and $\alpha\alpha\alpha$R, and $\alpha\alpha\beta$ S+R steranes). This is related to the timing of biomarker release, source and biodegradation effects.

5. There is a correlation between reservoir age and the effective maturity (Rc) of expulsion of liquid petroleum from the Permian source rock. Liquid petroleum in Jurassic reservoirs show, on average, a lower maturity compared to liquid petroleum in Triassic reservoirs which in turn have a slightly lower maturity level compared to liquid petroleum in Permian reservoirs. Initially expelled petroleum from the effective Permian source rocks will have a slightly lower maturity level when entering the secondary migration pathway compared with later expulsion over the 'oil window'. Jurassic reservoirs, most distant from the 'source kitchen' will be charged by a 'migration front' of lower maturity. Gas composition varies systematically with locality. Higher wet gas contents occur to the south on the Wunger Ridge becoming progressively drier to the north on the Roma Shelf. Although this trend parallels the present-day maturity gradient for the Permian, a correlation with gas maturity based on carbon isotopic composition is less well defined.

6. The timing of the main phase of gas generation, at or following that of the liquid phase, is assumed critical to efficient secondary migration of petroleum to the reservoir.

CONTINUING AND FUTURE WORK

- Investigate the use of carbon isotopes, in particular, compound specific isotopic analysis (CSIA) on individual components to access the controls of evaporative fractionation, maturation and biodegradation on the composition of petroleum.

- Undertake a more detailed examination of the origin of CO_2 and its role in petroleum generation and expulsion.

- Under lithostratigraphic and sequence boundary control, delineate the distribution of Permian source quality in terms of liquid and gas proneness. Integrate the source quality and maturation with basin development to evaluate the volumetric and compositional history of evolved petroleum and their relationships with known petroleum occurrences.

ACKNOWLEDGMENTS

The author wishes to thank the technical staff of the Isotope and Organic Geochemistry Laboratories for their support. In particular, Philip Fletcher is thanked for his assistance in Rock Eval and TOC analysis and with Zoltan Horvath undertook solvent extraction and column chromatography. Oil distillation cuts were completed by Zoltan Horvath. Lesley Dowling conducted the isotopic

© Australian Geological Survey Organisation 1994

measurements of the gas components while Eleanor Laing and Algis Juodvalkis performed isotopic analysis of the liquid hydrocarbon samples. Janet Hope is thanked for assistance in organisation of the data and preliminary drafting of the figures and tables. The author is also indebted to Russell Korsch, Andrew Murray and Roger Summons for their critical reviews and helpful discussions. This study could not have been undertaken without the generosity of AGL Petroleum (now Santos Ltd.), Bridge Petroleum Ltd., Central Queensland Natural Gas, Command Petroleum Holdings NL, Crusader Ltd. and Oil Company of Australia NL who provided many of the gas and liquid petroleum samples.

© Australian Geological Survey Organisation 1994

REFERENCES

Allen, R.J., 1976 - Surat Basin. *In* Leslie, R.B. Evans, H.J. and Knight, C.L. (editors) *Economic geology of Australia and Papua New Guinea, Volume 3* - Petroleum Australasian Institute of Mining and Metallurgy, Melbourne, 266-272.

Alexander, R., Kagi, R., Woodhouse, G.W. and Volkman, J.K., 1983 - The geochemistry of some biodegraded Australian oils. *American Association of Petroleum Geologists Bulletin*, **65**, 235-250.

Alexander, R., Kagi, R.I., Rowland, S.J., Sheppard, P.N., and Chirila, T.V., 1985 - The effects of thermal maturity on distributions of dimethylnaphthalenes and trimethylnaphthalenes in some ancient sediments and petroleum. *Geochimica et Cosmochimica Acta*, **49**, 385-395.

Alexander, R., Noble, R.A., and Kagi, R.I., 1987 - Fossil resin biomarkers and their application in oil to source-rock correlation, Gippsland basin, Australia. *The APEA Journal*, **27**, 63-72.

Alexander, R., Larcher, A.V., and Kagi, R.I., 1988 - The use of plant-derived biomarkers for correlation of oils with source rocks in the Cooper/Eromanga basin system, Australia. *The APEA Journal*, **28**, 310-324.

Boreham C.J. and Powell T.G., 1987 - Sources and preservation of organic matter in the Cretaceous Toolebuc Formation, eastern Australia. *Organic Geochemistry*, **11**, 433-449.

Boreham, C.J., Crick, I.H. and Powell, T.G., 1988 - Alternative calibration of the methylphenanthrene index against vitrinite reflectance: Application to maturity measurements in oils and sediments. *Organic Geochemistry*, **12**, 289-294.

Boreham C. J. and Powell T. G., 1991 - Variation in pyrolysate composition of sediments from the Jurassic Walloon Coal Measures, eastern Australia as a function of thermal maturation. *Organic Geochemistry* **17**, 723-733.

Brooks, J.D., Gould, K. and Smith, J.W., 1969 - Isoprenoid hydrocarbons in coal and petroleum. *Nature*, **222**, 257-259.

Carmichael, D.C. and Boreham, C.J., 1994 - Permian source rock quality in the southern Taroom Trough. *Sedimentary Basins of Eastern Australia Seminar*, Geological Survey of Queensland, 6 September, Abstract.

Chosson, P., Sieskind, O. and Albrecht, P., 1992 - In vitro biodegradation of steranes and terpanes: A clue to understanding geological situations. *In* Moldowan, J.M., Albrecht, P. and Philp, R.P. (editors) *Biological markers in sediments and petroleum*, 320-349.

© Australian Geological Survey Organisation 1994

Chung, H.M., Claypool, G.E., Rooney, M.A. and Squires, R.M., 1994 - Source characteristics of marine oils as indicated by carbon isotopic ratios of volatile hydrocarbons. *American Association of Petroleum Geologists Bulletin*, **78**, 396-408.

Clayton, C.J., 1991 - Effect of maturity on carbon isotope ratio of oils and condensates. *Organic Geochemistry*, **17**, 887-899.

Dzou, L.I. and Hughes, W.B., 1993 - Geochemistry of oils and condensates, K field, offshore Taiwan: a case study in migration fractionation. *Organic Geochemistry*, **20**, 437-462.

Elliott L., 1989 - The Surat and Bowen Basins. *The APEA Journal*, **29**, 398-416.

England, W.A., Mackenzie, A.S., Mann, D.M. and Quigley, T.M., 1987 - The movement and entrapment of petroleum fluids in the subsurface: *Journal of the Geological Society, London*, **144**, 327-347.

Falkner, A.J. and Fielding, C.R., 1990 - Late Permian coal-bearing depositional systems of the Bowen Basin. *Proceedings of the Bowen Basin Symposium*, Mackay, 1990. Geological Society of Australia, Queensland Division, 36-41.

Fielding, C.R., Falkner, A.J., Kassan, J., and Draper, J.J., 1990 - Permian and Triassic depositional systems in the Bowen Basin. *Proceedings of the Bowen Basin Symposium*, Mackay, 1990. Geological Society of Australia, Queensland Division, 21-25.

Gelwicks, J.T., Risatti, J.B. and Hayes, J.M., 1989 - Carbon isotope effects associated with autotrophic acetogenesis. *Organic Geochemistry*, **14**, 442-446.

Gelwicks, J.T., Risatti, J.B. and Hayes, J.M., 1994 - Carbon isotope effects associated with aceticlastic methanogenesis. *Applied Environmental Microbiology*, **60**, 467-472.

Gray, A.R.G., 1989 - Petroleum Resources Assessment and Development Subprogram, Petroleum resources of Queensland (Review to June 30, 1989) Department of Resource Industries, Queensland.

Hawkins, P.J., Genn, D.L.P. and Green, P.M., 1991 - Source rock evaluation of the Basal Jurassic, Birkhead Formation and Westbourne Formation, Northern Eromanga Basin. *Queensland Resource Industries Record* 1991/24.

Hawkins, P.J., Jackson, K.S., and Horvath, Z., 1992 - Regional geology, petroleum geology, and hydrocarbon potential of the southern Taroom Trough, Bowen basin, Queensland. *Queensland Geology*, **3**, 1-42.

Hoffmann C.F., Mackenzie, A.S., Lewis, C.A., Maxwell, J.R., Oudin, J.C., Durand, B. and Vanderbroucke, M., 1984 - A biological marker study of coals, shales and

© Australian Geological Survey Organisation 1994

oils from the Mahakam Delta, Indonesia. *Chemical Geology*, **42**, 1-23.

Jackson, K.S, Hawkins, P.J. and Bennett, A.J.R., 1980 - Regional facies and geochemical evaluation of the southern Denison Trough, Queensland. *The APEA Journal*, **20**, 143-158.

James, A.T., 1983 - Correlation of natural gas by use of carbon isotopic distribution between hydrocarbon components. *American Association of Petroleum Geologists Bulletin*, **67**, 1176-1191.

James, A.T., 1990 - Correlation of reservoired gases using the carbon isotope compositions of wet gas components. *American Association of Petroleum Geologists Bulletin*, **74**, 1441-1458.

James, A.T. and Burns, B.J. 1984 - Microbial alteration of subsurface natural gas accumulations. *American Association of Petroleum Geologists Bulletin*, **68**, 957-960.

Korsch, R.J., Wake-Dyster, K.D., Johnstone, D.W., 1990 - Deep seismic profiling across the Bowen Basin. *Proceedings of the Bowen Basin Symposium, Mackay*, 1990. Geological Society of Australia, Queensland Division, 10-14.

Mallett, C.W., Russell, N., and McLennan, T., 1990 - Thermal history of the Bowen Basin. *Proceedings of the Bowen Basin Symposium, Mackay*, 1990. Geological Society of Australia, Queensland Division, 15-20.

Moran, W.R. and Gussow, W.C., 1963 - The history of the discovery and geology of the Moonie oil field, Queensland, Australia. *Proceedings of the 6th World Petroleum Conference*, **1**, 595-609.

Morante, R., Veevers, J.J., Andrew, A.S. and Hamilton, P.J., 1994 - Determination of the Permian-Triassic in Australia from carbon isotope stratigraphy. *The APEA Journal*, **34**, 330-336.

Morton, D., Smyth, M. and Sherwood, N., 1993 - A uniquely attractive area for oil exploration in the southern Bowen basin. *In* Swarbrick, C.J. & Morton, D.J. (Eds.). *Proceedings of the NSW Petroleum Symposium*, NSW Branch, Petroleum Exploration Society of Australia. pp. 23.

Murray, C.G., 1990 - Tectonic evolution and Metallogenesis of the Bowen Basin. *Proceedings of the Bowen Basin Symposium*, Mackay, 1990. Geological Society of Australia, Queensland Division, 201-212.

Noble, R.A, Alexander, R. and Kagi, R.I., 1985 - The occurrence of bisnorhopane, trisnorhopane, and 25-norhopanes as free hydrocarbons in some Australian shales. *Organic Geochemistry*, **8**, 171-176.

© Australian Geological Survey Organisation 1994

Palmer, S.E., 1993 - Effects of biodegradation and water washing on crude oil composition. *In* Engel, M.H. and Macko, S.A. (editors) *Organic Geochemistry: Principles and Applications*, 511-533.

Peters, K.E. and Moldowan, J.M., 1993 - *The Biomarker Guide: Interpreting molecular fossils in petroleum and ancient sediments.* Prentice Hall, New Jersey, 363 p.

Philp, R.P., 1983 - Correlation of crude oils from the San Jorges Basin, Argentina. *Geochimica et Cosmochimica Acta*, **47**, 267-275.

Philp, R.P., and Gilbert, T.D., 1986 - A geochemical investigation of oils and source rocks from the Surat basin. *The APEA Journal*, **26**, 172-186.

Powell, T.G and McKirdy, D.M., 1973 - Relationship between ratio of pristane to phytane, crude oil composition and geological environment in Australia. *Nature*, **243**, 37-39.

Powell, T.G., 1988a - Development in concepts of hydrocarbon generation from terrestrial organic matter. *Petroleum resources of China and related subjects, Texas, CircumPacific Council of Energy and Mineral Resources Earth Sciences Series*, **10**, 807-824.

Powell, T.G., 1988b - Pristane/phytane ratio as environmental indicator. *Nature*, **333**, 604.

Powell T.G., Boreham C.J., Smyth M., Russel N. and Cook A.C., 1991 - Petroleum source rock assessment in non-marine sequences: pyrolysis and petrographic analysis of Australian coals and carbonaceous shales. *Organic Geochemistry*, **17**, 375-394.

Radke, M., 1988 - Application of aromatic compounds as maturity indicators in source rocks and crude oils. *Marine and Petroleum Geology*, **5**, 224-236.

Radke, M., and Welte, D.H., 1983 - The methylphenanthrene index (MPI): A maturity parameter based on aromatic hydrocarbons *In* Brooks, J. and Welte, D.H (editors) *Advances in Organic Geochemistry*, 1981, Wiley, Chichester, pp 504-512.

Rigby, D. and Smith, J.W., 1981 - An isotopic study of gases and hydrocarbons in the Cooper Basin. *The APEA Journal*, **21**, 222-229.

Schoell, M., 1983 - Genetic characterisation of natural gases. *American Association of Petroleum Geologists Bulletin*, **67**, 2225-2238.

Schoell, M., 1984 - Stable isotopes in petroleum research. *In* Brooks, J. and Welte, D.H. (editors) *Advances in Petroleum Geology, Volume 1*, 251-245.

© Australian Geological Survey Organisation 1994

Seifert, W.K. and Moldowan, J.M., 1981 - Palaeoreconstruction by biological markers. *Geochimica et Cosmochimica Acta*, **45**, 783-794.

Seifert, W.K. and Moldowan, J.M. (1986) Use of biological markers in petroleum exploration. *In* Jones, R.B (editor) *Methods in Geochemistry and Geophysics*, **24**, 261-290. New York, Elsevier.

Smith, J.W. and Pallasser, R.J., 1994 - Microbial origin of coal-bed methane. *Organic Geochemistry*, in press.

Sofer, Z., 1984 - Stable carbon isotope composition of crude oils: application to source depositional environments and petroleum alteration. *American Association of Petroleum Geologists Bulletin*, **68**, 31-49.

Sofer, Z., Zumberge, J.E. and Lay, V., 1986 - Stable carbon isotopes and biomarkers as tools in understanding genetic relationships, maturation, biodegradation, and migration in crude oils in the Northern Peruvian Oriente (Maranon) Basin. *Organic Geochemistry*, **10**, 377-389.

Summons, R.E., Volkman, J.R. and Boreham, C.J., 1987 - Dinosterane and other steroidal hydrocarbons of dinoflagellate origin in sediments and petroleum. *Geochimica et Cosmochimica Acta*, **51**, 3075-3082.

Summons, R.E. and Jahnke, L.L., 1992 - Hopenes and hopanes methylated in ring-A: correlation of the hopanoids from extant methylotrophic bacteria with their fossil analogues. *In* Moldowan, J.M., Albrecht, P. and Philp, R.P. (editors) *Biological markers in sediments and petroleum*, 182-200.

Summons, R.E., Thomas, J., Maxwell, J.R. and Boreham, C.J., 1992 - Secular and environmental constraints on the occurrence of dinosterane in sediments. *Geochimica et Cosmochimica Acta*, **56**, 2437-2444.

Talukdar, S., Gallango, O. and Chin-A-Lien, M., 1986 - Generation and migration of hydrocarbons in the Maracaibo Basin, Venezuela: An integrated basin study. *Organic Geochemistry*, **10**, 261-279.

Talukdar, S., Gallango, O. and Riggiero, A., 1988 - Generation and migration of oil in the Maturin subbasin, eastern Venezuela Basin. *Organic Geochemistry*, **13**, 537-547.

Thomas, B.M., Osborne, D.G. and Wright, A.J., 1982 - Hydrocarbon habitat of the Bowen/Surat Basin. *The APEA Journal*, **22**, 213-226.

Thompson, K.F.M., 1988 - Gas-condensate migration and oil fractionation in deltaic systems. *Marine and Petroleum Geology*, **5**, 237-246.

Tissot, B. and Welte, D.H., 1984 - *Petroleum Formation and Occurrence.* Springer-

© Australian Geological Survey Organisation 1994

Verlag, New York, 699 p.

Totterdell, J.M., Wells, A.T., Brakel, A.T., Korsch, R.J. and Nicoll, M.G., 1991 - Sequence stratigraphic interpretation of seismic data in the Taroom Trough, Bowen and Surat basins, Queensland. *Bureau of Mineral Resources Record* 1991/102.

Traves, D.M., 1965 - Petroleum in the Roma-Springsure area. *Proceedings of the 8th Commonwealth Mining and Metallurgy Congress*, **5**, 147-156.

van Grass, G., 1986 - Biomarker distributions in asphaltenes and kerogens analysed by flash-pyrolysis-gas chromatography-mass spectrometry. *Organic Geochemistry*, **10**, 1127-1135.

Vincent, P.W., Mortimore, I.R., and McKirdy, D.M., 1985 - Hydrocarbon generation, migration and entrapment in the Jackson-Naccowlah area, ATP 256P, southwestern Queensland. *The APEA Journal*, **25**, 62-84.

Volkman, J.K., Alexander, R., Kagi, R., Woodhouse, G.W., 1983 - Demethylated hopanes in crude oils and their application in petroleum geochemistry. *Geochimica et Cosmochimica Acta*, **47**, 1033-1040.

Volkman, J.K. and Maxwell, J.R., 1986 - Acyclic isoprenoids as biological markers. *In* Johns, B. (editor) *Methods in Geochemistry and Geophysics*, **24**, 1-42. New York, Elsevier.

West N., Alexander R. and Kagi R.I., 1990 - The use of silicalite for rapid isolation of branched and cyclic alkane fractions of petroleum. *Organic Geochemistry*, **15**, 499-501.

Whiticar, M.J., Faber, E. and Schoell, M., 1986 - Biogenic methane formation in marine and freshwater environments: CO_2 reduction vs. acetate fermentation - isotope evidence. *Geochimica et Cosmochimica Acta*, **50**, 693-709.

© Australian Geological Survey Organisation 1994

Table 1 Oils and condensates analysed.

Location	Well Name	Age	Formation	AGSO No	DST No.	Depth Range	Lat.	Long.
Denison Trough Area								
	Westgrove 3	Permian	Aldebaran Sst	391	cond >250C	-	-25.5667	148.4333
	Rolleston 1	Permian	Catherine Sst	390	Prod Test 1	888.0 - 908.0	-24.5631	148.6311
	Rolleston 1	Permian	Catherine Sst	534	Prod Test 1	888.0 - 908.0	-24.5631	148.6311
	Rolleston 3	Permian	Freitag Fm	548	cond	-	-24.5486	148.6311
	Rolleston 3	Permian	Freitag Fm	549	separator oil	-	-24.5486	148.6311
	Merivale 5	Permian	Aldebaran Sst	550	DST 2	1351.0 - 1380.2	-25.2759	148.5056
	Yellowbank 3	Permian	Aldebaran Sst	547	cond	-	-25.4261	148.3770
Taroom Trough Area								
East	Conloi 1	Jurassic	Evergreen Fm (Lw)	78	DST 5	1314.0 - 1318.0	-26.4283	149.9633
	Conloi 1	Jurassic	Evergreen Fm (Lw)	217	DST 5	1314.0 - 1318.0	-26.4283	149.9633
	Rockwood 1	Jurassic	Evergreen Fm	97	DST 1	1143.0 - 1159.0	-26.9803	150.3694
	Bennett 1	Jurassic	Precipice Sst	215		1625.0 - 1656.0	-27.2211	150.2183
	Leichhardt 2	Jurassic	Precipice Sst	216	DST 4	1648.0 - 1653.0	-27.2500	150.1964
	Moonie 1	Jurassic	Precipice Sst	50	DST 1	1770.0 - 1780.0	-27.7483	150.2570
	Moonie 1	Jurassic	Precipice Sst	565		1767.3 - 1780.1	-27.7483	150.2570
	Moonie 2	Jurassic	Precipice Sst	566		1766.3 - 1771.2	-27.7542	150.2486
	Moonie 4	Jurassic	Precipice Sst	567		1764.2 - 1770.9	-27.7708	150.2383
	Moonie 10	Jurassic	Precipice Sst	568		1774.0 - 1777.6	-27.7406	150.2631
	Moonie 11	Jurassic	Precipice Sst	569		1753.2 - 1765.4	-27.7639	150.2344
	Moonie 15	Jurassic	Precipice Sst	570		1771.7 - 1774.0	-27.7617	150.2378
	Moonie 18	Jurassic	Precipice Sst	571		1761.2 - 1774.0	-27.7528	150.2539
	Moonie 21	Jurassic	Precipice Sst	572		1756.6 - 1765.4	-27.7700	150.2386
	Moonie 27	Jurassic	Precipice Sst	573		1763.9 - 1768.2	-27.7625	150.2386
	Moonie 28	Jurassic	Precipice Sst	574		1763.6 - 1769.7	-27.7567	150.2470
	Moonie 29	Jurassic	Precipice Sst	575		1763.0 - 1774.0	-27.7519	150.2497
	Moonie 30	Jurassic	Precipice Sst	576		1778.8 - 1781.9	-27.7361	150.2675
	Moonie 31	Jurassic	Precipice Sst	577		1766.9 - 1774.3	-27.7467	150.2531
	Moonie 32	Jurassic	Precipice Sst	578		1764.8 - 1772.1	-27.7494	150.2508
	Moonie 33	Jurassic	Precipice Sst	579		1761.2 - 1764.8	-27.7592	150.2417
	Moonie 34	Jurassic	Precipice Sst	580		1758.7 - 1765.1	-27.7633	150.2453
	Moonie 35	Jurassic	Precipice Sst	581		1770.0 - 1774.6	-27.7633	150.2453
	Moonie 37	Jurassic	Precipice Sst	582		1768.2 - 1777.6	-27.7381	150.2603
	Rockwood North 1	Jurassic	Precipice Sst	55	DST 1	1234.0 - 1251.0	-26.9456	150.3956
	Cabawin 1	Permian	Blackwater Gp	385	Prod Test 3	3050.0 - 3100.0	-27.4961	150.1895
Roma Shelf	Anabranch 1	Jurassic	Evergreen Fm (Lw)	214	DST 2	1277.0 - 1285.0	-26.8139	148.8653
	Blyth Creek 1	Jurassic	Precipice Sst	386	DST 1	1154.0 - 1164.0	-26.6228	148.9514
	Bony Creek 6	Jurassic	Precipice Sst	212	DST 1	1315.5 - 1374.6	-26.7333	148.9717

© Australian Geological Survey Organisation 1994

Table 1 (cont).

