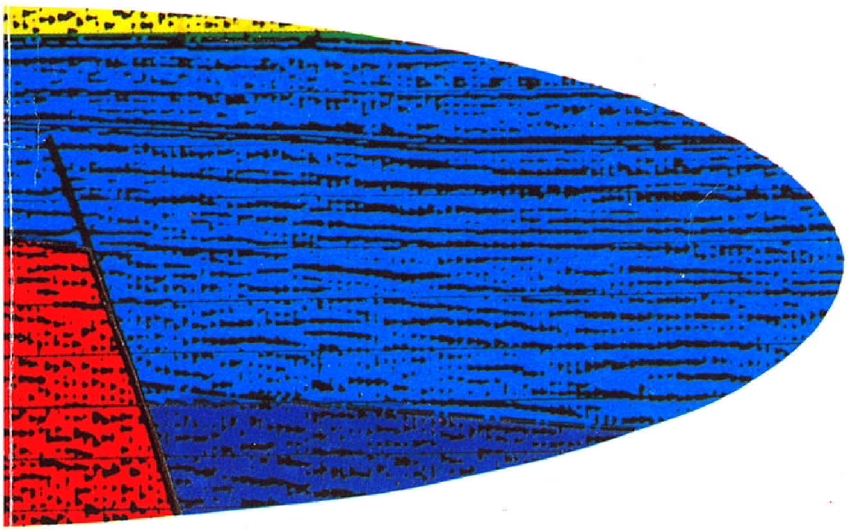
VIMP

VICTORIAN INITIATIVE FOR MINERALS & PETROLEUM



CRETACEOUS SOURCE ROCKS OF THE ONSHORE GIPPSLAND BASIN, VICTORIA

VIMP REPORT 54

K. MEHIN AND M.P. BOCK

July 1998

Natural Resources and Environment

AGRICULTURE
RESOURCES
CONSERVATION
LAND MANAGEMENT

VIMP Report 54

Cretaceous source rocks of the onshore Gippsland Basin, Victoria

K. Mehin and M.P. Bock

July 1998

Bibliographic reference:
MEHIN, K. AND BOCK, M.P., 1998. Cretaceous source rocks onshore Gippsland Basin, Victoria. *Victorian Initiative for Minerals and Petroleum Report* **54**. Department of Natural Resources and Environment.

ISSN 1323 4536
ISBN 0 7306 9433X

This report may be purchased from:
Business and Petroleum Centre
Department of Natural Resources and Environment
8th Floor, 240 Victoria Parade
East Melbourne Victoria 3002

For further technical information contact:
Manager
Petroleum Development
Department of Natural Resources and Environment
PO Box 500
East Melbourne Victoria 3002

Authorship and acknowledgements:
We take this opportunity to express our gratitude to Dr. M Woollands, Manager Basin Studies, who kindly reviewed and offered helpful suggestions in improving earlier drafts. We would like to thank K. Jonasson for editing, J. Kinder, Manager Geological drafting, and also special thanks to L. Mok for formatting the manuscript.

Contents

List of tables

Abstract

This report documents the results of geochemical analyses and burial history reconstructions of Cretaceous source rocks in 10 Victorian onshore wells (sampled as part of the VIMP onshore Gippsland Basin Project).

Although several organic rich horizons exist, the potential of Cretaceous source rocks to generate oil and gas onshore Gippsland has been found to be generally lower than offshore. The maturity of the Cretaceous source rocks in the onshore region, generally increases basinward within the Seaspray Depression.

Gas-prone macerals usually predominate in the Strzelecki and Golden Beach Groups. Oil-prone macerals tend to be more abundant in the thicker, marginally-mature sediments.

The peak time for the generation and expulsion of hydrocarbons within the onshore region of the basin was during the mid-Cretaceous. In general, there was only one distinct pulse of hydrocarbon expulsion, around 100 Ma. This is due to regional uplift during the Early Cretaceous, which hindered sedimentation during Late Cretaceous time. By contrast, towards the offshore area (Golden Beach West 1), two distinct phases of hydrocarbon expulsion occurred. The first event occurred between 115 to 95 Ma (late Early Cretaceous), and the second one during the 80 to 40 Ma period. This was due to rapid subsidence and associated structuring in the offshore area, resulting in a thicker Late Cretaceous and Tertiary section being deposited. These thick Tertiary units acted as a regional seal, and prevented the loss of hydrocarbons to the surface.

1 Introduction

The Gippsland Basin, the easternmost basin within the Bassian Rift System, is an elongate easterly trending sedimentary basin which straddles the present eastern Victorian coastline (Fig. 1). The onshore part of the basin extends from southwest of Western Port Bay to Venus Bay west of Wilsons Promontory. On the other side of Wilsons Promontory, it extends onshore and offshore to the east and southeast. The northern to northwestern onshore boundaries of the basin are defined where the Cretaceous rocks pinch out. The basin covers an area of some 46 000 sq km, 70% of which lies offshore. It has an average width of about 300 km and a sedimentary section of up to 8 km in depth.

The discovery of oil near Lakes Entrance in 1924 initiated the Gippsland Basin as an oil producing basin, with the Lakes Entrance Field producing about 10 000 barrels of heavy, biodegraded crude from an Oligocene glauconitic sandstone (Cunningham Greensand Member), capped by the Lakes Entrance Formation. Production was intermittent with the field ceasing production in 1956. Later offshore discoveries made the basin the richest producing basin in Australia. The basin has so far yielded 3446.5 MB oil and 4779.5 BCF gas. Remaining reserves total 629.9 MB oil and 4827.8 BCF gas. In spite of all the exploration activity that has been carried out in the basin, as a whole, exploration over the onshore region is still relatively sparse. Most of the 165 onshore hydrocarbon wells had been drilled during the 1960's in East Gippsland.

While most of the early offshore drilling targeted top Latrobe structural features, more recent exploration activity has now focused on combined stratigraphic-structural plays. Some of the largest petroleum fields discovered have stratigraphic trapping elements, including Kingfish and Flounder with 1.3 billion barrels and 115 MB oil plus 155 BCF wet gas reserves, respectively. So while searching for combined stratigraphic-structural plays offshore has proved productive, no similar exploration activity has taken place onshore, because potential traps are generally thought to have been flushed by freshwater.

The present study focuses on the Cretaceous source rock potential. A total of 43 core and cuttings samples from nine onshore wells was selected by reference to geophysical well logs. Analyses include total organic carbon (TOC) determination, Rock-Eval pyrolysis, maceral content and vitrinite reflectance. Five samples were selected for additional geochemical analyses such as pyrolysis-gas chromatography (Py-GC) and gas chromatography-mass spectrometry (GC-MS). The results of other analyses and additional information from well completion reports have also been incorporated (see Appendix 1 for details). The maturation data coupled with a geohistory plot for the nine wells analysed, plus one additional well, was used to give an indication of the amount of hydrocarbon expulsion that has occurred within each well.

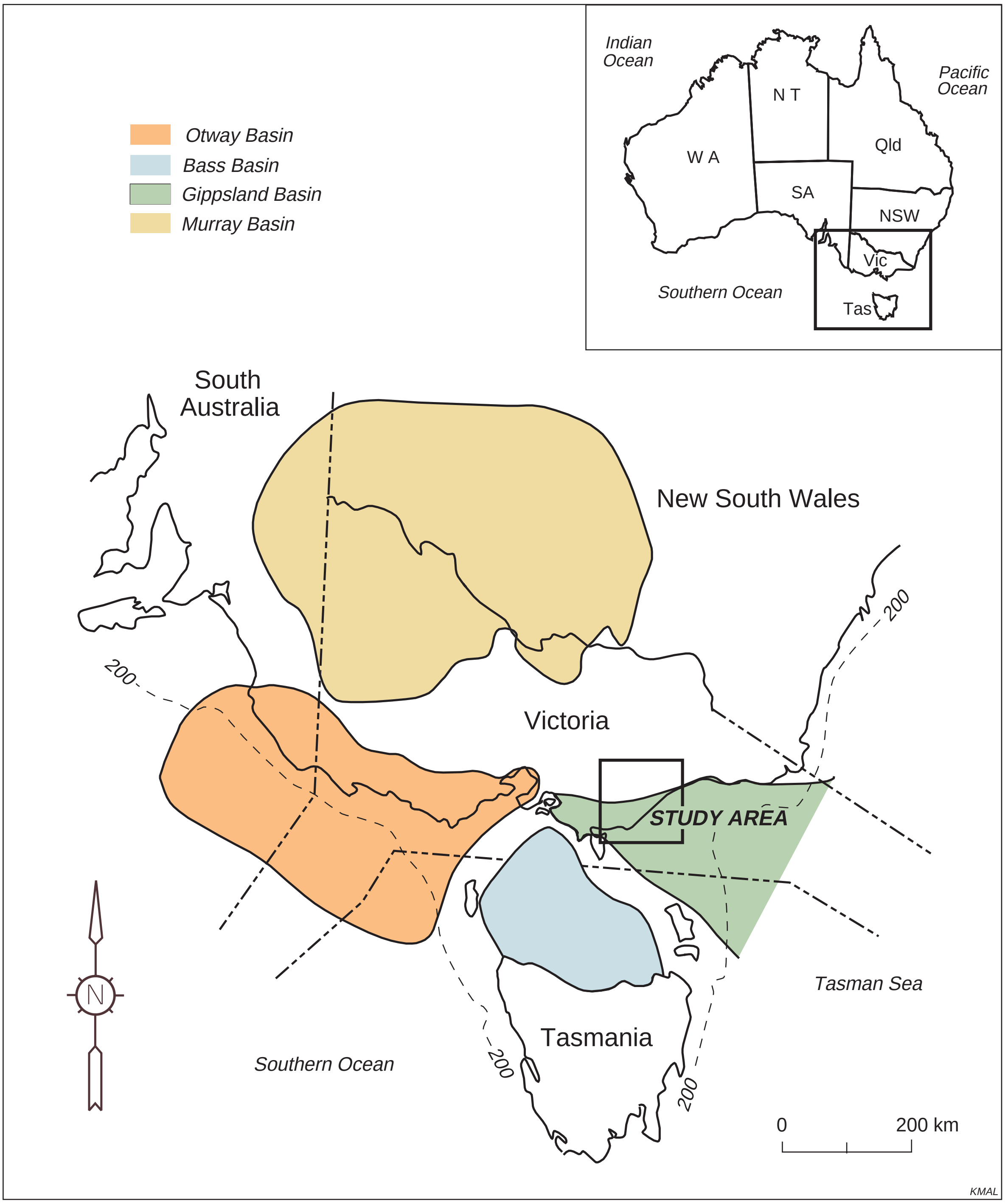


Figure 1
Location of the Gippsland Basin study area.

2 Gippsland Basin

2.1 Structural setting

The Bassian Rift System has three major basin components — the Otway, Bass and Gippsland Basins (Fig. 1). These basins developed in response to the rifting and break-up of the continental landmass comprising Australia, Antarctica and the Lord Howe Rise. The Late Cretaceous development of the Gippsland Basin as a separate entity began around 96 Ma with regional crustal extension, development of syn-rift troughs and volcanism. Two rifting events are recognised (Carey, 1970). The first, the Bassian Rift event, separated Australia from Antarctica and the second, the Tasman Rift, separated Australia from the Lord Howe Rise/Campbell Plateau (Fig. 2).

The Gippsland Basin strikes across the continental shelf, between the southeast of mainland Australia and Tasmania.

The regional tectonic framework is important in order to construct accurate histories of maturation, migration and entrapment of hydrocarbons. In this report, the basin is considered in terms of both its regional setting and local controls on deposition.

2.2 Tectonic framework

The structure and stratigraphy of the Gippsland Basin is well presented in a series of publications and papers by Boutakoff (1964), Carey (1970), Douglas and Ferguson (1976, 1988), Deighton *et al*. (1976), Falvey and Mutter (1981), Cande and Mutter (1982), Veevers (1984; 1986), Etheridge *et al*. (1985), Thompson (1986), Williamson *et al*. (1987), Rahmanian *et al*. (1990), Willcox and Stagg (1990), Lowry and Longley (1991), Featherstone *et al*., (1991), Duddy and Green (1992), Willcox *et al*. (1992), Moore *et al*. (1992), Hill *et al*. (1995), Chiupka (1996) and Megallaa (1993).

Sedimentation during the first rifting event commenced in the earliest Cretaceous (approximately 130 Ma), in response to the development of a pre-breakup depression which extended along the entire southern margin of mainland Australia. This Early Cretaceous depression developed into a complex rift system up to several hundred kilometres wide (Veevers, 1984). Deposition during this phase was continuous between the Otway, Bass and Gippsland Basins (Fig. 2).

The Gippsland Basin is a symmetrical basin in a north-south direction with a deep central depression, bounded by more stable northern and southern terraces and platforms. Along its east-west trend, the basin is asymmetrical which is probably the result of faster subsidence in the east. Extension between Lord Howe Rise and mainland Australia during the Late Cretaceous led to the opening of the Tasman Sea and caused folding of the Jurassic-Middle Cretaceous Strzelecki Group (Moore *et al*., 1992; Rahmanian *et al*., 1990).

Several phases of positive structural inversion occurred in the Gippsland Basin from early Late Cretaceous to the present day creating the major hydrocarbon bearing structures (Veevers, 1984; Duddy & Green, 1992). The first major deformation activity occurred during the Middle to Late Eocene time as intensive east-west shear movements which were associated with the formation of northeast-southwest compressional anticlines.

In the onshore area, the Late Cretaceous movements were also accompanied by volcanism along the western margin of the basin. Another major event occurred in Late Miocene which was also associated with shear movements and rejuvenating the formation of anticlinal structures. The last tectonic event was the "Kosciusko" Uplift during Late Pliocene to Early Pleistocene which was more effective in the northern part of the basin and caused a basinward tilting of the sediments (Douglas & Ferguson, 1976).

The major structural setting of the basin consists of a series of en echelon anticlines which are the result of the shear movements. These structures, together with the unconformable surface of the Latrobe Group reservoir (Fig. 4), have provided many hydrocarbon traps within the offshore area (Etheridge *et al*., 1985; Williamson *et al*., 1987; Featherstone *et al*., 1991; Lowry & Longley, 1991; Megallaa *et al*., 1998).

The anticlines are the result of inversion of previous extensional faults; with some component of dextral shearing. These structures are sealed regionally by the overlying Seaspray Group (Featherstone *et al*., 1991). Similar anticlinal features are also

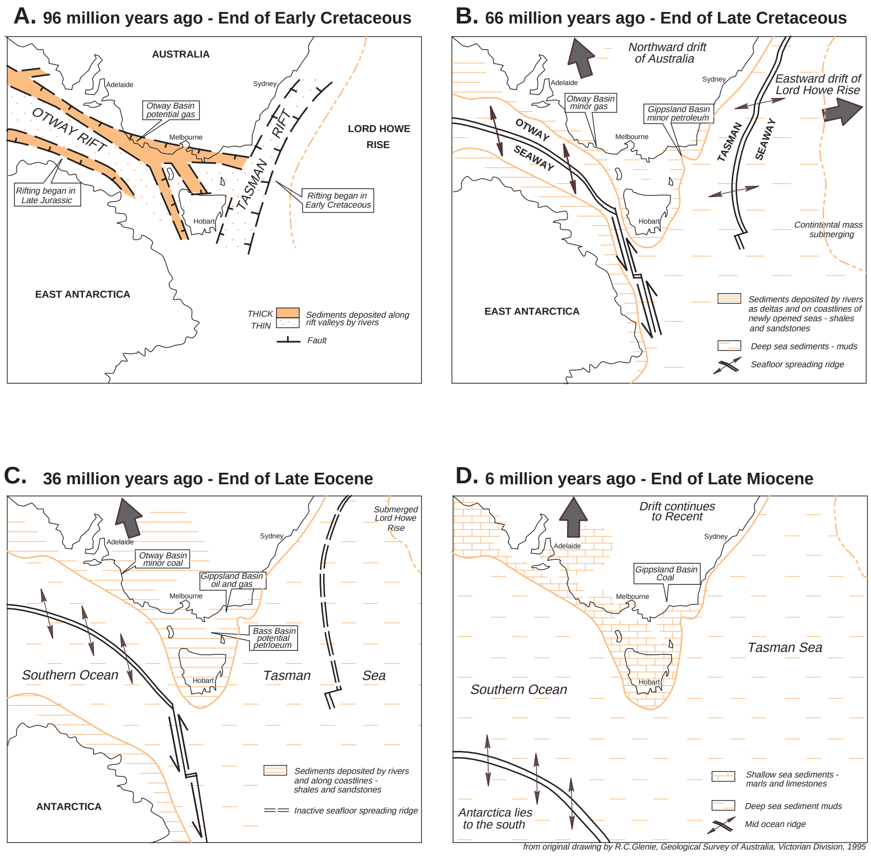


Figure 2

Plate tectonic evolution of the Gippsland Basin. (After Glenie, 1995).

a End of Early Cretaceous: Broad rift complex exists along the southern margin of mainland Australia.

b End of Late Cretaceous: The Southern Ocean has formed and breakup has occurred along the eastern margin of Australia with the Gippsland Basin left as a failed rift.

c End of Late Eocene: Continued separation between Australia and Antarctica. Deposition of marine sediments in the offshore region.

d End of Late Miocene: Coals deposited in the onshore Gippsland Basin.

present onshore. The Carrajung antiform (also known as the Balook Block) in the south Gippsland Hills is the most dominant feature. This antiform is a northeast-southwest structure, which is bounded to the SE and NW respectively by the Yarram and Budgeree faults (Fig. 3). The structural trend of the Carrajung feature continues northeast and then swings eastward as the Baragwanath Anticline.

2.3 Stratigraphic evolution

Extensive accounts of the geology of the basin can be found in Hocking (1976), James and Evans (1971), Douglas and Ferguson (1976; 1988), Blake (1980), Thompson (1986), Lowry (1987; 1988), Lowry and Longley (1991), Abele *et al.* (1988), Rahmanian *et al.* (1990), Featherstone *et al.* (1991), Partridge (1994), and Bernecker *et al.* (1997).

A generalised stratigraphy of the Gippsland onshore region is presented in Figure 4.

Strzelecki Group

The Strzelecki Group comprises the first sediments to have accumulated in the early stage of the Gippsland rift basin. It consists of at least 3000 m of interbedded non-marine greywackes, mudstones, sandstones, conglomerates, minor coals and volcanics deposited in lacustrine, swamp and floodplain environments. The Tyers Conglomerate was deposited as a wedge of Early Neocomian coarse clastics in an ENE-trending depocentre, and finer grained time equivalents were deposited on the Palaeozoic erosional surface of granites and metamorphic units. Overlying this Early Neocomian episode is the lithologically distinctive Wonthaggi Formation of the upper Strzelecki Group. Onshore wells Loy Yang 1A, Sunday Island 1 and Wellington Park 1 indicate this section to consist of interbedded volcano-lithic sandstones, siltstones and shale with minor coal units.

Golden Beach Group

The Golden Beach Group was deposited on the upper Strzelecki Group erosional surface, representating a major change from volcanogenic to a quartzose provenance. During this episode the central offshore part of the basin was subsiding rapidly (Rahmanian *et al.*, 1990) resulting in the preservation of a Golden Beach interval exceeding 600 m which extends into the onshore area of the Seaspray Depression (Chiupka, 1996). The presence of late Santonian-Campanian dinoflagellates and glauconite indicate marine incursions during the later stages of this depositional episode (Willcox *et al.*, 1992, Megallaa, 1993).

Borehole and seismic data indicate the Golden Beach Group to be truncated by early normal displacement of the Rosedale and Darriman Faults. The preserved stratigraphic section (Strzelecki and Golden Beach) appears to have been tilted to the ESE and partially eroded. Continued fault displacement caused the northern and southern Strzelecki Terraces to form as elevated features beyond these faults and preserved thick units of Golden Beach Group in the central part of the basin (Chiupka, 1996). Regionally, these events are considered to coincide with the opening of the Tasman Sea from about 80 Ma (Rahmanian *et al.*, 1990).

Latrobe Group

Overlying the Strzelecki Group onshore is the Latrobe Group, which, in the northwest region of the basin, has been divided into five formations. Immediately overlying the Strzelecki Group is a sandy sequence of limited distribution, of Eocence or Palaeocene age. Above this sandy unit lie the Thorpdale Volcanics which are mainly basaltic lavas of Eocene age. Overlying the Thorpdale Volcanics are the Traralgon and Morwell Formations of Oligo-Miocene age (Douglas & Ferguson, 1988). These formations are the local continuation of non-marine deposition in this area during marine sedimentation of the Seaspray Group in the eastern part. Towards the east (Seaspray Depression area), subdivision of the Latrobe Group has not as yet been published and it gradually becomes congruent to stratigraphy of the offshore area.

In the Seaspray Depression area of the basin, the Latrobe Group sediments consist of non-marine fine to very coarse-grained poorly cemented sandstones, siltstones, mudstones, coals and shales of Late Cretaceous to Oligocene age. The recognised facies within the Latrobe Group include fluvial, deltaic, coal swamp, littoral, lacustrine and shallow marine in the basin.

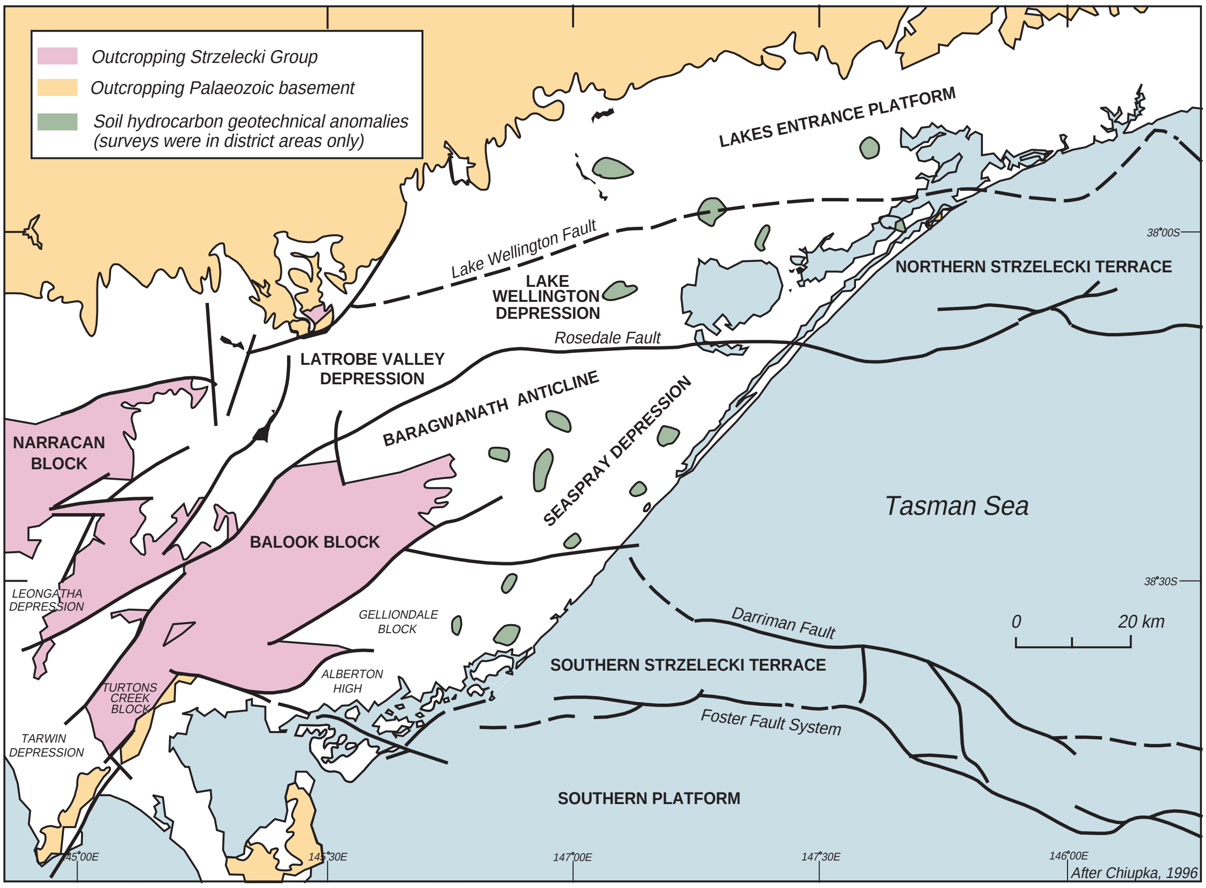


Figure 3
Map showing major faults and folds, onshore Gippsland Basin.

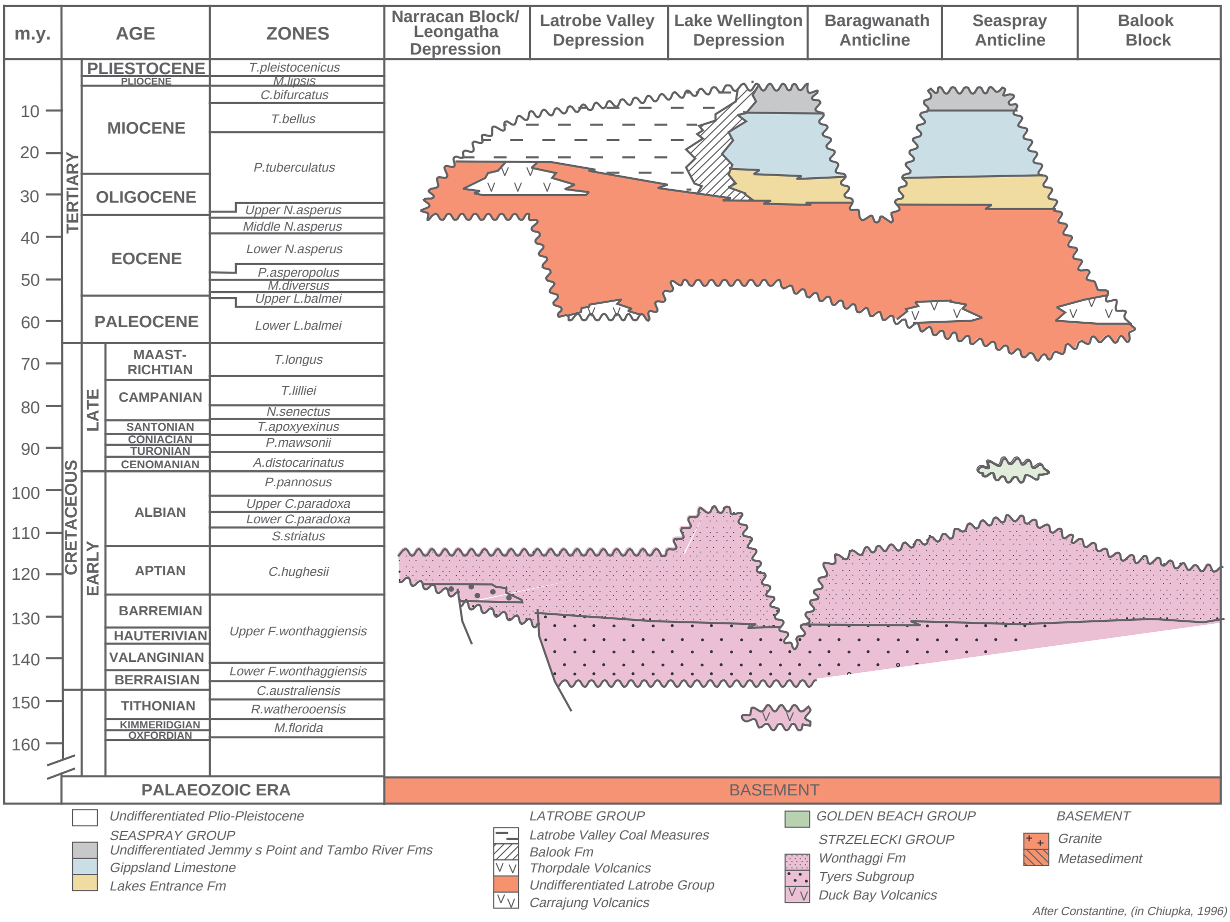


Figure 4
Generalised chronostratigraphic chart of the Gippsland Basin.

In the Latrobe Valley area, the Latrobe Group is a Palaeocene to Eocene sandy sequence. This sequence is of limited extent underlying the Eocene Thorpdale basaltic volcanics. The Thorpdale Formation is overlain by the continuation of non-marine sediments of the Traralgon/Balook Formations and Latrobe Valley Coal Measures Formation of Oligocene to Miocene age. Towards the east, the Latrobe Group is similar to the existing succession found offshore.

Seaspray Group

The Seaspray Group is a sequence of marine sediments overlying the Latrobe Group and covers the entire offshore area as well as most of the onshore area. The marine transgression commenced in the Early Oligocene and reached its maximum extension in the Early Miocene, before gradually retreating. This group has been divided into three formations as follows:

The **Lakes Entrance Formation** overlies the unconformity surface of the Latrobe Group and consists of a basal sand and gravel member, a glauconitic sandstone member, a micaceous marl member and an interbedded marl and limestone member. This formation is considered to be a regional seal for nearly all of the gas and oil fields in the offshore region.

The **Gippsland Limestone Formation** overlies the Lakes Entrance Formation and consists of marls and calcarenite which represent the period of maximum marine transgression in the Miocene. The maximum thickness of this formation is approximately 800 m in the offshore area.

The **Jemmy’s Point Formation** of Miocene to Early Pliocene consists of marls and marly limestone which are overlain by shoreline beach sands, marls and claystone.

Sale Group

The Sale Group consists of Late Pliocene age non-marine sands and clays.

3 Depositional framework

3.1 Jurassic–Early Cretaceous

Deposition in the Gippsland Basin commenced in the Jurassic, laying non-marine sediments in a rapidly subsiding fluvial plain.

The depositional environment remained unchanged during the Lower Cretaceous when over 3000 m of Strzelecki Group sediments accumulated in the onshore Gippsland Basin.

Tectonic activity in the Middle Cretaceous deformed these sediments and after a period of erosion, deposition of younger sediments occurred, progressively onlapping in a westerly direction over the Mid Cretaceous unconformity surface.

3.2 Late Cretaceous–Oligocene

During the Late Cretaceous to Oligocene, the Gippsland Basin is generally considered to be a depositional basin receiving various non-marine sediments.

In the offshore area, the presence of local shallow marine sediments, particularly in the southeast part of the basin, indicates periodic marine incursion into the basin due either to eustasy or rapid subsidence. In general, the sediments of this time interval are the Latrobe Group and in terms of environmental origin, they consist of six distinct depositional facies within the entire Gippsland Basin. These facies are:

- Fluvial
- Deltaic
- Coaly Swamp
- Littoral
- Lacustrine
- Shallow Marine

In the onshore area, generally only three of the six facies are present. These facies are: Fluvial, Coaly Swamp and Lacustrine. The geographical distribution of these facies in the successive geological time units within the Latrobe Group sediments of the onshore area are as follows:

Late Cretaceous

This time unit consists of calcareous shales, silts, minor coals and poorly sorted sandstones, probably of lacustrine origin. The sediments of this unit onlap the unconformity surface on the Strzelecki Group towards the west. This unit is generally named the Golden Beach Group. The onshore distribution of this unit is limited to the axis of the basin in the vicinity of the coastline.