Location	Well Name	Age	Formation	AGSO No	DST No.	Depth Range	Lat.	Long.
Roma Shelf (cont.)	Duarran 2	Jurassic	Precipice Sst	207	DST 1	1253.0 - 1338.0	-26.6822	148.7997
	Maffra 2	Jurassic	Precipice Sst	221	DST 2	1275.3 - 1287.5	-26.7411	148.7931
	Richmond 1	Jurassic	Precipice Sst	43	DST 1	1222.1 - 1237.9	-26.6750	148.8833
	Richmond 5	Jurassic	Precipice Sst	210	DST 1	1266.4 - 1277.1	-26.7000	148.8705
	Richmond 7	Jurassic	Precipice Sst	205	DST 1	1240.9 - 1248.8	-26.6983	148.8786
	Richmond 10	Jurassic	Precipice Sst	211	DST 1	1239.9 - 1261.3	-26.7014	148.8622
	Borah Creek 5	Triassic	Moolayember Fm	586	separator oil	1473.0 - 1482.0	-27.1081	148.8519
	Combarngo 1	Triassic	Showgrounds Sst	387	DST 5	1546.9 - 1547.9	-26.8500	149.1500
	Snake Creek 1	Triassic	Showgrounds Sst	41	DST 1	1515.1 - 1547.9	-26.8431	149.1217
	Waratah 4	Triassic	Showgrounds Sst	588	DST 1	1623.7 - 1656.0	-27.0150	148.9675
	Washpool 1	Triassic	Showgrounds Sst	589	tank oil	1577.0 - 1603.0	-27.1622	148.9769
	Sunnybank 1	Triassic	Rewan Gp	54	DST 2	1786.0 - 1806.0	-26.9403	149.2250
	Sunnybank 3	Triassic	Rewan Gp	225	DST 14	1810.0 - 1829.0	-26.9403	149.2172
	Sunnybank 2	Permian	Bandanna Fm	113	DST 11	1870.0 - 1889.0	-26.9403	149.2331
	Sunnybank 2	Permian	Bandanna Fm	213	DST 10	2002.5 - 2009.2	-26.9403	149.2331
	Wallumbilla South 1	Permian	Peawaddy Fm	209	DST 1	1723.0 - 1757.0	-26.6483	149.1833
	Dirinda 1	Devonian	Timbury Hills Fm	81	DST 2	1159.0 - 1174.0	-26.6797	148.6756
Wunger Ridge	Alton 1	Jurassic	Evergreen Fm	136	DST 1	1847.0 - 1865.0	-27.9383	149.3717
	Riverslea 1	Jurassic	Evergreen Fm	431	DST 2	1507.0 - 1517.1	-27.3481	148.7445
	Riverslea 3	Jurassic	Evergreen Fm (Lw)	587	DST 1	1520.3 - 1547.1	-27.3481	148.7414
	Beardmore 1	Triassic	Showgrounds Sst	559	DST 1	1850.0 - 1855.4	-27.7547	148.9881
	Fairymount 1	Triassic	Showgrounds Sst	585	DST 2	2049.3 - 2057.4	-28.0406	149.3136
	Harbour 1	Triassic	Showgrounds Sst	583	DST 2	1975.3 - 1987.8	-27.8103	149.2567
	Louise 2	Triassic	Showgrounds Sst	551	DST 1	2015.2 - 2027.2	-27.8200	149.2939
	McWhirter 1	Triassic	Showgrounds Sst	560	DST 1	1840.4 - 1850.1	-27.6956	148.9953
	Narrows 1	Triassic	Showgrounds Sst	556	DST 1	1975.0 - 1990.1	-27.8025	149.2531
	Rednook 1	Triassic	Showgrounds Sst	561	DST 1	2199.8 - 2224.3	-27.3194	149.2625
	Rednook 1	Triassic	Showgrounds Sst	563	DST 2	2224.5 - 2270.0	-27.3194	149.2625
	Renlim 1	Triassic	Showgrounds Sst	552	DST 1	1897.0 - 1903.0	-27.6442	149.1081
	Roswin 1	Triassic	Showgrounds Sst	546	DST 1	2058.0 - 2072.9	-27.4578	149.2300
	Silver Springs/Renlim	Triassic	Showgrounds Sst	554	tank cond	-	-27.6000	149.1000
	Sirrah 4	Triassic	Showgrounds Sst	553	DST 1	1971.2 - 2032.6	-27.6531	149.1669
	Taylor 5	Triassic	Showgrounds Sst	558	DST 2	2006.1 - 2018.7	-27.5558	149.2547
	Wunger 1	Triassic	Showgrounds Sst	46	DST 1	1915.0 - 1919.9	-27.6792	149.1261
	Yellowbank Creek 3	Triassic	Showgrounds Sst	557	DST 1	1850.0 - 1855.0	-27.7500	149.0136
	Yellowbank Creek North 1	Triassic	Showgrounds Sst	584	DST 2	1859.2 - 1870.0	-27.7261	149.0103
	Glen Fosslyn 1	Triassic	Rewan Fm	545	DST 2	2087.9 - 2098.2	-27.4936	149.2820
	Kinkabilla 1	Triassic	Cabawan Fm (Rewan Equiv)	219	DST 1	2922.0 - 2930.0	-27.5500	149.6439
	Warroon 3	Triassic	Rewan Fm	562	DST 3	2110.0 - 2139.0	-27.3432	149.2147
	Waggamba 1	Permian	Blackwater Gp	555	DST 4	2595.2 - 2621.0	-27.6631	149.4578

© Australian Geological Survey Organisation 1994

Table 2a Bulk compositional parameters in liquid petroleum.

Well	AGSO No	Age	Group	Oil Weight (mg)	Saturates (mg)	Aromatics (mg)	Aromatics %	SA %	SNA %	pr/ph	pr/n-C17	ph/n-C18	n-C12/n-C17	OEP-1	δ13C (sats)	δ13C (aroms)
Denison Trough Area																
Westgrove 3	391	Permian		114.7	57.2	16.5	22.39	30.27	47.34	2.72	0.29	0.06		1.15	-26.24	-25.14
Rolleston 1	390	Permian	C4	119.1	3.2	0.9	21.95	68.29	9.76						-25.54	-24.78
Rolleston 1	534	Permian	C4	113.3	77.1	5.6	6.77	22.12	71.11						-25.40	-24.45
Rolleston 3	548	Permian	C0	97.0	32.6	0.1	0.31	98.70	1.00							
Rolleston 3	549	Permian	C0	99.4	23.0	1.0	4.17	95.83								
Merivale 5	550	Permian	OC0	105.3	14.2	0.5	3.40	96.60		8.04			18.04		-25.52	-24.97
Yellowbank 3	547	Permian	OC0	100.8	17.0	0.5	2.86	92.29	4.86	10.12			6.09		-25.53	-25.42
Taroom Trough Area																
East																
Conloi 1	78	Jurassic	O4	128.2	74.4	37.6				2.98	biodeg		1.58		-26.32	-24.92
Conloi 1	217	Jurassic	O4	107.3	58.4	38.2	39.54	17.53	42.92	1.79	biodeg				-26.70	-25.11
Rockwood 1	97	Jurassic	#OC1	111.8	53.5	12.1	18.45	72.58	8.97	4.00	0.59	0.19	4.74		-26.05	-24.81
Bennett 1	215	Jurassic	O1a	90.5	46.2	10.9	19.09	78.48	2.43	4.91	0.35	0.07	0.84	1.09	-26.11	-25.24
Leichhardt 2	216	Jurassic	O3	106.3	54.0	21.3	28.29	41.59	30.12	4.75				1.02	-26.95	-25.35
Moonie 1	50	Jurassic	#O1b	98.5	87.6	11.7	11.78	61.75	26.47	4.17	0.50	0.11	0.43	1.08	-25.35	-24.84
Moonie 1	565	Jurassic	O1b	85.9	54.2	7.7	12.44	56.91	30.65	3.35	0.46		0.49	1.08	-25.29	-24.85
Moonie 2	566	Jurassic	O1c	94.6	49.9	18.4	26.94	35.80	37.26	3.37	0.49	0.13	0.44	1.09	-25.45	-24.86
Moonie 4	567	Jurassic	O2	100.2	63.0	12.1	16.11	48.66	35.23	3.86	0.66	0.14	0.15	1.07	-25.44	-24.46
Moonie 10	568	Jurassic	O1b	93.8	60.1	9.7	13.90	54.24	31.86	4.05	0.41	0.10	0.83	1.09	-25.27	-24.79
Moonie 11	569	Jurassic	O1c	95.1	46.1	10.5	18.55	36.65	44.80	3.91	0.58	0.13	0.28	1.07	-25.46	-24.82
Moonie 15	570	Jurassic	O1c	110.8	54.2	15.1	21.79	63.35	14.86	3.68	0.53	0.13	0.06	1.07	-25.35	-24.82
Moonie 18	571	Jurassic	O1c	100.4	54.1	13.3	19.73	22.47	57.79	3.79	0.49	0.12	0.52	1.07	-25.36	-24.83
Moonie 21	572	Jurassic	O1c	100.2	52.6	15.0	22.19	63.80	14.01	3.64	0.62	0.15	0.20	1.08	-25.46	-24.98
Moonie 27	573	Jurassic	O1c	109.3	44.1	28.4	39.17	26.76	34.06	4.12	0.57		0.29	1.07	-25.58	-25.17
Moonie 28	574	Jurassic	O1c	110.1	65.5	10.7	14.04	49.00	36.96	3.92	0.53	0.12	0.44	1.08	-25.73	-24.87
Moonie 29	575	Jurassic	O1a	109.5	55.0	12.2	18.15	47.47	34.38	4.18	0.36	0.09	1.11	1.07	-25.26	-24.86
Moonie 30	576	Jurassic	O1c	94.3	57.8	11.4	16.47	49.28	34.25	3.93	0.57		0.41	1.06	-25.41	-24.84
Moonie 31	577	Jurassic	O1b	109.3	71.1	15.8	18.18	56.45	25.36	3.93	0.46	0.11	0.61	1.09	-25.24	-24.88
Moonie 32	578	Jurassic	O1b	113.5	65.3	3.6	17.24	46.35	36.42	3.94	0.47	0.10	0.56	1.08	-25.38	-24.85
Moonie 33	579	Jurassic	O1c	98.0	56.4	12.8	18.50	35.86	45.64	4.40	0.53	0.11	0.36	1.07	-25.39	-24.91
Moonie 34	580	Jurassic	O2	95.4	55.4	22.7	29.07	41.14	29.79	4.21	0.61	0.13	0.22	1.08		
Moonie 35	581	Jurassic	O1c	91.1	53.4	10.5	16.43	71.87	11.70	4.23	0.52	0.11	0.29	1.09	-25.39	-24.79
Moonie 37	582	Jurassic	O1b	95.7	53.7	11.2	17.26	34.75	47.99	3.36	0.41	0.11	0.74	1.09	-25.30	-24.88
Rockwood North 1	55	Jurassic	O0	96.4	54.9	12.6	18.67	52.05	29.28	5.30	0.32	0.06	1.05	1.05	-26.01	-25.37
Cabawin 1	385	Permian	O0	109.0	59.2	16.8	22.11	35.83	42.06	5.13	0.33	0.07	1.06	1.05	-26.09	-25.16
Roma Shelf																
Anabranch 1	214	Jurassic	O0	104.0	47.7	12.8	21.16	47.31	31.54	4.22	0.32	0.08	1.20	1.08	-25.60	-25.08
Blyth Creek 1	386	Jurassic	OC0	104.2	34.3	1.3	3.65	92.49	3.85	3.17	0.38	0.20	45.69		-25.20	-26.16
Bony Creek 6	212	Jurassic	OC0	100.5	31.2	1.3	4.00	72.96	23.04	5.29	1.02	0.34	13.40		-25.25	-25.16

© Australian Geological Survey Organisation 1994

Table 2a (cont).

Well	AGSO No	Age	Group	Oil Weight (mg)	Saturates (mg)	Aromatics (mg)	Aromatics %	SA %	SNA %	pr/ph	pr/n-C17	ph/n-C18	n-C12/n-C17	OEP-1	δ13C (sats)	δ13C (aroms)
Roma Shelf (cont.)																
Duarran 2	207	Jurassic	O2	120.8	78.8	19.5	19.84	54.51	25.65	3.79	0.30	0.08	0.03	1.06	-25.79	-25.16
Maffra 2	221	Jurassic	O0	105.6	49.5	9.8	16.53	46.75	36.73	5.26	0.32	0.06	1.71	1.07	-25.59	-25.44
Richmond 1	43	Jurassic	O0	92.8	42.0	9.4	18.29	51.48	30.23	3.66	0.33	0.09	1.59	1.07	-25.48	-24.96
Richmond 5	210	Jurassic	O0	103.1	51.1	11.4	18.24	60.50	21.26	3.89	0.31	0.08	1.47	1.07	-25.45	-24.94
Richmond 7	205	Jurassic	OC0	122.4	5.8	0.7	10.77	83.08	6.15		0.18		25.89		-24.99	-25.19
Richmond 10	211	Jurassic	O0	105.9	43.9	11.8	21.18	52.02	26.80	5.57	0.31	0.06	1.57	1.08	-25.45	-24.96
Borah Creek 5	586	Triassic	O0	108.0	46.1	31.2	40.36	21.47	38.17	3.26	0.26	0.11	1.21	1.09	-23.89	-23.27
Combarngo 1	387	Triassic	O0	106.0	54.7	16.8	23.50	53.55	22.95	3.78	0.33	0.09	0.72	1.08	-26.04	-25.19
Snake Creek 1	41	Triassic	O0	86.7	38.0	7.3	16.11	47.81	36.07	4.92	0.33	0.08	2.68	1.07	-25.56	-25.01
Waratah 4	588	Triassic	O1b	106.1	67.1	24.9	27.07	41.57	31.36	4.17	0.91	0.18	0.90	1.12	-23.80	-23.48
Washpool 1	589	Triassic	O0	101.6	65.3	16.8	20.46	42.95	36.59	3.19	0.28	0.09	1.06	1.08	-25.30	-24.29
Sunnybank 1	54	Triassic	#O0	110.4	68.1	25.9	27.55	39.12	33.33	3.51	0.31	0.09	0.29	1.08	-25.75	-25.21
Sunnybank 3	225	Triassic	O0	91.3	38.9	15.0	27.83	51.96	20.21	5.12	0.32	0.06	0.75	1.07	-26.00	-25.31
Sunnybank 2	113	Permian	#O1a	118.9	58.7	26.9	31.43	32.92	35.66	3.12	0.28	0.08	0.39	1.09	-25.89	-25.13
Sunnybank 2	213	Permian	O1a	112.4	50.2	18.7	27.14	45.90	26.96	3.40	0.29	0.08	0.66	1.07	-25.85	-25.16
Wallumbilla South 1	209	Permian	OC0	100.9	1.8	0.3	14.29	61.90	23.81	6.52	0.31	0.05	22.59	1.43	-25.70	-25.19
Dirinda 1	81	Devonian	O0	88.3	41.6	10.3	19.85	48.89	31.26	3.71	0.25	0.07	1.32	1.05		
Wunger Ridge																
Alton 1	136	Jurassic	O0	88.4	53.4	9.0	14.42	65.04	20.54	5.14	0.32	0.06	0.86	1.09	-24.62	-24.33
Riverslea 1	431	Jurassic	O5	104.0	54.3	29.6	35.28	12.30	52.42						-24.71	-23.70
Riverslea 3	587	Jurassic	O5	118.0	67.5	37.0	35.41	23.90	40.69	3.32	0.87	0.22	0.92	1.12	-24.49	-23.67
Beardmore 1	559	Triassic	O0	111.3	58.9	11.1	15.86	55.53	28.61	4.25	0.28	0.07	1.17	1.08	-25.26	-25.09
Fairymount 1	585	Triassic	O0	103.6	49.5	11.4	18.66	42.30	39.04	3.67	0.32	0.09	1.01	1.12	-24.63	-24.51
Harbour 1	583	Triassic	O1a	108.5	53.8	12.7	19.10	42.07	38.83	4.74	0.24	0.05	1.19	1.07	-25.60	-25.24
Louise 2	551	Triassic	O0	99.0	41.3	9.3	18.38	53.05	28.57	4.28	0.25	0.06	1.57	1.05		
McWhirter 1	560	Triassic	O0	91.6	55.9	8.1	12.66	60.27	27.08	4.18	0.29	0.07	1.22	1.08	-25.02	-24.73
Narrows 1	556	Triassic	O0	97.3	33.7	8.5	20.14	51.11	28.75	5.28	0.27	0.06	1.73	1.06	-25.00	-24.82
Rednook 1	561	Triassic	C0	98.7	2.4	0.8	25.00	75.00		1.68					-27.09	-27.39
Rednook 1	563	Triassic	O1a	97.4	59.2	14.3	19.46	46.72	33.83	3.53	0.27	0.07	0.79	1.05	-24.89	-24.58
Renlim 1	552	Triassic	OC0	97.8	26.6	4.1	13.36	64.98	21.66	6.82	0.53	0.11	35.42		-24.69	-24.87
Roswin 1	546	Triassic	OC0	114.7	44.5	0.8	1.77	88.41	9.82	7.13	_	_	8.09		-25.73	-25.26
Silver Springs/Renlim	554	Triassic	OC0	98.2	14.5	18.2	55.66	11.09	33.26	7.73	0.35	0.08	14.14		-24.50	-24.61
Sirrah 4	553	Triassic	OC0	103.0	12.6	0.8	5.97	67.16	26.87	4.20					-25.55	-25.07
Taylor 5	558	Triassic	O0	91.5	41.0	15.2	27.05	41.58	31.37	5.07	0.31	0.06	1.31	1.08	-24.43	-23.85
Wunger 1	46	Triassic	#O0	85.6	14.5	3.2	18.08	60.62	21.30	3.75	0.31	0.09	0.22	1.07	-25.56	-24.90
Yellowbank Creek 3	557	Triassic	O0	94.7	46.9	13.0	21.70	41.50	36.80	5.34	0.28	0.06	1.35	1.06	-25.13	-24.84
Yellowbank Creek Nort	584	Triassic	O0	107.1	40.0	9.7	19.52	52.31	28.17	3.80	0.28	0.08	1.39	1.08	-25.06	-24.82
Glen Fosslyn 1	545	Triassic	O1a	96.0	56.7	13.9	19.69	45.78	34.53	3.57	0.25	0.07	0.66	1.09	-24.92	-24.75
Kinkabilla 1	219	Triassic	O1a	112.8	60.4	11.4	15.88	48.79	35.33	4.77	0.28	0.06	0.96	1.09	-26.00	-25.19
Warroon 3	562	Triassic	O1a	104.7	49.5	12.9	20.67	36.49	42.84	4.07	0.27	0.07	0.91	1.08	-25.25	-24.72
Waggamba 1	555	Permian	O0	98.8	38.4	10.5	21.47	39.26	39.26	4.72	0.25	0.06	1.42	1.08	-25.64	-25.13

© Australian Geological Survey Organisation 1994

Footnote to Table 2a.

saturates (sats) = saturated hydrocarbons; aromatics (aroms) = aromatic hydrocarbons; SA = silicalite adduct; SNA = silicalite non-adduct ; pr = pristane; ph = phytane; OEP-1 (odd-to-even predominance) = (n-C_{25} + 6 x n-C_{27} + n-C_{29}) / 4 x (n-C_{26} + n-C_{28}); $\delta^{13}C$ = carbon isotopic composition ($^{o}/_{oo}$).
oils that have lost their light ends due to evaporation on storage.

© Australian Geological Survey Organisation 1994

Table 2b Bulk compositional parameters in sediments.

Well	AGSO No	Formation	Depth Range	Age	TOC %	Tmax °C	S1	S2	S3	PI	HI	OI
Denison Trough Area												
Maranoa Colliery	6278	Walloon CM	o/c	Jurassic								
Dawson River 1	5278	Evergreen Fm	82.00 - 82.00	Jurassic	1.15	437	0.03	0.58	0.09	0.05	50	8
Dawson River 1	5279	Evergreen Fm	97.02 - 97.02	Jurassic	1.27	439	0.03	0.61	0.07	0.05	48	6
Dawson River 1	5280	Evergreen Fm	122.12 - 122.12	Jurassic	1.00	435	0.01	0.43	0.05	0.02	43	5
Dawson River 1	5281	Evergreen Fm	130.23 - 130.23	Jurassic	0.81	437	0.04	0.55	0.00	0.07	68	0
GSQ Mundubbera 1	5287	Evergreen Fm	321.46 - 321.48	Jurassic	0.70	440	0.01	0.31	0.01	0.03	44	1
GSQ Mundubbera 1	5288	Evergreen Fm	343.59 - 343.64	Jurassic	1.39	438	0.01	0.66	0.37	0.01	47	27
GSQ Mundubbera 1	5289	Evergreen Fm	358.47 - 358.49	Jurassic	1.29	439	0.02	0.68	0.35	0.03	53	27
GSQ Mundubbera 1	5290	Evergreen Fm	359.08 - 359.08	Jurassic	1.01	353	0.00	0.01	2.11		1	209
GSQ Mundubbera 1	5291	Evergreen Fm	360.45 - 360.48	Jurassic	0.50	438	0.01	0.15	0.00	0.06	30	0
GSQ Mundubbera 1	5292	Evergreen Fm	365.23 - 365.25	Jurassic	1.36	439	0.00	0.57	0.30		42	22
Warrong 1	6489	Moolayember Fm	189.93 - 189.93	Triassic	0.11	333	0.00	0.01	0.00	0.00	9	0
Warrong 1	6490	Moolayember Fm	434.50 - 434.50	Triassic	0.19	276	0.00	0.03	0.00	0.00	16	0
Arcturus 1	5066	Bandanna Fm	595.76 - 595.84	Permian	3.21	433	0.30	2.47	2.48	0.11	77	77
Emerald Ns 7	5298	Bandanna Fm	98.85 - 98.85	Permian	55.10	437	3.04	46.85	6.38	0.06	85	12
GSQ Eddystone 5	3652	Bandanna Fm	333.32 - 334.96	Permian	59.00	461	13.77	187.73	6.41	0.07	318	11
GSQ Emerald 1	3649	Bandanna Fm	111.33 - 111.33	Permian	38.70	446	4.68	120.93	3.59	0.04	312	9
GSQ Taroom 8	5294	Bandanna Fm	510.10 - 510.10	Permian	29.80	439	1.55	54.04	3.00	0.03	181	10
GSQ Taroom 8	5295	Bandanna Fm	520.00 - 520.00	Permian	61.10	437	6.65	115.46	10.78	0.05	189	18
GSQ Taroom 8	5296	Bandanna Fm	530.00 - 530.00	Permian	64.70	437	5.73	125.68	12.45	0.04	194	19
GSQ Taroom 8	3655	Bandanna Fm	544.80 - 544.81	Permian	1.64	452	0.91	14.04	0.94	0.06	856	57
GSQ Taroom 8	5297	Bandanna Fm	549.80 - 549.80	Permian	67.10	438	7.15	121.51	9.38	0.06	181	14
Rolleston 1	5070	Bandanna Fm	274.42 - 274.42	Permian	56.50	435	0.90	107	17.50	0.01	189	31
Westgrove 2	5075	Bandanna Fm	457.82 - 457.92	Permian	2.06	436	0.09	1.77	4.51	0.05	86	219
	5277	Rangal CM Upper Newlands Seam	o/c	Permian	73.10	444	3.28	137.41	2.83	0.02	188	4
Rolleston 1	5071	Black Alley Shale	430.38 - 430.48	Permian	2.31	444	0.07	1.89	1.07	0.04	82	46
Warrinilla North 1	5080	Peawaddy Fm	1002.19 - 1002.19	Permian	1.25	460	0.08	0.61	0.48	0.12	49	38
Blake Central Mine	5274	Collinsville CM	o/c	Permian	71.90	466	10.65	142.91	0.37	0.07	199	1
Garrick West Mine	5273	Collinsville CM	o/c	Permian	72.20	500	0.35	8.61	0.00	0.04	12	0
Scott Denison	5276	Collinsville CM	o/c	Permian	39.90	449	6.08	108.04	0.92	0.05	271	2
Cometside 1	5068	Ingelara Fm	992.44 - 992.54	Permian	2.17	446	0.34	1.24	1.14	0.22	57	53
Rolleston 1	5072	Ingelara Fm	873.67 - 873.67	Permian	2.26	446	0.19	1.18	0.88	0.14	52	39
Nebo West	5272	Moranbah CM	o/c	Permian	67.60	549	0.00	2.92	0.00		4	0
GSQ Springsure 17	3654	Aldebaran Fm	625.75 - 625.78	Permian	49.90	446	2.03	29.48	3.75	0.06	59	8
Rolleston 1	5073	Aldebaran Fm	1217.08 - 1217.10	Permian	0.84	458	0.10	0.35	0.14	0.22	42	17
Glentulloch 1	5069	Cattle Creek Fm	853.45 - 853.58	Permian	3.33	436	0.69	4.72	0.69	0.13	142	21
GSQ Eddystone 4	3651	Cattle Creek Fm	592.88 - 592.91	Permian	1.56	438	0.18	8.76	0.36	0.02	562	23
Warrinilla 1	5077	Cattle Creek Fm	1124.73 - 1124.73	Permian	1.47	446	0.36	1.15	0.43	0.24	78	29
Warrinilla 1	5078	Cattle Creek Fm	1411.55 - 1411.55	Permian	1.45	446	0.33	1.01	0.36	0.25	70	25
Warrinilla North 1	5081	Cattle Creek Fm	1764.50 - 1764.61	Permian	2.50	448	0.67	2.87	0.56	0.19	115	22
Warrinilla North 1	5082	Cattle Creek Fm	1901.98 - 1901.98	Permian	1.52	450	0.42	0.89	0.42	0.32	59	28

© Australian Geological Survey Organisation 1994

Table 2b (cont).

Well	AGSO No	Formation	Depth Range	Age	TOC %	Tmax °C	S1	S2	S3	PI	HI	OI
Denison Trough Area (cont.)												
GSQ Emerald 1	3648	Reids Dome Beds	315.30 - 315.34	Permian	47.20	441	2.03	108.47	6.10	0.02	230	13
GSQ Emerald 1	3650	Reids Dome Beds	407.62 - 407.66	Permian	64.10	385	3.63	19.24	10.00	0.16	30	16
GSQ Springsure 14	3653	Reids Dome Beds	291.76 - 291.77	Permian	53.30	432	5.43	251.57	3.85	0.02	472	7
GSQ Taroom 11-11A	3656	Reids Dome Beds	517.19 - 517.20	Permian	8.91	443	3.09	74.49	2.51	0.04	836	28
GSQ Taroom 11-11A	3657	Reids Dome Beds	601.48 - 601.49	Permian	42.90	443	11.96	131.81	6.06	0.08	307	14
GSQ Taroom 11-11A	3658	Reids Dome Beds	764.74 - 764.77	Permian	59.90	472	0.89	3.21	2.67	0.22	5	4
Warrinilla 1	5079	Reids Dome Beds	1907.77 - 1907.77	Permian	0.70	485	0.05	0.27	1.25	0.16	39	179
Warrinilla North 1	5083	Reids Dome Beds	2043.50 - 2043.50	Permian	4.48	458	0.79	3.82	0.88	0.17	85	20
Westgrove 3	5076	Reids Dome Beds	1716.43 - 1716.48	Permian	1.40	476	0.30	0.86	0.39	0.26	61	28
Taroom Trough Area												
Cabawin 1	6399	Orallo Fm	741.31 - 741.41	Cretaceou	1.05	432	0.06	1.07	0.00	0.05	102	0
Cabawin 1	6400	Orallo Fm	847.58 - 847.66	Cretaceou	0.60	446	0.01	0.33	0.06	0.03	55	10
Cabawin 1	6401	Walloon CM	1283.90 - 1284.10	Jurassic	1.19	434	0.05	1.53	0.00	0.03	129	0
Cabawin 1	6402	Walloon CM	1284.10 - 1284.19	Jurassic	46.50	425	6.65	146.51	12.93	0.04	315	28
Cabawin 1	6403	Walloon CM	1494.60 - 1494.66	Jurassic	1.05	438	0.11	1.15	1.52	0.09	110	145
Cabawin 1	6404	Walloon CM	1495.40 - 1495.52	Jurassic	13.90	437	2.18	90.76	1.70	0.02	653	12
Cabawin 1	6405	Hutton Sst	1749.60 - 1749.70	Jurassic	19.50	431	4.06	90.7	3.31	0.04	465	17
Bellbird 1 (Sydoc)	6521	Evergreen Fm	1943.70 - 1943.70	Jurassic	2.27	434	0.21	6.38	0.00	0.03	281	0
Canaan 1	6488	Evergreen Fm	269.52 - 269.52	Jurassic	0.73	436	0.00	0.28	2.44	0.00	38	334
Dawson River 6	5282	Evergreen Fm	44.14 - 44.14	Jurassic	4.61	441	0.06	3.61	2.25	0.02	78	49
Dawson River 6	5283	Evergreen Fm	79.55 - 79.55	Jurassic	2.34	440	0.03	1.47	0.99	0.02	63	42
Dawson River 6	5284	Evergreen Fm	82.60 - 82.63	Jurassic	0.75	446	0.00	0.05	0.42		7	56
Dawson River 6	5285	Evergreen Fm	94.54 - 94.54	Jurassic	1.31	438	0.02	0.52	0.24	0.04	40	18
Dawson River 6	5286	Evergreen Fm	149.99 - 149.99	Jurassic	0.79	442	0.01	0.26	0.00	0.04	33	0
Juandah 1	6484	Evergreen Fm	1268.40 - 1268.40	Jurassic	1.62	437	0.02	0.79	0.00	0.02	49	0
Tingan 1	6487	Evergreen Fm	1480.60 - 1480.60	Jurassic	0.56	428	0.00	0.97	0.00	0.00	173	0
Wandoan 1	6545	Evergreen Fm	956.38 - 956.38	Jurassic	0.55	434	0.03	0.34	0.00	0.08	62	0
Burunga 1	6530	Evergreen Fm (Upper Unit)	390.59 - 390.59	Jurassic	1.67	430	0.00	1.06	6.62	0.00	63	396
Cockatoo Creek 1	6411	Precipice Sst	155.45 - 158.50	Jurassic	0.90	421	0.20	0.79	0.00	0.20	88	0
Wandoan 1	6546	Moolayember Fm	1195.90 - 1195.90	Triassic	1.26	432	0.08	0.95	0.00	0.08	75	0
Wandoan 1	1826	Moolayember Fm	1196.20 - 1196.20	Triassic	1.09							
Warrong 1	6490	Moolayember Fm	434.50 - 434.50	Triassic	0.19	276	0.00	0.03	0.00	0.00	16	0
Cabawin 1	6406	Moolayember Fm (Upper Unit)	2200.40 - 2200.45	Triassic	0.98	435	0.15	2.04	0.04	0.07	208	4
Cabawin 1	1818	Moolayember Fm (Upper Unit)	2200.90 - 2200.90	Triassic	0.95							
Glenhaughton 1	1816	Moolayember Fm (Upper Unit)	225.90 - 225.90	Triassic	0.39							
Glenhaughton 1	6485	Moolayember Fm (Upper Unit)	228.55 - 228.55	Triassic	0.67	443	0.00	0.28	0.00	0.00	42	0
Bellbird 1 (Sydoc)	6522	Moolayember Fm Snake Creek Mudsto	2261.50 - 2261.50	Triassic	1.68	436	0.11	1.66	3.18	0.06	99	189
Cabawin 1	6407	Moolayember Fm Snake Creek Mudsto	2256.80 - 2256.94	Triassic	1.28	437	0.18	1.51	0.00	0.11	118	0
Cabawin 1	1819	Moolayember Fm Snake Creek Mudsto	2257.40 - 2257.40	Triassic	0.75							

© Australian Geological Survey Organisation 1994

Table 2b (cont).

Well	AGSO No	Formation	Depth Range	Age	TOC %	Tmax °C	S1	S2	S3	PI	HI	OI
Taroom Trough Area (cont.)												
Glenhaughton 1	5235	Clematis Gp	947.30 - 947.30	Triassic								
Cabawin 1	5241	Rewan Gp	2331.10 - 2331.10	Triassic	0.08							
Cockatoo Creek 1	6412	Rewan Gp	520.91 - 521.01	Triassic	0.09	344	0.00	0.03	0.00		33	0
Cockatoo Creek 1	5240	Rewan Gp	657.55 - 657.55	Triassic	0.11							
Flinton 1	5243	Rewan Gp	2423.60 - 2423.60	Triassic	0.09							
Glenhaughton 1	5236	Rewan Gp	1900.10 - 1900.10	Triassic								
Wandoan 1	1827	Rewan Gp	2532.90 - 2532.90	Triassic	0.15							
Wandoan 1	5239	Rewan Gp	1860.19 - 1860.19	Triassic	0.14							
Cabawin 1	3671	Blackwater Gp	3034.41 - 3034.51	Permian	26.40	445	1.42	32.67	8.57	0.04	124	32
Cabawin 1	6408	Blackwater Gp	3034.50 - 3034.55	Permian	22.57	442	6.82	27.85	2.29	0.20	123	10
Cabawin 1	3674	Blackwater Gp	3082.57 - 3082.67	Permian	30.50	442	8.00	161.09	35.09	0.05	528	115
Cabawin 1	6409	Blackwater Gp	3082.60 - 3082.71	Permian	12.63	443	5.97	45.5	1.06	0.12	360	8
Cabawin 1	1820	Blackwater Gp	3088.30 - 3088.30	Permian	0.49							
Glenhaughton 1	1817	Blackwater Gp	2082.30 - 2082.30	Permian	1.88							
Glenhaughton 1	5237	Blackwater Gp	2207.10 - 2207.10	Permian								
Undulla 1	6563	Blackwater Gp	1985.60 - 1985.60	Permian	0.65	448	0.03	0.38	15.55	0.07	58	2392
Wandoan 1	1828	Blackwater Gp	2859.80 - 2859.80	Permian	1.19							
Wandoan 1	5242	Blackwater Gp	3017.10 - 3017.20	Permian	2.19	510	0.02	0.23	0.02	0.08	11	1
Wandoan 1	1829	Blackwater Gp	3017.80 - 3017.80	Permian	1.96							
Wandoan 1	6547	Blackwater Gp	3180.30 - 3180.30	Permian	1.69	465	0.44	0.86	0.17	0.34	51	10
Burunga 1	6531	Blackwater Gp Baralaba CM	726.95 - 726.95	Permian	0.76	482	0.03	0.25	0.00	0.11	33	0
Cockatoo Creek 1	6413	Blackwater Gp Baralaba CM	1127.20 - 1127.20	Permian	0.54	454	0.06	0.27	0.00	0.18	50	0
Cockatoo Creek 1	1822	Blackwater Gp Baralaba CM	1127.40 - 1127.40	Permian	0.43							
Cockatoo Creek 1	5233	Blackwater Gp Baralaba CM	1430.10 - 1430.20	Permian	3.53	426	0.01	0.12	2.55	0.08	3	72
Cockatoo Creek 1	6414	Blackwater Gp Baralaba CM	1430.80 - 1430.83	Permian	4.33	440	0.40	4.57	0.00	0.08	106	0
Bengalla 1	6486	Back Creek Gp	2113.98 - 2113.98	Permian	1.88	443	0.35	0.55	0.00	0.39	29	0
Cabawin 1	6410	Back Creek Gp	3380.70 - 3380.80	Permian	0.52	458	0.15	0.44	0.19	0.25	85	37
Cabawin 1	1821	Back Creek Gp	3381.50 - 3381.50	Permian	0.48							
Coonardoo 1	6480	Back Creek Gp	1640.20 - 1640.20	Permian	27.24	441	6.97	58.68	0.48	0.11	215	2
Glenhaughton 1	5238	Back Creek Gp	2658.80 - 2658.80	Permian								
Goondiwindi 1	6482	Back Creek Gp	1959.60 - 1959.60	Permian	2.07	439	0.11	2.49	0.25	0.04	120	12
Southwood 1	5074	Back Creek Gp	3003.54 - 3003.61	Permian	1.38	438	0.21	0.69	0.13	0.23	50	9
Southwood 1	5293	Back Creek Gp	3003.80 - 3003.96	Permian	1.91	438	0.20	0.74	0.00	0.21	39	0
Undulla 1	6564	Back Creek Gp	2148.50 - 2148.50	Permian	0.65	451	0.07	0.36	0.00	0.16	55	0
Burunga 1	6542	Back Creek Gp Gyranda Fm	1798.20 - 1798.20	Permian	0.69	450	0.08	0.31	0.00	0.21	45	0
Cockatoo Creek 1	6415	Back Creek Gp Gyranda Fm	1620.00 - 1620.11	Permian	1.05	451	0.13	0.48	0.00	0.21	46	0
Cockatoo Creek 1	1823	Back Creek Gp Gyranda Fm	1620.40 - 1620.40	Permian	0.81							
Cockatoo Creek 1	6416	Back Creek Gp Gyranda Fm	1700.80 - 1700.91	Permian	0.95	449	0.18	0.7	0.00	0.20	74	0
Cockatoo Creek 1	6417	Back Creek Gp Gyranda Fm	2008.40 - 2008.43	Permian	0.75	460	0.14	0.42	0.00	0.25	56	0
Burunga 1	6543	Back Creek Gp Flat Top Fm	2123.40 - 2123.40	Permian	0.81	460	0.16	0.38	0.00	0.30	47	0
Cockatoo Creek 1	5067	Back Creek Gp Flat Top Fm	2659.10 - 2659.13	Permian	0.32	398	0.03	0.07	0.02	0.30	22	6

© Australian Geological Survey Organisation 1994

Table 2b (cont).

Well	AGSO No	Formation	Depth Range	Age	TOC %	Tmax °C	S1	S2	S3	PI	HI	OI
Taroom Trough Area (cont.)												
Cockatoo Creek 1	6418	Back Creek Gp Flat Top Fm	2659.70 - 2659.85	Permian	0.93	405	0.00	0.02	0.00		2	0
Cockatoo Creek 1	1824	Back Creek Gp Flat Top Fm	2659.70 - 2659.70	Permian	0.26							
Cockatoo Creek 1	6419	Back Creek Gp Flat Top Fm	2755.70 - 2755.83	Permian	0.17	342	0.01	0.06	0.00	0.14	35	0
Burunga 1	6544	Back Creek Gp Barfield Fm	2958.30 - 2958.30	Permian	3.37	500	0.10	1.13	0.00	0.08	34	0
Cockatoo Creek 1	6420	Back Creek Gp Barfield Fm	3132.50 - 3132.57	Permian	1.18	504	0.02	0.21	0.00	0.09	18	0
Cockatoo Creek 1	5234	Back Creek Gp Barfield Fm	3133.00 - 3133.10	Permian	1.19	456	0.27	2.58	0.21	0.09	217	18
Cockatoo Creek 1	1825	Back Creek Gp Barfield Fm	3467.40 - 3467.40	Permian	0.96							
Cockatoo Creek 1	6421	Back Creek Gp Barfield Fm	3558.30 - 3558.36	Permian	1.11	417	0.01	0.08	0.00	0.11	7	0

© Australian Geological Survey Organisation 1994

Table 2b (cont).

Well	AGSO No	Formation	Depth Range	Age	Sample extracted (g)	EOM (mg)	EOM used (mg)	Sats (mg)	Aroms (mg)	NSO's (mg)	Sats %	Aroms %	NSO's %	ppm HC	mg HC /gTOC
Denison Trough Area															
Maranoa Colliery	6278	Walloon CM	o/c	Jurassic	20.26	735.7	735.7	6.6	17.2	110.9	0.9	2.3	15.1	1175	
Dawson River 1	5278	Evergreen Fm	82.00 - 82.00	Jurassic	6.31	8.7	8.7	1.2	0.7	3.8	13.8	8.0	43.7	301	26.2
Dawson River 1	5279	Evergreen Fm	97.02 - 97.02	Jurassic	23.81	22.3	22.3	4.0	2.2	10.7	17.9	9.9	48.0	260	20.5
Dawson River 1	5280	Evergreen Fm	122.12 - 122.12	Jurassic	17.95	20.5	20.5	3.1	2.3	10.0	15.1	11.2	48.8	301	30.1
Dawson River 1	5281	Evergreen Fm	130.23 - 130.23	Jurassic	8.18	15.5	15.5	1.6	2.3	5.7	10.3	14.8	36.8	477	58.9
GSQ Mundubbera 1	5287	Evergreen Fm	321.46 - 321.48	Jurassic	26.53	6.7	6.7	1.0	0.6	3.4	14.9	9.0	50.7	60	8.6
GSQ Mundubbera 1	5288	Evergreen Fm	343.59 - 343.64	Jurassic	34.97	17.8	17.8	2.3	1.3	7.5	12.9	7.3	42.1	103	7.4
GSQ Mundubbera 1	5289	Evergreen Fm	358.47 - 358.49	Jurassic	22.05	19.8	19.8	1.2	0.8	7.0	6.1	4.0	35.4	91	7.0
GSQ Mundubbera 1	5290	Evergreen Fm	359.08 - 359.08	Jurassic	14.44	7.0	7.0	0.7	0.4	1.9	10.0	5.7	27.1	76	7.5
GSQ Mundubbera 1	5291	Evergreen Fm	360.45 - 360.48	Jurassic	21.43	12.0	12.0	1.1	1.7	3.0	9.2	14.2	25.0	131	26.1
GSQ Mundubbera 1	5292	Evergreen Fm	365.23 - 365.25	Jurassic	23.76	17.2	17.2	1.1	0.6	5.7	6.4	3.5	33.1	72	5.3
Warrong 1	6489	Moolayember Fm	189.93 - 189.93	Triassic	33.31	1.8	1.8	0.3	0.2	0.8	16.7	11.1	44.4	15	13.6
Warrong 1	6490	Moolayember Fm	434.50 - 434.50	Triassic	32.76	8.2	8.2	1.0	0.3	4.6	12.2	3.7	56.1	40	20.9
Arcturus 1	5066	Bandanna Fm	595.76 - 595.84	Permian	46.54	99.8	99.8	5.2	16.2	55.4	5.2	16.2	55.5	460	14.3
Emerald Ns 7	5298	Bandanna Fm	98.85 - 98.85	Permian	9.61	128.9	54.4	2.0	7.9	36.4	3.7	14.5	66.9	2441	4.4
GSQ Eddystone 5	3652	Bandanna Fm	333.32 - 334.96	Permian	16.07	292.8	292.8	15.6	38.4	236.5	5.3	13.1	80.8	3360	5.7
GSQ Emerald 1	3649	Bandanna Fm	111.33 - 111.33	Permian	23.73	335.2	335.2	19.8	34.8	274.0	5.9	10.4	81.7	2301	5.9
GSQ Taroom 8	5294	Bandanna Fm	510.10 - 510.10	Permian	9.80	188.5	57.2	1.4	4.0	18.8	2.4	7.0	32.9	1816	6.1
GSQ Taroom 8	5295	Bandanna Fm	520.00 - 520.00	Permian	7.02	225.1	32.2	1.1	2.8	4.2	3.4	8.7	13.0	3884	6.4
GSQ Taroom 8	5296	Bandanna Fm	530.00 - 530.00	Permian	9.92	541.5	53.7	1.2	3.8	22.5	2.2	7.1	41.9	5083	7.9
GSQ Taroom 8	3655	Bandanna Fm	544.80 - 544.81	Permian	30.97	34.5	34.5	2.1	20.5	10.0	6.1	59.4	29.0	730	44.5
GSQ Taroom 8	5297	Bandanna Fm	549.80 - 549.80	Permian	9.71	339.5	54.7	2.0	5.4	21.5	3.7	9.9	39.3	4730	7.0
Rolleston 1	5070	Bandanna Fm	274.42 - 274.42	Permian	49.52	171.6	87.3	13.1	6.7	38.4	15.0	7.7	44.0	786	1.4
Westgrove 2	5075	Bandanna Fm	457.82 - 457.92	Permian	82.28	87.0	87.0	0.8	7.8	43.0	0.9	9.0	49.4	105	5.1
	5277	Rangal CM Upper Newlands Seam	o/c	Permian	23.99	341.7	55.6	2.9	12.2	24.4	5.2	21.9	43.9	3868	5.3
Rolleston 1	5071	Black Alley Shale	430.38 - 430.48	Permian	73.77	85.9	85.9	6.1	7.3	47.0	7.1	8.5	54.7	182	7.9
Warrinilla North 1	5080	Peawaddy Fm	1002.19 - 1002.19	Permian	112.14	95.5	49.9	3.3	7.1	15.8	6.6	14.2	31.7	177	14.2
Blake Central Mine	5274	Collinsville CM	o/c	Permian	13.34	148.1	51.1	3.8	15.2	21.6	7.4	29.7	42.3	4128	5.7
Garrick West Mine	5273	Collinsville CM	o/c	Permian	20.71	8.3	8.3	0.7	0.6	6.6	8.4	7.2	79.5	63	0.1
Scott Denison	5276	Collinsville CM	o/c	Permian	24.70	201.2	42.3	3.0	8.9	24.0	7.1	21.0	56.7	2292	5.7
Cometside 1	5068	Ingelara Fm	992.44 - 992.54	Permian	67.61	66.7	66.7	6.9	13.2	36.2	10.3	19.8	54.3	297	13.7
Rolleston 1	5072	Ingelara Fm	873.67 - 873.67	Permian	56.46	71.1	71.1	4.5	8.6	54.5	6.3	12.1	76.7	232	10.3
Nebo West	5272	Moranbah CM	o/c	Permian	14.69	2.5	2.5	0.4	0.2	1.4	16.0	8.0	56.0	41	0.1
GSQ Springsure 17	3654	Aldebaran Fm	625.75 - 625.78	Permian	41.67	1259.0	1259.0	186.9	136.1	924.2	14.8	10.8	73.4	7751	15.5
Rolleston 1	5073	Aldebaran Fm	1217.08 - 1217.10	Permian	63.97	36.3	36.3	3.0	6.5	7.8	8.3	17.9	21.5	149	17.7
Glentulloch 1	5069	Cattle Creek Fm	853.45 - 853.58	Permian	72.83	82.8	82.8	6.4	17.9	33.3	7.7	21.6	40.2	334	10.0
GSQ Eddystone 4	3651	Cattle Creek Fm	592.88 - 592.91	Permian	34.38	14.6	14.6	2.2	1.2	10.9	15.1	8.2	74.7	99	6.3
Warrinilla 1	5077	Cattle Creek Fm	1124.73 - 1124.73	Permian	103.41	48.8	48.8	5.2	2.8	16.9	10.7	5.7	34.6	77	5.3
Warrinilla 1	5078	Cattle Creek Fm	1411.55 - 1411.55	Permian	76.42	40.8	40.8	8.8	3.3	20.5	21.6	8.1	50.2	158	10.9
Warrinilla North 1	5081	Cattle Creek Fm	1764.50 - 1764.61	Permian	121.81	189.4	51.7	6.4	8.4	25.8	12.4	16.2	49.9	445	17.8
Warrinilla North 1	5082	Cattle Creek Fm	1901.98 - 1901.98	Permian	70.18	53.5	53.5	9.3	7.9	26.0	17.4	14.8	48.6	245	16.1

© Australian Geological Survey Organisation 1994

Table 2b (cont).