Paleocene

Deposition of non-marine sediments continued during Paleocene time covering progressively more areas towards the west. However, the main portion of the onshore area still remained beyond the depositional site at this time. The sediments of this time unit in the present onshore area consist of fluvial deposits, as braided streams and point bar sands, with some carbonaceous shales and coals.

Eocene

In the Eocene, the aggradational depositional environment extended further west and fluvial sediments in the form of alluvial fans, braided streams and point bar sands were deposited over the entire onshore area. These sediments in the western margin of the basin are locally called the Childers Formation and they often directly overlie the Strzelecki Group (Douglas & Ferguson, 1988).

In the Mid–Eocene, major volcanic activity spread lava flows of mainly basaltic origin over an extensive area along the western margin of the basin. The volcanic activity seems to have been accompanied by some tectonic uplift in this area causing an eastward depositional regression in the western margin of the basin. The uplifted areas remained beyond the depositional environment until the Pliocene time, when they were partially covered by non-marine sediments of the Sale Group. In the meantime, a local trough was formed in the Latrobe Valley area providing a suitable coal forming environment which remained unchanged until Late Miocene time.

The westward marine transgression in Oligo-Miocene time did not reach into this trough until the Late Miocene, when the eastern part of this trough was partially invaded by marine incursion. Sands and clays of the Jemmy's Point Formation were laid down at this time. Elsewhere onshore, the deposition of fluvial sands, gravel, clays and coals continued during the Mid-Late Eocene period. After a short period of non-deposition and erosion, marine transgression from the southeast gradually covered the main part of the onshore area.

3.3 Oligo-Miocene

During Oligo-Miocene times, a marine environment gradually prevailed in the main part of the basin and successive sediments of Lakes Entrance, Gippsland Limestone and Jemmy's Point Formations of the Seaspray Group were laid down. In the Latrobe Valley Trough, non-marine depositional conditions continued and thick coal seams were deposited.

3.4 Pliocene-Recent

By the end of Miocene time, the predominant marine environment began to retreat gradually and non-marine fluvial Sale Group sediments unconformably overlie the older sediments of various ages. This type of deposition continues to the present time.

4 Analytical results

Analyses were performed at the request of Department of Natural Resources and Environment (DNRE) on samples selected from eight exploration wells in the onshore Gippsland Basin. The analytical work was carried out by Geotechnical Services Pty Ltd (Geotech) in Perth, Western Australia. The eight wells sampled were:

- Burong 1
- Dutson Downs 1
- East Reeve 1
- Golden Beach West 1
- Merriman 1
- North Seaspray 1
- Rosedale 1
- Woodside 1

In addition data from the Loy Yang 1A well was included in the study (Capital Energy, 1995).

A further well, Wellington Park 1, was included in the study with burial history modelling (see Section 5).

Samples in the DNRE study were taken where gamma-ray, sonic, resistivity and density logs indicate probable organic concentrations in shales of the Latrobe, Golden Beach and Strzelecki Groups. Organic-richness, quality, type and maturity were determined by petrological and pyrolysis techniques. The results are presented in Table 1. Biomarker (Py-GC, GC-MS) and kinetic analyses (Geotech, 1997a, b) were carried out on individual samples from 5 of the 8 wells. These data enable trends to be established across the onshore region for each of the attributes, such as richness and maturity.

Source rock

The large hydrocarbon accumulations in the offshore Gippsland Basin can be explained largely by generation from within the Latrobe Group sediments, especially from within the mature sediments of coal swamp and lacustrine origin (Moore *et al*., 1992). Geochemical analysis indicates that:

1) The offshore gas province generally follows the extent of non-marine coal swamp sediment sequences of the Early to Late Eocene.

2) Onshore, equivalent source rocks, namely thick Late Eocene coal seams are present and therefore, there may be an extension of the gas province onshore within the western limit of the basin.

3) The oil in the offshore area is believed to have been generated from oil-prone mature Early Cretaceous coals and shales of lacustrine origin. In addition, some of the oil may have been generated from organic-rich marine sediments deposited during periods of marine incursion.

Organic richness

Only one value for total organic carbon (TOC) (0.51%) was measured in the Seaspray Group. Latrobe Group TOC values range from 0.2% to over 10%, while the Golden Beach Group values range from 0.25% to 10.58%. Strzelecki Group TOC values range from 0.21% to 26.83% within the coaly section (Table 2). The distribution of TOC in the Latrobe, Golden Beach and Strzelecki Groups based on these limited analytical results is displayed in Figures 5a, b, and c.

Maturity

Estimates of source rock maturity have been made using both geochemical and vitrinite reflectance analyses. The vitrinite maturity of the onshore Seaspray Group sample is 0.33%, indicating immaturity. The maturity of the Latrobe Group samples ranges from 0.31% to 0.51%, while the Golden Beach Group samples maturity ranges from 0.42% to 0.61%. The Strzelecki Group samples show maturity ranges from 0.35% to 1.04% (Table 3). In general, maturity increases with depth and average maturity for Latrobe, Golden Beach and Strzelecki Groups is displayed in Figures 6a, b, and c.

Kerogen type

The average hydrogen index (HI) value for the selected samples from the Seaspray Group is 145.

The Latrobe Group HI values range from 63 to 471. These values indicate a possible wide variety of organic facies kerogen types. The source quality varies from poor to very good the latter due to less oxidised conditions.

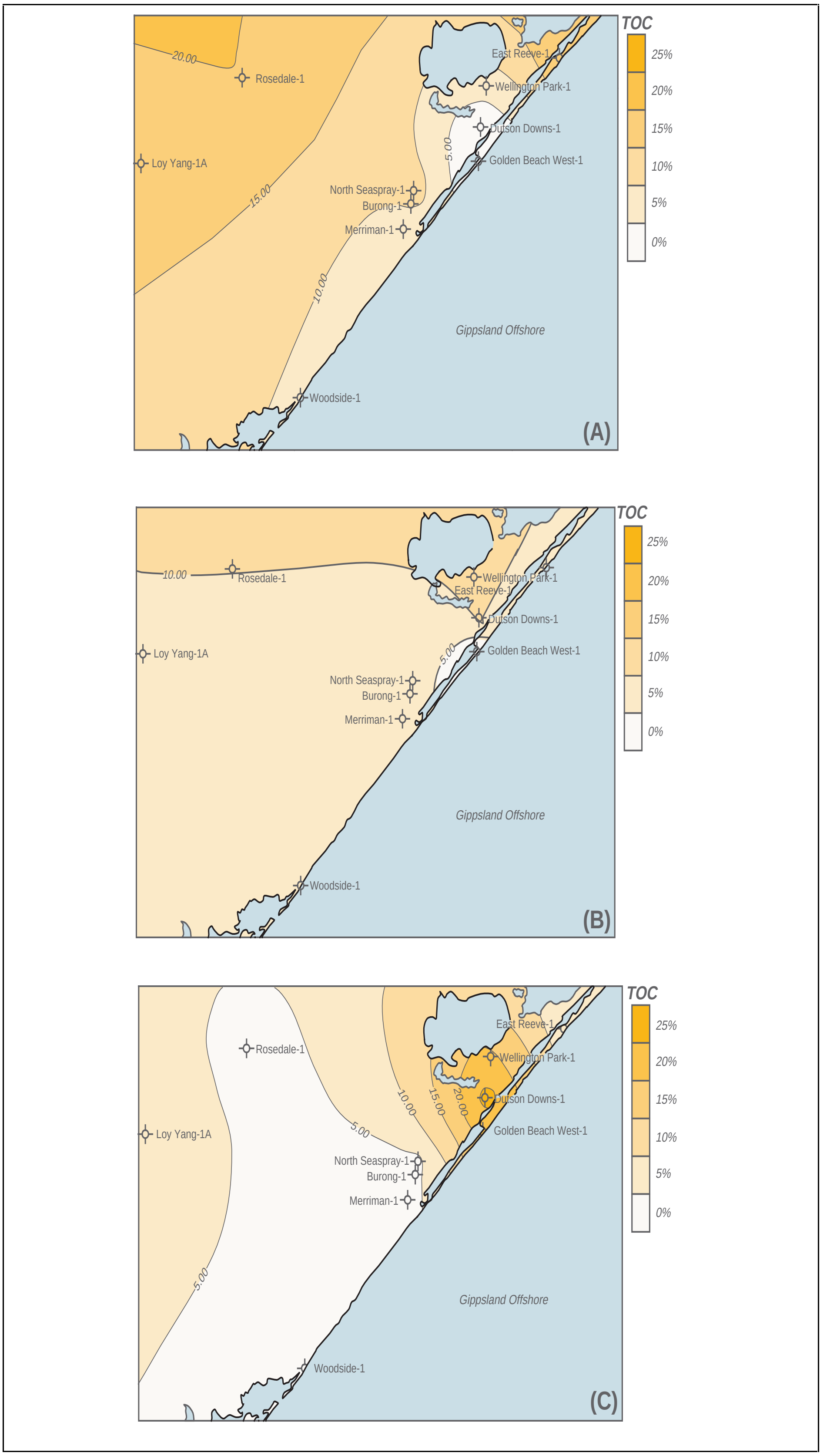


Figure 5

Richness or Total Organic Carbon values (TOC%).

a Latrobe Group

b Golden Beach Group

c Strzelecki Group

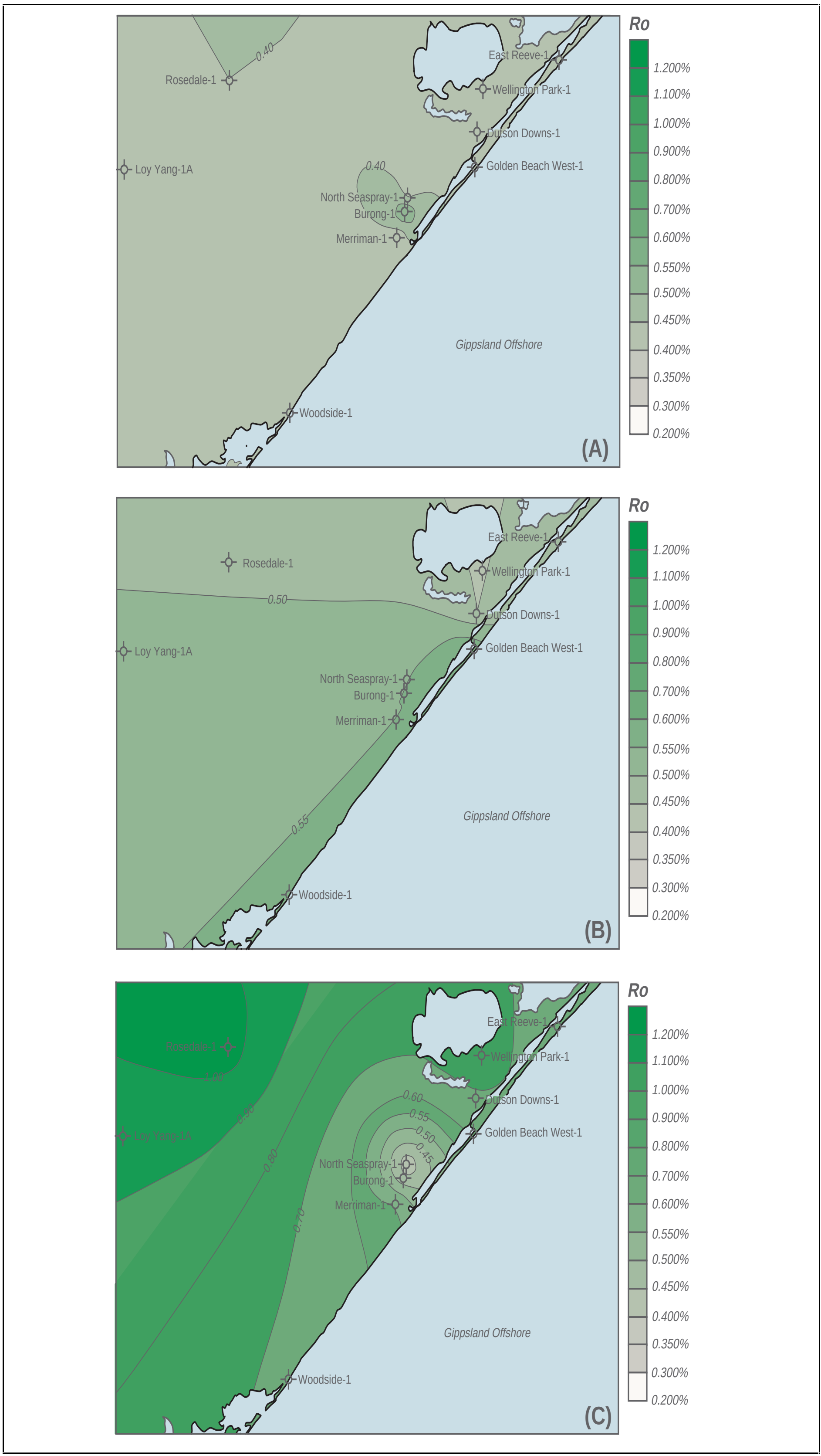


Figure 6
Maturity of the source rocks (Ro%).
a Latrobe Group
b Golden Beach Group
c Strzelecki Group

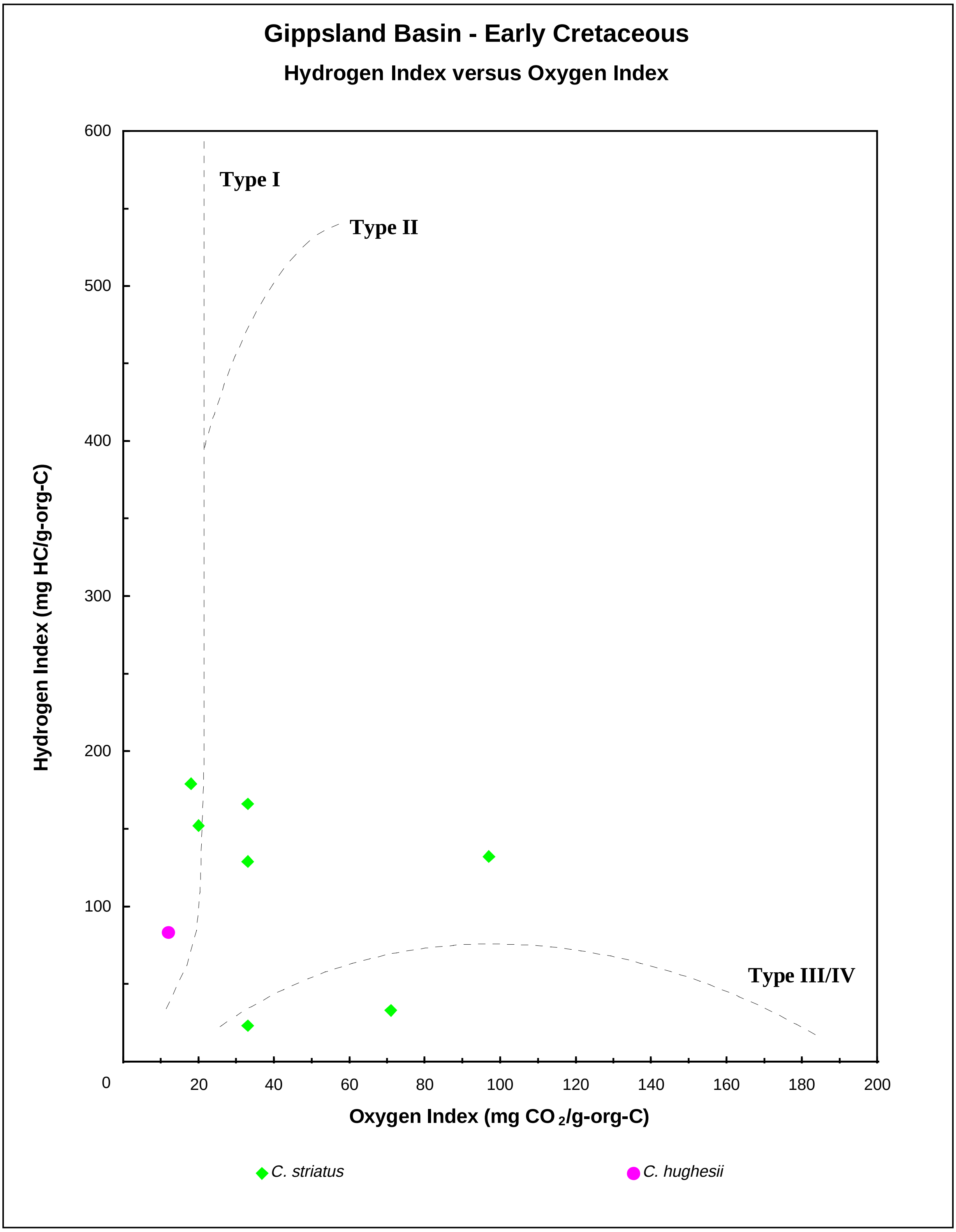


Figure 7a
The plot of hydrogen index versus oxygen index, Early Cretaceous, onshore Gippsland Basin.

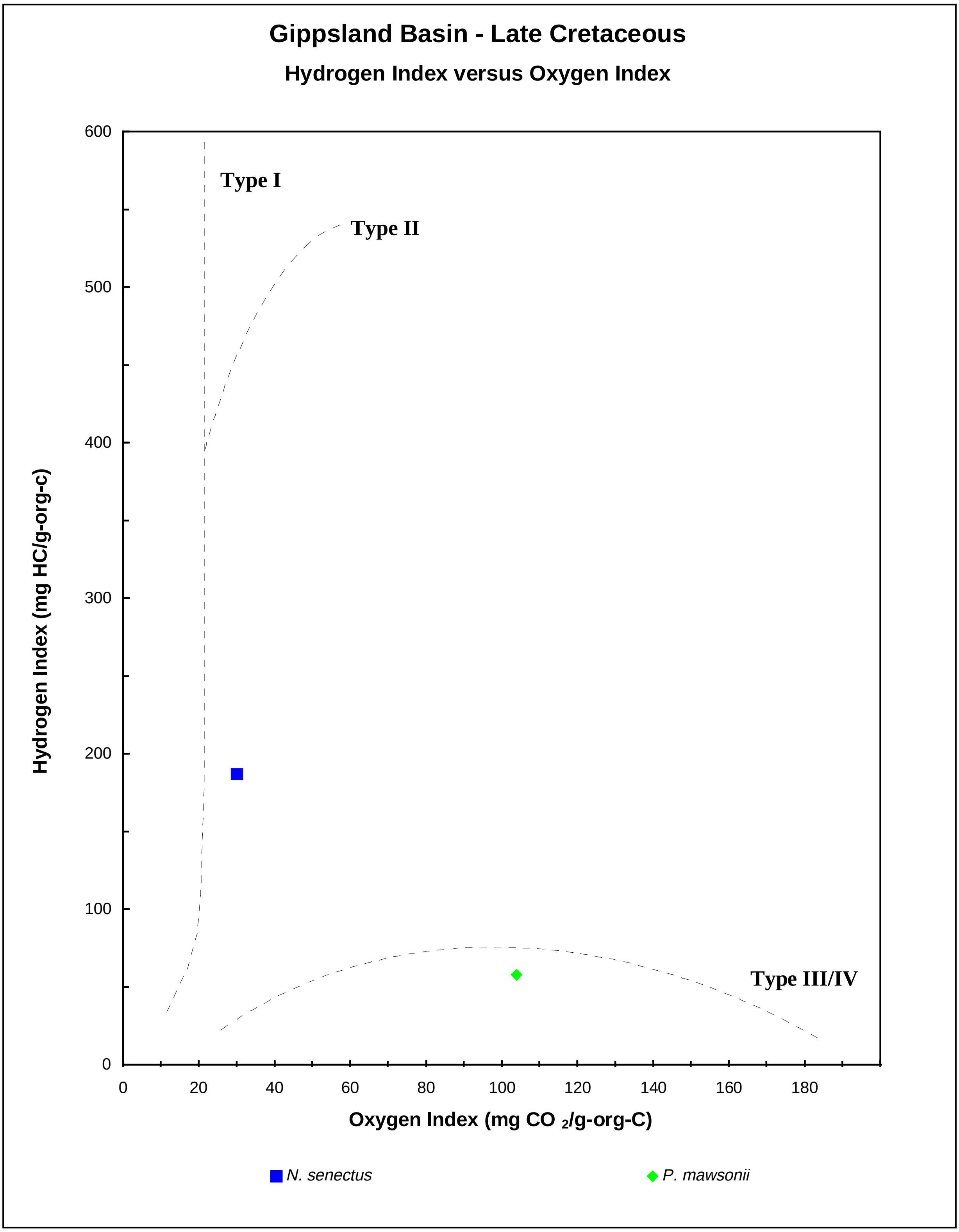


Figure 7b
The plot of hydrogen index versus oxygen index, Late Cretaceous, onshore Gippsland Basin.

Table 1 Rock-Eval pyrolysis, onshore Gippsland Basin

Well	Depth (mKB)	Spore-Pollen Zone	T max °C	S1 kg/tne	S2 kg/tne	S3 kg/tne	Generative Potential (S1 + S2)	S2/S3	PI	PC	TOC %	HI	OI
Burong 1	866	*N. asperus*	411	1.73	23.09	2.87	24.82	8.05	0.07	2.06	10.77	214	27
	1151		424	0.72	11.73	0.95	12.45	12.35	0.06	1.03	4.05	290	23
	1222	*L. balmei*	438	0.13	0.29	0.25	0.42	1.16	0.31	0.03	0.46	63	54
Dutson Downs 1	1295	*L. balmei*	427	0.15	1.64	0.24	1.79	6.83	0.08	0.15	0.99	169	25
	1499	*N. senectus*	424	0.92	19.78	3.17	20.70	6.24	0.04	1.72	10.58	187	30
	1810	*C. striatus*	425	1.90	34.71	8.92	36.61	3.89	0.05	3.04	26.83	129	33
East Reeve 1	1195	*P. tuberculatus*	423	0.09	0.21	2.16	0.30	0.10	0.30	0.02	0.26	81	831
	1323	*N. asperus*	423	1.83	48.79	4.75	50.62	10.27	0.04	4.20	18.92	258	25
	1500	*C. paradoxa*	428	0.22	3.82	1.00	4.04	3.82	0.05	0.34	2.76	138	36
	1585	*C. striatus*	425	0.19	3.49	0.66	3.68	5.29	0.05	0.31	2.3	152	20
	1600	*C. striatus*	430	0.46	11.43	1.14	11.89	10.03	0.04	0.99	6.39	179	18
Golden Beach West 1	978	*N. asperus*		0.17	0.17	0.26	0.34	0.65	0.50	0.03	0.2	85	130
	1777	*N. senectus*		0.90	0.19	0.90	1.09	0.21	0.83	0.09	0.25	76	360
	2210	*P. mawsonii*	434	0.32	0.88	2.51	1.20	0.35	0.27	0.10	1.16	76	216
Loy Yang 1A	1066	*P. notensis*	451	6.26	181.21	1.81	187.47	100.12	0.03	15.56	78.96	229	2
	1099		446	0.83	3.94	0.98	4.77	4.02	0.17	0.40	2.63	150	37
	1126		449	2.03	18.14	1.34	20.17	13.54	0.10	1.67	10.46	173	13
	1240		451	0.24	1.46	1.02	1.70	1.43	0.14	0.14	0.94	155	109
	1306		451	0.18	0.95	0.94	1.13	1.01	0.16	0.09	0.94	101	100
	1378	*P. notensis*	464	0.18	0.90	0.85	1.08	1.06	0.17	0.09	1.16	78	73
	1450		459	0.20	0.90	1.02	1.10	0.88	0.18	0.09	0.75	120	136
	1717		460	0.08	1.37	1.02	1.45	1.34	0.06	0.12	0.56	245	182
Merriman 1	982	*N. asperus*	407	0.79	8.79	2.60	9.58	3.38	0.08	0.80	6.24	141	42
	1481		427	0.79	15.03	1.91	15.82	7.87	0.05	1.31	7.43	202	26
	1722	*P. mawsonii*	436	0.27	1.31	2.32	1.58	0.56	0.17	0.13	2.24	58	104
North Seaspray 1	655	*N. asperus*	407	1.42	14.06	6.29	15.48	2.24	0.09	1.28	12.25	115	51
	979	*L. balmei*	429	0.88	27.99	1.27	28.87	22.04	0.03	2.40	5.94	471	21
	1147	*C. striatus*	420	0.33	6.85	1.35	7.18	5.07	0.05	0.60	4.12	166	33
	1499	*C. striatus*	425	0.14	1.48	1.09	1.62	1.36	0.09	0.13	1.12	132	97
Rosedale 1	438	*P. tuberculatus*	420	4.51	41.13	10.63	45.64	3.85	0.10	3.79	19.91	207	54
	1478	*P. notensis*	456	0.42	2.28	0.33	2.70	6.91	0.16	0.22	2.74	83	12
Woodside 1	678	*T. bellus*	414	0.10	0.33	1.35	0.43	0.24	0.23	0.04	0.51	65	265
	1234	*C. striatus*	433	0.08	0.58	0.68	0.66	0.85	0.12	0.05	0.74	78	92
	1636	*C. striatus*		0.04	0.09	0.13	0.13	0.69	0.31	0.01	0.39	23	33
	1758	*C. striatus*		0.04	0.07	0.15	0.11	0.47	0.36	0.01	0.21	33	71

Table 2 Depth of TOC%, Onshore Gippsland Basin

Well	Stratigraphic Unit	Interval (mKB)	Spore-Pollen	Depth of Sample (mKB)	Tmax°C	HI	OI	TOC%
Burong 1	Latrobe Group	655-1251	*N. asperus*	866	411	214	27	10.77
	Latrobe Group	" "		1151	424	290	23	4.05
	Latrobe Group	" "	*L. balmei*	1222	438	63	54	0.46
Dutson Downs 1	Latrobe Group	708-1440	*L. balmei*	1295	427	169	25	0.99
	Golden Beach Group	1440-1781	*N. senectus*	1499	424	187	30	10.58
	Strzelecki Group	1781-1862	*C. striatus*	1810	425	129	33	26.83
East Reeve 1	Latrobe Group	1182-1440	*P. tuberculatus*	1195	423	81	831	0.26
	Latrobe Group	" "	*N. asperus*	1323	423	258	25	18.92
	Strzelecki Group	1440-1622	*C. paradoxa*	1500	428	138	36	2.76
	Strzelecki Group	" "	*C. striatus*	1585	425	152	20	2.30
	Strzelecki Group	" "	*C. striatus*	1600	430	179	18	6.39
Golden Beach West 1	Latrobe Group	706-1702	*N. asperus*	978		85	130	0.20
	Golden Beach Group	1702-2290	*N. senectus*	1777		76	360	0.25
	Golden Beach Group	" "	*P. mawsonii*	2210	434	76	216	1.16
Merriman 1	Latrobe Group	697-1425	*N. asperus*	982	407	141	42	6.24
	Golden Beach Group	1425-1830		1481	427	202	26	7.43
	Golden Beach Group	" "	*P. mawsonii*	1722	436	58	104	2.24
North Seaspray 1	Latrobe Group	586-1104	*N. asperus*	655	407	115	51	12.25
	Latrobe Group	" "	*L. balmei*	979	429	471	21	5.94
	Strzelecki Group	1104-1524	*C. striatus*	1147	420	166	33	4.12
	Strzelecki Group	" "	*C. striatus*	1500	425	132	97	1.12
Rosedale 1	Latrobe Group	52-715	*P. tuberculatus*	438	420	207	54	19.91
	Strzelecki Group	715-1779	*P. notensis*	1478	456	83	12	2.74
Woodside 1	Seaspray Group	308-710	*T. bellus*	678	414	65	265	0.51
	Strzelecki Group	1000-1780	*C. striatus*	1234	433	78	92	0.74
	Strzelecki Group	" "	*C. striatus*	1636		23	33	0.39
	Strzelecki Group	" "	*C. striatus*	1758		33	71	0.21

Table 3 Depth of Ro %, Onshore Gippsland Basin

Well	Formation		Zone		Depth of Sample (mKB)	Ro %
	Stratigraphic Unit	Interval (mKB)	Spore-Pollen	Microplankton		
Burong 1	Lakes Entrance	552-655	*P. tuberculatus*	*Operculodinium*	644	
	Latrobe Group	655-1251	*N. asperus*		866	0.34
	Latrobe Group	" "			1151	0.38
	Latrobe Group	" "	*L. balmei*		1222	0.51
Dutson Downs 1	Latrobe Group	708-1440	*L. balmei*		1295	0.49
	Golden Beach Group	1440-1781	*N. senectus*		1499	0.49
	Strzelecki Group	1781-1862	*C. striatus*		1810	0.58
East Reeve 1	Latrobe Group	1182-1440	*P. tuberculatus*	*Operculodinium*	1195	0.34
	Latrobe Group	" "	*N. asperus*		1323	0.38
	Latrobe Group	" "	*N. asperus*		1396	
	Latrobe Group	" "	*N. asperus*		1408	
	Strzelecki Group	1440-1622	*C. paradoxa*		1500	0.50
	Strzelecki Group	" "	*C. striatus*		1509	
	Strzelecki Group	" "	*C. striatus*		1585	0.56
	Strzelecki Group	" "	*C. striatus*		1600	0.54
Golden Beach West 1	Latrobe Group	706-1702	*N. asperus*		978	0.38
	Latrobe Group	" "			1225	
	Golden Beach Group	1702-2290	*N. senectus*		1777	0.42
	Golden Beach Group	" "	*P. mawsonii*		2210	0.61
Merriman 1	Latrobe Group	697-1425	*N. asperus*	*G. extensa*	982	0.37
	Golden Beach Group	1425-1830			1481	0.42
	Golden Beach Group	" "	*P. mawsonii*	*Rimosicysta*	1722	0.55
North Seaspray 1	Latrobe Group	586-1104	*N. asperus*	*G. extensa*	655	0.33
	Latrobe Group	" "	*L. balmei*		979	0.39
	Strzelecki Group	1104-1524	*C. striatus*		1147	0.36
	Strzelecki Group	" "	*C. striatus*		1500	0.35
Rosedale 1	Latrobe Group	52-715	*P. tuberculatus*	*Operculodinium*	438	0.31
	Strzelecki Group	715-1779	*C. hughesi*		1478	1.04
Woodside 1	Seaspray Group	308-710	*T. bellus*	*Operculodinium*	678	0.33
	Strzelecki Group	1000-1780	*C. striatus*		1234	0.46
	Strzelecki Group	" "	*C. striatus*		1636	0.67
	Strzelecki Group	" "	*C. striatus*		1758	0.54

The Golden Beach Group HI values range from 58 to 202 and the Strzelecki Group HI values range from 23 to 179. The source rocks are therefore likely to generate mainly gas, although some minor oil generative potential is possible for type II/III macerals.

The plots of hydrogen index versus oxygen index for Early and Late Cretaceous are displayed in Figures 7a, and b. The plot of hydrogen index versus Tmax°C indicates that most of the samples analysed from the onshore wells are marginally mature. The exceptions are Loy Yang 1A and Rosedale 1, which show maturity of organic rich shale at these well locations (Fig. 8).