Well	AGSO No	Formation	Depth Range	Age	Sample extracted (g)	EOM (mg)	EOM used (mg)	Sats (mg)	Aroms (mg)	NSO's (mg)	Sats %	Aroms %	NSO's %	ppm HC	mg HC /gTOC
Denison Trough Area (cont.)															
GSQ Emerald 1	3648	Reids Dome Beds	315.30 - 315.34	Permian	4.84	191.5	191.5	11.2	14.6	163.9	5.8	7.6	85.6	5331	11.3
GSQ Emerald 1	3650	Reids Dome Beds	407.62 - 407.66	Permian	3.45	47.1	47.1	4.6	6.9	35.3	9.8	14.6	74.9	3333	5.2
GSQ Springsure 14	3653	Reids Dome Beds	291.76 - 291.77	Permian	5.80	114.9	114.9	16.7	19.0	78.0	14.5	16.5	67.9	6155	11.5
GSQ Taroom 11-11A	3656	Reids Dome Beds	517.19 - 517.20	Permian	1.20	9.2	9.2	0.2	0.2	8.8	2.2	2.2	95.7	333	3.7
GSQ Taroom 11-11A	3657	Reids Dome Beds	601.48 - 601.49	Permian	1.61	58.6	58.6	2.1	3.1	52.8	3.6	5.3	90.1	3230	7.5
GSQ Taroom 11-11A	3658	Reids Dome Beds	764.74 - 764.77	Permian	1.29	13.5	13.5	1.5	3.2	7.6	11.1	23.7	56.3	3643	6.1
Warrinilla 1	5079	Reids Dome Beds	1907.77 - 1907.77	Permian	97.14	18.1	18.1	1.7	2.4	10.6	9.4	13.3	58.6	42	6.0
Warrinilla North 1	5083	Reids Dome Beds	2043.50 - 2043.50	Permian	51.34	54.7	54.7	4.6	9.5	30.0	8.4	17.4	54.8	275	6.1
Westgrove 3	5076	Reids Dome Beds	1716.43 - 1716.48	Permian	76.68	47.8	47.8	6.2	5.9	27.7	13.0	12.3	57.9	158	11.3
Taroom Trough Area															
Cabawin 1	6399	Orallo Fm	741.31 - 741.41	Cretaceou	13.74	15.0	15.0	1.8	0.7	9.6	12.0	4.7	64.0	182	17.3
Cabawin 1	6400	Orallo Fm	847.58 - 847.66	Cretaceou	17.78	13.4	13.4	1.8	0.9	7.9	13.4	6.7	59.0	152	25.3
Cabawin 1	6401	Walloon CM	1283.90 - 1284.10	Jurassic	24.30	24.6	24.6	3.3	1.6	17.5	13.4	6.5	71.1	202	16.9
Cabawin 1	6402	Walloon CM	1284.10 - 1284.19	Jurassic	5.15	280.8	34.6	5.3	3.9	31.8	15.3	11.3	91.9	14498	31.2
Cabawin 1	6403	Walloon CM	1494.60 - 1494.66	Jurassic	14.41	21.7	21.7	3.1	1.6	13.7	14.3	7.4	63.1	326	31.1
Cabawin 1	6404	Walloon CM	1495.40 - 1495.52	Jurassic	15.39	190.5	43.8	6.5	8.3	35.5	14.8	18.9	81.1	4183	30.1
Cabawin 1	6405	Hutton Sst	1749.60 - 1749.70	Jurassic	6.10	123.3	28.4	2.6	5.5	19.7	9.2	19.4	69.4	5765	29.6
Bellbird 1 (Sydoc)	6521	Evergreen Fm	1943.70 - 1943.70	Jurassic	47.73	97.2	38.4	4.0	10.3	29.6	10.4	26.8	77.1	758	33.4
Canaan 1	6488	Evergreen Fm	269.52 - 269.52	Jurassic	27.71	16.7	16.7	0.5	0.6	10.1	3.0	3.6	60.5	40	5.4
Dawson River 6	5282	Evergreen Fm	44.14 - 44.14	Jurassic	21.12	64.8	64.8	3.6	3.3	22.6	5.6	5.1	34.9	327	7.1
Dawson River 6	5283	Evergreen Fm	79.55 - 79.55	Jurassic	15.86	15.4	15.4	1.6	0.3	5.3	10.4	1.9	34.4	120	5.1
Dawson River 6	5284	Evergreen Fm	82.60 - 82.63	Jurassic	15.09	3.6	3.6	0.8	0.2	2.0	22.2	5.6	55.6	66	8.8
Dawson River 6	5285	Evergreen Fm	94.54 - 94.54	Jurassic	13.93	9.1	9.1	1.3	0.5	4.7	14.3	5.5	51.6	129	9.9
Dawson River 6	5286	Evergreen Fm	149.99 - 149.99	Jurassic	21.88	9.0	9.0	0.9	0.5	4.5	10.0	5.6	50.0	64	8.1
Juandah 1	6484	Evergreen Fm	1268.40 - 1268.40	Jurassic	37.56	144.0	16.9	0.9	2.5	14.2	5.3	14.8	84.0	771	47.6
Tingan 1	6487	Evergreen Fm	1480.60 - 1480.60	Jurassic	64.40	24.7	24.7	1.8	2.7	14.2	7.3	10.9	57.5	70	12.5
Wandoan 1	6545	Evergreen Fm	956.38 - 956.38	Jurassic	31.83	23.9	23.9	1.5	1.6	12.8	6.3	6.7	53.6	97	17.7
Burunga 1	6530	Evergreen Fm (Upper Unit)	390.59 - 390.59	Jurassic	51.22	49.2	49.2	3.2	3.5	27.4	6.5	7.1	55.7	131	7.8
Cockatoo Creek 1	6411	Precipice Sst	155.45 - 158.50	Jurassic	11.61	14.2	14.2	2.1	0.8	10.6	14.8	5.6	74.6	250	27.8
Wandoan 1	6546	Moolayember Fm	1195.90 - 1195.90	Triassic	41.59	178.8	15.2	1.5	2.8	13.3	9.9	18.4	87.5	1216	96.5
Wandoan 1	1826	Moolayember Fm	1196.20 - 1196.20	Triassic	100.00	69.5	69.5	9.2	3.2	56.5	13.2	4.6	81.3	124	11.4
Warrong 1	6490	Moolayember Fm	434.50 - 434.50	Triassic	32.76	8.2	8.2	1.0	0.3	4.6	12.2	3.7	56.1	40	20.9
Cabawin 1	6406	Moolayember Fm (Upper Unit)	2200.40 - 2200.45	Triassic	12.20	13.8	13.8	1.5	1.4	8.7	10.9	10.1	63.0	238	24.3
Cabawin 1	1818	Moolayember Fm (Upper Unit)	2200.90 - 2200.90	Triassic	100.00	85.4	85.4	19.7	5.4	54.1	23.1	6.3	63.3	251	26.4
Glenhaughton 1	1816	Moolayember Fm (Upper Unit)	225.90 - 225.90	Triassic	100.00	29.9	29.9	5.1	2.8	20.3	17.1	9.4	67.9	79	20.3
Glenhaughton 1	6485	Moolayember Fm (Upper Unit)	228.55 - 228.55	Triassic	44.61	21.1	21.1	1.4	1.6	13.6	6.6	7.6	64.5	67	10.0
Bellbird 1 (Sydoc)	6522	Moolayember Fm Snake Creek Mudsto	2261.50 - 2261.50	Triassic	13.53	62.3	62.3	2.8	3.2	10.2	4.5	5.1	16.4	443	26.4
Cabawin 1	6407	Moolayember Fm Snake Creek Mudsto	2256.80 - 2256.94	Triassic	16.28	20.1	20.1	3.3	2.1	19.0	16.4	10.4	94.5	332	25.9
Cabawin 1	1819	Moolayember Fm Snake Creek Mudsto	2257.40 - 2257.40	Triassic	100.00	80.0	80.0	22.7	5.4	44.7	28.4	6.8	55.9	281	37.5

© Australian Geological Survey Organisation 1994

Table 2b (cont).

Well	AGSO No	Formation	Depth Range	Age	Sample extracted (g)	EOM (mg)	EOM used (mg)	Sats (mg)	Aroms (mg)	NSO's (mg)	Sats %	Aroms %	NSO's %	ppm HC	mg HC /gTOC
Taroom Trough Area (cont.)															
Glenhaughton 1	5235	Clematis Gp	947.30 - 947.30	Triassic											
Cabawin 1	5241	Rewan Gp	2331.10 - 2331.10	Triassic											
Cockatoo Creek 1	6412	Rewan Gp	520.91 - 521.01	Triassic	17.85	1.6	1.6	0.3	0.2	0.9	18.8	12.5	56.3	28	31.1
Cockatoo Creek 1	5240	Rewan Gp	657.55 - 657.55	Triassic											
Flinton 1	5243	Rewan Gp	2423.60 - 2423.60	Triassic											
Glenhaughton 1	5236	Rewan Gp	1900.10 - 1900.10	Triassic											
Wandoan 1	1827	Rewan Gp	2532.90 - 2532.90	Triassic	100.00	277.9	277.9	6.2	168.9	12.0	2.2	60.8	4.3	1751	1167.3
Wandoan 1	5239	Rewan Gp	1860.19 - 1860.19	Triassic											
Cabawin 1	3671	Blackwater Gp	3034.41 - 3034.51	Permian	16.65	255.0	255.0	56.6	49.4	143.5	22.2	19.4	56.3	6366	24.1
Cabawin 1	6408	Blackwater Gp	3034.50 - 3034.55	Permian	19.96	164.8	79.1	11.7	26.7	49.3	14.8	33.8	62.3	4008	17.8
Cabawin 1	3674	Blackwater Gp	3082.57 - 3082.67	Permian	13.74	209.9	59.3	6.8	16.1	35.5	11.5	27.2	59.9	5899	19.3
Cabawin 1	6409	Blackwater Gp	3082.60 - 3082.71	Permian	17.78	119.9	31.1	9.4	9.8	10.2	30.2	31.5	32.8	4163	33.0
Cabawin 1	1820	Blackwater Gp	3088.30 - 3088.30	Permian	100.00	103.8	103.8	18.2	4.0	80.9	17.5	3.9	77.9	222	45.3
Glenhaughton 1	1817	Blackwater Gp	2082.30 - 2082.30	Permian	100.00	22.8	22.8	3.2	3.6	15.5	14.0	15.8	68.0	68	3.6
Glenhaughton 1	5237	Blackwater Gp	2207.10 - 2207.10	Permian											
Undulla 1	6563	Blackwater Gp	1985.60 - 1985.60	Permian	55.50	36.9	36.9	1.3	3.5	28.9	3.5	9.5	78.3	86	13.3
Wandoan 1	1828	Blackwater Gp	2859.80 - 2859.80	Permian	100.00	37.4	37.4	6.5	4.8	25.7	17.4	12.8	68.7	113	9.5
Wandoan 1	5242	Blackwater Gp	3017.10 - 3017.20	Permian	120.34	84.1	50.3	10.6	5.1	29.6	21.1	10.1	58.8	218	10.0
Wandoan 1	1829	Blackwater Gp	3017.80 - 3017.80	Permian	100.00	59.9	59.9	13.1	7.0	39.1	21.9	11.7	65.3	201	10.3
Wandoan 1	6547	Blackwater Gp	3180.30 - 3180.30	Permian	21.20	33.1	33.1	7.4	4.8	11.7	22.4	14.5	35.3	575	34.1
Burunga 1	6531	Blackwater Gp Baralaba CM	726.95 - 726.95	Permian	29.04	10.9	10.9	1.8	0.7	7.7	16.5	6.4	70.6	86	11.3
Cockatoo Creek 1	6413	Blackwater Gp Baralaba CM	1127.20 - 1127.20	Permian	16.08	12.7	12.7	0.8	1.4	8.4	6.3	11.0	66.1	137	25.3
Cockatoo Creek 1	1822	Blackwater Gp Baralaba CM	1127.40 - 1127.40	Permian	100.00	47.4	47.4	5.1	5.4	36.1	10.8	11.4	76.2	105	24.4
Cockatoo Creek 1	5233	Blackwater Gp Baralaba CM	1430.10 - 1430.20	Permian	122.36	134.8	52.3	2.3	6.6	31.8	4.4	12.6	60.8	187	5.3
Cockatoo Creek 1	6414	Blackwater Gp Baralaba CM	1430.80 - 1430.83	Permian	15.59	50.4	50.4	4.3	9.6	36.6	8.5	19.0	72.6	892	20.6
Bengalla 1	6486	Back Creek Gp	2113.98 - 2113.98	Permian	39.76	53.8	53.8	6.6	14.6	21.7	12.3	27.1	40.3	533	28.4
Cabawin 1	6410	Back Creek Gp	3380.70 - 3380.80	Permian	9.20	8.3	8.3	1.8	0.9	7.8	21.7	10.8	94.0	293	56.4
Cabawin 1	1821	Back Creek Gp	3381.50 - 3381.50	Permian	100.00	40.7	40.7	12.3	2.1	25.7	30.2	5.2	63.1	144	30.0
Coonardoo 1	6480	Back Creek Gp	1640.20 - 1640.20	Permian	7.25	65.4	22.5	0.7	7.3	14.0	3.1	32.4	62.2	3207	11.8
Glenhaughton 1	5238	Back Creek Gp	2658.80 - 2658.80	Permian											
Goondiwindi 1	6482	Back Creek Gp	1959.60 - 1959.60	Permian	36.00	78.8	31.0	1.2	2.7	26.5	3.9	8.7	85.5	275	13.3
Southwood 1	5074	Back Creek Gp	3003.54 - 3003.61	Permian	70.43	95.9	95.9	9.6	20.8	38.8	10.0	21.7	40.5	432	31.3
Southwood 1	5293	Back Creek Gp	3003.80 - 3003.96	Permian	41.17	73.0	73.0	10.3	12.2	22.1	14.1	16.7	30.3	547	28.6
Undulla 1	6564	Back Creek Gp	2148.50 - 2148.50	Permian	45.07	37.1	37.1	2.5	4.0	24.4	6.7	10.8	65.8	144	22.2
Burunga 1	6542	Back Creek Gp Gyranda Fm	1798.20 - 1798.20	Permian	53.52	26.6	26.6	2.3	4.1	15.9	8.6	15.4	59.8	120	17.3
Cockatoo Creek 1	6415	Back Creek Gp Gyranda Fm	1620.00 - 1620.11	Permian	12.89	12.9	12.9	1.9	1.4	10.1	14.7	10.9	78.3	256	24.4
Cockatoo Creek 1	1823	Back Creek Gp Gyranda Fm	1620.40 - 1620.40	Permian	100.00	55.8	55.8	8.3	4.1	42.7	14.9	7.3	76.5	124	15.3
Cockatoo Creek 1	6416	Back Creek Gp Gyranda Fm	1700.80 - 1700.91	Permian	33.77	29.0	29.0	3.6	5.2	21.9	12.4	17.9	75.5	261	27.4
Cockatoo Creek 1	6417	Back Creek Gp Gyranda Fm	2008.40 - 2008.43	Permian	15.07	14.0	14.0	2.4	2.3	8.0	17.1	16.4	57.1	312	41.6
Burunga 1	6543	Back Creek Gp Flat Top Fm	2123.40 - 2123.40	Permian	28.61	31.3	31.3	2.2	4.5	17.3	7.0	14.4	55.3	234	28.9
Cockatoo Creek 1	5067	Back Creek Gp Flat Top Fm	2659.10 - 2659.13	Permian	88.38	11.5	11.5	1.6	2.9	4.4	13.9	25.2	38.3	51	15.9

© Australian Geological Survey Organisation 1994

Table 2b (cont).

Well	AGSO No	Formation	Depth Range	Age	Sample extracted (g)	EOM (mg)	EOM used (mg)	Sats (mg)	Aroms (mg)	NSO's (mg)	Sats %	Aroms %	NSO's %	ppm HC	mg HC /gTOC
Taroom Trough Area (cont.)															
Cockatoo Creek 1	6418	Back Creek Gp Flat Top Fm	2659.70 - 2659.85	Permian	36.12	2.9	2.9	0.2	0.2	1.8	6.9	6.9	62.1	11	1.2
Cockatoo Creek 1	1824	Back Creek Gp Flat Top Fm	2659.70 - 2659.70	Permian	100.00	6.2	6.2	0.9	1.0	4.0	14.5	16.1	64.5	19	7.3
Cockatoo Creek 1	6419	Back Creek Gp Flat Top Fm	2755.70 - 2755.83	Permian	30.62	5.5	5.5	0.2	0.6	2.6	3.6	10.9	47.3	26	15.4
Burunga 1	6544	Back Creek Gp Barfield Fm	2958.30 - 2958.30	Permian	21.90	13.2	13.2	0.4	4.3	7.3	3.0	32.6	55.3	215	6.4
Cockatoo Creek 1	6420	Back Creek Gp Barfield Fm	3132.50 - 3132.57	Permian	28.03	10.3	10.3	0.9	1.2	4.0	8.7	11.7	38.8	75	6.3
Cockatoo Creek 1	5234	Back Creek Gp Barfield Fm	3133.00 - 3133.10	Permian	134.25	11.1	11.1	1.3	1.0	8.2	11.7	9.0	73.9	17	1.4
Cockatoo Creek 1	1825	Back Creek Gp Barfield Fm	3467.40 - 3467.40	Permian	100.00	4.7	4.7	1.4	0.7	2.4	29.8	14.9	51.1	21	2.2
Cockatoo Creek 1	6421	Back Creek Gp Barfield Fm	3558.30 - 3558.36	Permian	27.44	5.1	5.1	0.7	0.9	3.4	13.7	17.6	66.7	58	5.3

© Australian Geological Survey Organisation 1994

Footnote to Table 2b.

TOC = total organic carbon.
Rock Eval parameters: Tmax, S1, S2, S3, PI, HI, OI.
solvent extract: EOM = extractable organic matter; sats and arom as above; NSO's = polar compounds; ppm HC = ppm (sats + aroms).

© Australian Geological Survey Organisation 1994

Table 3 Natural gas composition.

Well	Formation	Latitude	Longitude	N2 mole %	CO2 mole %	Methane mole %	Ethane mole %	Propane mole %	Iso-Butane mole %	n-Butane mole %	Iso-Pentane mole %	n-Pentane mole %	Hexane mole %	C7+ mole %
Denison Trough														
Merivale 5	Aldebaran Sst	-25.27585	148.50558	1.11	2.63	78.22	8.77	2.50	2.18	0.86	1.15	0.50	0.20	1.89
Rolleston 1	Freitag Fm	-24.56306	148.63111	2.79	1.68	87.50	3.87	1.34	0.29	0.29	0.27	0.17	0.32	1.48
Yellowbank 3	Aldebaran Sst	-25.42611	148.37695	0.41	29.23	49.99	8.97	4.99	1.44	1.82	0.74	0.64	0.23	1.54
Roma Shelf														
Beaufort 6	Showgrounds Ss	-26.59027	148.90944	1.30	0.58	90.44	3.98	1.19	0.20	0.15	0.08	0.03	0.01	0.79
Beldene 5	Moolayember Fm	-27.02361	148.66333	1.03	2.93	89.22	5.78	0.09	0.56	0.01	0.03	0.00	0.01	0.36
Kincora 7	Evergreen Fm	-27.06444	148.81778	0.41	0.16	88.86	7.26	1.72	1.07	0.05	0.30	0.00	0.00	0.17
Newstead 2	Evergreen Fm	-27.18722	148.88779	2.05	0.13	77.97	9.24	5.94	1.75	1.52	0.44	0.41	0.26	0.31
Pleasant Hills 20	Showgrounds Ss	-26.41278	149.01556	2.95	0.45	92.13	2.25	0.25	0.26	0.06	0.14	0.11	0.06	1.36
Wunger Ridge														
Silver Springs 1	Showgrounds Ss	-27.60000	149.10334	2.62	0.25	77.30	8.92	5.10	1.43	1.37	0.56	0.54	0.30	1.60
Sirrah 5	Showgrounds Ss	-27.64416	149.18194	1.00	0.30	52.69	14.91	15.87	6.37	5.24	1.69	1.35	0.34	0.26
Taylor 1	Showgrounds Ss	-27.55638	149.23777	0.00	0.20	65.21	14.61	10.19	3.26	3.51	1.23	1.05	0.26	1.22

© Australian Geological Survey Organisation 1994

Table 4 Ranking of Extent of Biodegradation.

Extent	Rank	Definition
None	0	Intact oil
Light	1	Lower homologues of n-alkanes lost
Light	2	General depletion of n-alkanes
Light	3	Only traces of n-alkanes remain
Moderate	4	No n-alkanes, isoprenoids intact
Moderate	5	Acyclic isoprenoids absent
Heavy	6	Steranes partly degraded
Heavy	7	Steranes degraded, Diasteranes intact
Very Heavy	8	Hopanes partly degraded
Very Heavy	9	Hopanes absent, Diasteranes attacked
Severe	10	C_{26}-C_{29} aromatic steroids attacked

Note 1: In cases where 25-norhopanes are formed, degradation of the hopanes may occur earlier, in conjunction with the loss of the steranes.

Note 2: The exact stage at which loss of phenanthrene and its alkylated homologues occurs is unknown but it is before loss of steranes begins and approximately contiguous with loss of acyclic isoprenoids.

© Australian Geological Survey Organisation 1994

Table 5a Maturity-dependent saturated biomarker ratios in liquid petroleum.

Well	AGSO No	Age	Group	20S C29 / 20R C29	20 abb C29 / 20R C29	%22S	C30 mor / C30 hop	Ts / Tm
Denison Trough Area								
Westgrove 3	391	Permian		1.07	2.49	60.16	0.06	0.99
Rolleston 1	390	Permian	C4	0.95	2.29	58.39	0.17	0.98
Rolleston 1	534	Permian	C4	0.60	1.55	67.83		1.82
Rolleston 3	548	Permian	C0	0.60	1.85	64.49		0.93
Rolleston 3	549	Permian	C0					
Merivale 5	550	Permian	OC0					
Yellowbank 3	547	Permian	OC0	0.83	2.62	54.07	0.15	0.52
Taroom Trough Area								
East								
Conloi 1	78	Jurassic	O4	1.18	2.97	60.01		0.49
Conloi 1	217	Jurassic	O4	1.12	2.90	55.95	0.11	0.44
Rockwood 1	97	Jurassic	#OC1	1.08	2.70	55.93	0.07	1.07
Bennett 1	215	Jurassic	O1a	0.86	2.20	66.38		0.71
Leichhardt 2	216	Jurassic	O3	1.14	2.70	57.13	0.09	1.28
Moonie 1	50	Jurassic	#O1b	1.15	2.86	59.11	0.08	1.09
Moonie 1	565	Jurassic	O1b	1.27	2.86	59.03	0.06	1.14
Moonie 2	566	Jurassic	O1c	1.11	2.43	62.25	0.09	1.24
Moonie 4	567	Jurassic	O2	1.29	3.27	58.27	0.06	1.35
Moonie 10	568	Jurassic	O1b	1.11	2.70	55.53	0.07	1.02
Moonie 11	569	Jurassic	O1c	1.02	2.56	58.01	0.10	1.16
Moonie 15	570	Jurassic	O1c	0.92	2.09	58.56	0.15	1.13
Moonie 18	571	Jurassic	O1c	0.85	2.32	58.60	0.06	0.90
Moonie 21	572	Jurassic	O1c	1.02	2.44	60.20	0.11	1.35
Moonie 27	573	Jurassic	O1c	0.85	2.27	62.36	0.08	1.13
Moonie 28	574	Jurassic	O1c	1.03	2.43	58.00	0.07	1.07
Moonie 29	575	Jurassic	O1a	1.23	2.95	56.38	0.06	1.24
Moonie 30	576	Jurassic	O1c	1.09	2.90	58.04	0.06	1.36
Moonie 31	577	Jurassic	O1b	1.25	3.14	58.14	0.07	1.44
Moonie 32	578	Jurassic	O1b	1.37	3.34	59.40	0.09	1.15
Moonie 33	579	Jurassic	O1c	1.08	2.74	59.33	0.13	1.07
Moonie 34	580	Jurassic	O2	1.11	2.70	58.89	0.09	1.17
Moonie 35	581	Jurassic	O1c	1.05	1.00	65.69	0.04	1.22
Moonie 37	582	Jurassic	O1b	1.12	2.60	57.66	0.08	1.23
Rockwood North 1	55	Jurassic	O0	1.15	2.66	57.98	0.10	1.19
Cabawin 1	385	Permian	O0	1.02	2.79	53.74	0.05	0.45
Roma Shelf								
Anabranch 1	214	Jurassic	O0	0.48	1.03	60.42		1.82
Blyth Creek 1	386	Jurassic	OC0	0.94	2.07	53.17	0.11	0.93
Bony Creek 6	212	Jurassic	OC0	1.00	3.03			0.47

© Australian Geological Survey Organisation 1994

Table 5a (cont).

Well	AGSO No	Age	Group	20S C29 / 20R C29	20 abb C29 / 20R C29	%22S	C30 mor / C30 hop	Ts / Tm
Roma Shelf (cont.)								
Duarran 2	207	Jurassic	O2	1.17	2.77	58.24	0.12	1.08
Maffra 2	221	Jurassic	O0	1.20	2.49	58.43	0.15	2.24
Richmond 1	43	Jurassic	O0	1.14	3.08	60.04	0.09	1.00
Richmond 5	210	Jurassic	O0	1.37	3.40	85.98	0.08	0.83
Richmond 7	205	Jurassic	OC0	1.11	2.22	57.16	0.11	0.89
Richmond 10	211	Jurassic	O0	0.99	2.49	59.24	0.10	0.93
Borah Creek 5	586	Triassic	O0	1.24	2.96	58.70	0.17	1.83
Combarngo 1	387	Triassic	O0	1.27	3.12	57.04	0.06	0.80
Snake Creek 1	41	Triassic	O0	0.77	2.00	61.11	0.11	0.85
Waratah 4	588	Triassic	O1b	1.03	2.16	56.13	0.14	2.30
Washpool 1	589	Triassic	O0	1.11	2.66	58.43	0.09	0.79
Sunnybank 1	54	Triassic	#O0	1.23	3.31	58.82	0.08	0.85
Sunnybank 3	225	Triassic	O0	1.45	3.72	58.37	0.06	0.75
Sunnybank 2	113	Permian	#O1a	0.31	0.81	47.44		0.78
Sunnybank 2	213	Permian	O1a	1.05	3.01	59.55	0.06	0.60
Wallumbilla South 1	209	Permian	OC0	0.95	2.32	58.72	0.11	0.93
Dirinda 1	81	Devonian	O0	1.12	2.67	59.31	0.12	1.28
Wunger Ridge								
Alton 1	136	Jurassic	O0	1.06	2.80	58.88	0.09	2.01
Riverslea 1	431	Jurassic	O5	0.97	2.36	50.53	0.18	1.45
Riverslea 3	587	Jurassic	O5	1.01	2.36	49.47	0.18	5.91
Beardmore 1	559	Triassic	O0	0.98	2.47	56.64	0.11	0.83
Fairymount 1	585	Triassic	O0	1.23	2.53	58.55	0.10	1.67
Harbour 1	583	Triassic	O1a	1.08	2.37	58.85	0.11	1.07
Louise 2	551	Triassic	O0	1.14	3.12	59.73	0.12	1.42
McWhirter 1	560	Triassic	O0	0.93	2.29	56.29	0.10	1.13
Narrows 1	556	Triassic	O0	1.58	3.53	59.91	0.12	1.05
Rednook 1	561	Triassic	C0			61.51	0.15	0.97
Rednook 1	563	Triassic	O1a	0.62	1.71	56.22		0.66
Renlim 1	552	Triassic	OC0					
Roswin 1	546	Triassic	OC0			59.41		0.83
Silver Springs/Renlim	554	Triassic	OC0					
Sirrah 4	553	Triassic	OC0	1.34	3.44			0.89
Taylor 5	558	Triassic	O0	0.99	3.96	65.61	0.06	1.18
Wunger 1	46	Triassic	#O0	1.07	2.17	59.98	0.11	1.97
Yellowbank Creek 3	557	Triassic	O0	1.36	3.67	55.32		0.91
Yellowbank Creek Nort	584	Triassic	O0	0.94	2.53	61.07	0.07	1.51
Glen Fosslyn 1	545	Triassic	O1a	0.71	2.07	55.41	0.07	0.84
Kinkabilla 1	219	Triassic	O1a	1.31	3.54	55.27	0.06	0.18
Warroon 3	562	Triassic	O1a	1.14	3.15	54.09	0.09	0.60
Waggamba 1	555	Permian	O0	1.90	4.81			

© Australian Geological Survey Organisation 1994

Table 5b Maturity-dependent saturated biomarker ratios in sediments.

Well	Formation	AGSO No	%20S	20S C29 / 20R C29	20abb C29 / 20R C29	%22S	C30mor / C30H	Ts / Tm
Denison Trough Area								
Maranoa Colliery	Walloon CM	6278	22.31	0.29	0.71	54.30	0.34	0.01
Dawson River 1	Evergreen Fm	5278	20.64	0.26	2.40	51.93	0.38	0.07
Dawson River 1	Evergreen Fm	5279	23.52	0.31	1.21	11.66	0.40	0.04
Dawson River 1	Evergreen Fm	5280	30.88	0.45	0.74	58.09	0.16	0.44
Dawson River 1	Evergreen Fm	5281	30.36	0.44	1.16	54.01	0.32	0.16
GSQ Mundubbera 1	Evergreen Fm	5287	19.72	0.25	2.07	35.03	0.38	0.90
GSQ Mundubbera 1	Evergreen Fm	5288	27.14	0.37	1.17	25.57	0.31	0.20
GSQ Mundubbera 1	Evergreen Fm	5289	15.83	0.19	0.89	25.10	0.46	0.08
GSQ Mundubbera 1	Evergreen Fm	5290	41.10	0.70	1.28	40.99	0.24	0.29
GSQ Mundubbera 1	Evergreen Fm	5291	36.84	0.58	1.36	46.73	0.21	0.54
GSQ Mundubbera 1	Evergreen Fm	5292	24.81	0.33	1.13	33.47	0.37	0.25
Warrong 1	Moolayember Fm	6489	42.86	0.75	1.87	55.76	0.10	0.79
Warrong 1	Moolayember Fm	6490	43.57	0.77	1.55	47.41	0.17	0.81
Arcturus 1	Bandanna Fm	5066	39.00	0.64	0.63	58.09	0.18	0.14
GSQ Eddystone 5	Bandanna Fm	3652	12.89	0.15	0.33	47.80	0.34	
GSQ Emerald 1	Bandanna Fm	3649	25.60	0.34	0.30	61.39	0.29	
GSQ Taroom 8	Bandanna Fm	3655	29.13	0.41	0.50	56.73	0.14	0.08
Rolleston 1	Bandanna Fm	5070	16.99	0.20	0.39	53.20	0.35	0.01
Rolleston 1	Black Alley Shale	5071	29.30	0.41	0.43	55.21	0.23	0.03
Cometside 1	Ingelara Fm	5068	43.04	0.76	2.12	56.80	0.10	0.45
Rolleston 1	Ingelara Fm	5072	45.05	0.82	0.76	59.05	0.21	0.06
GSQ Springsure 17	Aldebaran Fm	3654	17.67	0.21	0.43	40.00	0.27	0.06
Rolleston 1	Aldebaran Fm	5073	41.03	0.70	1.43	56.05	0.18	0.13
Glentulloch 1	Cattle Creek Fm	5069	49.78	0.99	1.66	57.32	0.13	0.14
GSQ Eddystone 4	Cattle Creek Fm	3651	27.73	0.38	0.75	55.94	0.12	0.53
GSQ Emerald 1	Reids Dome Beds	3648	47.46	0.90	0.62	64.03	0.21	0.01
GSQ Emerald 1	Reids Dome Beds	3650	46.42	0.87	0.46	61.00	0.28	0.02
GSQ Springsure 14	Reids Dome Beds	3653	49.99	1.00	2.00	58.17	0.02	0.67
GSQ Taroom 11-11A	Reids Dome Beds	3656	45.86	0.85	2.57	77.13	0.02	0.53
GSQ Taroom 11-11A	Reids Dome Beds	3657	52.14	1.09	0.95	62.46	0.23	0.02
GSQ Taroom 11-11A	Reids Dome Beds	3658	52.01	1.08	1.49	61.41	0.11	0.04
Warrinilla 1	Reids Dome Beds	5079	43.07	0.76	1.67	58.91	0.08	1.28
Taroom Trough Area								
Cabawin 1	Orallo Fm	6399	13.29	0.15	0.77	25.31	0.15	0.60
Cabawin 1	Orallo Fm	6400	16.93	0.20	0.72	26.04	0.17	0.46
Cabawin 1	Walloon CM	6401	13.37	0.15	0.74	38.47	0.32	0.04
Cabawin 1	Walloon CM	6402	14.78	0.17	0.61	49.09	0.34	0.01
Cabawin 1	Walloon CM	6403	23.94	0.31	0.62	55.08	0.25	0.15
Cabawin 1	Walloon CM	6404	25.00	0.33	0.72	54.22	0.25	0.05
Cabawin 1	Hutton Sst	6405	37.17	0.59	0.41	59.03	0.30	0.02
Bellbird 1	Evergreen Fm	6521	40.45	0.68	0.62	56.66	0.33	0.02
Canaan 1	Evergreen Fm	6488	16.64	0.20	0.82	35.40	0.36	0.08
Dawson River 6	Evergreen Fm	5282	22.62	0.29	1.41	17.48	0.31	0.09
Dawson River 6	Evergreen Fm	5283	6.04	0.06	0.46	17.23	0.45	0.05
Dawson River 6	Evergreen Fm	5284	37.06	0.59	1.05	35.92	0.25	0.32
Dawson River 6	Evergreen Fm	5285	14.95	0.18	0.97	17.48	0.25	0.19
Juandah 1	Evergreen Fm	6484	16.69	0.20	0.68	46.27	0.36	0.02

© Australian Geological Survey Organisation 1994

Table 5b (cont).

Well	Formation	AGSO No	%20S	20S C29 / 20R C29	20abb C29 / 20R C29	%22S	C30mor / C30H	Ts / Tm
Taroom Trough Area (cont.)								
Tingan 1	Evergreen Fm	6487	11.75	0.13	0.58	37.57	0.21	0.11
Wandoan 1	Evergreen Fm	6545	24.63	0.33	0.85	46.90	0.33	0.07
Burunga 1	Evergreen Fm (Upper Unit)	6530	5.43	0.06	0.39	23.78	0.46	0.01
Cockatoo Creek 1	Precipice Sst	6411	30.31	0.43	1.28	41.85	0.13	0.59
Wandoan 1	Moolayember Fm	1826	20.97	0.27	0.45	55.50	0.14	0.44
Wandoan 1	Moolayember Fm	6546	24.14	0.32	0.54	51.98	0.07	0.48
Cabawin 1	Moolayember Fm (Upper Unit)	6406	45.08	0.82	0.79	60.92	0.17	0.13
Cabawin 1	Moolayember Fm (Upper Unit)	1818	43.16	0.76	0.76	59.66	0.16	0.08
Glenhaughton 1	Moolayember Fm (Upper Unit)	1816	24.57	0.33	0.39	55.01	0.29	0.07
Glenhaughton 1	Moolayember Fm (Upper Unit)	6485	26.95	0.37	0.40	54.82	0.28	0.04
Bellbird 1	Moolayember Fm Snake Creek Mudst	6522	47.30	0.90	0.94	56.39	0.21	0.05
Cabawin 1	Moolayember Fm Snake Creek Mudst	6407	49.58	0.98	1.37	58.41	0.11	0.73
Cabawin 1	Moolayember Fm Snake Creek Mudst	1819	48.03	0.92	1.25	58.29	0.09	0.71
Cockatoo Creek 1	Rewan Gp	6412	42.31	0.73	1.80		0.12	1.30
Wandoan 1	Rewan Gp	1827	46.12	0.86	1.98	58.50	0.14	0.88
Cabawin 1	Blackwater Gp	6408	49.25	0.97	2.15	59.76	0.06	0.37
Cabawin 1	Blackwater Gp	6409	51.43	1.06	2.71	58.82	0.04	0.85
Cabawin 1	Blackwater Gp	1820	44.95	0.82	1.80	57.83	0.07	0.76
Coonardoo 1	Blackwater Gp	6480	46.82	0.88	2.79	57.97	0.08	0.09
Glenhaughton 1	Blackwater Gp	1817	49.70	0.99	2.16	58.51	0.08	1.17
Wandoan 1	Blackwater Gp	1828	44.61	0.81	1.84		0.07	2.11
Wandoan 1	Blackwater Gp	1829	38.99	0.64	1.82	55.61	0.15	2.30
Wandoan 1	Blackwater Gp	6547	53.64	1.16	2.53		0.07	10.79
Burunga 1	Blackwater Gp Baralaba CM	6531	23.46	0.31	0.75	42.51	0.39	0.07
Cockatoo Creek 1	Blackwater Gp Baralaba CM	6413	44.45	0.80	0.85	12.59	0.27	0.22
Cockatoo Creek 1	Blackwater Gp Baralaba CM	6414	43.28	0.76	0.76	60.78	0.17	0.05
Bengalla 1	Back Creek Gp	6486	51.38	1.06	2.79	58.48	0.06	0.14
Cabawin 1	Back Creek Gp	6410	50.94	1.04	2.62	58.39	0.06	0.98
Cabawin 1	Back Creek Gp	1821	48.78	0.95	2.30	58.47	0.09	0.82
Goondiwindi1	Back Creek Gp	6482	24.93	0.33	0.80	50.99	0.31	0.07
Southwood 1	Back Creek Gp	5074	53.22	1.14	2.92	57.50	0.07	0.73
Southwood 1	Back Creek Gp	5293	54.42	1.19	2.77	57.68	0.08	1.14
Undulla 1	Back Creek Gp	6563	52.44	1.10	1.45	58.52	0.18	0.08
Undulla 1	Back Creek Gp	6564	53.81	1.16	2.82	55.68	0.08	0.51
Burunga 1	Back Creek Gp Gyranda Fm	6542	51.38	1.06	2.62	57.85	0.08	0.52
Cockatoo Creek 1	Back Creek Gp Gyranda Fm	6415						
Cockatoo Creek 1	Back Creek Gp Gyranda Fm	1823	47.02	0.89	1.68	57.71	0.09	0.60
Cockatoo Creek 1	Back Creek Gp Gyranda Fm	6416	52.92	1.12	2.83	58.18	0.05	0.64
Cockatoo Creek 1	Back Creek Gp Gyranda Fm	6417	50.48	1.02	2.74	58.70	0.05	2.93
Burunga 1	Back Creek Gp Flat Top Fm	6543	50.89	1.04	2.66	55.83	0.06	2.40
Cockatoo Creek 1	Back Creek Gp Flat Top Fm	5067	45.55	0.84	1.73	55.86	0.10	0.94
Cockatoo Creek 1	Back Creek Gp Flat Top Fm	1824	40.83	0.69	1.46	58.38	0.14	0.76
Cockatoo Creek 1	Back Creek Gp Flat Top Fm	6418	49.79	0.99	2.27	56.68	0.07	1.30
Cockatoo Creek 1	Back Creek Gp Flat Top Fm	6419	50.75	1.03	1.91			1.26
Burunga 1	Back Creek Gp Barfield Fm	6544	55.29	1.24	2.68	61.00	0.06	1.08
Cockatoo Creek 1	Back Creek Gp Barfield Fm	6420	50.46	1.02	2.18	61.01	0.06	1.16
Cockatoo Creek 1	Back Creek Gp Barfield Fm	1825	41.90	0.72	1.31	59.41	0.11	1.36
Cockatoo Creek 1	Back Creek Gp Barfield Fm	6421	50.17	1.01	2.09	60.05	0.07	1.21

© Australian Geological Survey Organisation 1994

Footnote to Tables 5a and b.

20S C29 = 5α,14α,17α(H),24-ethylcholestane 20S
20R C29 = 5α,14α,17α(H),24-ethylcholestane 20R
20 abb C29 = 5α,14β,17β(H)-24-ethylcholestane 20(R+S)
%22S = 100 x 17α(H),21β(H)-29-homohopane 22S / 17α(H),21β(H)-29-homohopane (22S + 22R)
C30 mor = 17β(H),21α(H)-hopane (moretane)
C30 hop = 17α(H),21β(H)-hopane (hopane)
Ts = 18α(H)-22,29,30-trisnorhopane
Tm = 17α(H)-22,29,30-trisnorhopane

© Australian Geological Survey Organisation 1994

Table 6a Source-dependent saturated biomarker ratios in liquid petroleum.

Well	AGSO No	Age	Group	C29 hop / C30 hop	29.30 hop / C30 hop	28.30 hop / C30 hop	C31 Mehop / C30 hop	C30 diahop / C30 hop	C29 neohop / C29 hop	C29 25-norhop / C30hop	C30 tri / C30 hop	C27 ster / C29 ster	C28 ster / C29 ster	C30 ster / C29 ster	2+3Me ster / C29 ster	Me ster / 2+3Me ster	ΣC29 dia / ΣC29 ster	Σhop / Σster
Denison Trough Area																		
Westgrove 3	391	Permian		0.72	0.02	0.04	0.14	0.16		0.05		0.17	0.21		0.41	0.15	0.87	0.84
Rolleston 1	390	Permian	C4	0.91	0.12	0.16	0.19	0.31	0.42	0.38	0.10	0.35	0.28	0.04	0.35	0.31	0.71	0.51
Rolleston 1	534	Permian	C4	1.40					0.20			1.15	0.75				0.46	21.06
Rolleston 3	548	Permian	C0	1.70	0.21	0.11			0.14	0.25		0.29	0.27				0.38	2.89
Rolleston 3	549	Permian	C0															
Merivale 5	550	Permian	OC0															
Yellowbank 3	547	Permian	OC0	1.86					0.19			0.61	0.60				0.26	0.74
Taroom Trough Area																		
East																		
Conloi 1	78	Jurassic	O4	0.73	0.09	0.06	0.06	0.56	0.30	0.05		0.32	0.17		0.45	0.24	0.67	0.41
Conloi 1	217	Jurassic	O4	0.65				0.42	0.39	0.11		0.10	0.15		0.22	0.40	0.51	0.35
Rockwood 1	97	Jurassic	#OC1	0.83	0.04	0.02	0.14	0.22	0.32	0.02	0.03	0.16	0.12		0.42	0.33	0.40	1.91
Bennett 1	215	Jurassic	O1a	1.57					0.40	0.26		1.63	0.38				0.43	0.55
Leichhardt 2	216	Jurassic	O3	0.83	0.03	0.02	0.10	0.27	0.22	0.03		0.11	0.15		0.39	0.21	0.50	0.65
Moonie 1	50	Jurassic	#O1b	0.78	0.05	0.03	0.12	0.16	0.28	0.10		0.38	0.24		0.37	0.25	1.01	0.78
Moonie 1	565	Jurassic	O1b	1.12	0.01		0.09	0.18	0.09	0.14		0.12	0.26		0.56	0.51	0.96	0.48
Moonie 2	566	Jurassic	O1c	1.13	0.03	0.03	0.20	0.23		0.18		0.27	0.21		0.35	0.21	0.76	0.61
Moonie 4	567	Jurassic	O2	1.00			0.13	0.20		0.14		0.18	0.16		0.40		0.62	0.54
Moonie 10	568	Jurassic	O1b	0.76				0.13	0.15	0.05		0.16	0.10		0.31		0.78	1.27
Moonie 11	569	Jurassic	O1c	0.84			0.15	0.28		0.14		0.24	0.32		0.38	0.30	0.96	0.79
Moonie 15	570	Jurassic	O1c	0.85	0.04	0.02	0.19	0.28		0.15		0.13	0.19		0.44	0.66	0.62	0.92
Moonie 18	571	Jurassic	O1c	0.55				0.16	0.26	0.04		0.12	0.23				0.60	1.01
Moonie 21	572	Jurassic	O1c	0.68			0.12	0.17		0.10		0.12	0.23		0.34	0.57	0.52	2.24
Moonie 27	573	Jurassic	O1c	0.69			0.09	0.18	0.07	0.10	0.04	0.17	0.21		0.35	0.71	0.78	2.52
Moonie 28	574	Jurassic	O1c	0.58			0.11	0.19	0.33	0.08		0.06	0.19		0.39	0.49	0.61	1.06
Moonie 29	575	Jurassic	O1a	0.75			0.19	0.14	0.22	0.06		0.26	0.29		0.52	0.34	0.84	1.90
Moonie 30	576	Jurassic	O1c	0.90			0.14	0.20		0.08		0.16	0.22		0.37	0.26	0.67	0.66
Moonie 31	577	Jurassic	O1b	0.90			0.11	0.19	0.22	0.08		0.18	0.34		0.44	0.41	0.72	0.93
Moonie 32	578	Jurassic	O1b	0.66			0.10	0.18	0.10	0.14		0.21	0.16		0.59		0.56	0.71
Moonie 33	579	Jurassic	O1c	0.69			0.10	0.16	0.12	0.08		0.18	0.16		0.54		2.48	3.75
Moonie 34	580	Jurassic	O2	0.73	0.01	0.01	0.17	0.19	0.28	0.08		0.14	0.20		0.52		0.57	0.75
Moonie 35	581	Jurassic	O1c	0.55			0.08	0.10	0.38	0.02		0.28	0.25		1.05		1.20	2.85
Moonie 37	582	Jurassic	O1b	0.74			0.11	0.19	0.20	0.09		0.24	0.31		0.39	0.31	0.76	0.80
Rockwood North 1	55	Jurassic	O0	0.72	0.03	0.03	0.12	0.28	0.21	0.04		0.17	0.18		0.38	0.25	0.37	0.49
Cabawin 1	385	Permian	O0	0.33			0.07	0.47	0.77	0.07		0.17	0.17		0.39	0.30	0.65	1.19
Roma Shelf																		
Anabranch 1	214	Jurassic	O0	1.07					0.36			1.15	0.29				0.43	5.24
Blyth Creek 1	386	Jurassic	OC0	1.06	0.07	0.16	0.08	0.12	0.34	0.12	0.17	0.79	0.47	0.08	0.13	0.60	0.55	0.44
Bony Creek 6	212	Jurassic	OC0	0.63				0.34	0.27	0.13		0.16	0.18		0.28	0.48	0.66	0.43

© Australian Geological Survey Organisation 1994

Table 6a (cont).

Well	AGSO No	Age	Group	C29 hop / C30 hop	29.30 hop / C30 hop	28.30 hop / C30 hop	C31 Mehop / C30 hop	C30 diahop / C30 hop	C29 neohop / C29 hop	C29 25-norhop / C30hop	C30 tri / C30 hop	C27 ster / C29 ster	C28 ster / C29 ster	C30 ster / C29 ster	2+3Me ster / C29 ster	Me ster / 2+3Me ster	ΣC29 dia / ΣC29 ster	Σhop / Σster
Roma Shelf (cont.)																		
Duarran 2	207	Jurassic	O2	0.55	0.06	0.08	0.12	0.25	0.37	0.17		0.21	0.15		0.49	0.20	1.06	0.81
Maffra 2	221	Jurassic	O0	1.03	0.03	0.15	0.16	0.15	0.28	0.12		0.28	0.37		0.49	0.32	0.91	2.61
Richmond 1	43	Jurassic	O0	0.69	0.05	0.12	0.13	0.33	0.36	0.22		0.22	0.17		0.49	0.31	0.87	0.44
Richmond 5	210	Jurassic	O0	0.55	0.05	0.10	0.13	0.35	0.32	0.20	0.03	0.32	0.24		0.55		1.24	1.27
Richmond 7	205	Jurassic	OC0	1.21	0.11	0.13	0.07	0.08	0.43	0.13	0.15	1.22	0.66	0.08	0.52	0.38	1.95	0.53
Richmond 10	211	Jurassic	O0	0.52	0.06	0.11	0.13	0.34	0.31	0.11		0.09	0.16		0.34		0.79	0.91
Borah Creek 5	586	Triassic	O0	1.16	0.23	0.40	0.43	0.49	0.33	2.66		0.12	0.21		0.40	0.17	1.07	0.60
Combarngo 1	387	Triassic	O0	0.64	0.04	0.03	0.11	0.33	0.31	0.06		0.13	0.14		0.35	0.21	0.67	0.91
Snake Creek 1	41	Triassic	O0	0.81	0.07	0.11	0.13	0.27	0.25	0.13		0.44	0.23		0.33		1.00	
Waratah 4	588	Triassic	O1b	0.68	0.02	0.12	0.18	0.11	0.07	0.04		0.05	0.21		0.33		1.26	1.33
Washpool 1	589	Triassic	O0	0.69	0.04	0.07	0.27	0.45	0.30	0.57		0.11	0.15		0.54		0.76	0.60
Sunnybank 1	54	Triassic	#O0	0.63			0.10	0.28	0.30	0.06		0.19	0.18		0.45	0.36	1.03	0.73
Sunnybank 3	225	Triassic	O0	0.47	0.04	0.05	0.11	0.21	0.34	0.06		0.32	0.24		0.51	0.33	1.37	0.61
Sunnybank 2	113	Permian	#O1a	0.99					0.36			0.90	0.24				0.38	6.45
Sunnybank 2	213	Permian	O1a	0.43	0.02	0.03	0.09	0.35	0.50	0.04		0.18	0.24		0.51		1.20	0.89
Wallumbilla South 1	209	Permian	OC0	1.05	0.05	0.15	0.10	0.19	0.25	0.20	0.10	0.61	0.41	0.05	0.65	0.26	0.85	1.01
Dirinda 1	81	Devonian	O0	0.61	0.07	0.09	0.13	0.22	0.28	0.30		0.31	0.21		0.52	0.18	0.73	1.52
Wunger Ridge																		
Alton 1	136	Jurassic	O0	0.75	0.03	0.05	0.11	0.26	0.19	0.05		0.23	0.22		0.43	0.31	0.84	2.11
Riverslea 1	431	Jurassic	O5	0.85	0.08	0.14	0.21	0.27	0.37	0.43		0.15	0.16		0.45	0.23	0.76	1.28
Riverslea 3	587	Jurassic	O5	0.87	0.05	0.18	0.25	0.26	0.37	0.53		0.10	0.26		0.43	0.16	0.68	0.50
Beardmore 1	559	Triassic	O0	1.15	0.10	0.08	0.18	0.20	0.28	0.07		0.37	0.30		0.48	0.77	0.54	0.85
Fairymount 1	585	Triassic	O0	1.01	0.05	0.07	0.14	0.24	0.15	0.05		0.16	0.28		0.48		0.71	0.62
Harbour 1	583	Triassic	O1a	1.02	0.07	0.14	0.16	0.52	0.28	0.11		0.19	0.27		0.45	0.24	0.66	0.56
Louise 2	551	Triassic	O0	0.94			0.08	0.35	0.18	0.12		0.13	0.23		0.45	0.57	0.73	1.21
McWhirter 1	560	Triassic	O0	0.67	0.06	0.10		0.32	0.26	0.06		0.18	0.17		0.45		0.88	0.38
Narrows 1	556	Triassic	O0	0.78				0.33	0.20			0.15	0.38		0.55	0.44	1.04	
Rednook 1	561	Triassic	C0	0.71														
Rednook 1	563	Triassic	O1a	0.85				0.38	0.31	0.09							0.58	2.81
Renlim 1	552	Triassic	OC0															
Roswin 1	546	Triassic	OC0	1.46					0.24									
Silver Springs/Renlim	554	Triassic	OC0															
Sirrah 4	553	Triassic	OC0	0.95				0.31	0.25								1.36	0.60
Taylor 5	558	Triassic	O0	0.57				0.24	0.28	0.10							0.98	0.37
Wunger 1	46	Triassic	#O0	1.02	0.05	0.13	0.09	0.19	0.17	0.09	0.04	0.42	0.38		0.43	0.45	0.99	0.56
Yellowbank Creek 3	557	Triassic	O0	0.70				0.34	0.35	0.10		0.26	0.21		0.40	0.37	1.46	0.19
Yellowbank Creek Nort	584	Triassic	O0	0.86	0.04	0.07	0.10	0.19	0.23	0.08		0.22	0.30		0.63		0.86	0.69
Glen Fosslyn 1	545	Triassic	O1a	1.01	0.05	0.10	0.06	0.39	0.30	0.13		0.13	0.20		0.33	0.64	0.58	1.19
Kinkabilla 1	219	Triassic	O1a	0.71	0.06	0.05	0.14	0.99	0.63	0.08		0.40	0.27		0.42	0.27	0.95	0.14
Warroon 3	562	Triassic	O1a	0.52				0.41	0.43	0.04		0.15	0.17				0.66	1.70
Waggamba 1	555	Permian	O0														0.78	0.13

© Australian Geological Survey Organisation 1994

Table 6b Source-dependent saturated biomarker ratios in sediments.