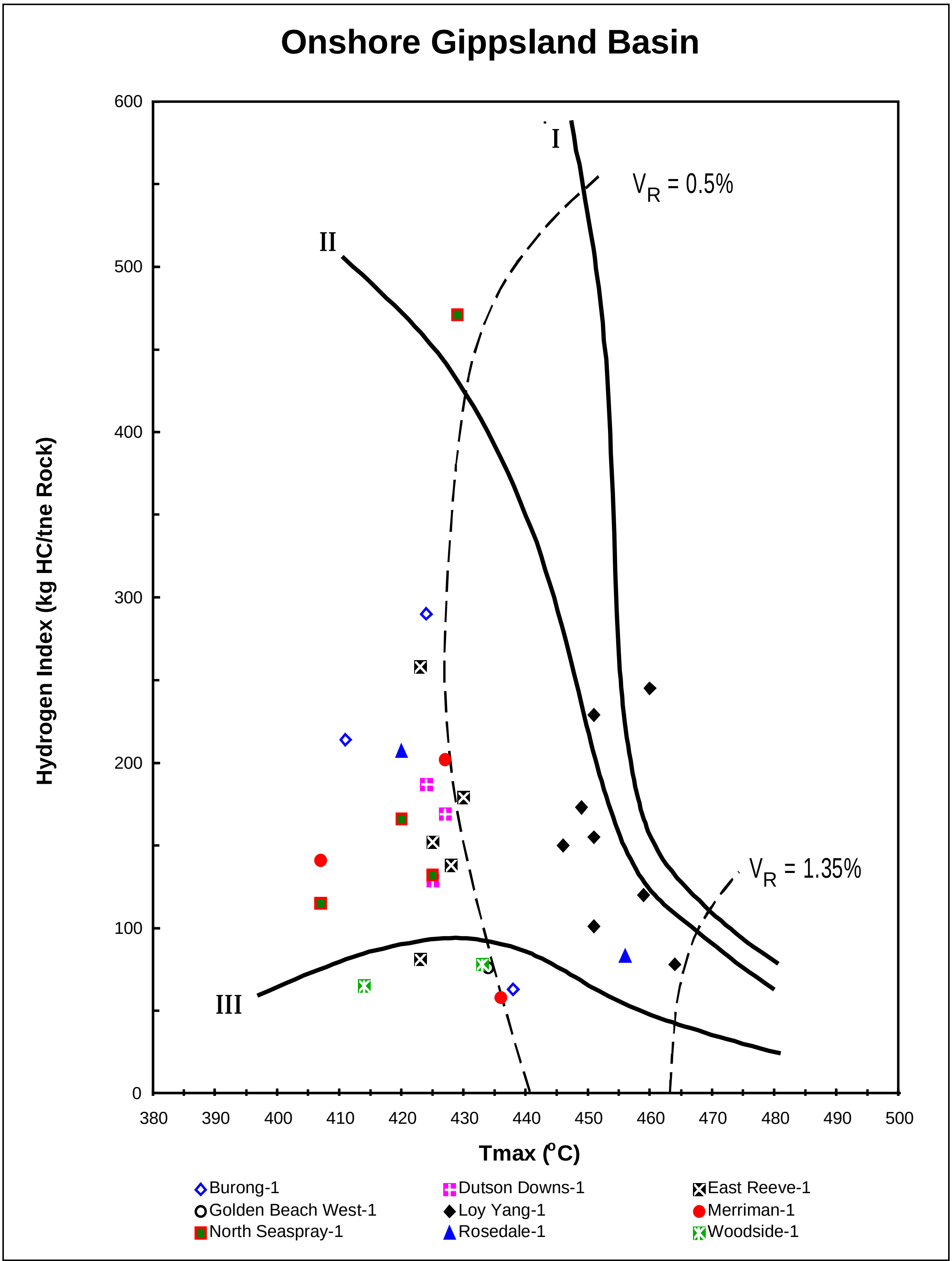


Figure 8

The plot of hydrogen index versus Tmax °C, onshore Gippsland Basin.

5 Thermal modelling

Data from the pre-Tertiary shaly rocks of 10 onshore wells plus overburden thickness were needed to provide an insight into the timing of heatflow pulses in the crust. We used WinBury V $^{2.1}$ software, a burial and thermal geohistory software package for Windows™, to model the palaeothermal parameters.

The present day heatflow was calculated from:

(i) surface temperature,

(ii) thermal conductivities derived from lithology, and

(iii) geothermal gradient maps that were constructed from bottom-hole temperature data.

Higher heatflow values existed prior to the mid-Cretaceous slow-drift phase of the Bassian Rift System. Heatflow declined later as a result of margin drift (McKenzie, 1978). There is a general decline in heatflow through the Late Cretaceous and Tertiary with the maximum heatflow through the crust at approximately 115 to 90 Ma (Fig. 9).

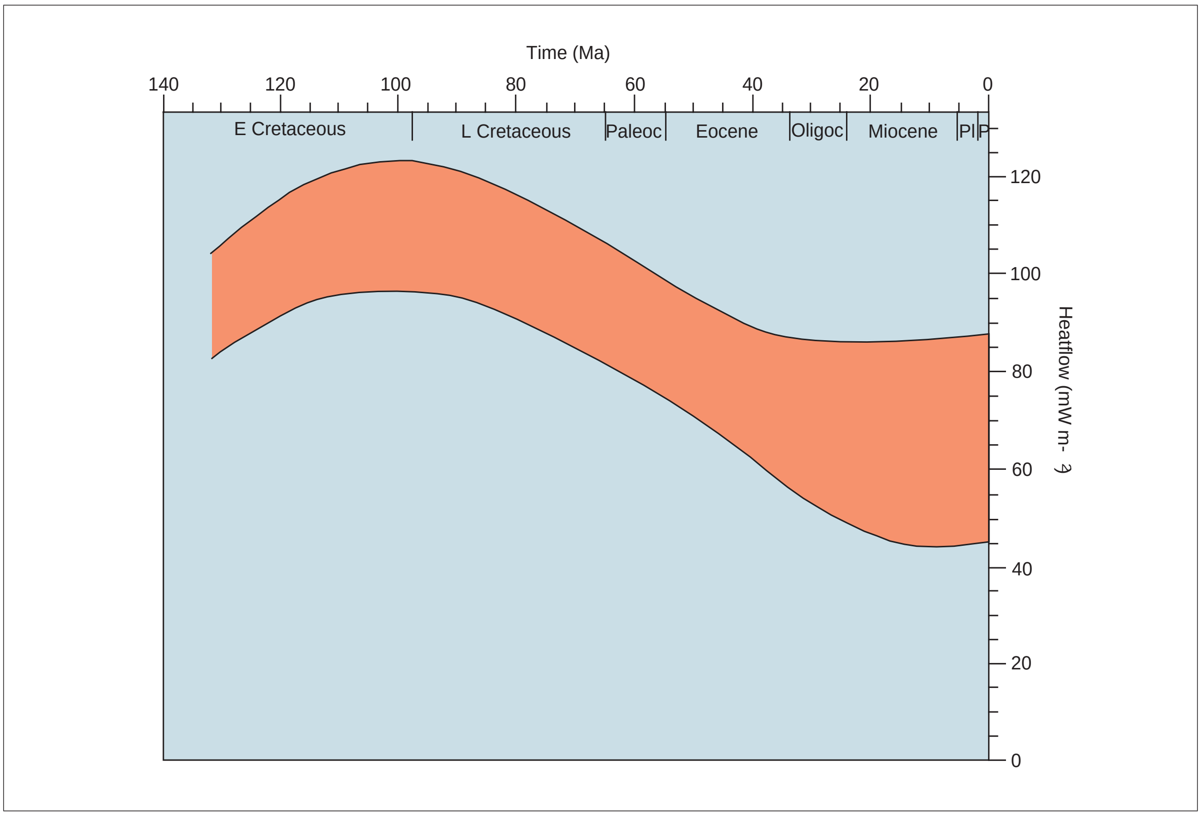


Figure 9
Heatflow versus time plot used in modelling.

6 Generation and expulsion of Oil and Gas

The peak times for the generation and expulsion of hydrocarbons for each well were obtained with the use of WinBury V$^{2.1}$ software.

Volumetric information was also gleaned from the graphical presentations (Appendix 1). In general, there was only one distinct period of hydrocarbon expulsion, but in some places (such as Golden Beach West 1 and Wellington Park 1) there were two. The first event occurred between 115 and 95 Ma and the second event occurred between 80 and 40 Ma. The modelling at Wellington Park 1 shows that expulsion continued after 40 Ma and is probably still in progress (Fig. 37).

7 Conclusions

This source rock study of the Early/Late Cretaceous sediments revealed that:

- Excellent source rocks exist where vitrinitic and liptinitic-rich organic shales of Early Cretaceous age underlie approximately 2000 m of Late Cretaceous to Tertiary rocks in the Seaspray Depression.

- Early Cretaceous onshore rocks are organically-richer than those of Late Cretaceous age.

- Characteristics of free hydrocarbons, based on the saturate GC data for the five extracts analysed, indicates:

  * Bimodal n-alkane profile, suggesting dual source input.

  * Strong odd-even predominance in the high molecule weight range, indicating significant terrestrial origin and/or immaturity.

  * Moderate pristane/phytane ratios (3.27-4.79), signifying oxic depositional environments.

- Burial history and geochemical modelling studies suggest that the Early Cretaceous (Strzelecki Group) rather than the Late Cretaceous (Latrobe Group) organic-rich shales have been the main source for the known oil and gas shows [similar to the Early Cretaceous source rock of the Otway Basin (Aptian/Albian age, *P. notensis* time zone), Mehin and Link 1996, 1997].

- The main period of oil generation and expulsion across the onshore region occurred at 115-95 Ma. In the northern region (Wellington Park 1) oil has been expelled since 40 Ma.

- In some parts of the onshore area where marginally mature to mature source rocks from the Early and Late Cretaceous exist, generation and expulsion can be demonstrated. Local tectonic events however may have had a negative effect on preservation.

References and Bibliography

ABELE, C., GLOE, C.S., HOCKING, J.B., HOLDGATE, G., KENLEY, P.R., LAWRENCE, C.R., RIPPER, D., THRELFALL, W.F. & BOLGER, P.F., 1988. Chapter 8. Tertiary. In: *Geology of Victoria,* J.G. Douglas & J.A. Ferguson, eds. Victorian Division Geological Society of Australia Inc., Melbourne, pp. 251-350.

BERNECKER, T., PARTRIDGE, A.D. & WEBB, J.A., 1997. Mid–Late Tertiary Deep–Water Temperate Carbonate Deposition, Offshore Gippsland Basin, Southeastern Australia. In: SEPM Special Publication No. 56, pp. 221-236.

BLAKE, W.J.R., 1980. Geology and hydrology of the Early Tertiary sediments of the Otway Basin. M.Sc. thesis, La Trobe University.

BOEUF, N.G. & DOUST, H., 1975. Structure and development of the southern margin of Australia. *Australian Petroleum Exploration Association Journal Volume* **15 (1)**, pp. 45-54.

BOUTAKOFF, N., 1964. Lakes Entrance Oil and continental shelf. *Australian Petroleum Exploration Association Journal Volume* **4**, pp. 99-110.

CANDE, S.C. & MUTTER, J.C., 1982. A revised identification of the oldest sea-floor spreading anomalies between Australia and Antarctica. *Earth Planetary Science Letters* **58**, pp. 151-160.

CAPITAL ENERGY N.L., 1995. Hydrocarbon Characterisation Study Loy Yang 1A Geotech report, March 1995, (Unpubl.)

CAREY, S.W., 1970. Australia, New Guinea and Melanesia in the current revolution in concepts of the evolution of the Earth. *Search* **1**, pp. 178-189.

CHIUPKA, J. W., MEGALLAA, M., JONASSON, K.E. & FRANKEL, E., 1997. Hydrocarbon Play Fairways of four Vacant Offshore Gippsland Basin Areas, Victoria, Acreage Release, 1997. *Victorian Initiative for Mineral and Petroleum Report* **42**. Department of Natural Resources and Environment.

CHIUPKA, J.W., 1996. Hydrocarbon Play Fairways of the Onshore Gippsland Basin, Victoria. *Victorian Initiative for Mineral and Petroleum Report* **30**. Department of Natural Resources and Environment.

COOK, A.C., 1981. Organic Petrology of a Suite of Samples from the Neocomian of the Gippsland Basin. Report prepared for Victor Petroleum and Resources Ltd., (Unpubl.)

DAVIDSON, J.K., 1977. The Tectonic Evolution of south-eastern Australia and its influence in hydrocarbon occurrences. *Abstract, The Carey Symposium - Tasmania.*

DEIGHTON, I., FALVEY, D.A. & TAYLOR, D.J., 1976. Depositional environments and geotectonic framework: southern Australia continental margin. *Australian Petroleum Exploration Association Journal Volume* **16 (1)**, pp. 25-36.

DOUGLAS, J.G. & FERGUSON, J.A., 1976. Geology of Victoria. *Geological Society of Australia, Victorian Division, Melbourne.*

DOUGLAS, J.G. & FERGUSON, J.A., 1988. Geology of Victoria. *Geological Society of Australia, Victorian Division, Melbourne.*

DUDDY, I.R. & GREEN, P.F., 1992. Tectonic development of the Gippsland Basin and Environs: Identification of key episodes using Apatite Fission Track Analysis (AFTA). *Gippsland Basin Symposium, Melbourne,* 22-23 June, pp. 111-120.

DUDDY, I.R., 1997. Focussing Exploration in the Otway Basin. *Australian Petroleum Exploration Association Journal Volume* **37 (1)**, pp. 178-191.

ETHERIDGE, M.A., BRANSON, J.C. & STUART-SMITH, P.G., 1985. Extensional basin-forming structures in Bass Strait and their importance for hydrocarbon exploration. *Australian Petroleum Exploration Association Journal Volume* **25 (1),** pp. 344-361.

FALVEY, D.A. & MUTTER, J.C., 1981. Regional plate tectonics and the evolution of Australia's passive continental margins. *Bureau of Mineral Resources Journal Australian Geology Geophysics* **6 (1)**, pp. 1-29.

FEATHERSTONE, P., AIGNER, T., BROWN, L. & KING, M., 1991. Stratigraphic modelling of the Gippsland Basin. *Australian Petroleum Exploration Association Journal Volume* **31 (1)**, pp. 105-114.

GEOTECH, 1997a. Hydrocarbon Characterisation Study - Gippsland Basin wells. Report prepared for Energy and Minerals Victoria by Geotechnical Services Pty Ltd., April 1997, (Unpubl.)

GEOTECH, 1997b. Source Rock Kinetics Analysis - Gippsland. Report prepared for Energy and Minerals Victoria by Geotechnical Services Pty Ltd., April 1997, (Unpubl.)

GLENIE, R.C., 1995. Introducing Victorian Geology. *Geological Society Australia (Victorian Division)* pp. 142-168.

HASKELL, T.R., 1972. Hydrocarbon Potential of the Mesozoic and basal Tertiary of the Gippsland Basins: A stratigraphic analysis. *Australian Petroleum Exploration Association Journal Volume* **12 (1)**, pp. 138-143.

HILL, K.A., FINLAYSON, D.M., HILL, K.C. & COOPER, G.T., 1995. Mesozoic tectonics of the Otway Basin region: the legacy of Gondwana and the active Pacific Margin—a review and on-going research. *Australian Petroleum Exploration Association Journal,Volume* **35 (1)**, pp. 467-493.

HOCKING, J. B., 1972. Geological Evolution and Hydrocarbon Habitat, Gippsland Basin. *Australian Petroleum Exploration Association Journal Volume* **12 (1)**, pp. 132-137.

HOCKING, J.B., 1976. Definition and revision of Tertiary stratigraphic units, onshore Gippsland Basin. *Department of Minerals and Energy Geological Survey of Victoria Report No. **11***, pp. 1-40.

HOLDGATE, G.R. & MCNICOL, M.D., 1992. New Directions - Old Ideas, Hydrocarbon Prospects of the Strzelecki Group Onshore Gippsland Basin. *Gippsland Basin Symposium, Melbourne,* 22-23 June, pp. 121-132.

JAMES, E.A. & EVANS, P.R., 1971. The stratigraphy of the offshore Gippsland Basin. *Australian Petroleum Exploration Association Journal Volume* **11 (1)**, pp. 71-74.

LOWRY, D.C. & LONGLEY, I.M., 1991. A new model for Mid-Cretaceous structural history of the northern Gippsland Basin. *Australian Petroleum Exploration Association Journal Volume* **31 (1)**, pp. 143-153.

LOWRY, D.C., 1987. A new play in the Gippsland Basin. *Australian Petroleum Exploration Association Journal Volume* **27 (1)**, pp. 164-172.

LOWRY, D.C., 1988. Alternate Cretaceous history of the Gippsland Basin. *Australian Journal Earth Sciences* **35,** pp. 181-194.

MCKENZIE, D., 1978. Some remarks on the development of sedimentary basins. *Earth Planetary Science Letters* **40**, pp. 25-32.

MEGALLAA, M., 1993. Tectonic evolution of the Gippsland Basin and hydrocarbon potential of its lower continental shelf. *Australian Petroleum Exploration Association Journal Volume* **33 (1)**, pp. 45-61.

MEGALLAA, M., BERNECKER, T., & FRANKEL, E., 1998. Hydrocarbon prospectivity of the Northern Terrace, offshore Gippsland Basin, for the 1998 Acreage Release. *Victorian Initiative for Mineral and Petroleum Report* **56**. Department of Natural Resources and Environment.

MEHIN, K. & LINK, A. G., 1997. Kitchens, Kettles and Cups of Hydrocarbons, Victorian Otway Basin. *Australian Petroleum Exploration Association Journal Volume* **37 (1)**, pp. 285-300.

MEHIN, K. & LINK, A.G., 1996. Early Cretaceous Source Rock Evaluation for

Oil and Gas Exploration, Victorian Otway Basin. *Victorian Initiative for Minerals and Petroleum Report* **31**. Department of Natural Resources and Environment.

MOORE, A.M.G., WILLCOX, J.B., EXON, N.F. & O'BRIEN, G.W., 1992. Continental shelf basins on the west Tasmanian margin. *Australian Petroleum Exploration Association Journal Volume* **32 (1)**, pp. 231-250.

MOORE, P.S., BURNS, B.J., EMMETT, J.K. AND GUTHRIE, D.A., 1992. Integrated Source Maturation and Migration Analysis, Gippsland Basin, Australia. *Australian Petroleum Exploration Association Journal Volume* **32 (1)**, pp. 313-324.

NAN TIE, M., 1983. Palaeo-environmental and past depositional history of the Cretaceous Strzelecki Group, Inverloch-Kilcundra. BSc Hon. Thesis, Monash University (unpubl.).

PARTRIDGE, A.D., 1994. Review of relinquished palynological slides from West Seahorse l, Gippsland Basin. *Biostrata Report* 1994/8, pp. 1-16 (unpubl.).

PHILLIP, G.M., 1957. The Jurassic sediments of the Tyers Group, Gippsland, Victoria. *Proc. Royal Society Victoria* ***70***, pp. 181-199.

RAHMANIAN, V.D., MOORE, P.S., MUDGE, W.J. & SPRING, D.E., 1990. Sequence stratigraphy and the habitat of hydrocarbons, Gippsland Basin, Australia. In: Brooks, J. (Ed.), Classic Petroleum Provinces, *Geological Society Special Publication* **50**, pp. 525-544.

RAYNER, B.L., 1981. Depositional environments and tectonic setting of the Lower Cretaceous Strzelecki Group, Gippsland. BSc. Hon. Thesis, Monash University (Unpublished).

THOMPSON, B.R., 1986. The Gippsland Basin—development and stratigraphy. In: R.C. Glenie (Ed) *Second South-eastern Australian Oil Exploration Symposium*, pp. 57-64.

VEEVERS, J.J., 1984. Morphotectonics of the divergent or rifted margins. In: Veevers, J.J. (Ed.), *Phanerozoic earth history of Australia*, pp. 168-210.

VEEVERS, J.J., 1986. Breakup of Australia and Antarctica estimated as mid-Cretaceous (95 ±5 Ma) from magnetic and seismic data at the continental margin. *Earth Planetary Science Letters* **77**, pp. 91-99.

WILLCOX, J.B. & STAGG, H.M.J., 1990. Australia's southern margin: a product of oblique extension. *Tectonophysics* **173**, pp. 269-281.

WILLCOX, J.B., COLWELL, J.B. & CONSTANTINE, A.E., 1992. New ideas on Gippsland Basin regional tectonics. In: Barton, C. (ed.), Energy, Economics and Environment - Gippsland Basin Symposium, *Australian Institute of Mining Metallurgy*, pp. 93-110.

WILLIAMSON, P.E., O'BRIEN, G.W., SWIFT, M.G., FELTON, E.A., SCHERL. A.S., LOCK, J., EXON, N.F., FALVEY, D. A. & MARLOW, M., 1987. Hydrocarbon Potential of the Otway Basin. *Australian Petroleum Exploration Association Journal Volume* **27 (1)**, pp. 173-194.

Appendix 1

Onshore Gippsland Wells

Burong 1
Dutson Downs 1
East Reeve 1
Golden Beach West 1
Loy Yang 1A
Merriman 1
North Seaspray 1
Rosedale 1
Wellington Park 1
Woodside 1

Burong 1

1 Introduction

Three samples from Burong 1 were collected (866, 1151 & 1222 m).

2 Source rock richness

The total organic carbon (TOC) values for the three samples analysed are in the range of 0.46 to 10.77%, which indicates that they have fair to very good source potential (Tables 4 & 5). The shallower samples show gas and some liquid hydrocarbon potential with HI ≥ 214 g HC/kg rock (Table 4). The macerals are dominated by either vitrinite or inertinite with some occasional liptinite (Table 5).

3 Rock-Eval pyrolysis

Rock-Eval pyrolysis analysis was performed on the three samples. The S1 values range from 0.13 to 1.73 kg/tne and S2 values vary from 0.29 to 23.09 kg/tne. These values suggest low to high levels of free hydrocarbons. Hydrocarbon index (HI) values also range from low (63) to high (290). The Tmax°C values range from 411°C to 438°C, characterising these samples as immature to marginally mature (Fig. 10). The S1 value for the shallowest sample at 866 m with a TOC of 10.77%, is 1.73 kg/tne, indicating a moderate level of free hydrocarbons (Fig. 11). The S2 value of 23.09 kg/tne, the Tmax of 411°C and the HI value of 214 suggest that gas-prone, marginally mature source rocks exist at this level.

4 Saturate gas chromatography and gas chromatography-mass spectrometry

The sample at 1151 m was analysed by pyrolysis gas chromatography (Py-GC). The Py-GC traces consist of well defined alkane/alkene pairs which extend out to C31 (Fig. 12). The determination of results of alkane/alkene is presented in Table 6.

The C15 to C31 alkane plus alkene value is approximately 11.73% (calculated as percentage of S2) and characterises the kerogen as having significant potential to generate oil (Tables 6, 7 & 8). This assessment corresponds to the HI value of 290 obtained by Rock-Eval pyrolysis. Solvent extraction of the 1151 m sample yielded 1128.4 ppm of extract.

The saturate gas chromatography (GC) trace consists of alkane peaks, mainly in the C12 to C33 region. There is a very low proportion of small numbered carbons and the amount of higher molecular weight hydrocarbons falls away rapidly after C14 (Fig. 12). The pristane/phytane ratio of 4.07 suggests a relatively oxidising depositional environment.

5 Vitrinite reflectance

Vitrinite reflectance measurements showed that organic maturity increases with depth, however all three samples were immature (0.34, 0.38 & 0.51%, respectively). The oil window lies between 1979 and 2828 m at this well (Fig. 13a).

6 Geohistory

Subsidence at the Burong 1 site was generally uniform at 98 m/million years until 95 Ma. From 90 Ma, subsidence continued at a much slower rate of about 15 m/million years thereafter, until the present (Fig. 13b).

7 Hydrocarbon expulsion

Minor oil and gas expulsion commenced at about 110 Ma, peaking around 108 Ma for oil and 100 Ma for gas. Rates of early stage expulsion from the Strzelecki Group was calculated at around 659 bbl/m^2 of oil; the amount of gas expelled was around 571 bbl equiv/m^2 of source rock (Fig. 13c).

Table 4 Burong 1, Rock-Eval pyrolysis

Depth (m KB)	Spore-Pollen Zone	Tmax °C	S1 kg/tne	S2 kg/tne	S3 kg/tne	Generative Potential (S1 + S2)	S2/S3	PI	PC	TOC %	HI	OI
866	*N. asperus*	411	1.73	23.09	2.87	24.82	8.05	0.07	2.06	10.77	214	27
1151		424	0.72	11.73	0.95	12.45	12.35	0.06	1.03	4.05	290	23
1222	*L. balmei*	438	0.13	0.29	0.25	0.42	1.16	0.31	0.03	0.46	63	54

Table 5 Burong 1 Maceral, vitrinite reflectance, lithologic and richness (TOC) data

Depth (m KB)	866	1151	1222
	N. asperus	*N. asperus*	*L. balmei*
Vitrinite Reflectance			
Mean Ro %	0.34	0.38	0.51
Min to Max %	0.28-0.39	0.26-0.52	0.68-1.34
Sample No. Determination	26	25	17
Maceral Proportion			
Vitrinite % (V)	84.18	68.18	
Inertinite % (I)	0.67	13.64	100.0
Liptinite % (L)	15.15	18.18	
Organic Matter			
Relative Maceral Abundance	V>>L>I	V>L>I	I
DOM %		Ab	Cm
Liptinite/Exinite Macerals			
Liptodetrinite		Cm; Y-O	Ra; Y-O
Sporinite	Cm; yO	Ab; Y-yO	
Cutinite			
Bituminite			
Resinite	Cm; Y-O		
Phytoplankton			
Lamalginite			
Liptinite (mostly oxidised)		Ab	Ra
TOC%	10.77	4.05	0.46
Lithology	Shaly coal	Pyritic claystone to shaly coal	Silty sandstone

Vr = very rare   Ra = rare   Sp = sporadic   Cm = Common   Ab = abundant
mY = mid yellow   dO = dark orange   B = black   yO = yellowish orange   iO = intense orange

Table 6 Burong 1 (1151 m SWC) — Alkane and alkene determination by Pyrolysis-GC

Carbon No.	Alkane + Alkene			Alkane			Alkene			Alkane/Alkene
	A	B	C	A	B	C	A	B	C	
5	5.533	0.649	0.160	2.511	0.295	0.073	3.022	0.354	0.088	0.83
6	2.993	0.351	0.087	1.456	0.171	0.042	1.537	0.180	0.045	0.95
7	2.311	0.271	0.067	1.174	0.138	0.034	1.137	0.133	0.033	1.03
8	1.803	0.211	0.052	0.858	0.101	0.025	0.945	0.111	0.027	0.91
9	1.427	0.167	0.041	0.666	0.078	0.019	0.761	0.089	0.022	0.88
10	1.685	0.198	0.049	0.933	0.109	0.027	0.752	0.088	0.022	1.24
11	1.429	0.168	0.041	0.656	0.077	0.019	0.773	0.091	0.022	0.85
12	1.344	0.158	0.039	0.643	0.075	0.019	0.701	0.082	0.020	0.92
13	1.227	0.144	0.036	0.644	0.076	0.019	0.583	0.068	0.017	1.10
14	1.326	0.156	0.038	0.497	0.058	0.014	0.829	0.097	0.024	0.60
15	1.077	0.126	0.031	0.611	0.072	0.018	0.466	0.055	0.013	1.31
16	0.809	0.095	0.023	0.413	0.048	0.012	0.396	0.046	0.011	1.04
17	0.949	0.111	0.027	0.631	0.074	0.018	0.318	0.037	0.009	1.98
18	0.792	0.093	0.023	0.455	0.053	0.013	0.337	0.040	0.010	1.35
19	0.764	0.090	0.022	0.461	0.054	0.013	0.303	0.036	0.009	1.52
20	0.819	0.096	0.024	0.480	0.056	0.014	0.339	0.040	0.010	1.42
21	0.795	0.093	0.023	0.515	0.060	0.015	0.280	0.033	0.008	1.84
22	0.829	0.097	0.024	0.560	0.066	0.016	0.269	0.032	0.008	2.08
23	0.840	0.099	0.024	0.551	0.065	0.016	0.289	0.034	0.008	1.91
24	0.823	0.097	0.024	0.530	0.062	0.015	0.293	0.034	0.008	1.81
25	0.734	0.086	0.021	0.484	0.057	0.014	0.250	0.029	0.007	1.94
26	0.588	0.069	0.017	0.449	0.053	0.013	0.139	0.016	0.004	3.23
27	0.501	0.059	0.015	0.393	0.046	0.011	0.108	0.013	0.003	3.64
28	0.378	0.044	0.011	0.295	0.035	0.009	0.083	0.010	0.002	3.55
29	0.244	0.029	0.007	0.210	0.025	0.006	0.034	0.004	0.001	6.18
30	0.167	0.020	0.005	0.146	0.017	0.004	0.021	0.002	0.001	6.95
31	0.115	0.013	0.003	0.093	0.011	0.003	0.022	0.003	0.001	4.23

A= % of resolved compounds in S_2 B = mg/g rock (Rock-Eval) C = (mg/g rock)/TOC

Table 7 Burong 1 (1151 m SWC) — EOM analysis

1) Extracted Organic Matter (EOM) ppm

Depth (m KB)	Weight of Rock Extd (g)	Total Extract (ppm)	Loss on Column (ppm)	Hydrocarbons			Non-hydrocarbons		
				Saturates (ppm)	Aromatics (ppm)	HC Total (ppm)	NSO's (ppm)	Asphalt (ppm)	Non HC Total (ppm)
1151	3.5	1128.4	nd	nd	nd	nd	nd	nd	nd

2) Percentages and Ratios of EOM

Depth (m KB)	Hydrocarbons			Non-hydrocarbons			EOM(mg)/ TOC (g)	SAT(mg)/ TOC (g)	SAT/ AROM	ASPH/ NSO	HC/ Non HC
	% SAT	% AROM	% HC's	% NSO's	% ASPH	% Non HC's					
1151	nd	nd	nd	nd	nd	nd	27.9	nd	nd	nd	nd

3) Alkane Ratios

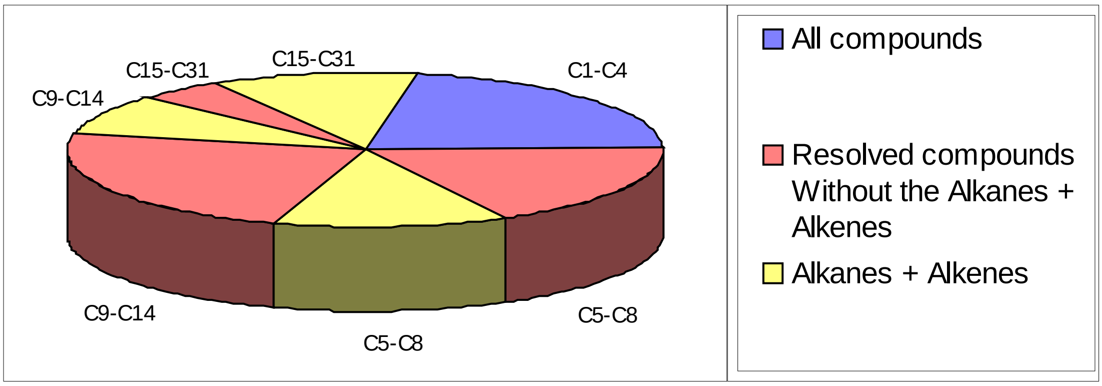
Depth (m KB)	Prist/Phyt	Prist/n-C17	Phyt/n-C18	CPI(1)	CPI(2)	(C21+C22)/(C28+C29)
1151	4.07	2.05	0.48	2.52	2.37	0.23

nC12-nC31 Percentage Concentrations in Saturate Fraction

nC12%	nC13%	nC14%	nC15%	nC16%	nC17%	iC19%	nC18%	iC20%	nC19%	nC20%
2.0	6.2	11.0	4.0	3.5	1.7	3.6	1.8	0.9	1.9	2.6
nC21%	nC22%	nC23%	nC24%	nC25%	nC26%	nC27%	nC28%	nC29%	nC30%	nC31%
1.6	1.9	3.7	3.1	10.7	4.8	11.4	4.3	10.5	2.6	6.2