Well	Formation	AGSO No	C29hop / C30hop	29.30 hop / C30 hop	28.30 hop / C30 hop	C31 Mehop / C30 hop	C30 diahop / C30 hop	C29 neohop / C29 hop	C30 tri / C30 hop	C27 ster / C29 ster	C28 ster / C29 ster	C30 ster / C29 ster	2+3Me ster / C29 ster	4Me ster / 2+3Me ster	ΣC29 dia / ΣC29 ster	ΣHop / ΣSter
Denison Trough Area																
Maranoa Colliery	Walloon CM	6278	0.86	0.02	0.01	0.09	0.03			0.07	0.22		0.71	0.13	0.39	4.6
Dawson River 1	Evergreen Fm	5278	1.24	0.02	1.25	0.08	0.02	0.06		0.12	0.14		0.05	2.78		5.1
Dawson River 1	Evergreen Fm	5279	1.10		0.01	0.06		0.03		0.17	0.16		0.11	1.95		14.8
Dawson River 1	Evergreen Fm	5280	0.78		0.36	0.09	0.02	0.36		0.26	0.24		0.30	1.23		8.4
Dawson River 1	Evergreen Fm	5281	1.38		0.62	0.11	0.06	0.09		0.29	0.34		0.46	0.37		5.0
GSQ Mundubbera 1	Evergreen Fm	5287	1.01			0.17		0.17		0.31	0.34		1.02			3.6
GSQ Mundubbera 1	Evergreen Fm	5288	0.63		0.49		0.05	0.06		0.24	0.28					3.4
GSQ Mundubbera 1	Evergreen Fm	5289	0.63	0.04	0.04	0.09	0.02	0.12		0.31	0.44		0.66			7.3
GSQ Mundubbera 1	Evergreen Fm	5290	0.77			0.14		0.11		0.99	0.80					3.0
GSQ Mundubbera 1	Evergreen Fm	5291	0.56					0.33		0.35	0.48		0.48			3.3
GSQ Mundubbera 1	Evergreen Fm	5292	0.72					0.09		0.20	0.33					4.7
Warrong 1	Moolayember Fm	6489	0.89	0.06	0.06	0.11	0.03	0.31	0.048	1.04	0.60	0.045	0.56	0.55	0.69	1.0
Warrong 1	Moolayember Fm	6490	1.01	0.08	0.22	0.10	0.03		0.073	1.79	1.26	0.058	0.58	0.42	0.69	0.6
Arcturus 1	Bandanna Fm	5066	0.75	0.02	0.34	0.09	0.05	0.15		0.06	0.10		0.17	0.14	0.68	1.5
GSQ Eddystone 5	Bandanna Fm	3652	1.07		1.85	0.03	0.01			0.04	0.13		0.52		0.31	16.4
GSQ Emerald 1	Bandanna Fm	3649	1.27	0.00		0.01				0.04	0.03		0.24		0.29	
GSQ Taroom 8	Bandanna Fm	3655	0.54			0.03	0.01	0.13		0.09	0.09		0.31		1.06	1.9
Rolleston 1	Bandanna Fm	5070	1.28	0.01	0.02	0.07	0.02			0.03	0.08		0.64	0.08	0.35	5.6
Rolleston 1	Black Alley Shale	5071	0.77	0.02	0.01	0.05	0.04	0.08		0.10	0.09		0.22	0.14	0.47	2.8
Cometside 1	Ingelara Fm	5068	0.59	0.02	0.29	0.09	0.06	0.21		0.33	0.19		0.63	0.49	0.65	4.4
Rolleston 1	Ingelara Fm	5072	1.03	0.02	0.09	0.07	0.04	0.08		0.20	0.14	0.009	0.20	0.11	0.59	3.7
GSQ Springsure 17	Aldebaran Fm	3654	0.54		0.01	0.04	0.01	0.15		0.19	0.13		0.23		0.38	1.0
Rolleston 1	Aldebaran Fm	5073	0.77	0.04	0.13	0.08	0.05	0.13		0.22	0.23		0.34	0.24	0.71	3.6
Glentulloch 1	Cattle Creek Fm	5069	0.89	0.08	0.40	0.09	0.08	0.19		0.09	0.16		0.17	0.10	1.26	1.0
GSQ Eddystone 4	Cattle Creek Fm	3651	0.76	0.04	0.03	0.03	0.03	0.29		1.22	0.55	0.053	0.19		0.69	2.0
GSQ Emerald 1	Reids Dome Beds	3648	1.79			0.08	0.03			0.02	0.22		0.23		0.44	
GSQ Emerald 1	Reids Dome Beds	3650	1.16	0.00		0.09				0.05	0.21		0.27		0.18	2.4
GSQ Springsure 14	Reids Dome Beds	3653	0.52	0.01		0.06	0.05	0.19		0.21	0.33		0.11	3.35	0.27	5.3
GSQ Taroom 11-11A	Reids Dome Beds	3656	0.97	0.00		0.00				0.88	0.28				1.83	19.1
GSQ Taroom 11-11A	Reids Dome Beds	3657	2.35	0.01		0.07	0.03			0.03	0.03		0.22		0.29	3.0
GSQ Taroom 11-11A	Reids Dome Beds	3658	0.85	0.00		0.05	0.02	0.06		0.05	0.08		0.23		0.26	5.2
Warrinilla 1	Reids Dome Beds	5079	0.91	0.08	0.10	0.12	0.22	0.45	0.097	0.78	0.57	0.055	0.34	0.65	0.66	0.8
Taroom Trough Area																
Cabawin 1	Orallo Fm	6399	0.41	0.02	0.41	0.15	0.03	0.45		0.15	0.19	0.004	0.24	0.55	0.84	1.7
Cabawin 1	Orallo Fm	6400	0.49	0.02	0.09	0.13	0.05	0.21	0.012	0.18	0.21	0.005	0.39	0.23	0.77	1.0
Cabawin 1	Walloon CM	6401	0.69	0.01	0.01	0.14	0.04	0.03		0.05	0.14		0.66	0.10	0.65	2.7
Cabawin 1	Walloon CM	6402	0.89	0.01	0.00	0.07	0.03			0.04	0.18		0.75	0.08	0.36	4.6
Cabawin 1	Walloon CM	6403	0.97	0.02	0.10	0.09	0.05	0.08		0.10	0.19		0.33	0.11	0.69	1.8
Cabawin 1	Walloon CM	6404	1.14	0.02	0.19	0.09	0.05			0.18	0.22		0.49	0.72	0.75	4.4
Cabawin 1	Hutton Sst	6405	1.30	0.02	0.00	0.07	0.04			0.07	0.19		0.46	0.08	0.40	7.4
Bellbird 1	Evergreen Fm	6521	1.11	0.02	0.05	0.06	0.04			0.17	0.22		0.39	0.14	0.69	3.7
Canaan 1	Evergreen Fm	6488	0.81	0.02	0.54	0.09	0.02	0.03	0.009	0.26	0.23	0.008	0.54	0.18	0.68	3.9
Dawson River 6	Evergreen Fm	5282	0.68		0.95	0.14	0.04	0.05		0.14	0.26		0.64			6.0
Dawson River 6	Evergreen Fm	5283	0.70			0.07		0.05		0.48	0.34		0.34			6.4
Dawson River 6	Evergreen Fm	5284	0.82	0.03	0.06	0.12		0.13		0.62	0.50					5.1
Dawson River 6	Evergreen Fm	5285	0.52		0.14	0.08	0.06	0.26		0.21	0.21		0.59	0.30		6.2
Juandah 1	Evergreen Fm	6484	0.74	0.01	0.02	0.07	0.04		0.001	0.09	0.19		0.45	0.16	0.77	4.9

© Australian Geological Survey Organisation 1994

Table 6b (cont).

Well	Formation	AGSO No	C29hop / C30hop	29,30 hop / C30 hop	28,30 hop / C30 hop	C31 Mehop / C30 hop	C30 diahop / C30 hop	C29 neohop / C29 hop	C30 tri / C30 hop	C27 ster / C29 ster	C28 ster / C29 ster	C30 ster / C29 ster	2+3Me ster / C29 ster	4Me ster / 2+3Me ster	ΣC29 dia / ΣC29 ster	ΣHop / ΣSter
Taroom Trough Area (cont.)																
Tingan 1	Evergreen Fm	6487	0.81	0.02	0.04	0.08	0.02			0.11	0.16		0.32	0.31	0.68	3.8
Wandoan 1	Evergreen Fm	6545	1.02	0.03	0.27	0.05	0.03		0.007	0.26	0.29	0.010	0.51	0.09	0.85	3.8
Burunga 1	Evergreen Fm (Upper Unit)	6530	0.65	0.01	0.02	0.12	0.02			0.19	0.18		0.37	0.21	0.24	10.7
Cockatoo Creek 1	Precipice Sst	6411	0.60	0.03	0.30	0.11	0.06	0.36	0.110	0.55	0.52	0.041	0.65	0.37	0.62	0.8
Wandoan 1	Moolayember Fm	1826	0.26	0.01	0.28	0.05	0.06	0.46		0.12	0.21		0.12	0.44	0.52	1.6
Wandoan 1	Moolayember Fm	6546	0.20	0.01	0.17	0.02	0.02			0.17	0.34		0.16	0.44	0.47	1.4
Cabawin 1	Moolayember Fm (Upper Unit)	6406	0.95	0.02	0.18	0.07	0.10			0.12	0.26		0.34	0.18	0.68	2.8
Cabawin 1	Moolayember Fm (Upper Unit)	1818	1.13	0.03	0.21	0.05	0.13	0.12		0.06	0.14		0.19		0.70	3.3
Glenhaughton 1	Moolayember Fm (Upper Unit)	1816	1.14	0.02	0.16	0.08	0.01			0.15	0.13	0.005	0.17		0.18	2.8
Glenhaughton 1	Moolayember Fm (Upper Unit)	6485	0.96	0.01	0.21	0.07	0.03			0.18	0.27	0.004	0.20	0.32	0.15	1.8
Bellbird 1	Moolayember Fm Snake Creek Mudst	6522	1.12	0.02	0.02	0.03	0.06		0.018	0.33	0.23	0.022	0.37	0.18	0.36	2.6
Cabawin 1	Moolayember Fm Snake Creek Mudst	6407	0.44	0.02	0.12	0.04	0.08	0.40	0.013	0.46	0.37	0.010	0.34	0.28	1.02	2.5
Cabawin 1	Moolayember Fm Snake Creek Mudst	1819	0.66	0.02	0.12	0.01	0.09	0.40		0.30	0.16		0.16		1.63	2.6
Cockatoo Creek 1	Rewan Gp	6412	1.11					0.21		0.83	0.69				1.03	0.6
Wandoan 1	Rewan Gp	1827	0.87	0.11	0.08	0.12	0.06	0.38	0.060	0.96	0.51	0.088	0.66		0.68	1.3
Cabawin 1	Blackwater Gp	6408	0.45	0.02	0.00	0.13	0.07	0.13		0.12	0.23		0.63	0.23	0.49	3.3
Cabawin 1	Blackwater Gp	6409	0.48	0.03	0.00	0.09	0.08	0.16		0.28	0.26		0.85	0.29	0.51	3.6
Cabawin 1	Blackwater Gp	1820	0.68	0.03	0.04	0.05	0.14	0.28		0.55			0.27		0.68	2.9
Coonardoo 1	Blackwater Gp	6480	0.75	0.02	0.01	0.08	0.06			0.49	0.38		1.53	0.30	0.56	16.2
Glenhaughton 1	Blackwater Gp	1817	1.17	0.10	0.07	0.13	0.06	0.24	0.072	1.39	0.77	0.065	0.42		0.61	0.7
Wandoan 1	Blackwater Gp	1828	0.66				0.54	0.66		1.33	0.81				1.40	0.5
Wandoan 1	Blackwater Gp	1829	0.91				0.64	0.50		0.45	0.07				0.71	0.6
Wandoan 1	Blackwater Gp	6547	0.53				2.89	1.46		0.77	0.49		0.48		1.18	0.2
Burunga 1	Blackwater Gp Baralaba CM	6531	0.98	0.03	0.02	0.09	0.02		0.015	0.30	0.27	0.012	0.47	0.12	0.43	3.4
Cockatoo Creek 1	Blackwater Gp Baralaba CM	6413	0.98	0.04	0.04	0.07	0.03		0.024	0.47	0.29	0.010	0.39	0.10	0.89	1.3
Cockatoo Creek 1	Blackwater Gp Baralaba CM	6414	0.95	0.02	0.00	0.06	0.04			0.09	0.08		0.32	0.08	0.56	3.6
Bengalla 1	Back Creek Gp	6486	0.37	0.01	0.04	0.09	0.48	1.13	0.038	1.00	0.67	0.064	0.45	0.31	2.13	0.6
Cabawin 1	Back Creek Gp	6410	0.55	0.03	0.02	0.08	0.11	0.36	0.030	1.55	0.72	0.049	0.57	0.42	1.05	1.1
Cabawin 1	Back Creek Gp	1821	0.88	0.07	0.04	0.08	0.13	0.27	0.046	0.71	0.34		0.24		0.58	1.7
Goondiwindi1	Back Creek Gp	6482	0.65	0.02	0.03	0.08	0.06		0.004	0.07	0.11	0.003	0.46		1.06	1.0
Southwood 1	Back Creek Gp	5074	0.58	0.02	0.02	0.06	0.13	0.36		0.20	0.12	0.027	0.33	0.33	1.04	1.3
Southwood 1	Back Creek Gp	5293	0.64			0.07	0.13	0.34		0.40	0.16	0.043	0.38	0.51	1.33	1.2
Undulla 1	Back Creek Gp	6563	1.10	0.03	0.02	0.07	0.04			0.31	0.23	0.009	0.33	0.08	0.67	1.9
Undulla 1	Back Creek Gp	6564	0.85	0.02	0.01	0.06	0.16		0.014	0.57	0.36	0.041	0.30	0.13	1.18	0.8
Burunga 1	Back Creek Gp Gyranda Fm	6542	0.73	0.02	0.01	0.06	0.11			0.35	0.29	0.046	0.34	0.21	0.47	1.2
Cockatoo Creek 1	Back Creek Gp Gyranda Fm	6415														
Cockatoo Creek 1	Back Creek Gp Gyranda Fm	1823	0.66	0.01	0.01	0.04	0.03	0.19		0.13	0.07		0.13	1.95	0.42	8.3
Cockatoo Creek 1	Back Creek Gp Gyranda Fm	6416	0.55	0.02	0.01	0.06	0.04	0.16		0.30	0.25	0.025	0.76	0.45	0.51	5.1
Cockatoo Creek 1	Back Creek Gp Gyranda Fm	6417	0.34	0.01	0.02	0.09	0.23	0.72	0.036	0.29	0.26	0.011	0.45	0.40	0.57	0.6
Burunga 1	Back Creek Gp Flat Top Fm	6543	0.55	0.06	0.04	0.09	0.42	0.73	0.046	0.64	0.46	0.044	0.38	0.31	0.45	0.4
Cockatoo Creek 1	Back Creek Gp Flat Top Fm	5067	1.70	0.18	0.16	0.12	0.02	0.26	0.073	0.94	0.45	0.052	0.32	0.35	0.51	0.9
Cockatoo Creek 1	Back Creek Gp Flat Top Fm	1824	0.87	0.06	0.16	0.09	0.08	0.30	0.094	0.85	0.75	0.114	0.54	0.86	0.43	1.2
Cockatoo Creek 1	Back Creek Gp Flat Top Fm	6418	1.02	0.07	0.09	0.11	0.06	0.22	0.141	1.20	0.90	0.149	0.67	0.57	0.80	0.5
Cockatoo Creek 1	Back Creek Gp Flat Top Fm	6419	0.83	0.04	0.10			0.45		1.28	1.09				0.66	0.5
Burunga 1	Back Creek Gp Barfield Fm	6544	1.01	0.08	0.08	0.13	0.07	0.29	0.068	1.89	1.05	0.133	0.68	0.28	0.57	0.8
Cockatoo Creek 1	Back Creek Gp Barfield Fm	6420	0.88	0.08	0.08	0.10	0.03	0.41	0.144	1.82	1.20	0.099	0.77	0.47	0.77	0.4
Cockatoo Creek 1	Back Creek Gp Barfield Fm	1825	1.32	0.13	0.13	0.11	0.06	0.23	0.112	2.13	0.74	0.086	0.50	0.70	0.74	1.1
Cockatoo Creek 1	Back Creek Gp Barfield Fm	6421	0.97	0.08	0.09	0.11	0.04	0.25	0.099	1.88	1.06	0.094	0.59	0.59	0.67	0.5

© Australian Geological Survey Organisation 1994

Footnote to Tables 6a and b.

C29 hop = 17α(H),21β(H)-30-norhopane
C30 hop = 17α(H),21β(H)-hopane
29,30 hop = 29,30-bisnorhopane
28,30 hop = 28,30-bisnorhopane
C31 Mehop = (2α- + 3β-)methylhopane
C30 diahop = 17α-diahopane
C30 neohop = 18α(H),21β(H)-30-norneohopane (C_{29} Ts)
C29 25-norhop = 17α(H),21β(H)-25-norhopane
C30 tri = tricyclohexaprenane (cheilanthanes) 22(S+R)
C27 ster = 5α,14α,17α(H)-cholestane 20R
C28 ster = 5α,14α,17α(H)-24-methylcholestane 20R
C29 ster = 5α,14α,17α(H)-24-ethylcholestane 20R
C30 ster = 5α,14α,17α(H)-24-*n*-propylcholestane 20R
2+3Me ster = (2α + 3β)-methyl-5α,14α,17α(H)-24-ethylcholestane 20R
Me ster = unknown C_{30} methyl steranes including 4α-methyl-5α,14α,17α(H)-24-ethylcholestane 20R + 4α,23,24-trimethyl-5α,14α,17α(H)-cholestane 20R
C29 dia = 13β,17α(H)-dia-24-ethylcholestane 20(S+R)
C29 ster = 5α,14α,17α(H)-24-ethylcholestane 20(S+R) + 5α,14β,17β(H)-24-ethylcholestane 20(R+S) + 5β,14α,17α(H)-24-ethylcholestane 20R
hop = (C_{27} trisnorhopane (Ts + Tm + 17β(H)) + C_{29} (30-norhopane + moretane + 17β(H),21β(H)) + C_{30} hopane + moretane + 17β(H),21β(H)) + C_{31} (homohopane + homomoretane + 17β(H),21β(H)) + C_{32} (bishomohopane + bishomomoretane + 17β(H),21β(H)))
ster = (C_{27} + C_{28} + C_{29} sterane (ααα(S+R) + αββ(R+S) + βαα(R))

© Australian Geological Survey Organisation 1994

Table 7 Carbon isotopic composition of gases.

Well	Methane (‰)	sd	CO2 (‰)	sd	Ethane (‰)	sd	Propane (‰)	sd	iso-Butane (‰)	sd	n-Butane (‰)	sd	iso-Pentane (‰)	sd	n-Pentane (‰)	sd
Denison Trough																
Merivale 5	-41.18	0.91	4.94	0.17	-26.41	0.28	-19.77	0.23	-25.27	0.30	-21.49	0.57	-24.42	0.21	-23.33	0.80
Rolleston 1	-39.91	1.80	-18.44	2.57	-32.45	0.30	-28.86	0.52	-	-	-27.52	0.46	-	-	-	-
Yellowbank 3	-38.93	2.62	-8.08	0.51	-26.63	0.52	-25.13	0.37	-25.49	0.28	-24.76	0.27	-24.85	0.62	-24.35	0.41
Yellowbank 3 (repeat)	-38.63		-7.75		-26.98		-25.14		-25.58		-25.15		-24.35		-25.04	
Roma Shelf																
Beaufort 6	-37.30	0.15	-	-	-27.27	0.42	-26.05	0.09	-	-	-	-	-	-	-	-
Beldene 5	-35.49	1.44	-	-	-26.67	0.42	-25.57	0.45	-	-	-	-	-	-	-	-
Kincora 7	-33.16	0.69	-	-	-25.60	0.32	-15.85	0.20	-24.85	0.41	-24.29	0.28	-	-	-	-
Newstead 2	-31.93	0.37	-	-	-25.02	0.51	-24.52	0.33	-25.13	0.57	-23.75	0.51	-23.65	0.27	-23.05	0.13
Pleasant Hills 20	-42.98	1.96	-	-	-25.39	0.35	-	-	-	-	-	-	-	-	-	-
Wunger Ridge																
Silver Springs 1	-38.02	1.65	-	-	-25.85	0.22	-24.96	0.11	-24.68	0.41	-24.23	0.21	-24.55	0.19	-23.78	0.17
Sirrah 5	-37.82	2.58	-	-	-25.64	0.10	-24.91	0.22	-24.83	0.39	-24.78	0.25	-24.48	0.31	-25.09	0.44
Taylor 1	-34.42	0.18	-	-	-25.68	0.10	-25.46	0.23	-25.55	0.21	-25.15	0.27	-25.19	0.59	-24.69	0.27

sd = standard deviation (‰)

© Australian Geological Survey Organisation 1994

Table 8 Geochemical parameters for selected Bowen Basin coals.

Well	AGSO No			Formation	Ro	Rc	Tmax	S1	S2	S3	PI	S2/S3	PC	TOC	HI	OI
Baralaba	5317	PS943	RC7294	Rangal CM	2.08		512	0.60	33.73	1.46	0.02	23.10	2.86	79.8	42	2
Cook Colliery	5327	PS2501		Rangal CM	0.92	1.08	452	7.25	132.78	2.40	0.05	55.33	11.66	68.4	194	4
Curragh Mine	5328	PS2502		Rangal CM	1.28	1.13	468	5.89	114.87	1.69	0.05	67.97	10.06	73.0	157	2
Humboldt 2173	5324	PS1948	RC12578	Rangal CM	1.78		494	1.37	55.39	0.98	0.02	56.52	4.73	72.6	76	1
Humboldt 2180	5323	PS1945	RC12572	Rangal CM	1.68	1.56	492	1.17	54.92	1.21	0.02	45.39	4.67	65.4	84	2
Kianga	5319	PS952	RC7303	Rangal CM	0.80		444	4.09	145.95	8.24	0.03	17.71	12.50	74.1	197	11
Moura Mine	5320	PS953	RC7304	Rangal CM			449	4.00	131.48	7.02	0.03	18.73	11.29	67.8	194	10
Moura Mine	5321	PS954	RC7305	Rangal CM	0.90		450	5.00	154.50	6.07	0.03	25.45	13.29	74.2	208	8
Moura Mine	5329	PS2504		Rangal CM			435	2.69	143.55	6.39	0.02	22.46	12.18	71.1	202	9
NS 31R	5316	PS642	RC6911	Rangal CM	1.18	1.00	459	4.66	116.17	5.02	0.04	23.14	10.06	70.6	165	7
NS 37	5315	PS381	RC2015	Rangal CM	0.87		440	1.96	122.74	12.00	0.02	10.23	10.39	64.6	190	19
NS 42	5314	PS382	RC2016	Rangal CM	0.63		436	1.88	90.04	22.06	0.02	4.08	7.66	61.9	145	36
South Blackwater Mine	5330	PS2505		Rangal CM	1.05		446	5.42	135.74	2.30	0.04	59.02	11.76	69.7	195	3
Talbot 239	5322	PS1830	RC11810	Rangal CM	0.73	0.90	436	3.30	128.07	5.96	0.03	21.49	10.94	65.2	196	9
Talbot 592	5325	PS1961	RC12619	Rangal CM	1.87		504	0.87	37.13	0.82	0.02	45.28	3.16	70.0	53	1
Talbot 803	5326	PS2044	RC13061	Rangal CM	0.80		435	3.53	120.90	4.29	0.03	28.18	10.36	65.7	184	7
Yarrabee Mine	5318	PS946	RC7297	Rangal CM	2.59		547	0.00	5.22	2.46	0.00	2.12	0.43	76.8	7	3
Blair Athol	5348	PS2418		Blair Athol CM	0.68	0.88	436	1.30	96.90	6.08	0.01	15.94	8.18	66.6	145	9
Cairns County 35	5335	PS1127	RC8305	German Creek CM	1.72	1.88	486	2.02	66.78	1.83	0.03	36.49	5.73	59.8	112	3
Cairns County 43/44	5336	PS1148	RC8436	German Creek CM	1.54		478	4.62	92.81	1.10	0.05	84.37	8.11	66.2	140	2
Cairns County 50/51	5340	PS1196	RC8520	German Creek CM	1.01	0.96	450	6.71	158.61	3.23	0.04	49.11	13.77	68.6	231	5
Gregory Mine	5341	PS2503		German Creek CM	0.98		443	7.60	179.54	3.34	0.04	53.75	15.59	68.6	262	5
NS 10	5332	R138	RC7102	German Creek CM	0.53	0.64	433	2.31	118.81	11.13	0.02	10.67	10.09	48.5	245	23
NS 46	5333	PS1024	RC7692	German Creek CM	0.80	0.78	439	4.45	159.48	8.75	0.03	18.23	13.66	63.8	250	14
NS 53	5334	PS1034	RC7739	German Creek CM	0.70		434	3.51	147.32	10.04	0.02	14.67	12.56	60.7	243	17
NS 6	5331	R150	RC6892	German Creek CM	0.59		434	1.67	110.54	8.52	0.01	12.97	9.35	53.4	207	16
Talbot 69/70	5337	PS1161	RC8457	German Creek CM	1.32	1.37	472	6.80	117.40	1.15	0.05	102.09	10.35	64.9	181	2
Talbot 73	5338	PS1171	RC8476	German Creek CM	1.28		471	8.40	125.80	1.15	0.06	109.39	11.18	66.8	188	2
Talbot 75/76	5339	PS1195	RC8509	German Creek CM	1.12		462	9.02	138.77	2.91	0.06	47.69	12.31	65.7	211	4
Clermont 20	5346	PS1701	RC11707	Wolfang CM	0.65	0.69	434	2.09	129.46	11.75	0.02	11.02	10.96	68.1	190	17
Clermont 20	5347	PS1703	RC11709	Wolfang CM	0.72		438	1.75	108.88	8.05	0.02	13.53	9.21	67.3	162	12
GSQ Emerald 1	5344	PS1392	RC9406	Reid's Dome Beds	0.82		433	6.94	160.41	8.03	0.04	19.98	13.94	69.1	232	12
GSQ Emerald 1	5345	PS1395	RC9412	Reid's Dome Beds	0.86		438	5.99	139.00	5.59	0.04	24.87	12.08	69.7	199	8
GSQ Taroom 11/11A	5342	PS1249	RC8895	Reid's Dome Beds	0.60		430	5.60	161.06	7.53	0.03	21.39	13.88	59.3	272	13
GSQ Taroom 11/11A	5343	PS1252	RC9017	Reid's Dome Beds	0.85	0.83	435	4.69	145.71	7.09	0.03	20.55	12.53	59.7	244	12

© Australian Geological Survey Organisation 1994

Table 9a Aromatic biomarkers in liquid petroleum.

Well	AGSO No	Age	Group	DNR-1	TNR-1	MPI-1	Rc	1,2,3TMN / 1,3,6TMN	1-MP / 9-MP	1,7-DMP / X	RETENE / 9-MP	LOG(123 136TMN)	LOG(1/9 MP)	LOG(17-DMP X)	LOG(RET/ 9MP)
Denison Trough Area															
Westgrove 3	391	Permian		9.54	3.43	1.05	1.03	0.34	0.96	0.73	0.22	-0.46	-0.02	-0.14	-0.66
Rolleston 1	390	Permian	C4	3.83	0.59	0.63	0.78	0.42	0.71	0.38	0.12	-0.38	-0.15	-0.42	-0.92
Rolleston 1	534	Permian	C4	5.93	0.58	0.54	0.72	0.35	0.74	0.32	0.04	-0.45	-0.13	-0.49	-1.37
Rolleston 3	548	Permian	C0	3.89	0.72	0.48	0.69	0.57	0.73	0.35	0.28	-0.24	-0.14	-0.46	-0.55
Rolleston 3	549	Permian	C0	4.91	0.78	0.33	0.60	0.44	0.83	0.30	0.09	-0.36	-0.08	-0.52	-1.07
Merivale 5	550	Permian	OC0	5.30	0.66	0.46	0.67	0.41	0.64	0.33	0.24	-0.38	-0.19	-0.49	-0.62
Yellowbank 3	547	Permian	OC0	5.13	0.81	0.59	0.76	0.88	0.75	0.44	0.02	-0.06	-0.12	-0.35	-1.78
Taroom Trough Area															
East															
Conloi 1	78	Jurassic	O4	6.09	0.76	1.54	1.32	0.24	0.88	0.32	0.14	-0.62	-0.06	-0.50	-0.84
Conloi 1	217	Jurassic	O4	6.67	0.72	1.48	1.29	0.23	0.82	0.28	0.13	-0.63	-0.08	-0.55	-0.89
Rockwood 1	97	Jurassic	#OC1	9.56	0.89	0.74	0.84	0.22	0.76	0.45	0.17	-0.65	-0.12	-0.34	-0.77
Bennett 1	215	Jurassic	O1a	5.27	0.68	0.81	0.89	0.52	0.78	0.48	0.21	-0.28	-0.11	-0.32	-0.67
Leichhardt 2	216	Jurassic	O3	6.16	0.67	0.98	0.99	0.41	0.78	0.42	0.39	-0.39	-0.11	-0.37	-0.41
Moonie 1	50	Jurassic	#O1b	6.91	0.83	0.92	0.95	0.38	0.61	0.30	0.20	-0.41	-0.22	-0.53	-0.69
Moonie 1	565	Jurassic	O1b	8.09	0.78	0.92	0.95	0.38	0.61	0.29	0.18	-0.42	-0.22	-0.54	-0.74
Moonie 2	566	Jurassic	O1c	7.66	0.88	0.90	0.94	0.37	0.54	0.27	0.17	-0.43	-0.26	-0.56	-0.77
Moonie 4	567	Jurassic	O2	8.96	0.93	0.93	0.96	0.36	0.63	0.28	0.18	-0.44	-0.20	-0.55	-0.73
Moonie 10	568	Jurassic	O1b	7.89	0.89	0.91	0.95	0.36	0.65	0.29	0.17	-0.44	-0.18	-0.54	-0.76
Moonie 11	569	Jurassic	O1c	7.95	0.88	0.88	0.93	0.35	0.69	0.29	0.17	-0.45	-0.16	-0.54	-0.77
Moonie 15	570	Jurassic	O1c	8.91	0.89	0.93	0.96	0.35	0.66	0.28	0.17	-0.45	-0.18	-0.55	-0.76
Moonie 18	571	Jurassic	O1c	8.90	0.86	0.91	0.95	0.34	0.64	0.28	0.18	-0.47	-0.20	-0.55	-0.74
Moonie 21	572	Jurassic	O1c	8.62	0.81	0.94	0.96	0.34	0.64	0.28	0.04	-0.47	-0.20	-0.55	-1.35
Moonie 27	573	Jurassic	O1c	8.35	0.81	0.93	0.96	0.36	0.65	0.28	0.18	-0.44	-0.19	-0.56	-0.76
Moonie 28	574	Jurassic	O1c	8.34	0.81	0.92	0.95	0.35	0.62	0.28	0.18	-0.45	-0.21	-0.55	-0.73
Moonie 29	575	Jurassic	O1a	8.19	0.83	0.91	0.95	0.35	0.66	0.29	0.16	-0.46	-0.18	-0.54	-0.80
Moonie 30	576	Jurassic	O1c	8.05	0.85	0.92	0.95	0.35	0.65	0.29	0.16	-0.46	-0.18	-0.54	-0.78
Moonie 31	577	Jurassic	O1b	8.43	0.89	0.93	0.96	0.34	0.67	0.28	0.17	-0.47	-0.17	-0.55	-0.76
Moonie 32	578	Jurassic	O1b	8.38	0.81	0.93	0.96	0.35	0.64	0.29	0.19	-0.45	-0.19	-0.53	-0.72
Moonie 33	579	Jurassic	O1c	8.10	0.91	0.92	0.95	0.35	0.62	0.30	0.18	-0.45	-0.21	-0.52	-0.74
Moonie 34	580	Jurassic	O2	8.11	0.88	0.91	0.95	0.34	0.65	0.32	0.16	-0.47	-0.19	-0.49	-0.79
Moonie 35	581	Jurassic	O1c	8.38	0.91	0.94	0.96	0.36	0.65	0.29	0.20	-0.44	-0.18	-0.53	-0.70
Moonie 37	582	Jurassic	O1b	8.05	0.91	0.93	0.96	0.34	0.66	0.30	0.20	-0.47	-0.18	-0.53	-0.71
Rockwood North 1	55	Jurassic	O0	3.74	0.69	0.74	0.84	0.45	0.60	0.34	0.18	-0.34	-0.22	-0.47	-0.75
Cabawin 1	385	Permian	O0	5.58	0.61	1.04	1.03	0.23	0.73	0.39	0.03	-0.63	-0.14	-0.41	-1.50
Roma Shelf															
Anabranch 1	214	Jurassic	O0	4.63	0.67	0.56	0.73	0.97	1.21	0.54	1.52	-0.01	0.08	-0.26	0.18
Blyth Creek 1	386	Jurassic	OC0	2.52	0.61	0.73	0.84	2.86	0.88	0.46	0.25	0.46	-0.06	-0.34	-0.61
Bony Creek 6	212	Jurassic	OC0	1.80	0.50	0.53	0.72	1.81	0.87	0.55	0.13	0.26	-0.06	-0.26	-0.88

© Australian Geological Survey Organisation 1994

Table 9a (cont).

Well	AGSO No	Age	Group	DNR-1	TNR-1	MPI-1	Rc	1,2,3TMN / 1,3,6TMN	1-MP / 9-MP	1,7-DMP / X	RETENE / 9-MP	LOG(123 136TMN)	LOG(1/9 MP)	LOG(17-DMP X)	LOG(RET/ 9MP)
Roma Shelf (cont.)															
Duarran 2	207	Jurassic	O2	3.97	0.62	0.63	0.78	1.09	1.01	0.57	0.43	0.04	0.01	-0.24	-0.37
Maffra 2	221	Jurassic	O0	3.06	0.51	0.51	0.71	2.14	1.17	0.73	0.65	0.33	0.07	-0.13	-0.19
Richmond 1	43	Jurassic	O0	3.54	0.63	0.43	0.66	1.02	0.61	0.45	0.96	0.01	-0.22	-0.35	-0.02
Richmond 5	210	Jurassic	O0	4.72	0.71	0.74	0.84	0.67	0.82	0.41	0.20	-0.18	-0.09	-0.39	-0.70
Richmond 7	205	Jurassic	OC0	2.14	0.59	0.61	0.77	0.75	0.79	0.40	0.10	-0.13	-0.10	-0.40	-1.01
Richmond 10	211	Jurassic	O0	4.20	0.59	0.66	0.79	1.03	0.84	0.40	0.24	0.01	-0.08	-0.39	-0.62
Borah Creek 5	586	Triassic	O0	6.11	0.91	0.85	0.91	0.37	0.49	0.25	0.10	-0.43	-0.31	-0.59	-1.02
Combarngo 1	387	Triassic	O0	5.33	0.69	0.98	0.99	0.34	0.69	0.37	0.07	-0.47	-0.16	-0.43	-1.13
Snake Creek 1	41	Triassic	O0	4.88	0.65	0.69	0.82	0.65	0.84	0.44	0.96	-0.19	-0.08	-0.36	-0.02
Waratah 4	588	Triassic	O1b	5.41	0.80	0.79	0.87	0.69	0.71	0.32	0.50	-0.16	-0.15	-0.49	-0.30
Washpool 1	589	Triassic	O0	5.51	0.77	1.04	1.03	0.55	0.73	0.32	0.11	-0.26	-0.14	-0.49	-0.96
Sunnybank 1	54	Triassic	#O0	4.08	0.62	1.08	1.05	0.31	0.61	0.35	0.10	-0.50	-0.21	-0.46	-1.00
Sunnybank 3	225	Triassic	O0	5.54	0.62	0.93	0.96	0.34	0.63	0.33	0.07	-0.47	-0.20	-0.48	-1.15
Sunnybank 2	113	Permian	#O1a	4.09	0.66	1.03	1.02	0.35	0.70	0.35	0.06	-0.45	-0.15	-0.46	-1.25
Sunnybank 2	213	Permian	O1a	5.58	0.65	0.82	0.89	0.30	0.77	0.30	0.01	-0.52	-0.11	-0.52	-2.04
Wallumbilla South 1	209	Permian	OC0	1.04	0.65	0.71	0.83	1.11	1.10	0.62	0.64	0.04	0.04	-0.21	-0.20
Dirinda 1	81	Devonian	O0	4.59	0.60	0.73	0.84	0.50	0.60	0.28	0.20	-0.30	-0.22	-0.55	-0.71
Wunger Ridge															
Alton 1	136	Jurassic	O0	2.96	0.54	0.59	0.76	1.17	0.89	0.46	0.20	0.07	-0.05	-0.34	-0.70
Riverslea 1	431	Jurassic	O5	4.54	0.52	0.58	0.75	0.83	1.04	0.41	0.63	-0.08	0.02	-0.39	-0.20
Riverslea 3	587	Jurassic	O5	5.12	0.57	0.66	0.80	0.80	0.72	0.32	1.53	-0.10	-0.14	-0.50	0.18
Beardmore 1	559	Triassic	O0	4.32	0.69	0.80	0.88	0.67	0.69	0.36	0.19	-0.17	-0.16	-0.44	-0.72
Fairymount 1	585	Triassic	O0	4.15	0.62	0.73	0.84	0.73	0.72	0.39	0.14	-0.14	-0.14	-0.40	-0.86
Harbour 1	583	Triassic	O1a	4.81	0.65	0.74	0.85	0.84	0.88	0.36	0.41	-0.08	-0.06	-0.45	-0.38
Louise 2	551	Triassic	O0	5.33	0.70	0.70	0.82	0.53	0.77	0.32	0.06	-0.27	-0.12	-0.50	-1.21
McWhirter 1	560	Triassic	O0	5.13	0.65	0.78	0.87	0.64	0.65	0.33	0.16	-0.20	-0.19	-0.48	-0.81
Narrows 1	556	Triassic	O0	5.48	0.64	0.74	0.84	0.56	0.63	0.30	0.10	-0.25	-0.20	-0.52	-1.00
Rednook 1	561	Triassic	C0	4.39	0.93	1.07	1.04	0.78	1.03	0.50	0.11	-0.11	0.01	-0.30	-0.97
Rednook 1	563	Triassic	O1a	3.35	0.52	0.78	0.87	0.33	0.57	0.29	0.06	-0.49	-0.25	-0.53	-1.24
Renlim 1	552	Triassic	OC0	5.83	0.68	0.59	0.75	0.46	0.85	0.28	0.01	-0.33	-0.07	-0.55	-2.16
Roswin 1	546	Triassic	OC0	3.19	0.52	0.55	0.73	0.56	0.55	0.28	0.04	-0.25	-0.26	-0.55	-1.38
Silver Springs/Renlim	554	Triassic	OC0	5.93	0.65	0.57	0.74	0.48	0.67	0.19	0.00	-0.32	-0.18	-0.73	-2.90
Sirrah 4	553	Triassic	OC0	5.78	0.78	0.62	0.77	0.50	0.77	0.39	0.03	-0.30	-0.11	-0.41	-1.51
Taylor 5	558	Triassic	O0	6.71	0.75	0.99	0.99	0.42	0.62	0.30	0.13	-0.38	-0.20	-0.52	-0.87
Wunger 1	46	Triassic	#O0	4.83	0.68	0.67	0.80	0.68	0.67	0.38	0.06	-0.17	-0.17	-0.42	-1.25
Yellowbank Creek 3	557	Triassic	O0	5.63	0.68	0.83	0.90	0.57	0.66	0.34	0.16	-0.24	-0.18	-0.47	-0.78
Yellowbank Creek Nori	584	Triassic	O0	5.43	0.73	0.79	0.88	0.55	0.73	0.35	0.13	-0.26	-0.13	-0.45	-0.89
Glen Fosslyn 1	545	Triassic	O1a	4.72	0.55	0.77	0.86	0.42	0.63	0.31	0.09	-0.38	-0.20	-0.51	-1.06
Kinkabilla 1	219	Triassic	O1a	1.78	0.40	0.73	0.84	0.25	0.56	0.33	0.04	-0.61	-0.25	-0.49	-1.43
Warroon 3	562	Triassic	O1a	4.58	0.64	0.83	0.90	0.38	0.54	0.29	0.06	-0.42	-0.26	-0.53	-1.24
Waggamba 1	555	Permian	O0	7.09	0.77	0.86	0.91	0.29	0.71	0.39	0.04	-0.54	-0.15	-0.41	-1.38

© Australian Geological Survey Organisation 1994

Table 9b Aromatic biomarkers in sediments.

Well Name	AGSO No	Age	DNR-1	TNR-1	MPI-1	Rc	1,2,5 TMN / 1,3,6TMN	1-MP / 9-MP	1,7-DMP / X	Retene / 9-MP
Denison Trough Area										
Maranoa Colliery	6278	Jurassic	0.36	0.20	0.18	0.51	24.19	1.51	2.69	11.34
Dawson River 1	5278	Jurassic		1.23	0.51	0.70	10.73	1.17	1.43	0.73
Dawson River 1	5279	Jurassic	2.52	1.13	0.42	0.65	2.90	1.18	1.54	0.24
Arcturus 1	5066	Permian	3.50	0.75	0.47	0.68	0.78	0.56	0.30	0.06
Rolleston 1	5070	Permian	3.95	0.71	0.66	0.80	0.88	0.13	1.17	0.06
Westgrove 2	5075	Permian	3.05	0.93	0.54	0.72	1.29	0.41	0.45	0.07
Cook Colliery	5327	Permian	3.17	1.14	1.13	1.08	0.94	0.69	0.43	0.01
Curragh Mine	5328	Permian	4.29	1.22	1.21	1.13	0.30	0.77	0.43	0.01
Humboldt 2180	5323	Permian	15.35	2.78	1.94	1.56	0.03	0.85	0.30	0.00
NS 31R	5316	Permian	0.85	0.79	1.01	1.00	0.66	0.65	0.38	0.00
Talbot 239	5322	Permian	1.28	0.61	0.83	0.90	1.60	0.66	0.47	0.05
Rolleston 1	5071	Permian	4.62	1.08	0.54	0.73	1.13	0.53	0.44	0.07
Warrinilla North 1	5080	Permian	4.90	1.45	0.58	0.75	1.32	0.65	0.35	0.07
Blair Athol	5348	Permian	2.29	0.77	0.80	0.88	3.21	0.62	1.11	0.70
Cairns County 35	5335	Permian	10.60	3.47	2.46	1.88	0.04	0.76	0.32	0.00
Cairns County 50/51	5340	Permian	0.64	0.47	0.94	0.96	2.45	0.59	0.61	0.11
NS 10	5332	Permian	2.70	0.50	0.39	0.64	1.20	0.32	0.47	4.46
NS 46	5333	Permian	1.85	0.52	0.63	0.78	1.62	0.27	0.95	1.40
Talbot 69/70	5337	Permian	0.54	1.38	1.62	1.37	0.16	0.64	0.43	0.01
Cometside 1	5068	Permian	5.13	1.33	0.75	0.85	0.43	0.72	0.38	0.02
Rolleston 1	5072	Permian	5.30	1.50	0.49	0.70	1.64	0.59	0.33	0.03
Clermont 20	5346	Permian	0.97	0.35	0.48	0.69	1.56	0.39	1.02	1.81
Rolleston 1	5073	Permian	3.42	1.33	0.49	0.69	0.98	0.59	0.31	0.03
Glentulloch 1	5069	Permian	6.12	1.15	0.53	0.72	0.95	0.83	0.47	0.14
Warrinilla 1	5077	Permian	2.57	1.53	0.63	0.78	0.96	0.85	0.54	0.01
Warrinilla 1	5078	Permian	2.07	1.38	0.66	0.80	0.97	0.79	0.43	0.01
Warrinilla North 1	5081	Permian	5.20	1.68	0.56	0.73	0.59	0.75	0.38	0.02
Warrinilla North 1	5082	Permian	5.41	1.48	0.67	0.80	0.26	0.80	0.40	0.01
GSQ Taroom 11/11A	5343	Permian	3.47	0.84	0.72	0.83	3.17	0.96	1.04	3.21
Warrinilla 1	5079	Permian	4.39	3.15	1.06	1.04	0.10	0.63	0.26	0.01
Warrinilla North 1	5083	Permian	5.47	1.31	0.73	0.84	0.52	0.77	0.56	0.01
Westgrove 3	5076	Permian	7.24	1.33	1.17	1.10	0.12	0.71	0.36	0.01

© Australian Geological Survey Organisation 1994

Table 9b (cont).