Table 8 Burong 1 (1151 m) — Pyrolysis gas chromatography

	Parameter	A	B	C	No. Units
C1-C4	abundance (all compounds)	21.59	2.53	0.63	
C5-C8	abundance (all resolved compounds)	30.49	3.58	0.88	
C5-C8	abundance (alkanes + alkenes)	12.64	1.48	0.37	
C9-C14	abundance (all resolved compounds)	31.98	3.75	0.93	
C9-C14	abundance (alkanes + alkenes)	8.44	0.99	0.24	
C15-C31	abundance (all resolved compounds)	15.93	1.87	0.46	
C15-C31	abundance (alkanes + alkenes)	11.22	1.32	0.33	
C9-C31	abundance (all resolved compounds)	47.91	5.62	1.39	
C9-C31	abundance (alkanes + alkenes)	19.66	2.31	0.57	
C5-C31	abundance (all resolved compounds)	78.41	9.20	2.27	
C5-C31	abundance (alkanes + alkenes)	32.30	3.79	0.94	
C5-C31	alkane abundance	17.37	2.03	0.50	
C5-C31	alkene abundance	14.99	1.76	0.43	
C5-C8	alkane / alkene				0.90
C9-C14	alkane / alkene				0.92
C15-C31	alkane / alkene				1.84
C5-C31	alkane / alkene				1.16
(C1-C5)/C6+					0.42
R					1.45



A = % of resolved compounds in S2
B = mg/g rock (Rock-Eval)
C = (mg/g rock)/TOC
R = m + p-xylene/n-octane

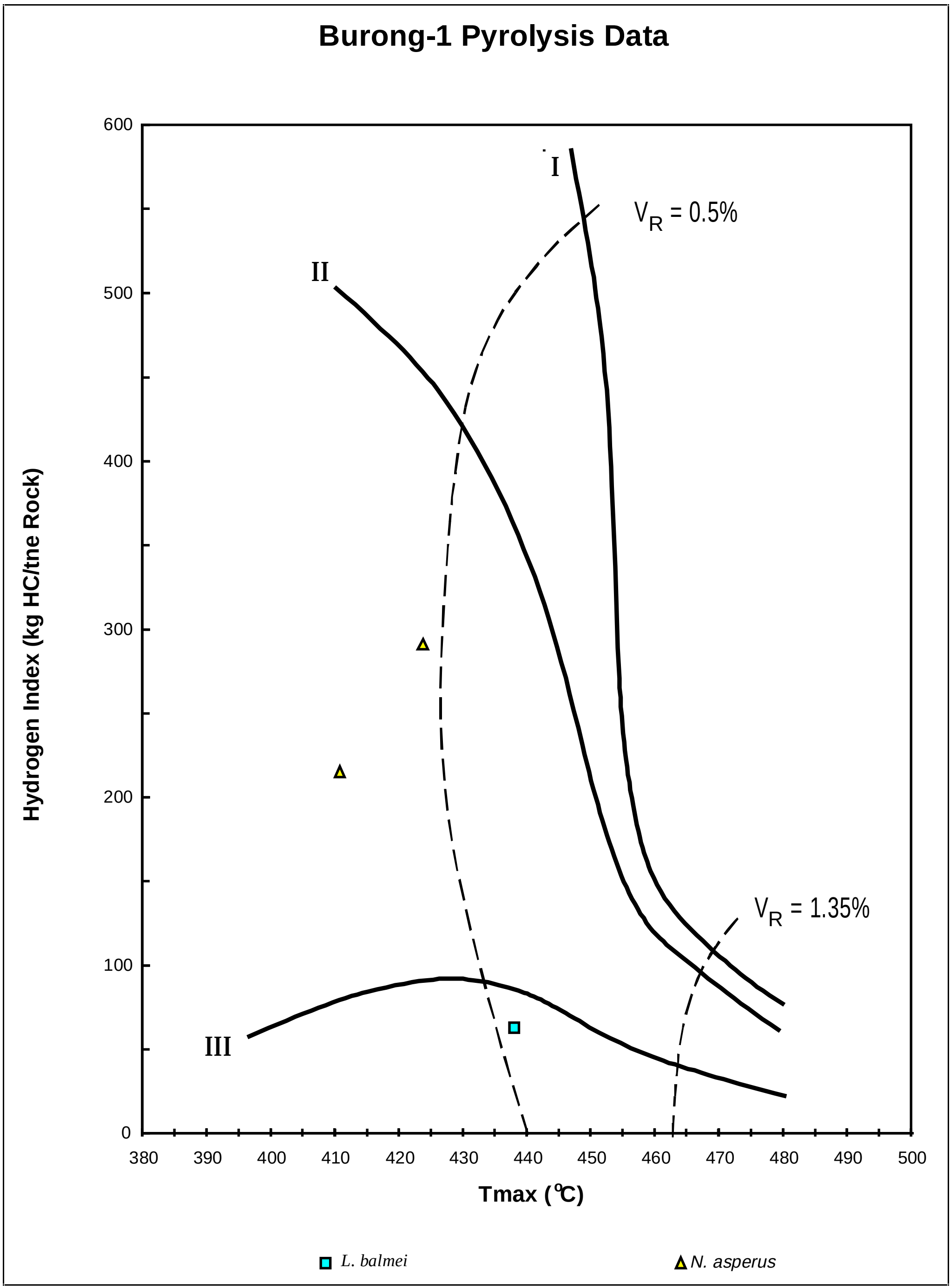


Figure 10
Burong 1: HI versus Tmax ºC plot.

Burong 1

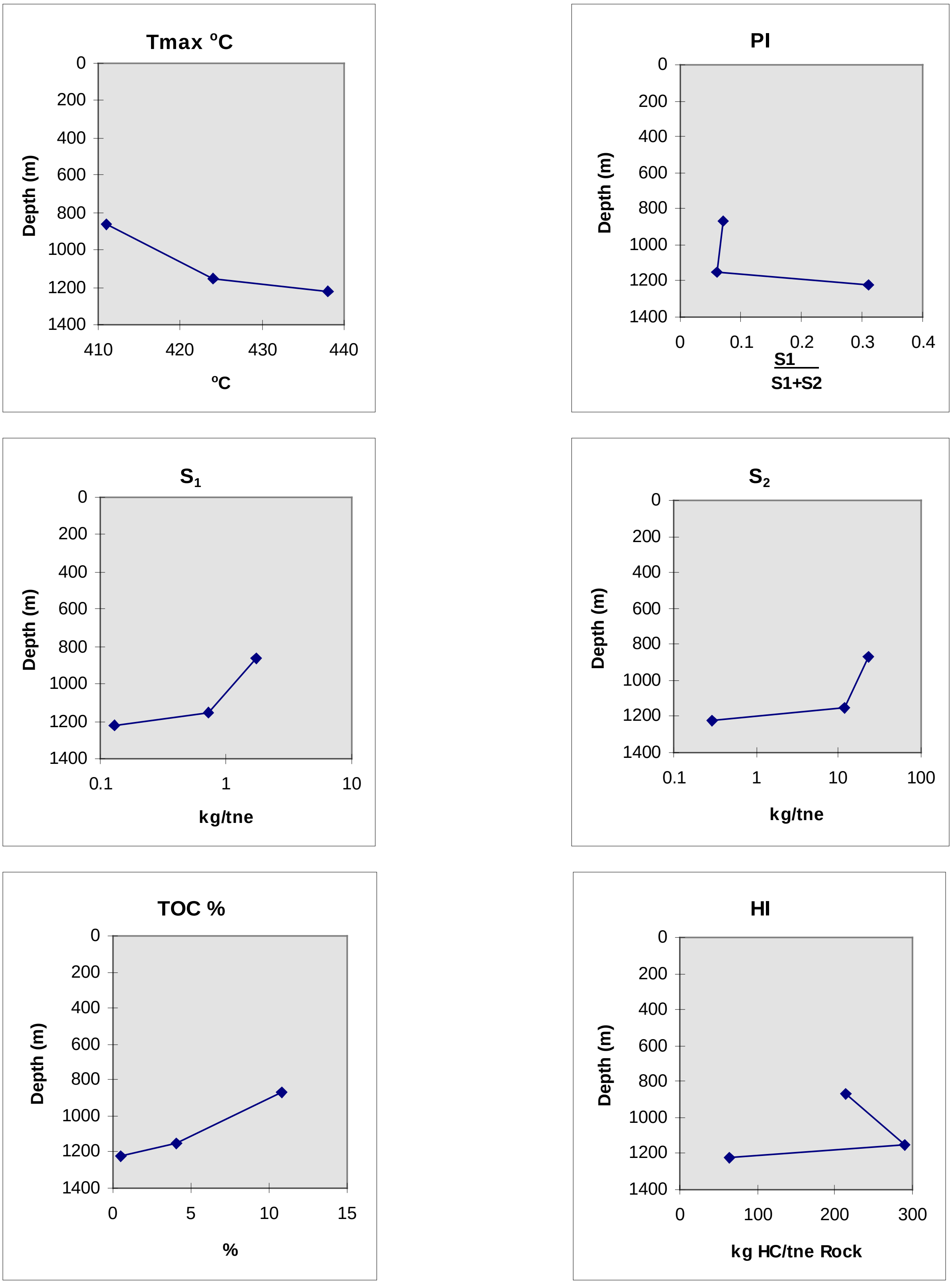


Figure 11
Burong 1: (a) Tmax °C; (b) S1; (c) S2; (d) PI; (e) TOC %; (f) HI.

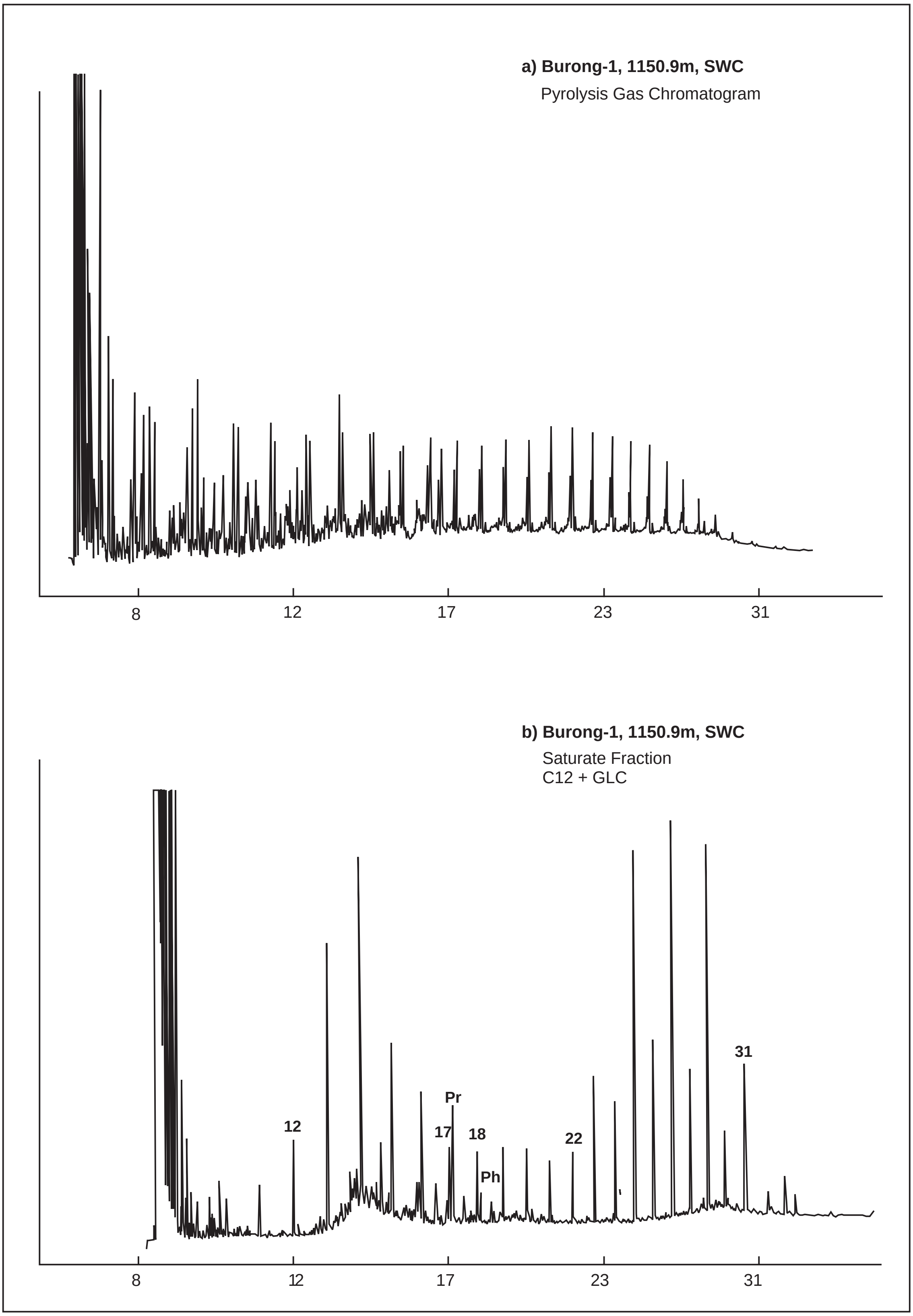


Figure 12
Burong 1, (1151 m): — Pyrolysis gas chromatographs.
(a) SWC; (b) Saturate fraction, C12+ of SWC

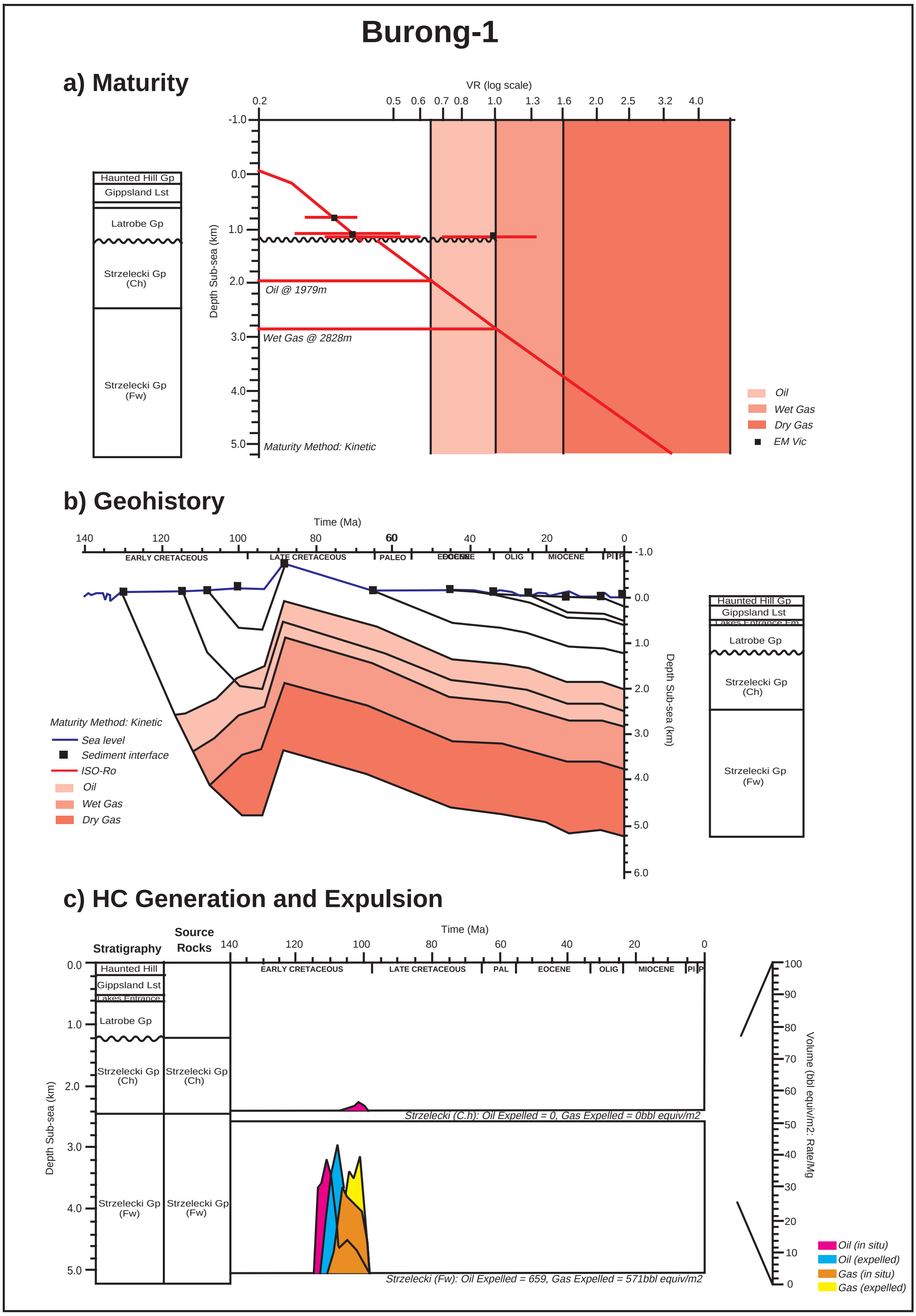


Figure 13

Burong 1: (a) Maturity plot; (b) Geohistory; (c) Hydrocarbon expulsion.

Dutson Downs 1

1 Introduction

Three samples from Dutson Downs 1 were collected (1295, 1499 & 1810 m).

2 Source rock richness

The total organic carbon (TOC) values for the three samples analysed are in the range of 0.99 to 26.83%, which indicates that they have fair to excellent source potential (Tables 9 & 10). The macerals are dominated by vitrinite with some inertinite and minor liptinite.

3 Rock-Eval Pyrolysis

Rock-Eval pyrolysis was performed on the three samples. For the two shallower samples, the S1 values range from 0.15 to 0.92 kg/tne and S2 values vary between 1.64 and 19.78 kg/tne. These values suggest fair to moderate levels of free hydrocarbons. Hydrocarbon index (HI) values are low (169-187). Immaturity is indicated by the Tmax values of 427°C and 424°C (Fig. 14). The sample at 1810 m has an S1 value of 1.90 kg/tne with a TOC of 26.83%, indicating a moderate level of free hydrocarbons (Fig. 15). The S2 value of 34.71 kg/tne, the Tmax of 425 °C and the HI value of 129 suggest that oil-prone, marginally mature source rocks exist at this level.

4 Saturate gas chromatography and gas chromatography-mass spectrometry

The sample at 1499 m was further analysed by pyrolysis gas chromatography (Py-GC). The Py-GC traces consist of well defined alkane/alkene pairs which extend out to C29. The C15 to C31 alkane plus alkene value is approximately 11.22% (calculated as percentage of S2) and characterises the kerogen as being of mixed oil and gas-proneness (Table 11). Solvent extraction of the 1499 m sample yielded 7043 ppm and showed a bimodal distribution in the alkanes. This indicates contribution from two sources with a significant contribution from terrestrially derived organic matter. The pristane/phytane ratio of 4.02 suggests a relatively oxidising depositional environment (Table 12) and pyrolysis gas chromatography results are displayed in Table 13. Also the branched/cyclic gas chromatography-mass spectrometry (GC-MS) data supports this profile (Figs 15 & 16).

5 Vitrinite reflectance

Vitrinite reflectance measurements are immature, with the samples ranging from 0.39 to 0.58%. The oil window lies between 1801 and 2655 m at this well (Fig. 17a).

6 Geohistory

Subsidence at the Dutson Downs 1 site was generally uniform at 108 m/million years until 105 Ma when a slow down of subsidence occurred. This was followed by a dramatic slow down in subsidence at a rate of 13 m from 100 to 90 Ma. After that subsidence continued at a rate of about 24 m/million years until 80 Ma. From then on, subsidence continued at a much slower rate of about 16 m/million year thereafter, until the present (Fig. 17b).

7 Hydrocarbon expulsion

Minor oil and gas expulsion commenced at about 110 Ma, peaking around 105 Ma. Rates of early stage expulsion from the Strzelecki Group were calculated to around 293 bbl/m^2 of oil; the amount of gas expelled was around 358 bbl equiv/m^2 of source rock (Fig. 17c).

Table 9 Dutson Downs 1, Rock-Eval pyrolysis

Depth (m KB)	Spore-Pollen Zone	T max oC	S1 kg/tne	S2 kg/tne	S3 kg/tne	Generative Potential (S1 + S2)	S2/S3	PI	PC	TOC %	HI	OI
1295	*L. balmei*	427	0.15	1.64	0.24	1.79	6.83	0.08	0.15	0.99	169	25
1499	*N. senectus*	424	0.92	19.78	3.17	20.70	6.24	0.04	1.72	10.58	187	30
1810	*C. striatus*	425	1.90	34.71	8.92	36.61	3.89	0.05	3.04	26.83	129	33

Table 10 Dutson Downs 1. Maceral, vitrinite reflectance, lithologic and richness (TOC) data

Depth (m KB)	1295	1499	1810
Spore-Pollen Zone	*L. balmei*	*N. senectus*	*C. striatus*
Vitrinite Reflectance			
Mean Ro %	0.39	0.45	0.58
Min to Max %	0.30-0.49	0.34-0.57	0.52-0.64
Sample No. Determination	27	30	25
Maceral Proportion			
Alginite %		0.73	
Exinite %	16.67	6.57	0.0
Vitrinite % (V)	76.67	80.29	66.67
Inertinite % (I)	6.67	12.41	33.33
Organic Matter	V>L>I	V>I>L	V>I
Relative Maceral Abundance	Cm-Ab	Ab	Sp-Cm
Liptinite/Exinite Macerals			
Liptodetrinite	Sp; Y-O	Sp; gY	Ra; O-dO
Sporinite	Sp; Y-O	Sp; Y-O	Ra; O-dO
Cutinite	Ra; O	Ra; O	
Bituminite			
Resinite		Sp; dO	
Phytoplankton		Ra (Botryococcus)	
Lamalginite			
Liptinite (mostly oxidised)	Sp-Cm	Sp-Cm	Sp
TOC%	0.99	10.58	26.83
Lithology	Argillaceous siltstone and coal	Argillaceous siltstone, sandstone and minor coal	Sandstone, siltstone and minor coal

Vr = very rare	Ra = rare	Sp = sporadic	Cm = Common
Ab = Abundant	mY = mid yellow	iO = intense orange	dO = dark orange
B = black	iY = intense yellow	Br = brown	

Table 11 Dutson Downs 1 (1499 m Cuttings) — Alkane and alkene determination by Pyrolysis-GC

Carbon No.	Alkane + Alkene			Alkane			Alkene			Alkane / Alkene
	A	B	C	A	B	C	A	B	C	
5	3.859	0.763	0.072	2.000	0.396	0.037	1.859	0.396	0.035	1.08
6	2.463	0.487	0.046	1.001	0.198	0.019	1.462	0.289	0.027	0.68
7	2.137	0.423	0.040	1.052	0.208	0.020	1.085	0.215	0.020	0.97
8	1.732	0.343	0.032	0.828	0.164	0.015	0.904	0.179	0.017	0.92
9	1.436	0.284	0.027	0.696	0.138	0.013	0.740	0.146	0.014	0.94
10	1.830	0.362	0.034	1.080	0.214	0.020	0.750	0.148	0.014	1.44
11	1.487	0.294	0.028	0.770	0.152	0.014	0.717	0.142	0.013	1.07
12	1.533	0.303	0.029	0.716	0.142	0.013	0.817	0.162	0.015	0.88
13	1.403	0.278	0.026	0.787	0.156	0.015	0.616	0.122	0.012	1.28
14	1.594	0.315	0.030	0.580	0.115	0.011	1.014	0.201	0.019	0.57
15	1.322	0.261	0.025	0.748	0.148	0.014	0.574	0.144	0.011	1.30
16	1.091	0.216	0.020	0.545	0.108	0.010	0.546	0.108	0.010	1.00
17	1.228	0.243	0.023	0.886	0.175	0.017	0.342	0.068	0.006	2.59
18	0.890	0.176	0.017	0.491	0.097	0.009	0.399	0.079	0.007	1.23
19	0.852	0.169	0.016	0.540	0.107	0.010	0.312	0.062	0.006	1.73
20	0.901	0.178	0.017	0.534	0.106	0.010	0.367	0.073	0.007	1.46
21	0.826	0.163	0.015	0.507	0.100	0.009	0.319	0.063	0.006	1.59
22	0.819	0.162	0.015	0.533	0.105	0.010	0.286	0.057	0.005	1.86
23	0.767	0.152	0.014	0.489	0.097	0.009	0.278	0.055	0.005	1.76
24	0.756	0.150	0.014	0.463	0.092	0.009	0.293	0.058	0.005	1.58
25	0.633	0.125	0.012	0.386	0.076	0.007	0.247	0.049	0.005	1.56
26	0.497	0.098	0.009	0.362	0.072	0.007	0.135	0.027	0.003	2.68
27	0.434	0.086	0.008	0.306	0.061	0.006	0.128	0.025	0.002	2.39
28	0.308	0.061	0.006	0.228	0.045	0.004	0.080	0.016	0.001	2.85
29	0.166	0.033	0.003	0.141	0.028	0.003	0.025	0.005	0.000	5.64
30	0.119	0.024	0.002	0.097	0.019	0.002	0.022	0.004	0.000	4.41
31	0.072	0.014	0.001	0.054	0.011	0.001	0.018	0.004	0.000	3.00

A= % of resolved compounds in S_2 B = mg/g rock (Rock-Eval) C = (mg/g rock)/TOC

Table 12 Dutson Downs 1 (1499 m Cuttings) — EOM analysis

1) Extracted Organic Matter (EOM) ppm

Depth (m KB)	Weight of Rock Extd (g)	Total Extract (ppm)	Loss on Column (ppm)	Hydrocarbons			Non-hydrocarbons		
				Saturates (ppm)	Aromatics (ppm)	HC Total (ppm)	NSO's (ppm)	Asphalt (ppm)	Non HC Total (ppm)
1499	5.6	7043.3	5246.5	269.5	377.3	646.8	1149.9	nd	1149.9

2) Percentages and Ratios of EOM

Depth (m KB)	Hydrocarbons			Non-hydrocarbons			EOM(mg)/ TOC (g)	SAT(mg)/ TOC (g)	SAT/ AROM	ASPH/ NSO	HC/ Non HC
	%SAT	%AROM	%HC's	%NSO's	%ASPH	%Non HC's					
1499	15.0	21.0	36.0	64.0	nd	64.0	66.6	2.5	0.7	nd	0.6

3) Alkane Ratios

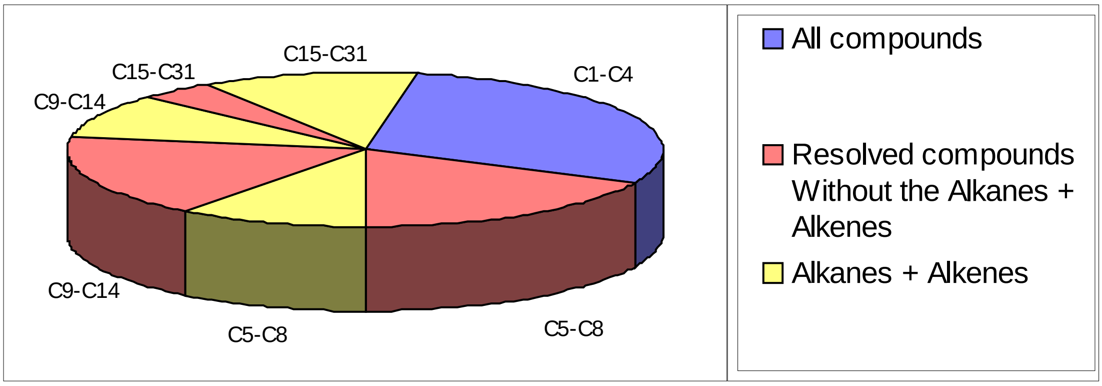
Depth (m KB)	Prist/Phyt	Prist/n-C17	Phyt/n-C18	CPI(1)	CPI(2)	(C21+C22)/(C28+C29)
1499	4.02	0.99	0.31	2.05	1.86	0.40

nC12-nC31 Percentage Concentrations in Saturate Fraction

nC12%	nC13%	nC14%	nC15%	nC16%	nC17%	iC19%	nC18%	iC20%	nC19%	nC20%
5.9	11.0	9.3	6.0	5.1	3.8	3.8	3.1	0.9	2.5	2.5
nC21%	nC22%	nC23%	nC24%	nC25%	nC26%	nC27%	nC28%	nC29%	nC30%	nC31%
2.0	2.3	3.4	2.9	5.7	3.5	7.3	3.5	7.2	2.3	5.9

Table 13 Dutson Downs 1 (1499 m) — Pyrolysis gas chromatography

	Parameter	A	B	C	No. Units
C1-C4	abundance (all compounds)	29.03	5.74	0.54	
C5-C8	abundance (all resolved compounds)	28.38	5.61	0.53	
C5-C8	abundance (alkanes + alkenes)	10.19	2.02	0.19	
C9-C14	abundance (all resolved compounds)	26.80	5.30	0.50	
C9-C14	abundance (alkanes + alkenes)	9.28	1.84	0.17	
C15-C31	abundance (all resolved compounds)	15.78	3.12	0.30	
C15-C31	abundance (alkanes + alkenes)	11.68	2.31	0.22	
C9-C31	abundance (all resolved compounds)	42.59	8.42	0.80	
C9-C31	abundance (alkanes + alkenes)	20.96	4.15	0.39	
C5-C31	abundance (all resolved compounds)	70.97	14.04	1.33	
C5-C31	abundance (alkanes + alkenes)	31.16	6.16	0.58	
C5-C31	alkane abundance	16.82	3.33	0.31	
C5-C31	alkene abundance	14.34	2.84	0.27	
C5-C8	alkane / alkene				0.92
C9-C14	alkane / alkene				0.99
C15-C31	alkane / alkene				1.67
C5-C31	alkane / alkene				1.17
(C1-C5)/C6+					0.55
R					1.61



A = % of resolved compounds in S2
B = mg/g rock (Rock-Eval)
C = (mg/g rock)/TOC
R = m + p-xylene/n-octane

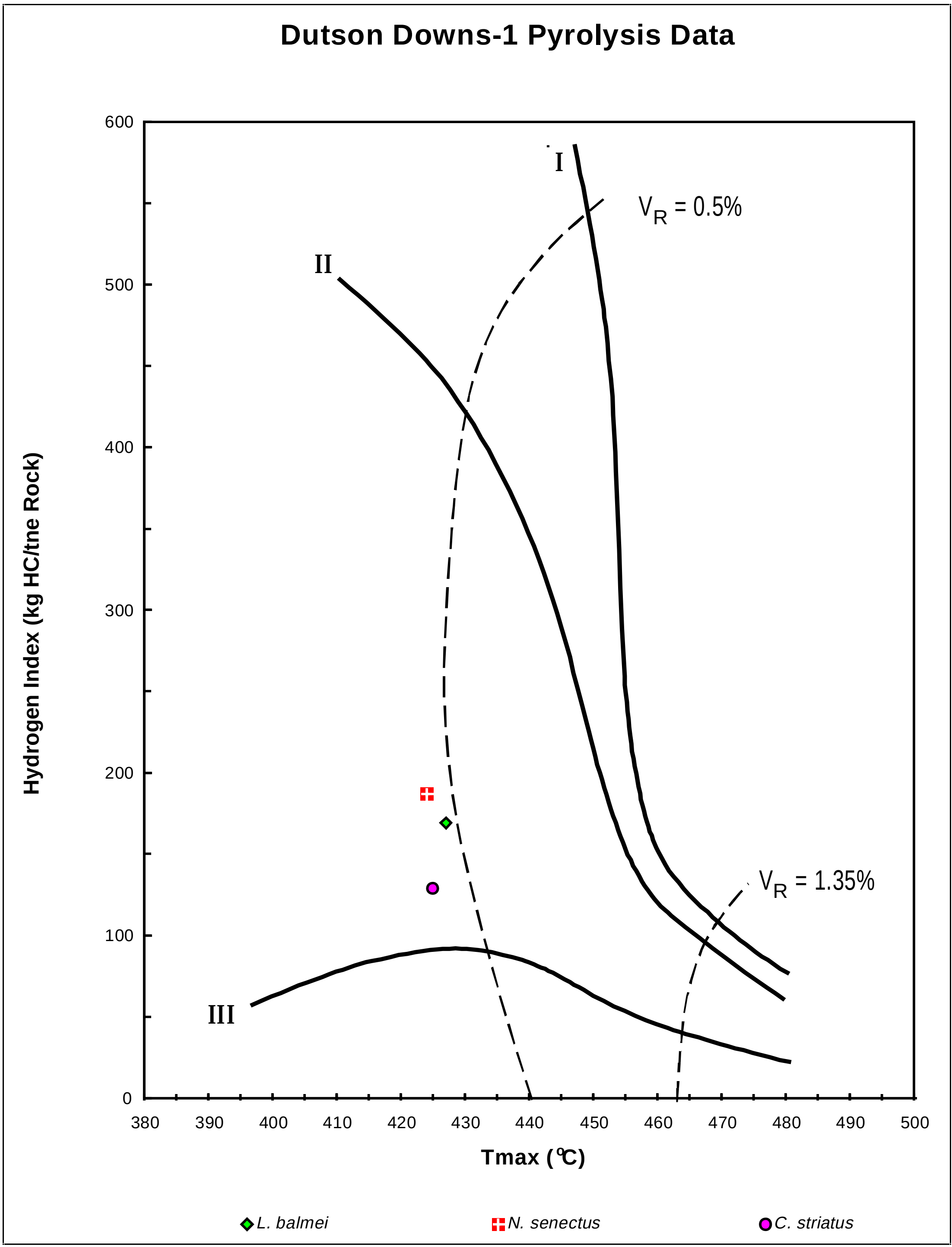


Figure 14

Dutson Downs 1: HI versus Tmax ºC plot.

Dutson Downs 1

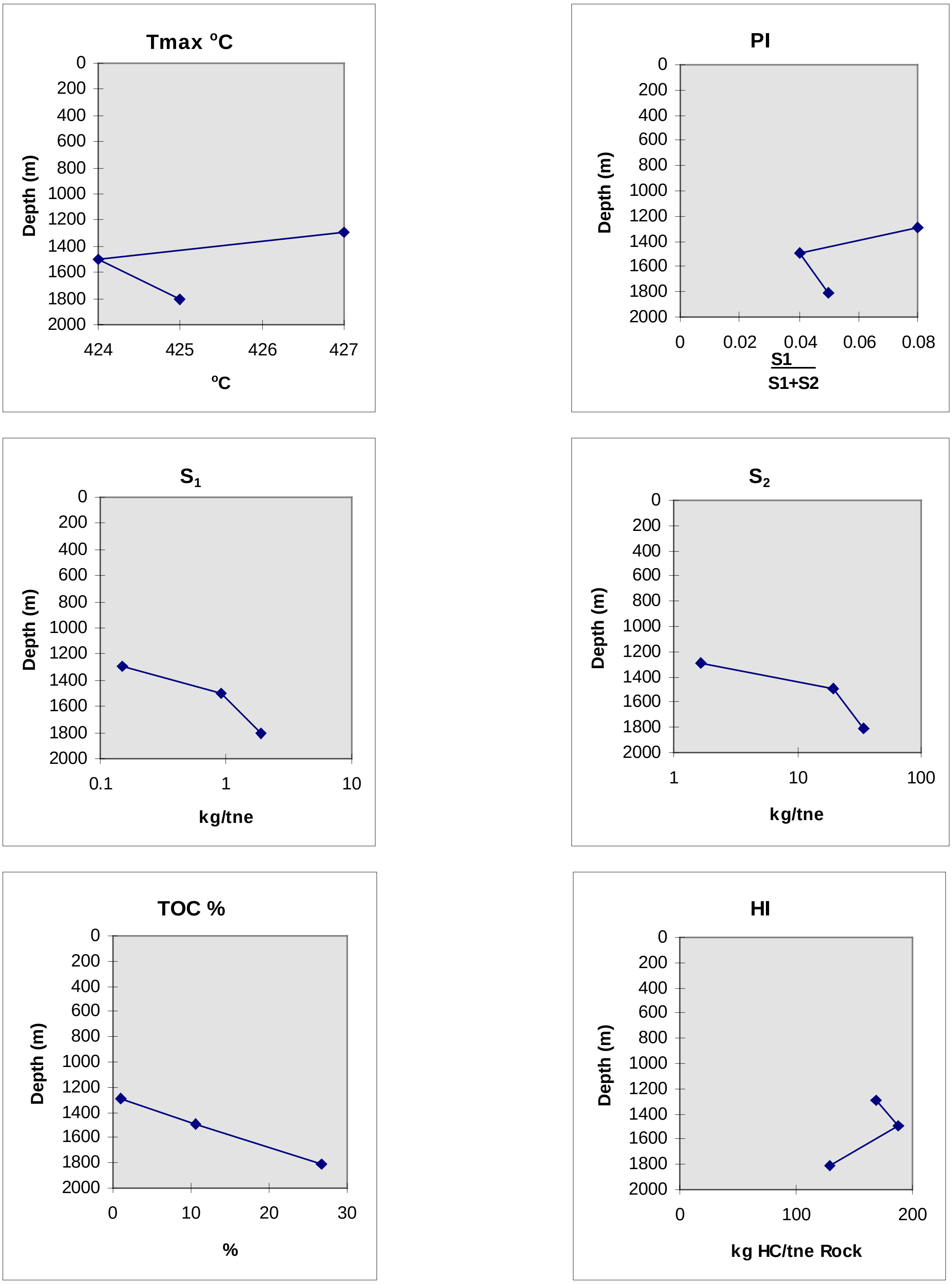


Figure 15

Dutson Downs 1: (a) Tmax °C; (b) S1; (c) S2; (d) PI; (e) TOC %; (f) HI.

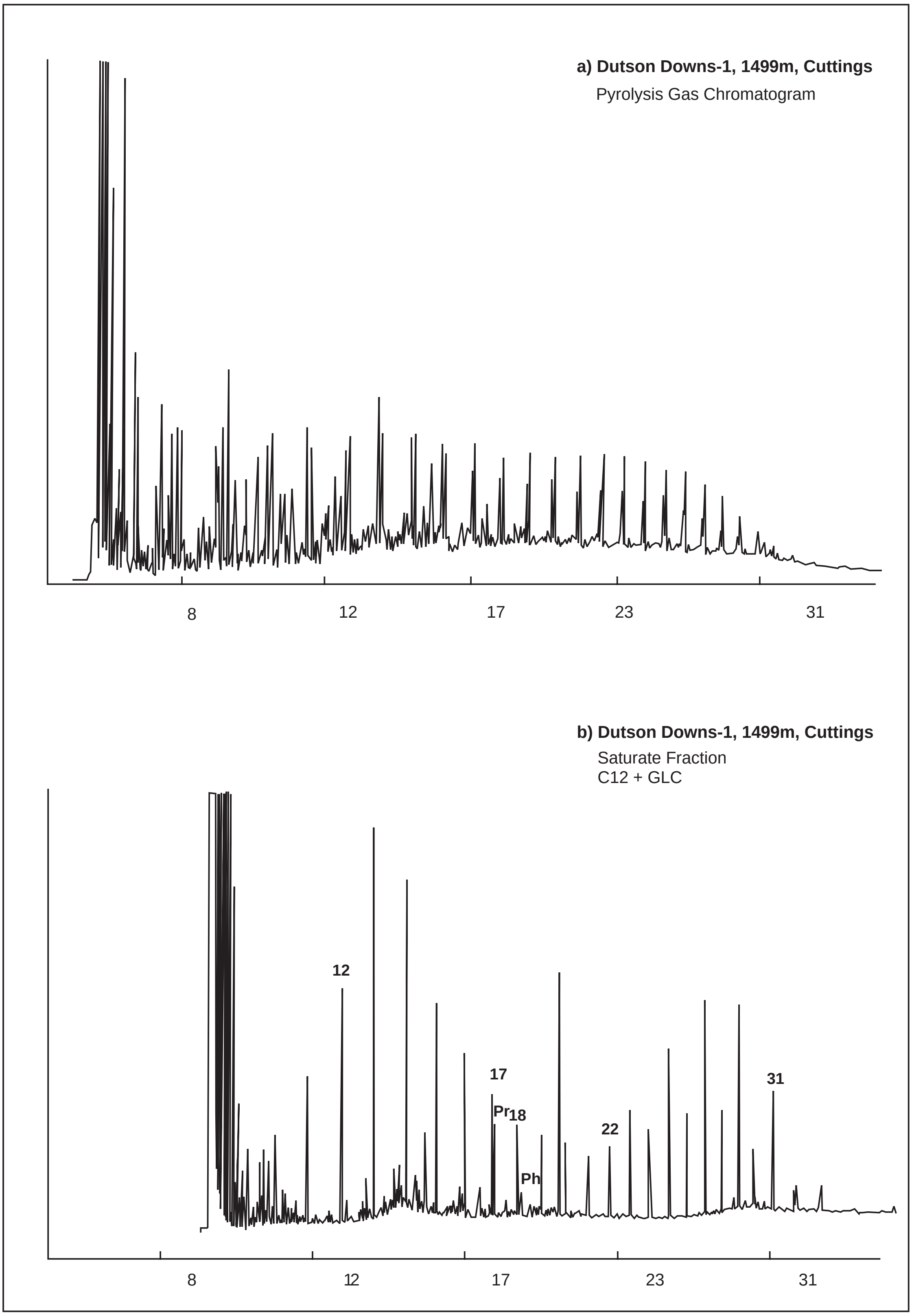


Figure 16

Dutson Downs 1, (1499 m): — Pyrolysis gas chromatographs.

(a) Cuttings; (b) Saturate fraction; C12+ of cuttings.

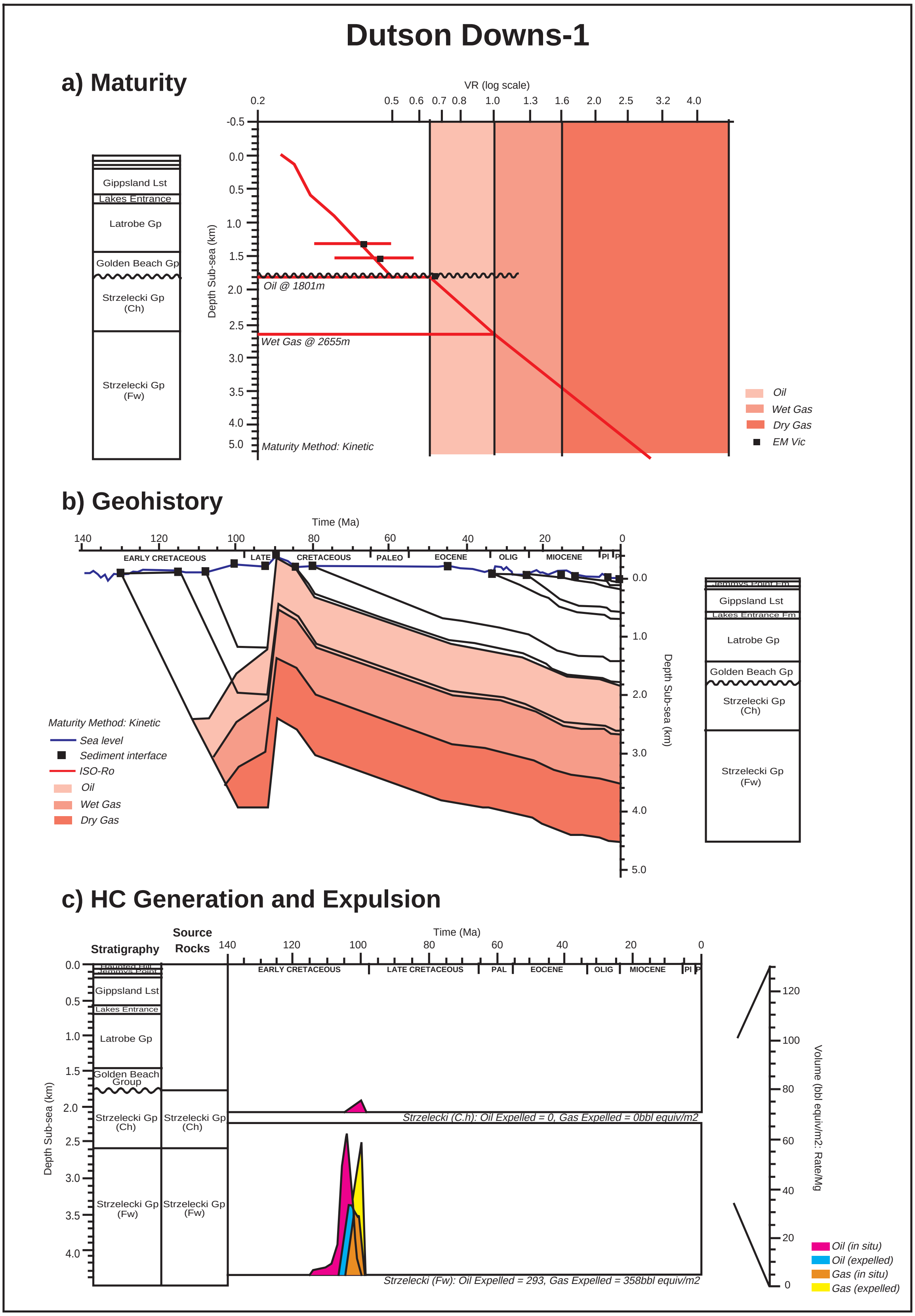


Figure 17
Dutson Downs 1: (a) Maturity plot; (b) Geohistory; (c) Hydrocarbon expulsion.

East Reeve 1

1 Introduction

Five samples from East Reeve 1 were collected (1195, 1323, 1499, 1585 & 1600 m).

2 Source rock richness

The total organic carbon (TOC) values for the five samples analysed are in the range of 0.26 to 18.92%, which indicates that they have poor to excellent source potential (Tables 14 & 15). In some of the samples the macerals are dominated by vitrinite, while in others inertinite or liptinite is dominant.

3 Rock-Eval Pyrolysis

Rock-Eval pyrolysis was performed on the five samples. In most of the samples S1 values range from 0.09 to 0.46 kg/tne, and S2 values vary between 0.21 and 11.43 kg/tne. These values suggest low to moderate levels of free hydrocarbons. Hydrocarbon index (HI) values are also low (81-179). Immaturity is indicated by the Tmax values ranging from 423°C to 430°C (Fig. 18). The sample at 1323 m has an S1 value of 1.83 kg/tne with a TOC of 18.92%, indicating a good level of free hydrocarbons (Fig. 19). The S2 value of 48.79 kg/tne, the Tmax of 423°C and the HI value of 258 suggest that oil-prone, marginally mature source rocks exist at this level.

4 Saturate gas chromatography and gas chromatography-mass spectrometry

The sample at 1499 m was further analysed by pyrolysis gas chromatography (Py-GC). The Py-GC traces consist of well defined alkane/alkene pairs which extend out to C31. The C15 to C31 alkane plus alkene value is approximately 7.47% (calculated as percentage of S2) and characterises the kerogen as being mixed oil and gas prone (Table 16). Solvent extraction of the 1323 m sample yielded 10703 ppm while extraction of the 1600 m sample yielded 3397 ppm. The sample from 1323 m showed a bimodal distribution in the alkanes. This indicates contribution from two sources, with a significant contribution from terrestrially derived organic matter.

The pristane/phytane ratio of 2.75 at 1323 m suggests a probable terrestrial depositional environment (Table 17). Also, the branched/cyclic gas chromatography-mass spectrometry (GC-MS) data supports this profile (Figs 19 & 20). The results of pyrolysis gas chromatography of the sample examined are displayed in Table 18.

5 Vitrinite reflectance

Vitrinite reflectance measurements are immature, with the samples ranging from 0.34 to 0.56%. The oil window lies between 1944 and 2735 m at this well (Fig. 21a).

6 Geohistory

Subsidence at the East Reeve 1 site was generally uniform at 140 m/million years until 100 Ma when a slow down of subsidence occurred. A dramatic reversal in subsidence then occurred from 93 to 90 Ma. After that subsidence continued at a steady rate of about 16 m/million years until 25 Ma when there was a slight increase in the subsidence rate for 10 million years. From then on, subsidence continued at a much slower rate of about 13 m/million years thereafter, until the present (Fig. 21b).

7 Hydrocarbon expulsion

The expulsion plot indicates oil in situ and no expulsion from Early Cretaceous source has occurred (Fig. 21c). Lack of expulsion of hydrocarbons at this location is due to uplift during Late Cretaceous to Tertiary time.

Table 14 East Reeve 1, Rock-Eval pyrolysis

Depth (m KB)	Spore-Pollen Zone	T max oC	S1 kg/tne	S2 kg/tne	S3 kg/tne	Generative Potential (S1 + S2)	S2/S3	PI	PC	TOC %	HI	OI
1195	*P. tuberculatus*	423	0.09	0.21	2.16	0.30	0.10	0.30	0.02	0.26	81	831
1323	*N. asperus*	423	1.83	48.79	4.75	50.62	10.27	0.04	4.20	18.92	258	25
1499	*C. paradoxa*	428	0.22	3.82	1.00	4.04	3.82	0.05	0.34	2.76	138	36
1585	*C. striatus*	425	0.19	3.49	0.66	3.68	5.29	0.05	0.31	2.3	152	20
1600	*C. striatus*	430	0.46	11.43	1.14	11.89	10.03	0.04	0.99	6.39	179	18

Table 15 East Reeve 1. Maceral, vitrinite reflectance, lithologic and richness (TOC) data

Depth (m KB)	1195	1323	1499	1585	1600
Spore-Pollen Zone	*P. tuberculatus*	*N. asperus*	*C. paradoxa*	*C. striatus*	*C. striatus*
Vitrinite Reflectance					
Mean Ro %	0.34	0.38	0.50	0.56	0.54
Min to Max %	0.24-0.45	0.24-0.45	0.36-0.66	0.38-0.68	0.41-0.67
Sample No. Determination	25	28	25	28	29
Maceral Proportion					
Alginite %					
Exinite %		3.27	20.0	14.29	10.0
Vitrinite % (V)	100.0	94.77	60.0	57.14	40.0
Inertinite % (I)		1.96	20.0	28.57	50.0
Organic Matter	V	V>L>I	V>I>L	V>I>L	I>V>L
Relative Maceral Abundance	Sp	Sp	Sp	Sp	Sp-Cm
Liptinite/Exinite Macerals					
Liptodetrinite	Ra; dO		Ra; dO	Ra; Y-O	Ra; O-dO
Sporinite		Sp; iY	Sp; gY-dO	Sp; Y-O	Sp; O-dO
Cutinite		Sp; dO		Ra; dO	Ra; dO
Bituminite					
Resinite		Sp; dY		Ra; O	
Phytoplankton					
Lamalginite	Ra; gY		Ra; gY		Ra; gY-O
Liptinite (mostly oxidised)	Ra	Sp	Sp	Ra	
TOC%	0.26	18.92	2.76	2.3	6.39
Lithology	Sandstone and claystone	Claystone, sandstone and coal	Claystone, siltstone and minor coal	Sandstone siltstone and coal	Claystone, sandstone and coal

Vr = very rare　Ra = rare　Sp = sporadic　Cm = Common
iY = intense yellow　mY = mid yellow　iO = intense orange　dO = dark orange
B = black　Br = brown

Table 16 East Reeve 1 (1323 m Cuttings) — Alkane and alkene determination by Pyrolysis-GC

Carbon No.	Alkane + Alkene			Alkane			Alkene			Alkane / Alkene
	A	B	C	A	B	C	A	B	C	
5	3.380	1.649	0.087	1.680	0.820	0.043	1.700	0.829	0.044	0.99
6	1.964	0.958	0.051	0.938	0.458	0.024	1.026	0.501	0.026	0.91
7	1.393	0.680	0.036	0.707	0.345	0.018	0.686	0.335	0.018	1.03
8	1.056	0.515	0.027	0.495	0.242	0.013	0.561	0.274	0.014	0.88
9	0.900	0.439	0.023	0.449	0.219	0.012	0.451	0.220	0.012	1.00
10	1.315	0.642	0.034	0.783	0.382	0.020	0.532	0.260	0.014	1.47
11	0.913	0.445	0.024	0.482	0.235	0.012	0.431	0.210	0.011	1.12
12	0.949	0.463	0.024	0.413	0.202	0.011	0.536	0.262	0.014	0.77
13	0.797	0.389	0.021	0.402	0.196	0.010	0.395	0.193	0.010	1.02
14	1.145	0.559	0.030	0.374	0.182	0.010	0.771	0.376	0.020	0.49
15	0.643	0.314	0.017	0.467	0.228	0.012	0.176	0.086	0.005	2.65
16	0.706	0.344	0.018	0.371	0.181	0.010	0.335	0.163	0.009	1.11
17	0.641	0.313	0.017	0.446	0.218	0.012	0.195	0.095	0.005	2.29
18	0.515	0.251	0.013	0.290	0.141	0.007	0.225	0.110	0.006	1.29
19	0.550	0.268	0.014	0.366	0.179	0.009	0.184	0.090	0.005	1.99
20	0.618	0.302	0.016	0.372	0.181	0.010	0.246	0.120	0.006	1.51
21	0.567	0.277	0.015	0.327	0.160	0.008	0.240	0.117	0.006	1.36
22	0.541	0.264	0.014	0.355	0.173	0.009	0.186	0.091	0.005	1.91
23	0.516	0.252	0.013	0.316	0.154	0.008	0.200	0.098	0.005	1.58
24	0.509	0.248	0.013	0.318	0.155	0.008	0.191	0.093	0.005	1.66
25	0.439	0.214	0.011	0.264	0.129	0.007	0.175	0.085	0.005	1.51
26	0.367	0.179	0.009	0.263	0.128	0.007	0.104	0.051	0.003	2.53
27	0.318	0.155	0.008	0.201	0.098	0.005	0.117	0.057	0.003	1.72
28	0.231	0.113	0.006	0.162	0.079	0.004	0.069	0.034	0.002	2.35
29	0.171	0.083	0.004	0.095	0.046	0.002	0.076	0.037	0.002	1.25
30	0.086	0.042	0.002	0.062	0.030	0.002	0.024	0.012	0.001	2.58
31	0.054	0.026	0.001	0.037	0.018	0.001	0.017	0.008	0.000	2.18

A = % of resolved compounds in S_2 B = mg/g rock (Rock-Eval) C = (mg/g rock)/TOC

Table 17 East Reeve 1 (1323 m Cuttings) — EOM analysis

1) Extracted Organic Matter (EOM) ppm

Depth (m KB)	Weight of Rock Extd (g)	Total Extract (ppm)	Loss on Column (ppm)	Hydrocarbons			Non-hydrocarbons		
				Saturates (ppm)	Aromatics (ppm)	HC Total (ppm)	NSO's (ppm)	Asphalt (ppm)	Non HC Total (ppm)
1323	9.4	10703.2	1479.7	616.5	2170.2	2786.8	6436.7	nd	6436.7

2) Percentages and Ratios of EOM

Depth (m KB)	Hydrocarbons			Non-hydrocarbons			EOM(mg)/ TOC (g)	SAT(mg)/ TOC (g)	SAT/ AROM	ASPH/ NSO	HC/ Non HC
	%SAT	%AROM	%HC's	%NSO's	%ASPH	%Non HC's					
1323	6.7	23.5	30.2	69.8	nd	69.8	56.6	3.3	0.3	nd	0.4

3) Alkane Ratios

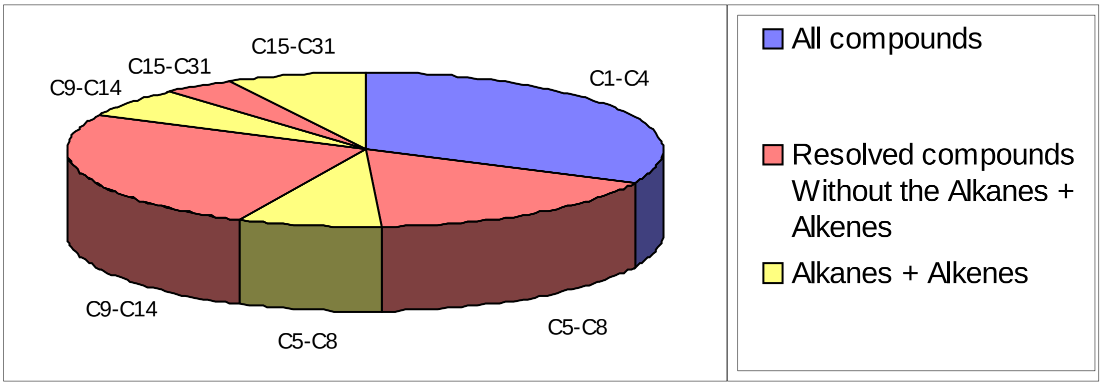
Depth (m KB)	Prist/Phyt	Prist/n-C17	Phyt/n-C18	CPI(1)	CPI(2)	(C21+C22)/(C28+C29)
1323	2.75	1.12	0.58	1.43	1.31	0.33

nC12-nC31 Percentage Concentrations in Saturate Fraction

nC12%	nC13%	nC14%	nC15%	nC16%	nC17%	iC19%	nC18%	iC20%	nC19%	nC20%
3.7	6.4	5.6	4.2	3.6	3.6	4.0	2.5	1.4	2.2	3.2
nC21%	nC22%	nC23%	nC24%	nC25%	nC26%	nC27%	nC28%	nC29%	nC30%	nC31%
2.2	2.7	3.8	4.1	6.2	5.8	9.2	6.5	8.3	3.9	7.1

Table 18 East Reeve 1 (1323 m) — Pyrolysis gas chromatography

	Parameter	A	B	C	No. Units
C1-C4	abundance (all compounds)	32.04	15.63	0.83	
C5-C8	abundance (all resolved compounds)	24.94	12.17	0.64	
C5-C8	abundance (alkanes + alkenes)	7.79	3.80	0.20	
C9-C14	abundance (all resolved compounds)	31.56	15.40	0.81	
C9-C14	abundance (alkanes + alkenes)	6.02	2.94	0.16	
C15-C31	abundance (all resolved compounds)	11.46	5.59	0.30	
C15-C31	abundance (alkanes + alkenes)	7.47	3.65	0.19	
C9-C31	abundance (all resolved compounds)	43.02	20.99	1.11	
C9-C31	abundance (alkanes + alkenes)	13.49	6.58	0.35	
C5-C31	abundance (all resolved compounds)	67.96	33.16	1.75	
C5-C31	abundance (alkanes + alkenes)	21.28	10.38	0.55	
C5-C31	alkane abundance	11.44	5.58	0.29	
C5-C31	alkene abundance	9.85	4.81	0.25	
C5-C8	alkane / alkene				0.96
C9-C14	alkane / alkene				0.93
C15-C31	alkane / alkene				1.71
C5-C31	alkane / alkene				1.16
(C1-C5)/C6+					0.61
R					2.78



A = % of resolved compounds in S2
B = mg/g rock (Rock-Eval)
C = (mg/g rock)/TOC
R = m + p-xylene/n-octane

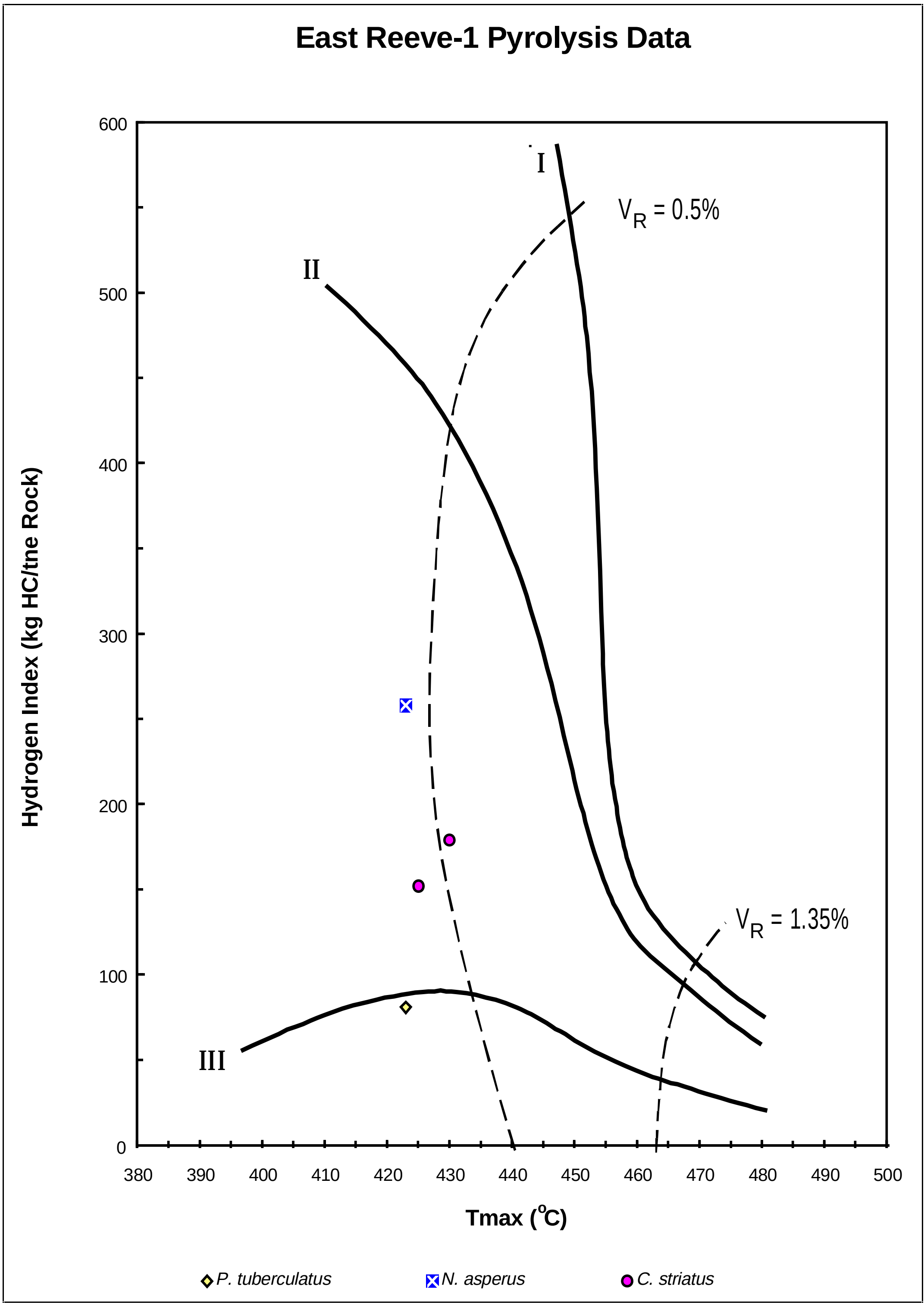


Figure 18
East Reeve 1: HI versus Tmax ºC plot.