Well Name	AGSO No	Age	DNR-1	TNR-1	MPI-1	Rc	1,2,5 TMN / 1,3,6TMN	1-MP / 9-MP	1,7-DMP / X	Retene / 9-MP
Taroom Trough Area										
Cabawin 1	6399	Cretaceo	2.51	0.90	0.47	0.68	3.49	2.27	0.81	5.44
Cabawin 1	6400	Cretaceo	3.80	0.89	0.76	0.86	2.94	0.44	0.64	5.44
Cabawin 1	6401	Jurassic	0.44	0.97	0.61	0.76	27.00	2.07	4.02	2.34
Cabawin 1	6402	Jurassic	0.31	0.99	0.48	0.69	34.34	2.66	10.03	4.03
Cabawin 1	6403	Jurassic	1.01	0.58	0.52	0.71	41.61	2.92	4.78	10.08
Cabawin 1	6404	Jurassic	0.46	0.34	0.32	0.59	38.22	5.62	15.01	28.30
Cabawin 1	6405	Jurassic	0.49	0.62	0.26	0.56	28.35	8.19	9.06	32.45
Bellbird 1	6521	Jurassic	1.79	0.63	0.51	0.71	3.49	1.23	0.81	0.38
Canaan 1	6488	Jurassic	0.67	0.76	0.55	0.73	9.57	1.13	1.47	1.13
Dawson River 6	5282	Jurassic	0.21	0.43	0.40	0.64	6.19	0.49	0.56	0.31
Juandah 1	6484	Jurassic	1.21	0.91	0.39	0.63	6.30	1.66	1.43	0.85
Tingan 1	6487	Jurassic	0.87	0.36	0.28	0.57	2.85	0.99	1.05	0.76
Wandoan 1	6545	Jurassic	1.80	1.01	0.47	0.68	4.68	1.50	1.38	0.62
Burunga 1	6530	Jurassic	2.45	0.73	0.35	0.61	5.58	1.73	2.13	0.28
Cockatoo Creek 1	6411	Jurassic		1.67	0.93	0.96	1.06	0.54	0.45	0.44
Wandoan 1	1826	Triassic			0.58	0.75		0.36	0.09	0.09
Wandoan 1	6546	Triassic	1.80	0.40	1.95	1.57	0.33	0.81	0.34	0.04
Warrong 1	6490	Triassic			0.53	0.72		0.73	0.66	0.12
Cabawin 1	1818	Triassic			0.55	0.73		0.52	0.31	0.04
Cabawin 1	6406	Triassic	0.78	1.26	0.61	0.76	2.25	0.97	0.60	0.12
Glenhaughton 1	1816	Triassic			0.47	0.68		0.40	0.27	26.37
Glenhaughton 1	6485	Triassic	1.13	0.88	0.55	0.73	3.19	0.92	0.82	0.66
Bellbird 1	6522	Triassic	1.96	0.96	0.64	0.79	4.76	0.79	0.40	0.04
Cabawin 1	6407	Triassic	1.17	1.06	0.73	0.84	0.93	0.86	0.53	0.05
Glenhaughton 1	5235	Triassic			1.17	1.10		0.53	1.22	1.24
Cockatoo Creek 1	6412	Triassic			0.85	0.91		0.90	0.69	0.56
Glenhaughton 1	5236	Triassic	5.02	2.76	1.04	1.03	0.10	0.54	0.28	0.04
Wandoan 1	5239	Triassic			0.36	0.62		0.66	1.10	2.74
Cabawin 1	1820	Permian		5.31	0.32	0.59	0.10	0.31	0.35	56.61
Cabawin 1	3671	Permian	2.40	0.80	0.73	0.84	1.09	0.99	0.75	0.09
Cabawin 1	3674	Permian	2.85	0.79	0.68	0.81	0.99	0.98	0.79	0.10
Cabawin 1	6409	Permian	2.79	0.83	0.73	0.84	0.92	0.94	0.79	0.14
Cabawin 1	6408	Permian	3.78	0.93	0.78	0.87	1.04	1.18	0.72	0.02
Glenhaughton 1	1817	Permian			2.74	2.05		0.66	0.23	0.03

© Australian Geological Survey Organisation 1994

Table 9b (cont).

Well Name	AGSO No	Age	DNR-1	TNR-1	MPI-1	Rc	1,2,5 TMN / 1,3,6TMN	1-MP / 9-MP	1,7-DMP / X	Retene / 9-MP
Taroom Trough Area (cont.)										
Glenhaughton 1	5237	Permian	15.97	5.85	1.90	1.54	0.04	0.81	0.37	0.04
Wandoan 1	1828	Permian	3.14	2.93	0.36	0.62	0.26	0.08		0.58
Wandoan 1	6547	Permian	6.73	1.48	1.59	1.36	0.12	1.21	0.42	0.08
Burunga 1	6531	Permian	2.26	1.29	1.04	1.02	0.92	0.78	0.46	0.11
Cockatoo Creek 1	5233	Permian	3.92	1.26	0.74	0.85	1.55	0.87	0.48	0.03
Cockatoo Creek 1	6413	Permian		1.32	0.54	0.72	1.08	0.55	0.41	0.08
Cockatoo Creek 1	6414	Permian	2.93	1.20	0.70	0.82	1.73	0.96	0.58	0.04
Cockatoo Creek 1	1822	Triassic			0.24	0.55		0.35	0.19	0.47
Bengalla 1	6486	Permian	7.13	1.76	1.00	1.00	0.18	0.86	0.38	0.01
Cabawin 1	1821	Permian			1.08	1.05		0.61	0.26	0.89
Cabawin 1	6410	Permian		1.17	0.88	0.93	2.62	0.75	0.56	0.11
Coonardoo 1	6480	Permian	3.82	1.27	0.73	0.84	0.89	0.96	0.41	0.04
Glenhaughton 1	5238	Permian		4.27	1.26	1.16	0.57	0.78	0.57	0.24
Goondiwindi 1	6482	Permian	2.89	1.07	0.70	0.82	1.03	0.72	0.36	0.12
Southwood 1	5074	Permian	4.05	1.25	0.64	0.79	0.65	0.77	0.39	0.03
Undulla 1	6564	Permian	2.63	1.41	0.75	0.85	0.64	1.00	0.49	0.05
Undulla 1	6563	Permian	2.59	1.11	0.67	0.80	1.16	0.96	0.50	0.15
Burunga 1	6542	Permian	2.47	1.41	0.90	0.94	0.79	1.08	0.47	0.04
Cockatoo Creek 1	6415	Permian	0.90	1.55	0.74	0.85	0.73	0.76	0.36	0.04
Cockatoo Creek 1	6416	Permian	1.92	1.29	0.79	0.87	0.35	0.90	0.31	0.04
Cockatoo Creek 1	6417	Permian	1.42	1.66	0.84	0.90	0.26	0.99	0.49	0.03
Cockatoo Creek 1	1823	Permian	34.37	0.39	1.07	1.04	0.12	0.49	0.26	0.14
Burunga 1	6543	Permian	4.27	1.34	0.93	0.96	0.22	1.11	0.54	0.03
Cockatoo Creek 1	5067	Permian	8.69	11.45	2.18	1.71	0.01	0.88	0.31	0.00
Cockatoo Creek 1	6418	Permian			2.73	2.04		0.95	0.47	0.26
Burunga 1	6544	Permian	24.18	6.38	2.15	1.69	0.11	1.17	0.28	0.01
Cockatoo Creek 1	1825	Permian			2.25	1.75		1.04	0.65	0.38
Cockatoo Creek 1	6420	Permian	3.50	4.55	1.74	1.44	0.26	1.05	0.41	0.10
Cockatoo Creek 1	6421	Permian			0.96	0.97		1.17	0.46	0.25
Cockatoo Creek 1	5234	Permian	30.50	4.45	1.94	1.56	0.44	0.80	0.30	0.09

© Australian Geological Survey Organisation 1994

Footnote to Tables 9a and b.

DNR-1 = (2,6-DMN + 2,7-DMN)/1,5-DMN)
TNR-1 = 2,3,6-TMN/(1,3,5-TMN + 1,4,6-TMN)
MPI-1 = 1.5 * (3-MP + 2-MP)/(phenanthrene + 9-MP + 1-MP
Rc = 0.4 + 0.6MPI-1 when Ro<1.35%; 2.3 - 0.6MPI-1 when Ro>1.35%
(Radke and Welte, 1983)
DMN = dimethylnaphthalene
TMN = trimethylnaththalene
MP = methylphenanthrene
DMP = dimethylphenanthrene
X = sum of selected DMP isomers.

© Australian Geological Survey Organisation 1994

Table 10 Stable carbon isotopic composition for petroleum distillation cuts.

Well	AGSO No.	Sample	<100°C ‰	<100°C %	100-150°C ‰	100-150°C %	150-200°C ‰	150-200°C %	200-250°C ‰	200-250°C %	250-300°C ‰	250-300°C %	>300°C ‰	>300°C %	Whole ‰
Yellowbank 3	557	oil	-22.69	8.8	-23.35	18.8	-23.89	16.3	-24.27	11.3	-24.86	15.0	-25.50	30.0	-24.98
Rednook 1	563	oil	-22.94	2.8	-23.43	5.6	-23.88	11.1	-24.25	13.9	-24.58	19.4	-25.11	47.2	-24.95
Yellowbank 3	547	cond.	-23.12	16.0	-23.97	20.0	-24.51	25.0	-25.28	25.0	**-25.69	14.0			-24.42
Rolleston 3	548	cond.	-24.27	9.0	-24.57	40.0	-24.93	42.0	*-25.27	9.0					
Merlvale 5	550	cond.	-22.88	22.0	-23.71	52.0	-24.38	16.0	*-25.78	10.0					
Rednook 1	561	cond.	-23.01	12.5	-23.55	56.3	^-24.28	25.0	^^-27.21	6.3					-24.00

^ = 150-170°C; ^^ = >170°C

* = >200°C; ** = >250°C

© Australian Geological Survey Organisation 1994

Table 11 Aromatic biomarker parameters for selected Jurassic sediments from other basins.

	Well	Depth (m)	Formation	AGSO No	DNR-1	TNR-1	MPI-1	Rc	1,2,5TMN / 1,3,6TMN	1-MP / 9-MP	1,7-DMP / X	RETENE / 9-MP
Clarence-Moreton Basin												
	Coaldale 1	244.44 244.44	Walloon CM	2313	2.33	0.92	0.66	0.80	1.15	1.31	1.28	0.03
	GSQ Ipswish 13	44.81 44.81	Walloon CM	1909	0.33	0.30	0.26	0.55	11.51	4.29	3.89	2.04
	GSQ Ipswish 13	163.12 163.12	Walloon CM	1914	2.47	0.97	0.59	0.75	2.40	1.15	1.12	1.03
	GSQ Ipswish 14	171.7 171.7	Walloon CM	1923	18.13	0.35	0.21	0.53	9.68	4.44	4.88	7.15
	Rosewood Mine	o/c o/c	Walloon CM	1649	2.83	8.15	0.05	0.43	42.54	0.37	0.83	53.94
	Tullymorgan 1	396.2 396.2	Walloon CM	1956	3.48	1.43	1.42	1.25	0.20	0.70	0.46	0.04
	Tullymorgan 1	542.6 542.6	Walloon CM	1957	11.18	3.07	2.09	1.66	0.04	0.73	0.44	0.01
	Tyalgum 1	155.65 155.65	Walloon CM	2316	1.04	0.40	0.47	0.68	4.17	1.29	1.10	0.43
North Eromanga Basin												
	Elvo 1	1362 1371	Westbourne Fm	5311			0.22	0.53		1.64	0.77	16.81
	Manuka 1	854.56 854.56	Westbourne Fm	5308			0.48	0.69		0.71	0.88	3.40
	Aramac 1	720 810	Birkhead Fm	5304	0.31	0.41	0.35	0.61	11.80	1.59	0.95	3.78
	Fermog 1	1348.7 1354.8	Birkhead Fm	5306	0.04	0.33	0.26	0.56	56.18	4.09	4.25	1.13
	Newlands 1	1460 1484.4	Birkhead Fm	5307	0.10	0.41	0.39	0.63	8.48	2.87	3.15	0.23
	Silsoc 1	1427 1487	Birkhead Fm	5303	1.43	0.65	0.54	0.72	2.82	2.09	2.04	0.16
	Stonehenge 1	1350 1390	Birkhead Fm	5301	0.71	0.89	0.59	0.75	2.72	1.73	1.82	0.16
	Elvo 1	1620 1626	Basal Jurassic	5299	0.22	0.61	0.52	0.71	12.41	1.20	1.07	0.93
	Goleburra 1	1197.9 1219.2	Basal Jurassic	5305		0.22	0.24	0.54	76.30	1.62	2.09	1.58
	Stonehenge 1	1595 1610	Basal Jurassic	5302		1.59	0.96	0.98	1.70	0.97	0.75	0.02
	Upshot 1	1100 1110	Basal Jurassic	5300	1.50	1.18	0.70	0.82	2.50	1.02	0.75	0.01

© Australian Geological Survey Organisation 1994

Table 12 Stable carbon isotopic composition of organic matter in sediments.

Well	AGSO No.	Formation	$\delta^{13}C$ ($^o/_{oo}$)	Std. Dev. **
Cabawin 1	6402	Walloon CM.	-22.92	0.06 (2)
Cabawin 1	6403	Walloon CM.	-24.41	0.14 (2)
Bellbird 1	6521	Evergreen Fm.	-24.54	0.09 (2)
Dawson River 6	5283	Evergreen Fm.	-24.80	0.22 (2)
Juandah 1	6484	Evergreen Fm.	-23.05	0.01 (2)
Tingan 1	6487	Evergreen Fm.	-24.01	0.31 (2)
Bellbird 1	6522	Moolayember Fm.	-27.88	0.03 (3)
Cabawin 1	6406	Moolayember Fm.	-27.17	0.16 (3)
Cabawin 1	6407	Moolayember Fm.	-27.63	0.15 (4)
Wandoan 1	6546	Moolayember Fm.	-25.99	0.08 (3)
Cabawin 1	5241	Rewan Gp.	-24.88	0.06 (2)
Cockatoo Creek 1	5240	Rewan Gp.	-22.65	0.07 (2)
Cockatoo Creek 1	6412	Rewan Gp.	-22.66	0.41 (2)
Wandoan 1	5239	Rewan Gp.	-21.86	0.08 (2)
AS 46	5333	Blackwater Gp.	-23.76	0.28 (2)
Cabawin 1	6408	Blackwater Gp.	-23.94	0.15 (4)
Cabawin 1	6409	Blackwater Gp.	-24.54	0.30 (2)
Wandoan 1	6547	Blackwater Gp.	-24.35	0.10 (3)
Cairns County 35	5335	German Creek CM	-24.06	0.09 (2)
Cairns County 43/44	5336	German Creek CM	-23.12	0.06 (2)
NS 10	5332	German Creek CM	-23.98	0.14 (2)
Talbot 69/70	5337	German Creek CM	-24.20	0.17 (3)
Talbot 75/76	5339	German Creek CM	-24.05	0.05 (3)
Burunga 1	6542	Back Creek Gp. Gyranda	-23.76	0.02 (2)
Cockatoo Creek 1	6417	Back Creek Gp. Gyranda	-23.95	0.03 (2)
Cockatoo Creek 1	5067	Back Creek Gp. Flat Top	-25.08	0.00 (2)
Coonardoo 1	6480	Back Creek Gp.	-23.45	0.23 (3)
Goondiwindi 1	6482	Back Creek Gp.	-22.77	0.01 (3)
Undulla 1	6564	Back Creek Gp. Gyranda	-23.73	0.00 (2)
Emerald 1	5344	Reids Dome Beds	-23.55	0.14 (3)

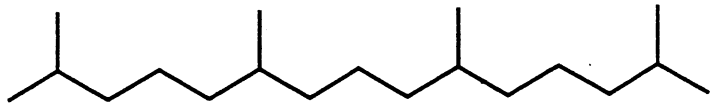
* see Table 2b for additional core information

** standard deviation (number of analyses)

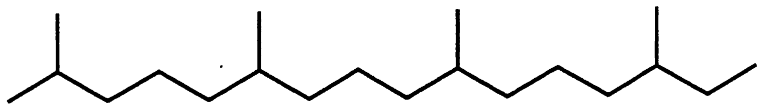
© Australian Geological Survey Organisation 1994

Saturated Acyclic Hydrocarbons

n-C15

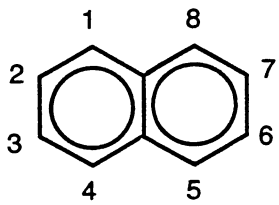


Pristane (C19)

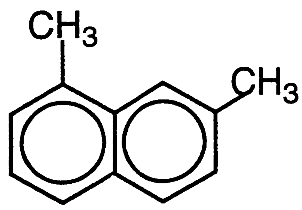


Phytane (C20)

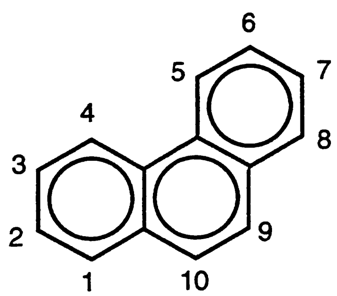
Aromatic Hydrocarbons



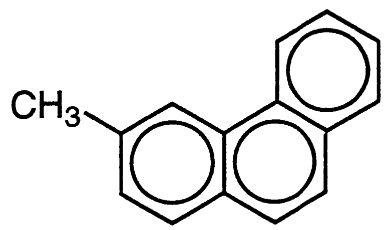
Naphthalene



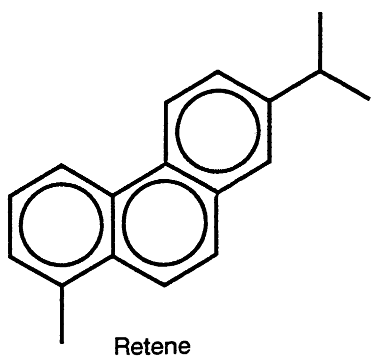
1,7-dimethylnaphthalene



Phenanthrene



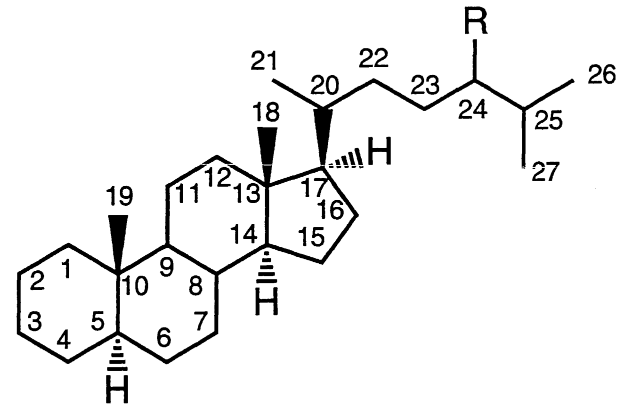
3-methylphenanthrene



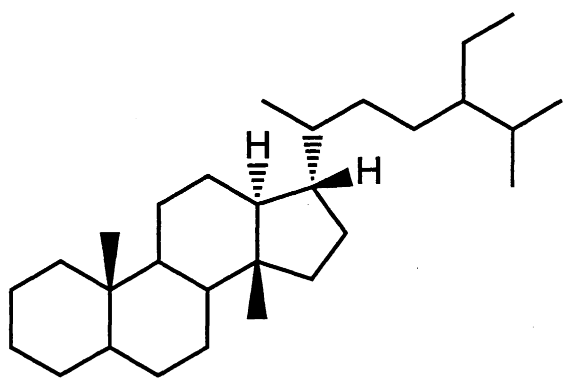
Retene

© Australian Geological Survey Organisation 1994

Steranes

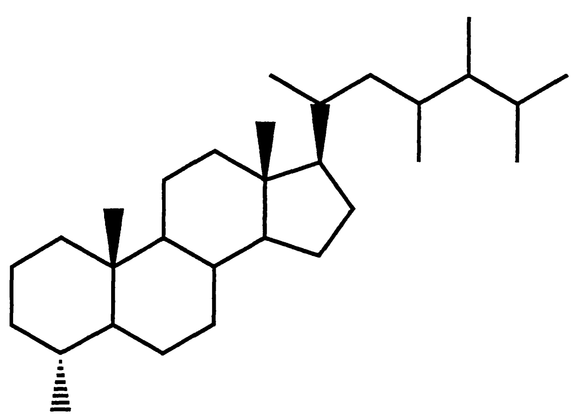


C27 R=H; C28 R=Me; C29 R=Et; C30 R=n-Pr
S and R diastereomers at C20; 5α(H),14α(H),17α(H) shown

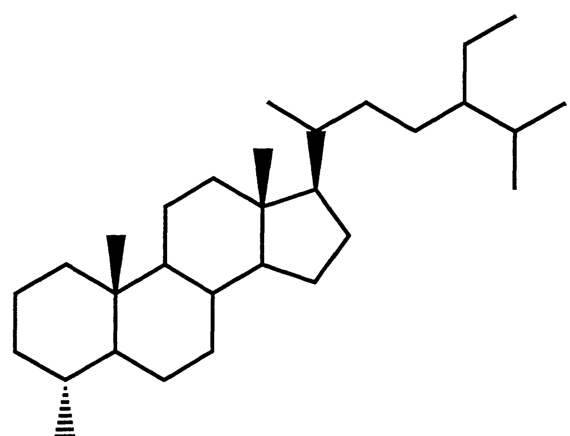


C29 13α(H),17β(H)-diasterane

Methylsteranes



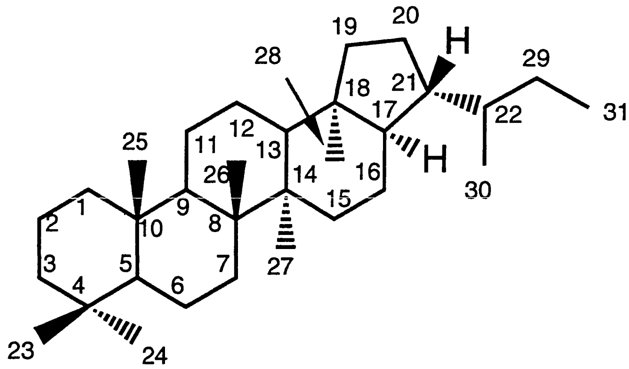
C30 Dinosterane



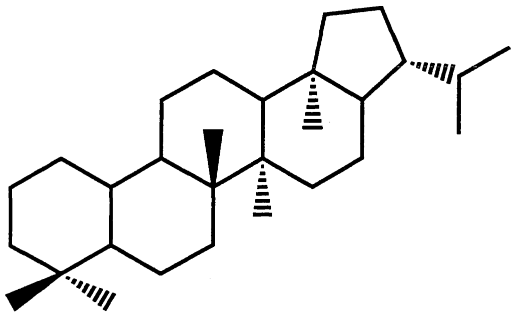
C30 4-methyl-24-ethylsterane

© Australian Geological Survey Organisation 1994

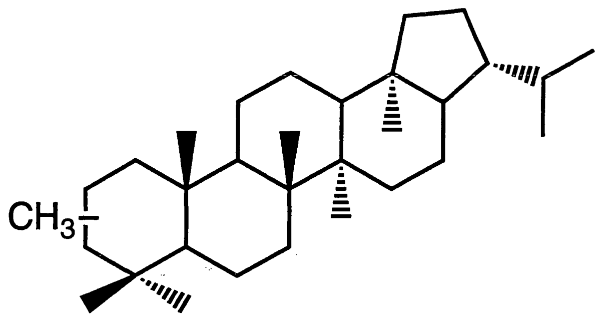
Hopanes



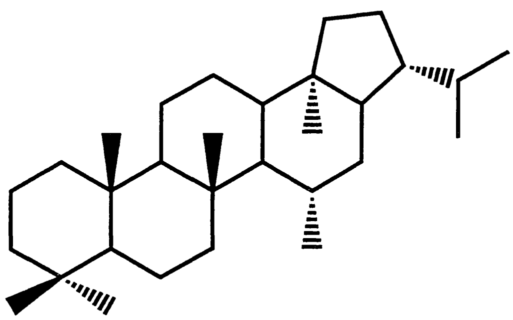
C31 homohopane shown; S and R Diastereomers at C22; 17α(H), 21β (H) configuration



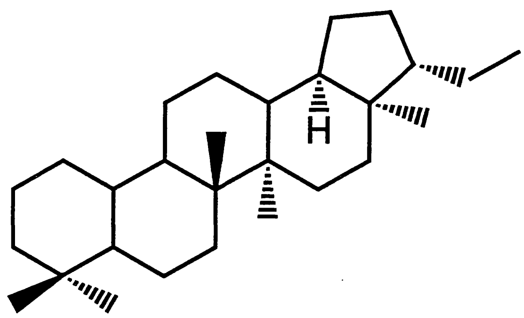
25-norhopane



2- and 3-methylhopane

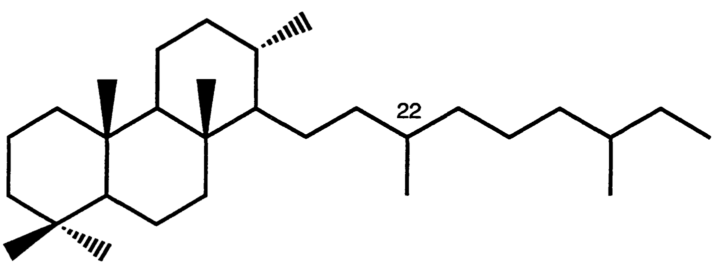


17α(H)-diahopane



18α(H)-30-norneohopane (C29Ts)

Cheilanthanes



© Australian Geological Survey Organisation 1994