East Reeve 1

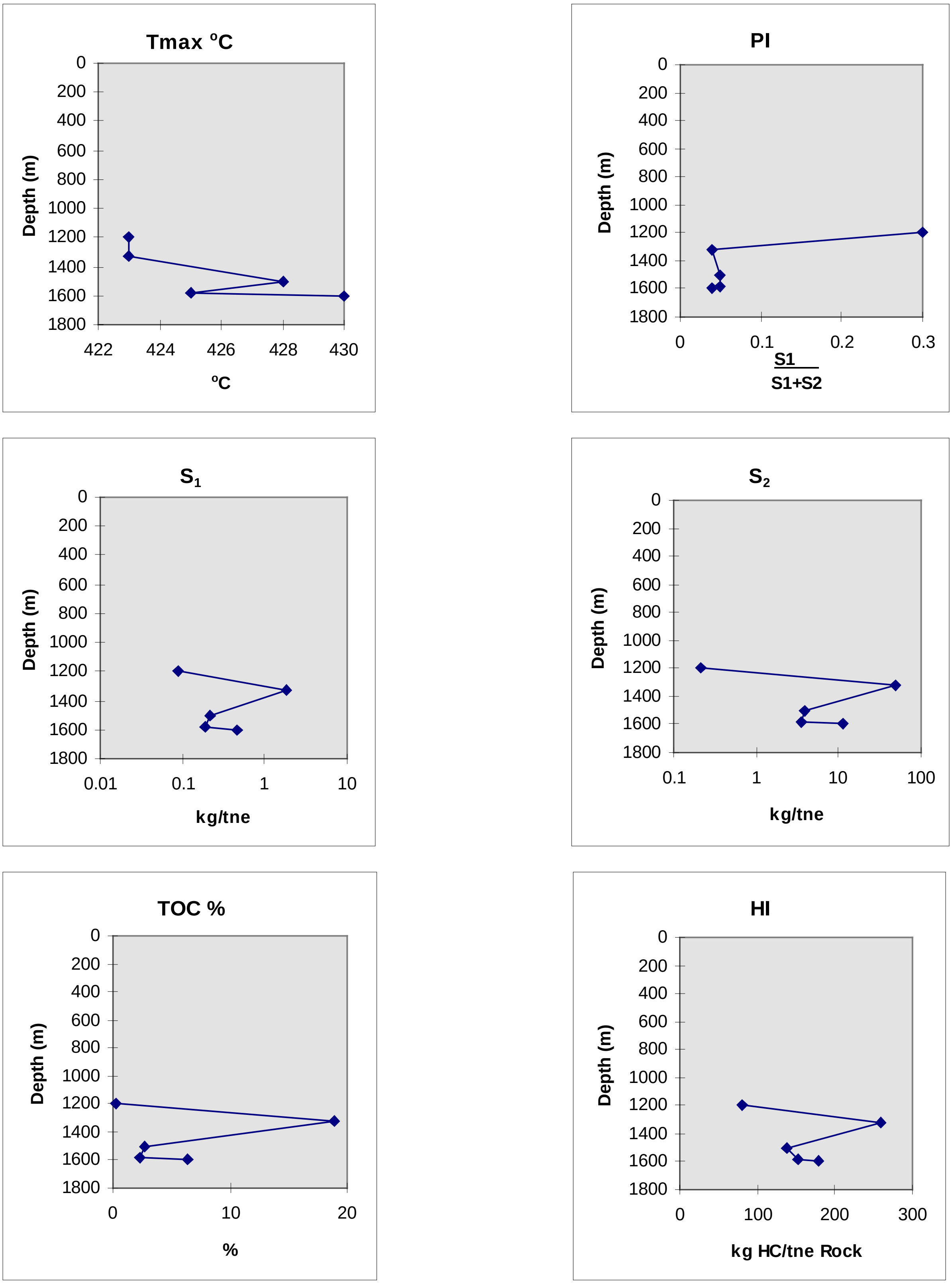


Figure 19
East Reeve 1: (a) Tmax °C; (b) S1; (c) S2; (d) PI; (e) TOC %; (f) HI.

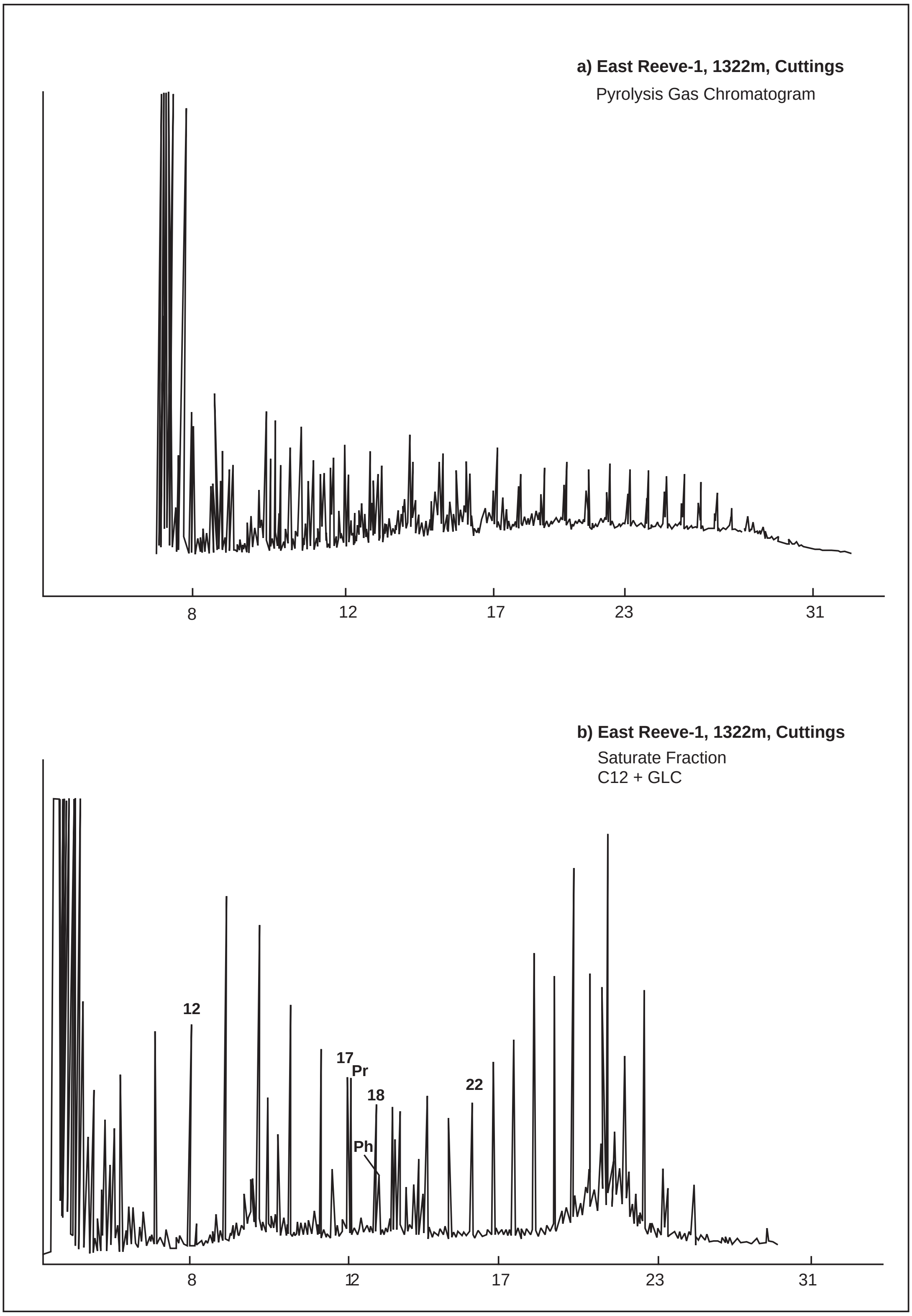


Figure 20

East Reeve 1, (1323 m): — Pyrolysis gas chromatographs .
(a) Cuttings;   (b) Saturate fraction, C12+ of cuttings

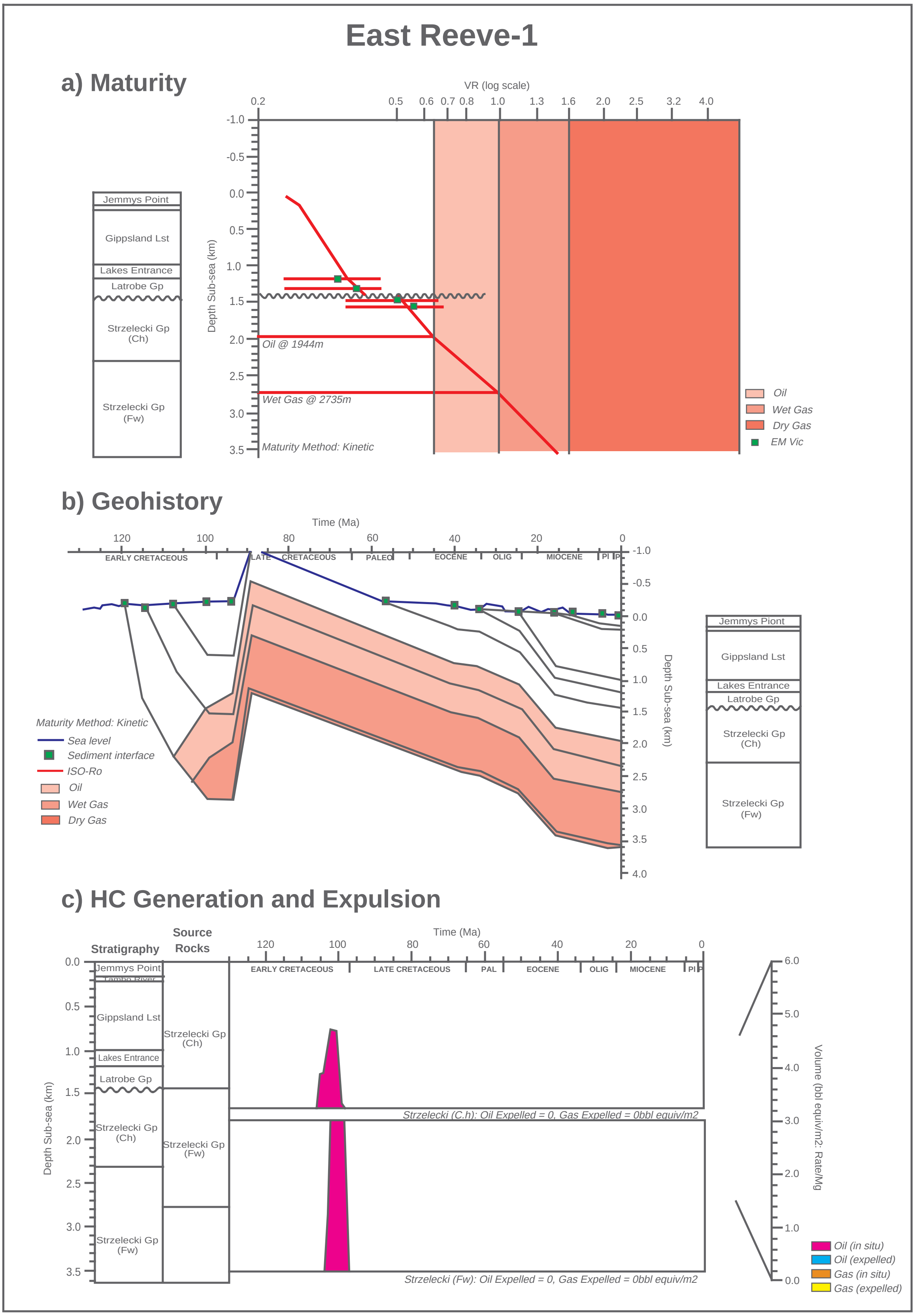


Figure 21
East Reeve 1: (a) Maturity plot; (b) Geohistory; (c) Hydrocarbon expulsion.

Golden Beach West 1

1 Introduction

Three samples from Golden Beach West 1 were collected (978, 1777 & 2210 m).

2 Source rock richness

The total organic carbon (TOC) values for the three samples analysed are in the range of 0.2 to 1.16%, which indicates that they have poor to fair source potential (Tables 19 & 20). The macerals are dominated either by vitrinite or by inertinite.

3 Rock-Eval Pyrolysis

The Rock-Eval pyrolysis analysis was performed on the three samples. The samples have S1 values ranging from 0.17 to 0.90 kg/tne, and S2 values vary between 0.17 and 0.88 kg/tne. These values suggest low levels of free hydrocarbons. Hydrocarbon index (HI) values are also low (76-85). Immaturity is indicated by the single Tmax value of 434 °C (Figs 22 & 23).

4 Vitrinite reflectance

Vitrinite reflectance measurements of the samples range from 0.38 to 0.61%, immature to marginally mature. The oil window lies between 2380 and 3357 m at this well (Fig. 24a).

5 Geohistory

Subsidence at the Golden Beach West 1 site was generally uniform at 125 m/million years until 100 Ma when subsidence slowed. A rapid subsidence occurred from 95 to 90 Ma. After that subsidence continued at a rate of about 140 m/million years until 80 Ma. From then on, subsidence continued at a much slower rate of about 17 m/million years until the present (Fig. 24b).

6 Hydrocarbon expulsion

Minor oil and gas expulsion commenced at about 115 Ma, peaking around 100 Ma, with a second, minor peak around 75 Ma. Rates of early stage expulsion from the Strzelecki Group were calculated to be around 800 bbl/m^2 of oil; the amount of gas expelled was around 538 bbl equiv/m^2 of source rock (Fig. 24c).

Table 19 Golden Beach West 1, Rock-Eval pyrolysis

Depth (m KB)	Spore-Pollen Zone	T max oC	S1 kg/tne	S2 kg/tne	S3 kg/tne	Generative Potential (S1 + S2)	S2/S3	PI	PC	TOC %	HI	OI
978	*N. asperus*		0.17	0.17	0.26	0.34	0.65	0.50	0.03	0.2	85	130
1777	*N. senectus*		0.90	0.19	0.90	1.09	0.21	0.83	0.09	0.25	76	360
2210	*P. mawsonii*	434	0.32	0.88	2.51	1.20	0.35	0.27	0.10	1.16	76	216

Table 20 Golden Beach West 1. Maceral, vitrinite reflectance, lithologic and richness (TOC) data			
Depth (m KB)	978	1777	2210
Spore-Pollen Zone	*N. asperus*	*N. senectus*	*P. mawsonii*
Vitrinite Reflectance			
Mean Ro %	0.38	0.42	0.61
Min to Max %	0.28-0.45	0.35-0.63	0.49-0.77
Sample No. Determination	27	15	27
Maceral Proportion			
Vitrinite % (V)	100.0		66.67
Inertinite % (I)		100.0	33.33
Liptinite % (L)			
Organic Matter			
Relative Maceral Abundance	V	I	V>I
DOM %	Ra	Ra-Sp	Cm
Liptinite/Exinite Macerals			
Liptodetrinite	Ra; Y-O	Ra; dO	Ra; O-dO
Sporinite	Ra; Y-O		Ra; O-dO
Cutinite			Ra; O
Bituminite			
Resinite			
Phytoplankton			
Lamalginite	Ra; Y	Ra; dO	Ra; O
Liptinite (mostly oxidised)	Ra	Ra	Ra
TOC%	0.2	0.25	1.16
Lithology	Sandstone siltstone and coal	Most sandstones are free of organic matter, but where organic matter is present the assemblage is rich in vitrinite	Sandstone, siltstone, carbonate and coal

Vr = very rare Ra = rare Sp = sporadic Cm = Common iY = intense yellow
mY = mid yellow iO = intense orange dO = dark orange B = black Br = brown

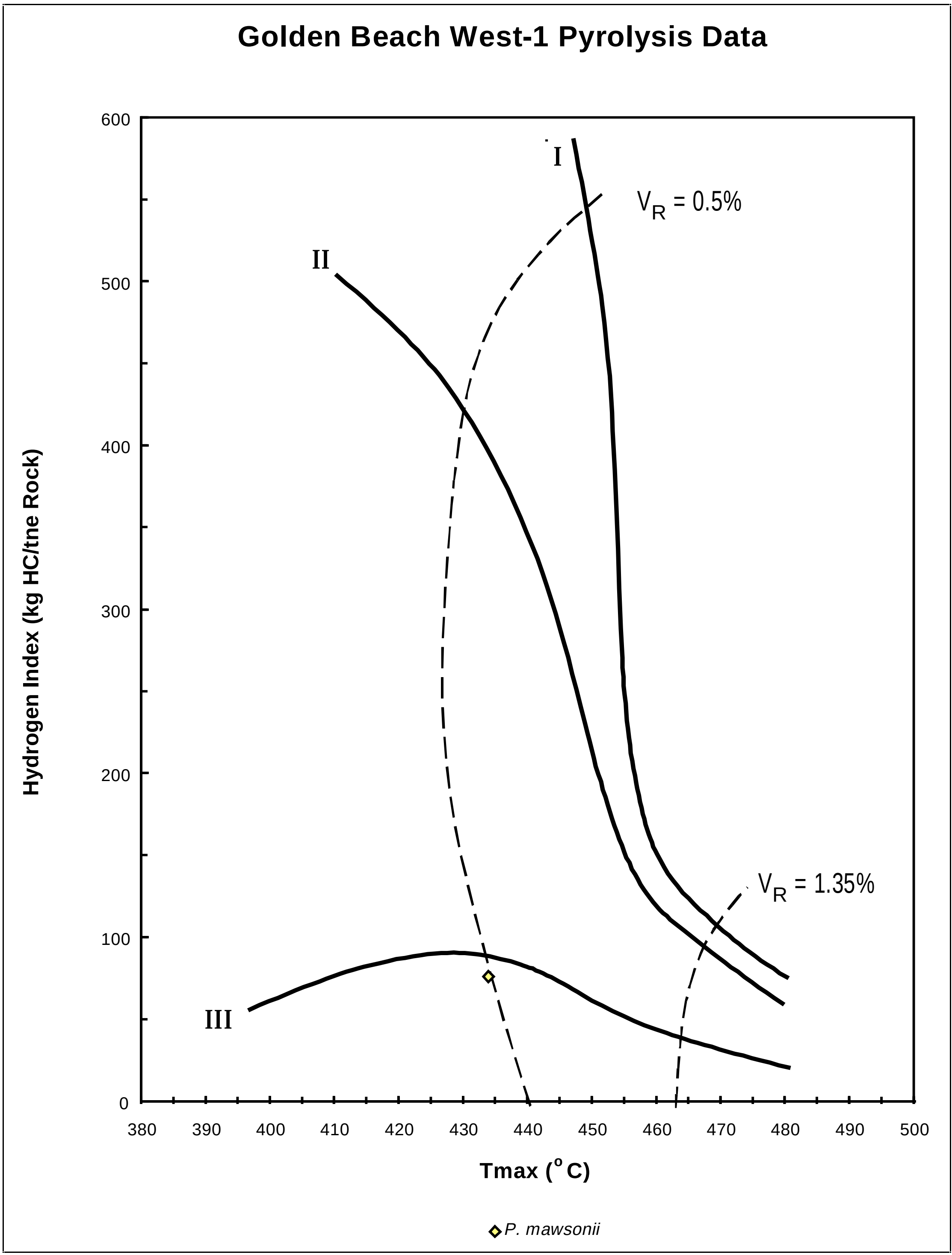


Figure 22
Golden Beach West 1: HI versus Tmax ºC plot.

Golden Beach West 1

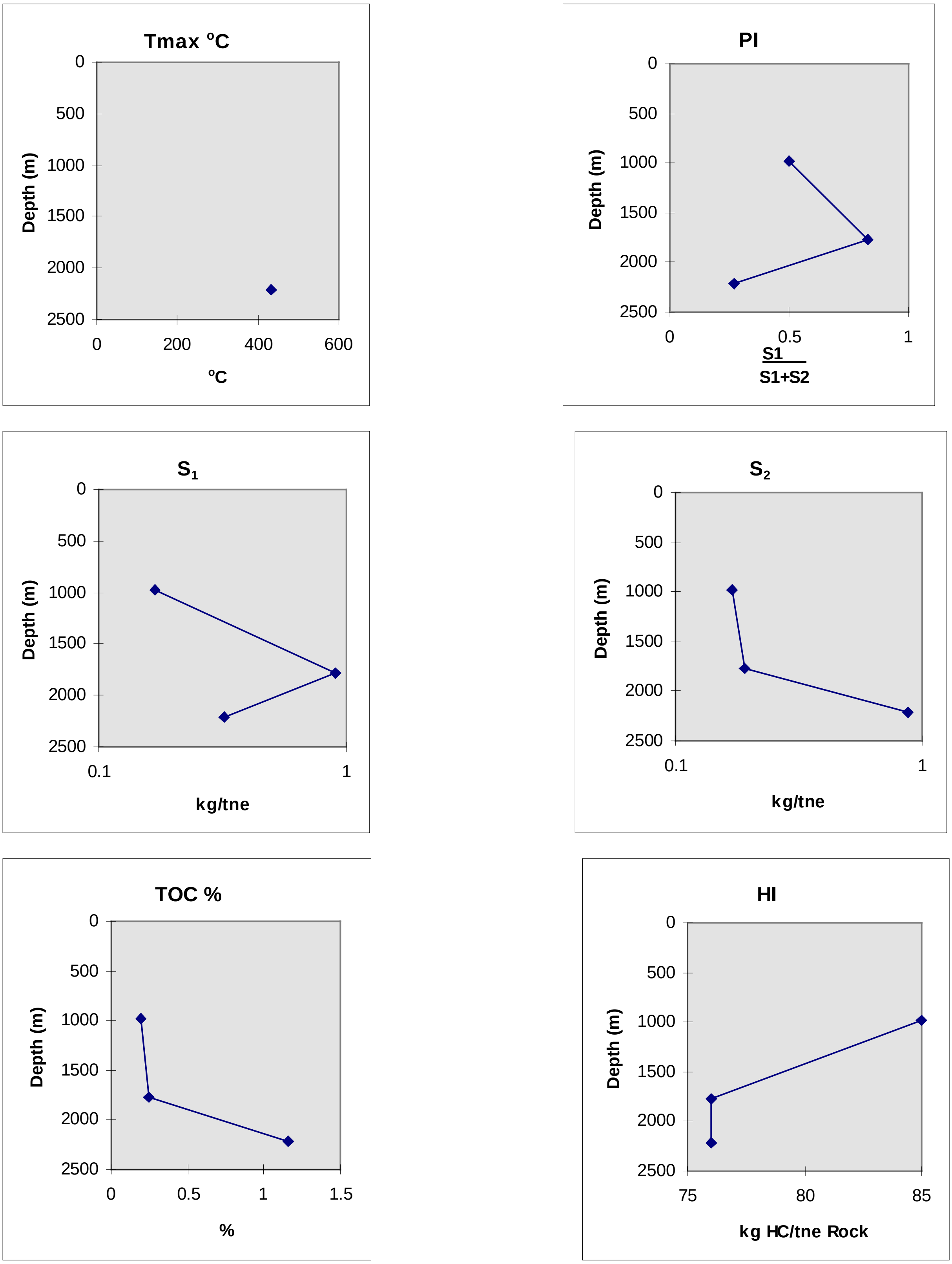


Figure 23

Golden Beach West 1: (a) Tmax °C; (b) S1; (c) S2; (d) PI; (e) TOC %; (f) HI.

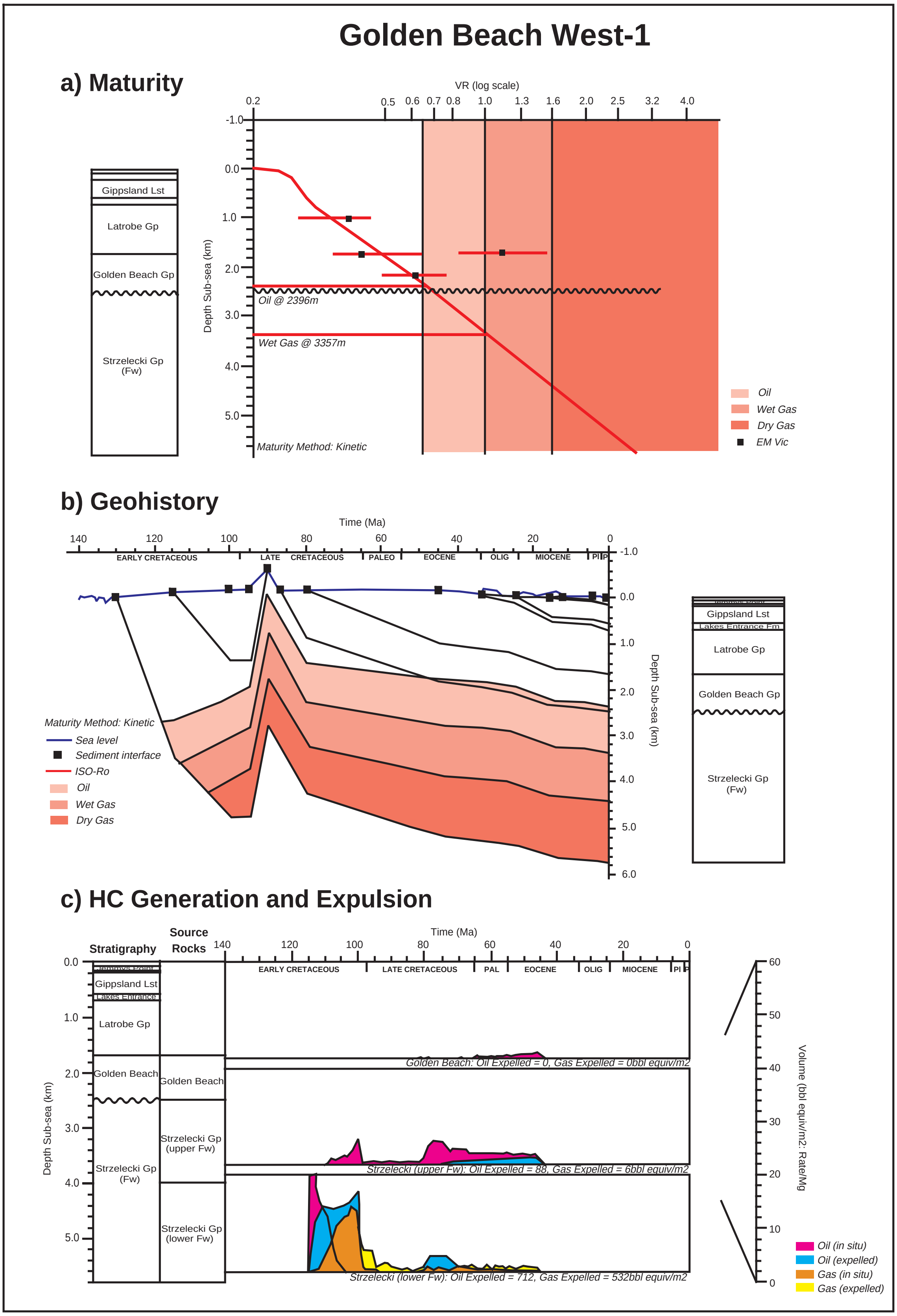


Figure 24
Golden Beach West 1: (a) Maturity plot; (b) Geohistory; (c) Hydrocarbon expulsion

Loy Yang 1A

1 Introduction

A total of fourteen samples from Loy Yang 1A were collected.

2 Source rock richness

The total organic carbon (TOC) values for the fourteen samples analysed are in the range of 0.56 to 18.10%, which indicates that they have fair to very good source potential. The sample at 1066 m, which recorded a TOC of 78.96%, was coal (Table 21).

3 Rock-Eval Pyrolysis

The Rock-Eval pyrolysis analysis was performed on the eight samples. The samples have S1 values ranging from 0.08 to 2.37 kg/tne (with a value of 6.26 at 1066 m) and S2 values vary between 0.89 and 34.75 kg/tne (with a value of 181.21 at 1066 m). These values suggest fair to good levels of free hydrocarbons. Hydrocarbon index (HI) values are fair to good (78-245). The maturity is in the oil window, as indicated by the Tmax range from 442°C to 464°C with the plots being displayed earlier in Figure 8.

4 Vitrinite reflectance

The oil window lies between 623 and 1300 m at this well (Fig. 25a).

5 Geohistory

Subsidence at the Loy Yang 1A site was generally uniform at 50 m/million years until 100 Ma when a slow down of subsidence occurred at a rate of 20 m/million years until 92 Ma. A dramatic reversal then occurred from 92 to 88 Ma. After that subsidence continued at a much slower rate of about 9 m/million years thereafter, until 6 Ma where there has been very gradual uplift to the present (Fig. 25b).

6 Hydrocarbon generation and expulsion

The expulsion plot indicates oil in situ and no expulsion from Early Cretaceous source has occurred (Fig. 25c). Lack of expulsion of hydrocarbons at this location is due to uplift and the lack of traps during Late Cretaceous to Tertiary time.

Table 21 Loy Yang 1A, Rock-Eval pyrolysis

Depth (m KB)	Spore-Pollen Zone	T max oC	S1 kg/tne	S2 kg/tne	S3 kg/tne	Generative Potential (S1 + S2)	S2/S3	PI	PC	TOC %	HI	OI
1066	*P. notensis*	451	6.26	181.21	1.81	187.47	100.12	0.03	15.56	78.96	229	2
1099	= *C. hughesii*	446	0.83	3.94	0.98	4.77	4.02	0.17	0.40	2.63	150	37
1126	"	449	2.03	18.14	1.34	20.17	13.54	0.10	1.67	10.46	173	13
1240	"	451	0.24	1.46	1.02	1.70	1.43	0.14	0.14	0.94	155	109
1306	"	451	0.18	0.95	0.94	1.13	1.01	0.16	0.09	0.94	101	100
1378	"	464	0.18	0.90	0.85	1.08	1.06	0.17	0.09	1.16	78	73
1450	"	459	0.20	0.90	1.02	1.10	0.88	0.18	0.09	0.75	120	136
1717	"	460	0.08	1.37	1.02	1.45	1.34	0.06	0.12	0.56	245	182

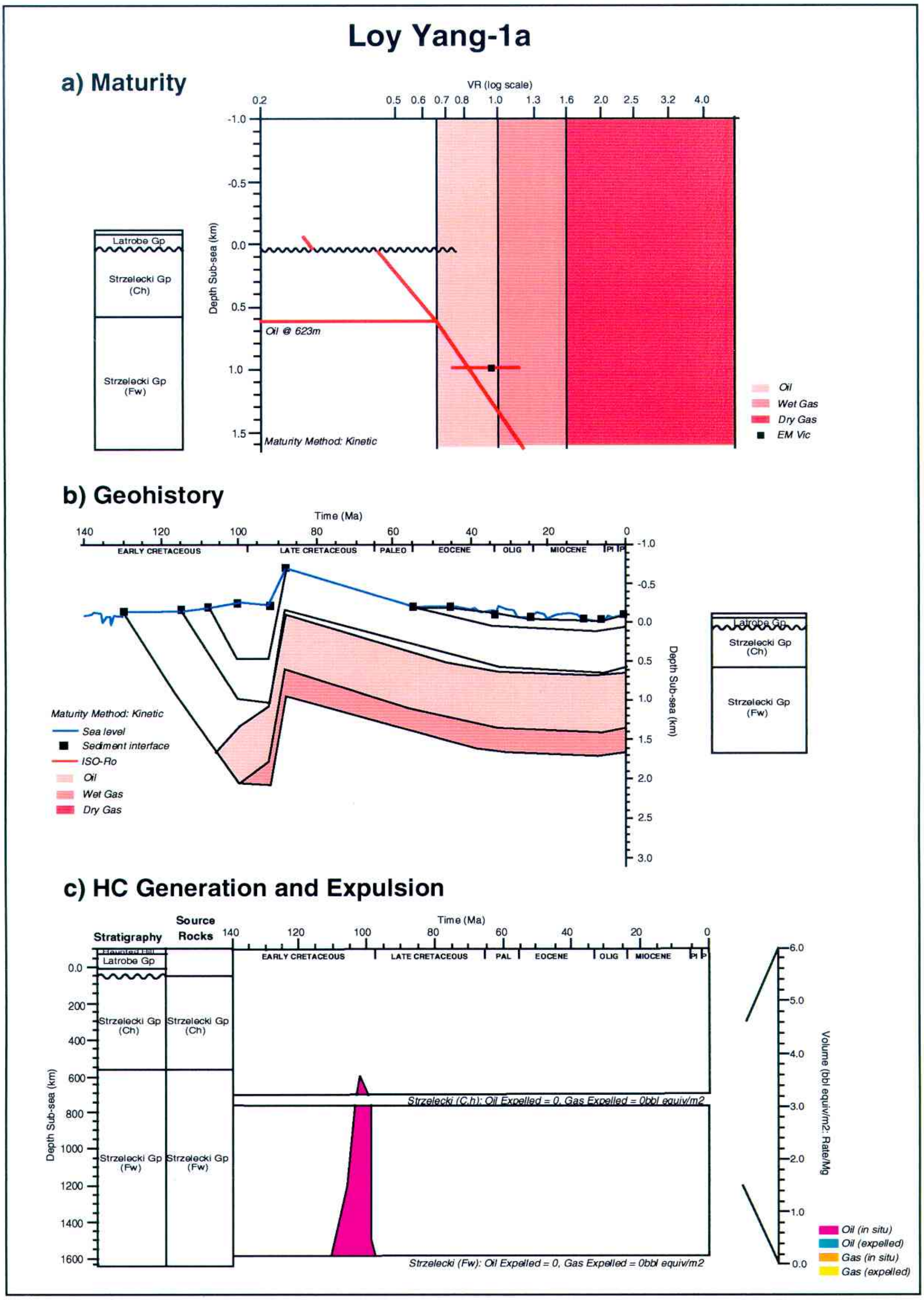


Figure 25
Loy Yang 1A; (a) Maturity Plot; (b) Geohistory; (c) Hydrocarbon expulsion.

Merriman 1

1 Introduction

Three samples from Merriman 1 were collected (981, 1481 & 1722 m).

2 Source rock richness

The total organic carbon (TOC) values for the three samples analysed are in the range of 2.24 to 7.43%, which indicates that they have good source potential (Tables 22 & 23). The macerals are dominated by vitrinite in the shallower samples and inertinite in the deepest sample.

3 Rock-Eval Pyrolysis

Rock-Eval pyrolysis was performed on the three samples. In the two shallowest samples, the S1 values are 0.79 kg/tne while in the deepest sample the S1 value is 0.27%. S2 values vary between 8.79 and 15.03 kg/tne in the shallowest samples, and in the deepest sample it is 1.31 kg/tne. These values suggest low levels of free hydrocarbons. Hydrocarbon index (HI) values are also low (58-202). Immaturity to marginal maturity is indicated by the Tmax values between 407 °C and 436 °C (Fig. 26). These values suggest that oil-prone, marginally mature source rocks exist at 1481 m.

4 Saturate gas chromatography and gas chromatography-mass spectrometry

The sample at 1481 m was further analysed by pyrolysis gas chromatography (Py-GC). The Py-GC traces consist of well defined alkane/alkene pairs which extend out to C31. The C15 to C31 alkane plus alkene value is approximately 11.30% (calculated as percentage of S2) and characterises the kerogen as being mixed oil and gas prone (Table 24). Solvent extraction of the 1481 m sample yielded 1591.5 ppm and showed a bimodal distribution in the alkanes. This indicates contribution from two sources, with a significant contribution from terrestrially derived organic matter. The pristane/phytane ratio of 3.27 suggests a relatively oxidising depositional environment (Table 25). The results of pyrolysis gas chromatography are displayed in Table 26. Also, the branched/cyclic gas chromatography-mass spectrometry (GC-MS) data supports this profile (Figs 27 & 28).

5 Vitrinite reflectance

Vitrinite reflectance measurements indicate immaturity, the samples ranging from 0.37 to 0.55%. The oil window lies between 1876 and 2590 m at this well (Fig. 29a).

6 Geohistory

Subsidence at the Merriman 1 site was generally uniform at 130 m/million years until 100 Ma when a slow down of subsidence occurred. A dramatic reversal then occurred from 95 to 90 Ma. After that, subsidence continued at a rate of about 120 m/million year until 80 Ma. From then on, subsidence continued at a much slower rate of about 15 m/million years thereafter, until the present, apart from a minor increase in the subsidence rate between 25 to 15 Ma (Fig. 29b).

7 Hydrocarbon expulsion

Minor oil and gas expulsion commenced at about 113 Ma, peaking around 100 Ma. Rates of early stage expulsion from the Strzelecki Group were calculated to be around 640 bbl/m^2 of oil; the amount of gas expelled was around 622 bbl equiv/m^2 of source rock (Fig. 29c).

Table 22 Merriman 1, Rock-Eval pyrolysis

Depth (m KB)	Spore-Pollen Zone	T max oC	S1 kg/tne	S2 kg/tne	S3 kg/tne	Generative Potential (S1 + S2)	S2/S3	PI	PC	TOC %	HI	OI
982	*N. asperus*	407	0.79	8.79	2.60	9.58	3.38	0.08	0.80	6.24	141	42
1481		427	0.79	15.03	1.91	15.82	7.87	0.05	1.31	7.43	202	26
1722	*P. mawsonii*	436	0.27	1.31	2.32	1.58	0.56	0.17	0.13	2.24	58	104

Table 23 Merriman 1 Maceral, vitrinite reflectance, lithologic and richness (TOC) data

Depth (m KB)	982	1481	1722
Spore-Pollen Zone	*N. asperus*		*P. mawsonii*
Vitrinite Reflectance			
Mean Ro %	0.37	0.42	0.55
Min to Max %	0.28-0.48	0.25-0.55	0.43-0.66
Sample No. Determination	26	28	27
Maceral Proportion			
Vitrinite % (V)	87.5	80.0	36.67
Inertinite % (I)	0.0	5.71	56.67
Liptinite % (L)	7.5	14.29	6.67
Organic Matter			
Relative Maceral Abundance	V>L	V>L>I	I>V>L
DOM %	Ab	Sp-Cm	Ab
Liptinite/Exinite Macerals			
Liptodetrinite	Sp; gY-O	Sp; gY-O	Sp; yO-O
Sporinite	Sp; gY-O	Sp; gY-O	
Cutinite		Ra; O	
Bituminite			
Resinite			
Phytoplankton			
Lamalginite	Sp; Y-dO	Ra; Y	
Liptinite (mostly oxidised)	Sp	Sp	Sp
TOC%	6.24	7.43	2.24
Lithology	Argillaceous siltstone, sandstone and coal	Argillaceous sandstone, siltstone and coal	Sandy siltstone and coal

Vr = very rare Ra = rare Sp = sporadic Cm = Common Ab = Abundant
iO = intense orange B = black mY = mid yellow dO = dark orange

Table 24 Merriman 1 (1481 m Cuttings) — Alkane and alkene determination by Pyrolysis-GC

Carbon No.	Alkane + Alkene			Alkane			Alkene			Alkane / Alkene
	A	B	C	A	B	C	A	B	C	
5	4.017	0.604	0.081	2.000	0.301	0.040	2.017	0.303	0.041	0.99
6	2.396	0.360	0.048	1.280	0.192	0.026	1.116	0.168	0.023	1.15
7	1.723	0.259	0.035	0.839	0.126	0.017	0.884	0.133	0.018	0.95
8	1.417	0.213	0.029	0.660	0.099	0.013	0.757	0.114	0.015	0.87
9	1.118	0.168	0.023	0.528	0.079	0.011	0.590	0.089	0.012	0.89
10	1.500	0.225	0.030	0.834	0.125	0.017	0.666	0.100	0.013	1.25
11	1.221	0.184	0.025	0.623	0.094	0.013	0.598	0.090	0.012	1.04
12	1.433	0.215	0.029	0.606	0.091	0.012	0.827	0.124	0.017	0.73
13	1.343	0.202	0.027	0.761	0.114	0.015	0.582	0.087	0.012	1.31
14	1.437	0.216	0.029	0.521	0.078	0.011	0.916	0.138	0.019	0.57
15	1.217	0.183	0.025	0.726	0.109	0.015	0.491	0.074	0.010	1.48
16	1.137	0.171	0.023	0.491	0.074	0.010	0.646	0.097	0.013	0.76
17	1.116	0.168	0.023	0.785	0.118	0.016	0.331	0.050	0.007	2.37
18	0.847	0.127	0.017	0.404	0.061	0.008	0.443	0.067	0.009	0.91
19	0.745	0.112	0.015	0.476	0.072	0.010	0.269	0.040	0.005	1.77
20	0.736	0.111	0.015	0.418	0.063	0.008	0.318	0.048	0.006	1.31
21	0.692	0.104	0.014	0.400	0.060	0.008	0.292	0.044	0.006	1.37
22	0.704	0.106	0.014	0.439	0.066	0.009	0.265	0.040	0.005	1.66
23	0.691	0.104	0.014	0.416	0.063	0.008	0.275	0.041	0.006	1.51
24	0.712	0.107	0.014	0.434	0.065	0.009	0.278	0.042	0.006	1.56
25	0.652	0.098	0.013	0.378	0.057	0.008	0.274	0.041	0.006	1.38
26	0.572	0.086	0.012	0.400	0.060	0.008	0.172	0.026	0.003	2.33
27	0.519	0.078	0.010	0.326	0.049	0.007	0.193	0.029	0.004	1.69
28	0.381	0.057	0.008	0.268	0.040	0.005	0.113	0.017	0.002	2.37
29	0.292	0.044	0.006	0.175	0.026	0.004	0.117	0.018	0.002	1.50
30	0.181	0.027	0.004	0.137	0.021	0.003	0.044	0.007	0.001	3.11
31	0.102	0.015	0.002	0.069	0.010	0.001	0.033	0.005	0.001	2.09

A= % of resolved compounds in S_2 B = mg/g rock (Rock-Eval) C = (mg/g rock)/TOC

Table 25 Merriman 1 (1481 m Cuttings) — EOM analysis

1) Extracted Organic Matter (EOM) ppm

Depth (m KB)	Weight of Rock Extd (g)	Total Extract (ppm)	Loss on Column (ppm)	Hydrocarbons			Non-hydrocarbons		
				Saturates (ppm)	Aromatics (ppm)	HC Total (ppm)	NSO's (ppm)	Asphalt (ppm)	Non HC Total (ppm)
1481	12.1	1591.5	338.1	197.9	288.6	486.5	766.9	nd	766.9

2) Percentages and Ratios of EOM

Depth (m KB)	Hydrocarbons			Non-hydrocarbons			EOM(mg)/ TOC (g)	SAT(mg)/ TOC (g)	SAT/ AROM	ASPH/ NSO	HC/ Non HC
	%SAT	%AROM	%HC's	%NSO's	%ASPH	%Non HC's					
1481	15.8	23.0	38.8	61.2	nd	61.2	21.4	2.7	0.7	nd	0.6

3) Alkane Ratios

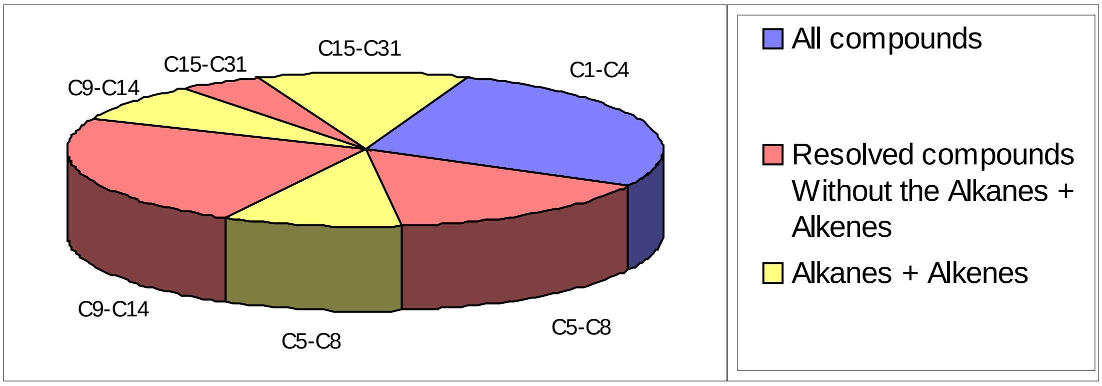
Depth (m KB)	Prist/Phyt	Prist/n-C17	Phyt/n-C18	CPI(1)	CPI(2)	(C21+C22)/(C28+C29)
1481	3.27	0.89	0.44	1.71	1.66	0.34

nC12-nC31 Percentage Concentrations in Saturate Fraction

nC12%	nC13%	nC14%	nC15%	nC16%	nC17%	iC19%	nC18%	iC20%	nC19%	nC20%
5.4	10.6	10.8	6.5	5.4	4.3	3.8	2.6	1.2	2.6	2.0
nC21%	nC22%	nC23%	nC24%	nC25%	nC26%	nC27%	nC28%	nC29%	nC30%	nC31%
1.8	2.0	2.8	2.6	5.9	3.6	6.5	4.3	6.8	3.3	5.4

Table 26 Merriman 1 (1481 m) — Pyrolysis gas chromatography

	Parameter	A	B	C	No. Units
C1-C4	abundance (all compounds)	27.22	4.09	0.55	
C5-C8	abundance (all resolved compounds)	24.93	3.75	0.50	
C5-C8	abundance (alkanes + alkenes)	9.55	1.44	0.19	
C9-C14	abundance (all resolved compounds)	32.05	4.82	0.65	
C9-C14	abundance (alkanes + alkenes)	8.05	1.21	0.16	
C15-C31	abundance (all resolved compounds)	15.80	2.37	0.32	
C15-C31	abundance (alkanes + alkenes)	11.30	1.70	0.23	
C9-C31	abundance (all resolved compounds)	47.84	7.19	0.97	
C9-C31	abundance (alkanes + alkenes)	19.35	2.91	0.39	
C5-C31	abundance (all resolved compounds)	72.78	10.94	1.47	
C5-C31	abundance (alkanes + alkenes)	28.90	4.34	0.58	
C5-C31	alkane abundance	15.39	2.31	0.31	
C5-C31	alkene abundance	13.31	2.03	0.27	
C5-C8	alkane / alkene				1.00
C9-C14	alkane / alkene				0.93
C15-C31	alkane / alkene				1.48
C5-C31	alkane / alkene				1.14
(C1-C5)/C6+					0.50
R					1.84



A = % of resolved compounds in S2
B = mg/g rock (Rock-Eval)
C = (mg/g rock)/TOC
R = m + p-xylene/n-octane

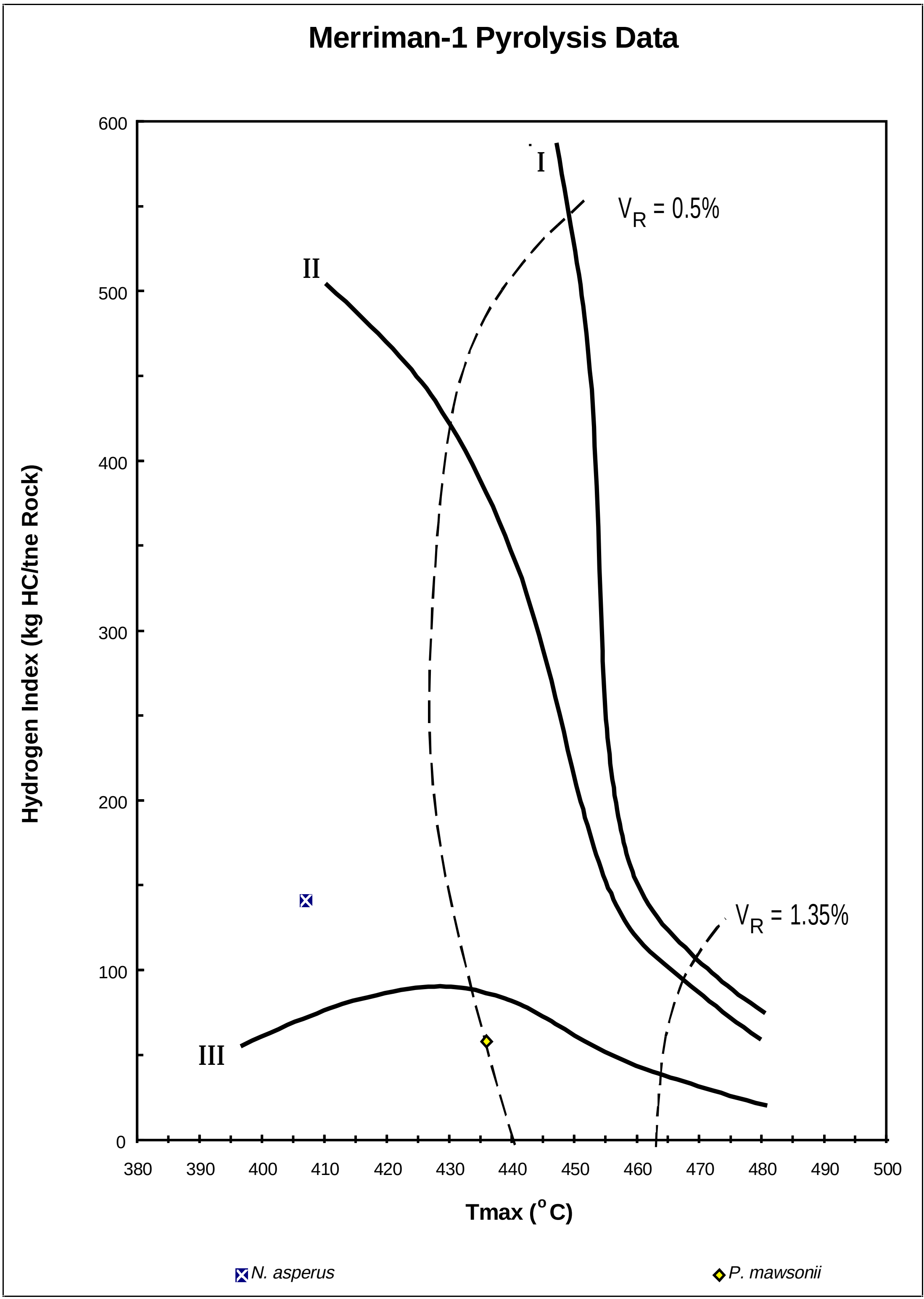


Figure 26
Merriman 1: HI versus Tmax ºC plot.

Merriman 1

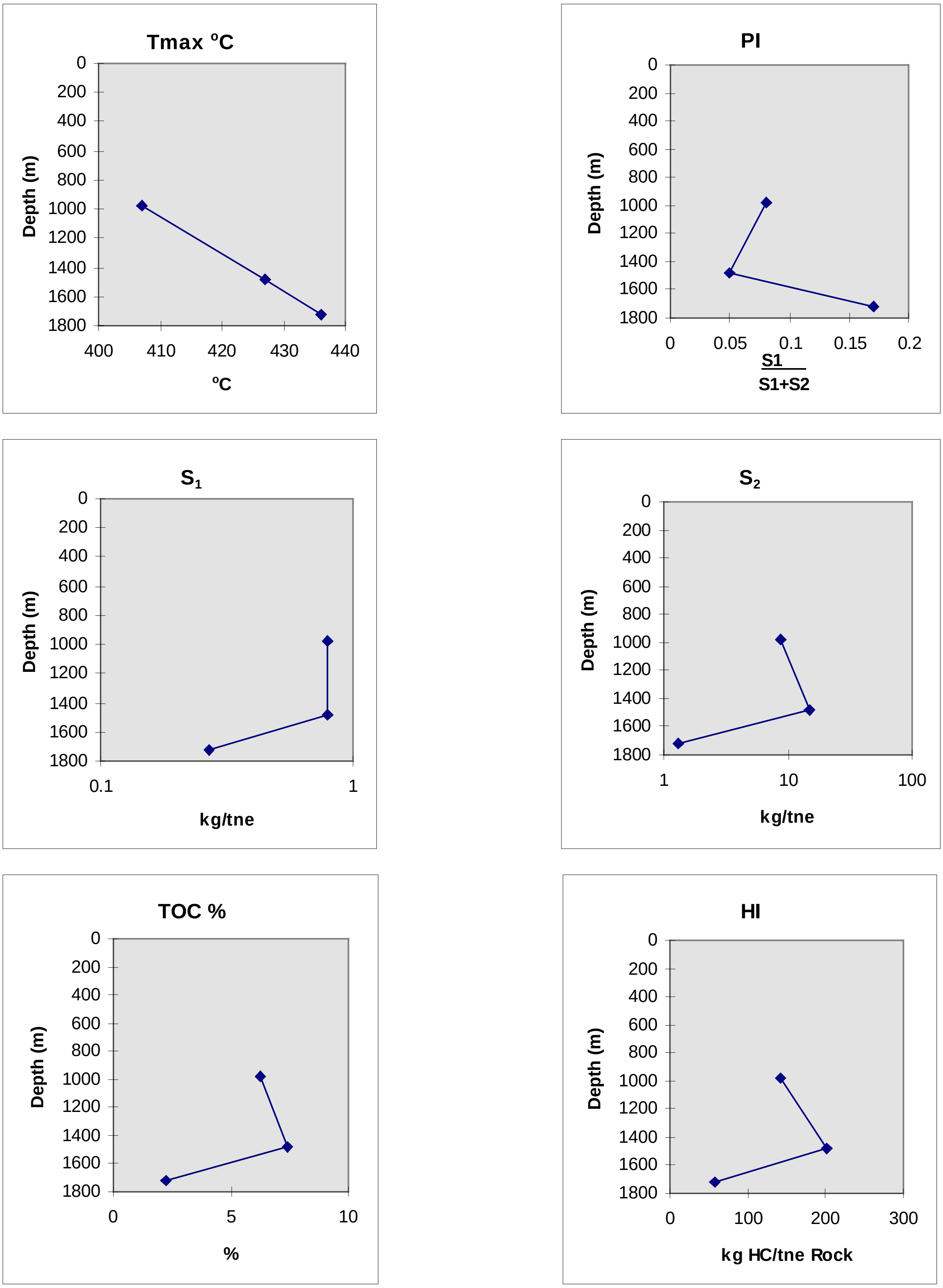


Figure 27
Merriman 1: (a) Tmax °C; (b) S1; (c) S2; (d) PI; (e) TOC %; (f) HI.

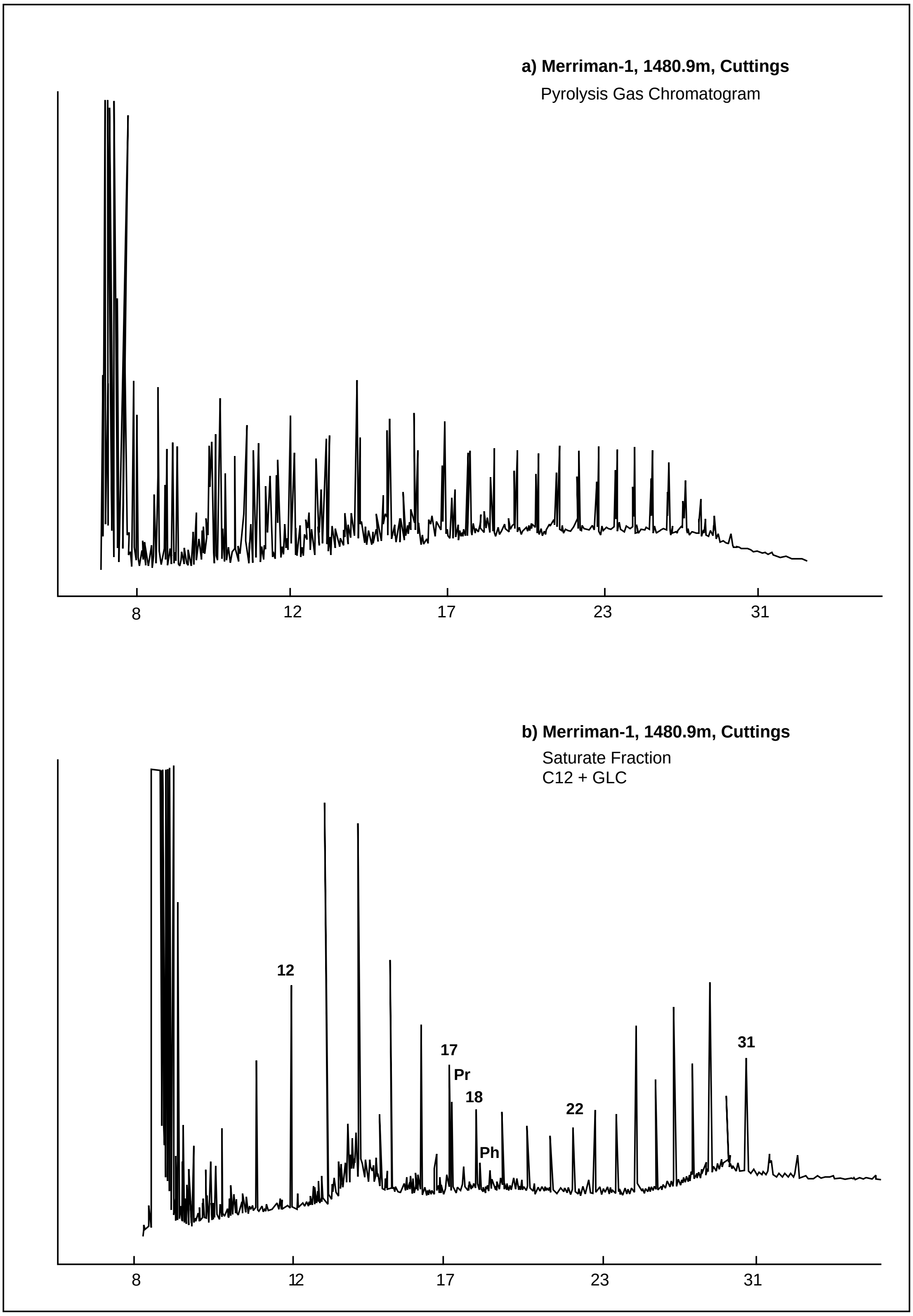


Figure 28

Merriman 1, (1481 m): — Pyrolysis gas chromatographs.
Cuttings; (b) Saturate fraction, C12+ of cuttings

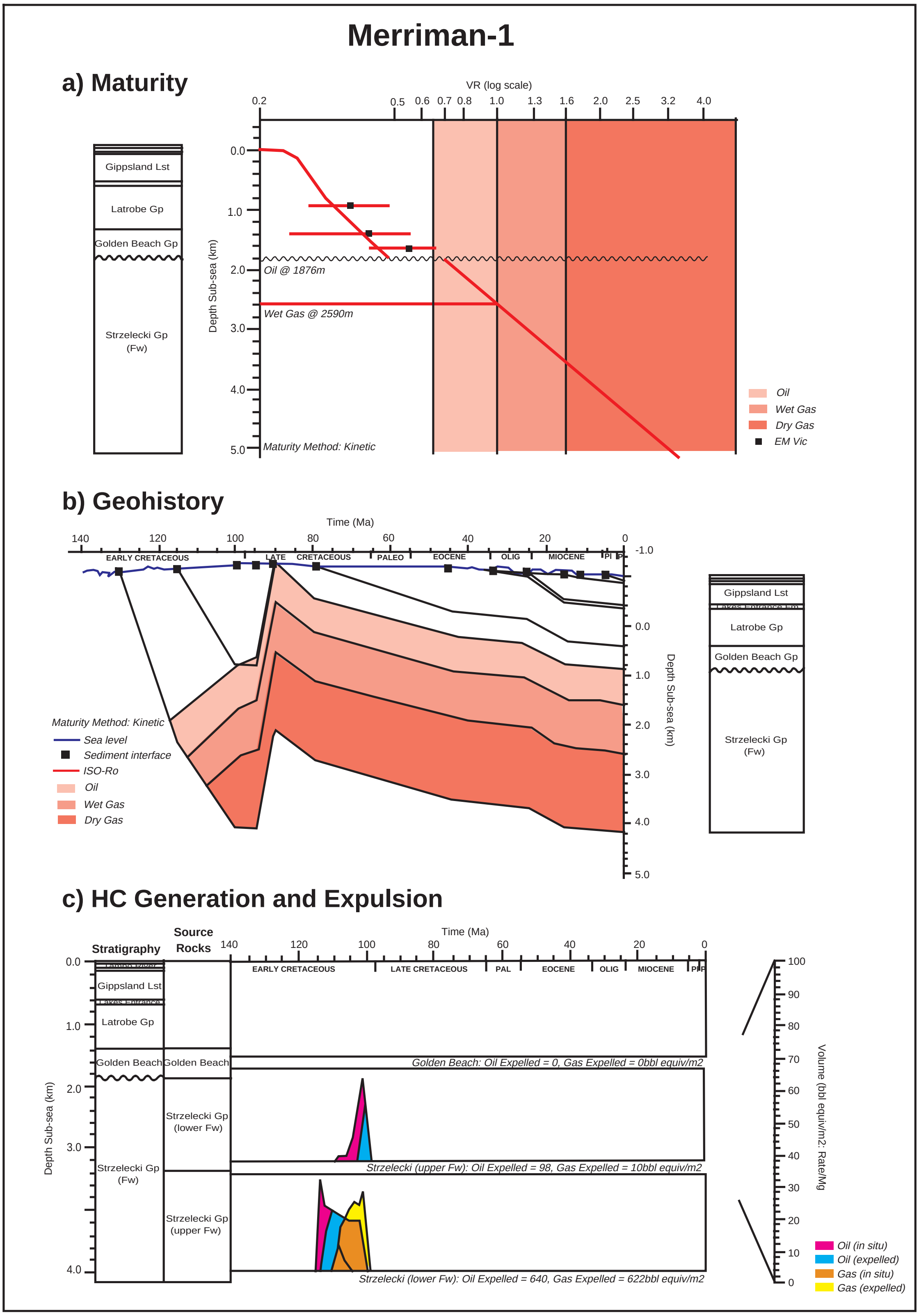


Figure 29

Merriman 1: (a) Maturity plot; (b) Geohistory; (c) Hydrocarbon expulsion.

North Seaspray 1

1 Introduction

Four samples from North Seaspray 1 were collected (655, 979, 1147 & 1500 m).

2 Source rock richness

The total organic carbon (TOC) values for the four samples analysed are in the range of 1.12 to 12.25% which indicates that they have fair to excellent source potential (Tables 27 & 28). The macerals are dominated by vitrinite with some liptinite.

3 Rock-Eval Pyrolysis

Rock-Eval pyrolysis was performed on the three samples. For the two shallowest samples, the S1 values range from 1.42 to 0.88 kg/tne and S2 values vary between 14.06 and 27.99 kg/tne. These values suggest low to high levels of free hydrocarbons. Hydrocarbon index (HI) values range from 115 to 471. These high HI values are indicative of type II kerogen. The deeper samples have S1 values of 0.33 and 0.14 kg/tne, with an S2 value of 6.85 and 1.48 kg/tne, and HI values of 166 and 132. Immaturity is indicated by the Tmax values from 407°C to 429°C (Fig. 30).

4 Saturate gas chromatography and gas chromatography-mass spectrometry

The sample at 979 m was further analysed by pyrolysis gas chromatography (Py-GC). The Py-GC traces consist of well defined alkane/alkene pairs which extend out to C31. The C15 to C31 alkane plus alkene value is approximately 24.56% (calculated as percentage of S2) and characterises the kerogen as being mixed oil and gas prone (Table 29). Solvent extraction of this 979 m sample yielded 1265 ppm and showed a bimodal distribution in the alkanes. This indicates contribution from two sources, with a significant contribution from terrestrially derived organic matter. The pristane/phytane ratio of 4.79 suggests a relatively oxidising depositional environment (Table 30). The results of the pyrolysis gas chromatography are shown in Table 31. Also, the branched/cyclic gas chromatography-mass spectrometry (GC-MS) data supports this profile (Figs 31 & 32).

5 Vitrinite reflectance

Vitrinite reflectance measurements of the samples range from 0.33 to 0.39%, indicating immaturity. The oil window lies between 2384 and 3270 m at this well (Fig. 33a).

6 Geohistory

Subsidence at the North Seaspray 1 site was generally uniform at 125 m/million years until 100 Ma when a slow down of subsidence occurred. A dramatic reversal then occurred from 93 to 90 Ma. From then on, subsidence continued at a much slower rate of about 15 m/million years thereafter, until the present (Fig. 33b).

7 Hydrocarbon expulsion

Minor oil and gas expulsion commenced at about 110 Ma, peaking around 107 Ma. Rates of early stage expulsion from the Strzelecki Group were calculated to around 658 bbl/m^2 of oil; the amount of gas expelled was around 336 bbl equiv/m^2 of source rock (Fig. 33c).

Table 27 North Seaspray 1, Rock-Eval pyrolysis

Depth (m KB)	Spore-Pollen Zone	T max oC	S1 kg/tne	S2 kg/tne	S3 kg/tne	Generative Potential (S1 + S2)	PI	S2/S3	PC	TOC %	HI	OI
655	*N. asperus*	407	1.42	14.06	6.29	15.48	0.09	2.24	1.28	12.25	115	51
979	*L. balmei*	429	0.88	27.99	1.27	28.87	0.03	22.04	2.40	5.94	471	21
1147	*C. striatus*	420	0.33	6.85	1.35	7.18	0.05	5.07	0.60	4.12	166	33
1499	*C. striatus*	425	0.14	1.48	1.09	1.62	0.09	1.36	0.13	1.12	132	97

Table 28 North Seaspray 1 Maceral, vitrinite reflectance, lithologic and richness (TOC) data

Depth (m KB)	655	979	1147	1499
Spore-Pollen Zone	*N. asperus*	*L. balmei*	*C. striatus*	*C. striatus*
Vitrinite Reflectance				
Mean Ro %	0.33	0.39	0.36	0.35
Min to Max %	0.25-0.45	0.28-0.49	0.27-0.47	0.26-0.57
Sample No. Determination	27	27	26	29
Maceral Proportion				
Vitrinite % (V)	92.16	50.00	88.24	89.29
Inertinite % (I)	1.96	1.67	2.94	3.57
Liptinite % (L)	5.88	48.33	8.82	7.14
Organic Matter				
Relative Maceral Abundance	V>L>I	V>L>I	V>L>I	V>L>I
DOM %	Sp	Ab	Ab	Cm
Liptinite/Exinite Macerals				
Liptodetrinite	Sp; gY-O	Cm; Y-O	Sp; Y-O	Sp; Y-O
Sporinite	Sp; gY-O	Cm; Y-O	Sp; Y	Sp; Y-O
Cutinite	Ra; dY	Ab; dY-O	Ra; O-dO	
Bituminite				
Resinite	Ra; iY	Ab; gY-iY		
Phytoplankton				
Lamalginite	Ra; Y		Ra; Y	
Liptinite (mostly oxidised)	Ra	Ab	Sp	Ra
TOC%	12.25	5.94	4.12	1.12
Lithology	Sandstone, argillaceous siltstone and coal	Argillaceous siltstone with coaly layers	Siltstone, claystone and coal	Siltstone, sandstone and coal

Vr = very rare　Ra = rare　Sp = sporadic　Cm = Common　Ab = Abundant
iO = intense orange　B = black　mY = mid yellow　dO = dark orange

Table 29 North Seaspray 1 (979 m Core) — Alkane and alkene determination by Pyrolysis-GC

Carbon No.	Alkane + Alkene			Alkane			Alkene			Alkane / Alkene
	A	B	C	A	B	C	A	B	C	
5	3.976	1.113	0.187	2.000	0.560	0.094	1.976	0.553	0.093	1.01
6	2.910	0.815	0.137	1.422	0.398	0.067	1.488	0.416	0.070	0.96
7	2.179	0.610	0.103	1.122	0.314	0.053	1.057	0.296	0.050	1.06
8	1.784	0.499	0.084	0.090	0.252	0.042	0.884	0.247	0.042	1.02
9	1.438	0.402	0.068	0.719	0.201	0.034	0.719	0.201	0.034	1.00
10	1.797	0.503	0.085	0.991	0.277	0.047	0.806	0.226	0.038	1.23
11	1.750	0.490	0.082	0.862	0.241	0.041	0.888	0.249	0.042	0.97
12	1.801	0.504	0.085	0.855	0.239	0.040	0.946	0.265	0.045	0.90
13	1.645	0.463	0.078	0.856	0.240	0.040	0.798	0.223	0.038	1.07
14	1.621	0.454	0.076	0.808	0.226	0.038	0.813	0.228	0.038	0.99
15	1.675	0.469	0.079	0.918	0.257	0.043	0.757	0.212	0.036	1.21
16	1.492	0.418	0.070	0.807	0.226	0.038	0.685	0.192	0.032	1.18
17	1.634	0.457	0.077	0.980	0.274	0.046	0.654	0.183	0.031	1.50
18	1.659	0.464	0.078	0.939	0.263	0.044	0.720	0.202	0.034	1.30
19	1.656	0.464	0.078	0.963	0.270	0.045	0.693	0.194	0.033	1.39
20	1.716	0.480	0.081	0.976	0.273	0.046	0.740	0.207	0.035	1.32
21	1.799	0.504	0.085	1.066	0.298	0.050	0.733	0.205	0.035	1.45
22	1.831	0.512	0.086	1.120	0.313	0.053	0.711	0.199	0.034	1.58
23	1.796	0.503	0.085	1.098	0.307	0.052	0.698	0.195	0.033	1.57
24	1.693	0.474	0.080	1.083	0.303	0.051	0.610	0.171	0.029	1.78
25	1.533	0.429	0.072	0.951	0.266	0.045	0.582	0.163	0.027	1.63
26	1.325	0.371	0.062	0.946	0.265	0.045	0.379	0.106	0.018	2.50
27	1.104	0.309	0.052	0.791	0.221	0.037	0.313	0.088	0.015	2.53
28	0.759	0.212	0.036	0.748	0.209	0.035	0.011	0.003	0.001	68.00
29	1.812	0.507	0.085	1.412	0.395	0.067	0.400	0.112	0.019	3.53
30	0.633	0.177	0.030	0.517	0.145	0.024	0.116	0.032	0.005	4.46
31	0.447	0.125	0.021	0.355	0.099	0.017	0.092	0.026	0.004	3.86

A= % of resolved compounds in S2 B = mg/g rock (Rock-Eval) C = (mg/g rock)/TOC

Table 30 North Seaspray 1 (979 m Core) — EOM analysis

1) Extracted Organic Matter (EOM) ppm

Depth (m KB)	Weight of Rock Extd (g)	Total Extract (ppm)	Loss on Column (ppm)	Hydrocarbons			Non-hydrocarbons		
				Saturates (ppm)	Aromatics (ppm)	HC Total (ppm)	NSO's (ppm)	Asphalt (ppm)	Non HC Total (ppm)
979	13.0	1265.1	61.3	268.4	260.7	529.0	674.7	nd	674.7

2) Percentages and Ratios of EOM

Depth (m KB)	Hydrocarbons			Non-hydrocarbons			EOM(mg)/ TOC (g)	SAT(mg)/ TOC (g)	SAT/ AROM	ASPH/ NSO	HC/ Non HC
	%SAT	%AROM	%HC's	%NSO's	%ASPH	%Non HC's					
979	22.3	21.7	43.9	56.1	nd	56.1	21.3	4.5	1.0	nd	0.8

3) Alkane Ratios

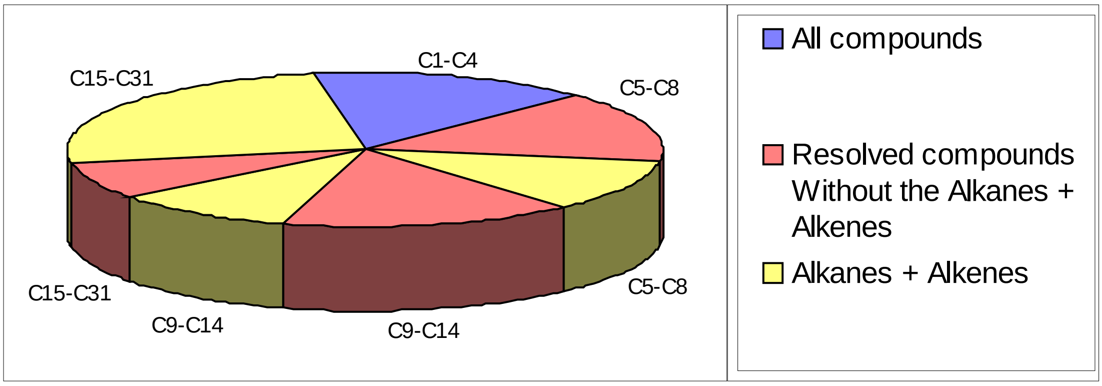
Depth (m KB)	Prist/Phyt	Prist/n-C17	Phyt/n-C18	CPI(1)	CPI(2)	(C21+C22)/(C28+C29)
979	4.79	0.91	0.34	2.24	2.13	0.26

nC12-nC31 Percentage Concentrations in Saturate Fraction

nC12%	nC13%	nC14%	nC15%	nC16%	nC17%	iC19%	nC18%	iC20%	nC19%	nC20%
1.5	4.7	7.1	9.5	13.5	11.8	10.7	6.6	2.2	3.6	1.9
nC21%	nC22%	nC23%	nC24%	nC25%	nC26%	nC27%	nC28%	nC29%	nC30%	nC31%
1.2	0.9	0.9	0.7	2.4	1.4	3.9	2.4	5.6	2.3	5.6

Table 31 North Seaspray 1 (979 m) — Pyrolysis gas chromatography

	Parameter	A	B	C	No. Units
C1-C4	abundance (all compounds)	15.38	4.31	0.72	
C5-C8	abundance (all resolved compounds)	25.77	7.21	1.21	
C5-C8	abundance (alkanes + alkenes)	10.85	3.04	0.51	
C9-C14	abundance (all resolved compounds)	26.17	7.32	1.23	
C9-C14	abundance (alkanes + alkenes)	10.06	2.82	0.47	
C15-C31	abundance (all resolved compounds)	32.68	9.15	1.54	
C15-C31	abundance (alkanes + alkenes)	24.56	6.88	1.61	
C9-C31	abundance (all resolved compounds)	58.85	16.47	2.77	
C9-C31	abundance (alkanes + alkenes)	34.63	9.69	1.63	
C5-C31	abundance (all resolved compounds)	84.62	23.68	3.99	
C5-C31	abundance (alkanes + alkenes)	45.47	12.73	2.14	
C5-C31	alkane abundance	26.21	7.33	1.23	
C5-C31	alkene abundance	19.27	5.39	0.91	
C5-C8	alkane / alkene				1.01
C9-C14	alkane / alkene				1.02
C15-C31	alkane / alkene				1.76
C5-C31	alkane / alkene				1.36
(C1-C5)/C6+					0.28
R					0.98



A = % of resolved compounds in S2
B = mg/g rock (Rock-Eval)
C = (mg/g rock)/TOC
R = m + p-xylene/n-octane

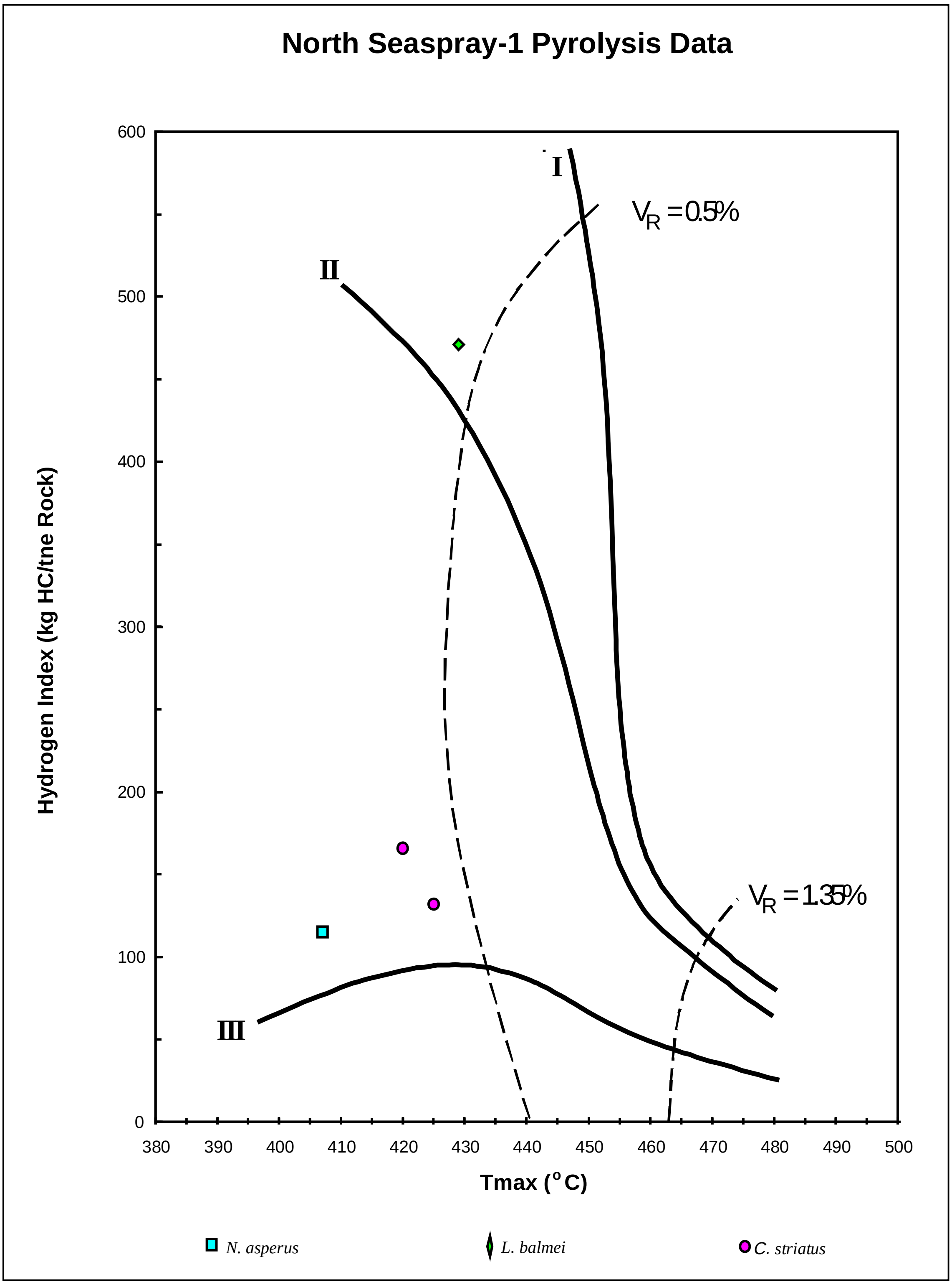


Figure 30
North Seaspray 1: HI versus Tmax ºC plot.

North Seaspray 1

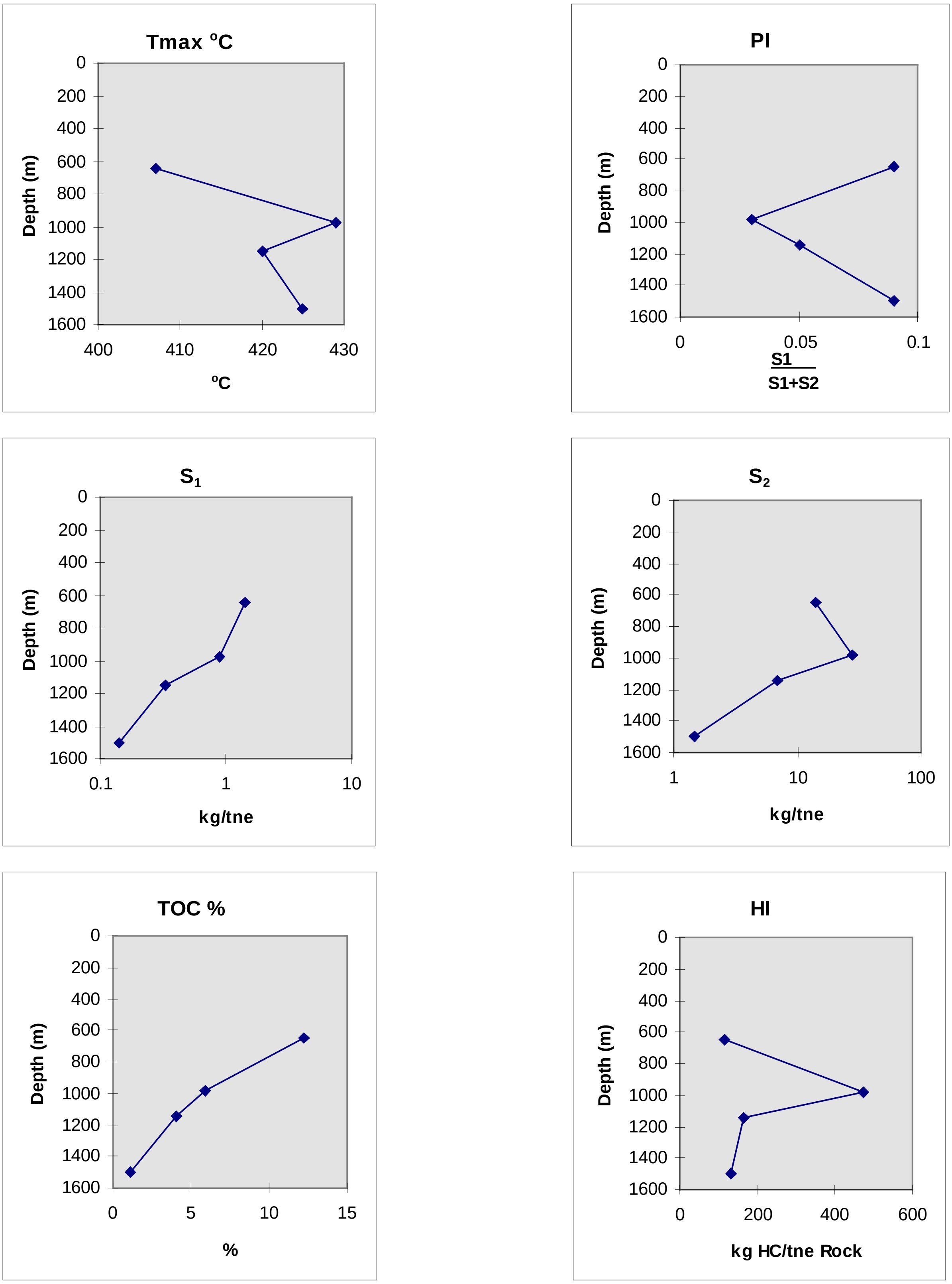


Figure 31
North Seaspray 1: (a) Tmax °C; (b) S1; (c) S2; (d) PI; (e) TOC %; (f) HI.

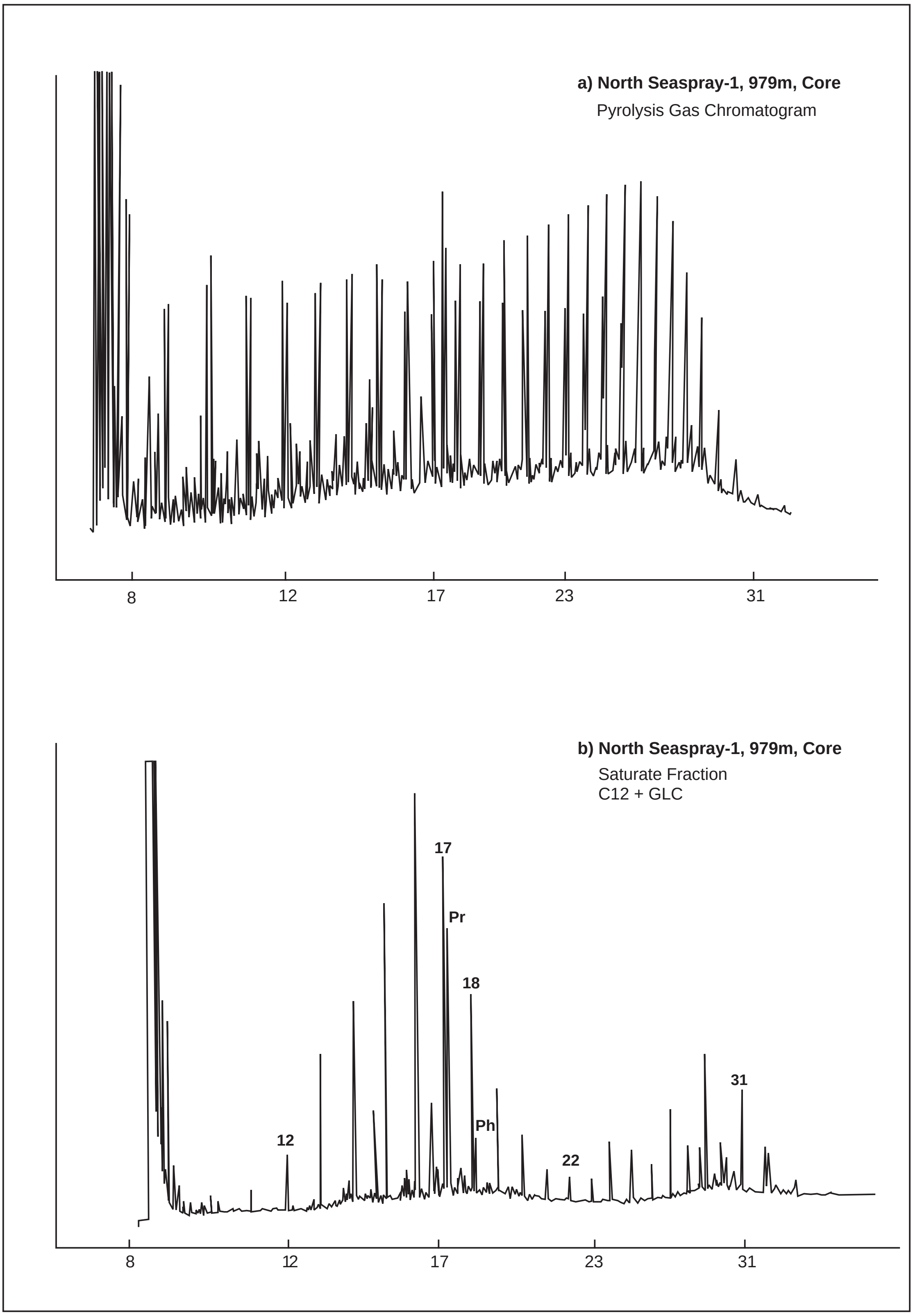


Figure 32
North Seaspray 1, (979 m): — Pyrolysis gas chromatographs .
(a) Core; (b) Saturate fraction, C12+ of core

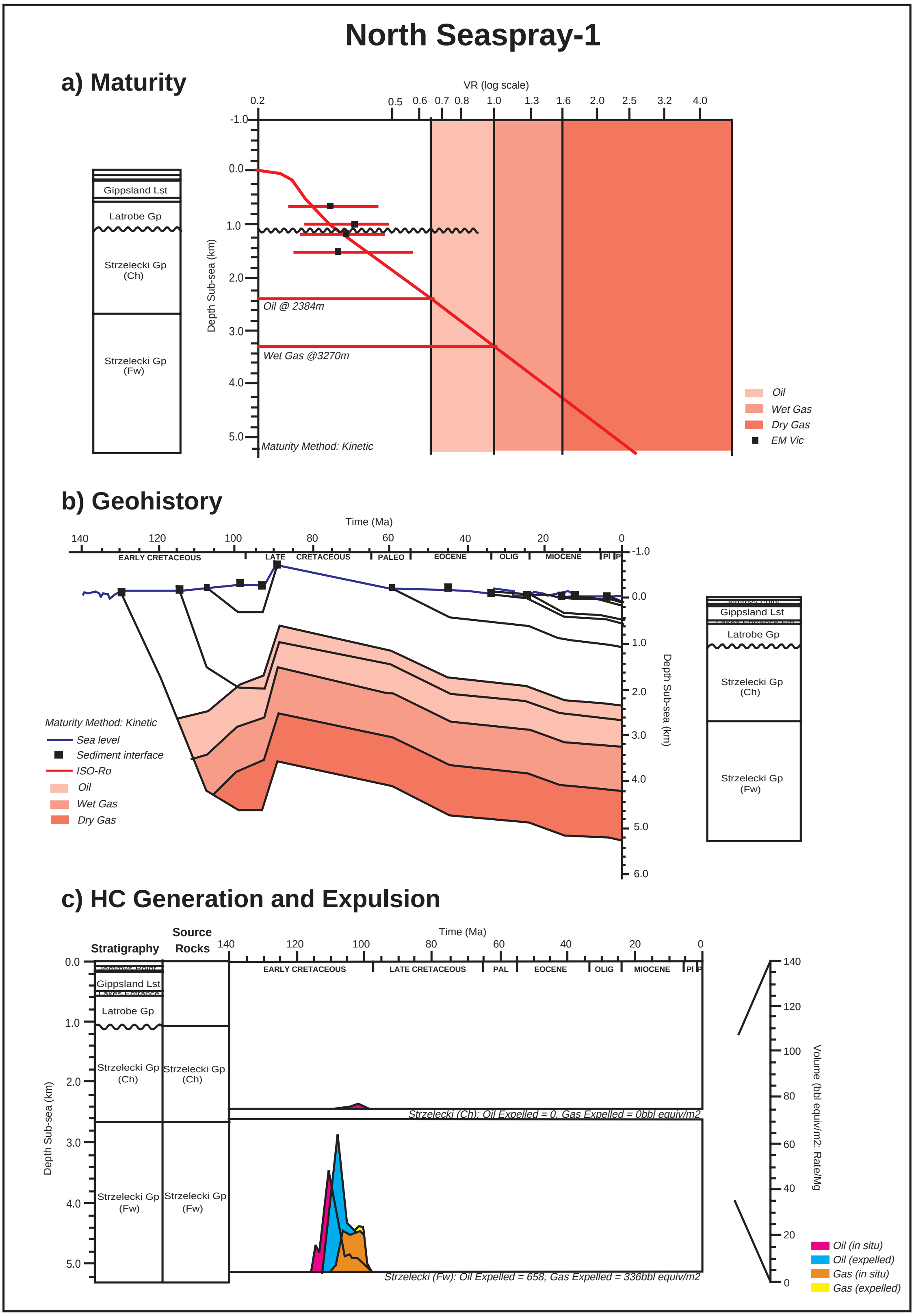


Figure 33

North Seaspray 1: (a) Maturity plot; (b) Geohistory; (c) Hydrocarbon expulsion.

Rosedale 1

1 Introduction

Four samples from Rosedale 1 were collected (438, 610, 914 & 1478 m) and analysed. All four of these samples were used for maturity determination.

2 Source rock richness

The total organic carbon (TOC) values for the two samples analysed are 19.91 and 2.74%, which indicates that they have fair to excellent source potential (Table 32). The macerals are dominated by vitrinite with some inertinite (Table 33).

3 Rock-Eval Pyrolysis

Rock-Eval pyrolysis was performed on the two samples. In the samples, the S1 values are 4.51 and 0.42 kg/tne, and S2 values are 41.13 and 2.28 kg/tne. These values suggest low to moderate levels of free hydrocarbons. Hydrocarbon index (HI) values are also low with results of 207 and 83. Tmax values indicate marginal maturity at 426°C and maturity at 460°C (Fig. 34). The results suggest that mainly gas-prone, mature source rocks exist at this level (Fig. 35).

4 Vitrinite reflectance

Four samples selected for vitrinite reflectance measurements (438, 610, 914 & 1478 m) show a range in maturity from 0.31 to 0.4% in the Latrobe Group, and 0.8 to 1.04 in the Strzelecki Group, indicating the Latrobe Group is immature while the Strzelecki Group is mature for oil. The oil window lies between 677 and 1400 m at this well (Fig. 36a). It is important to note that measured vitrinite reflectance (percentage Rmax) by Cook (1981), for a number of wells in the onshore Gippsland Basin, all indicate that the Strzelecki Group samples of coaly material to be early mature and within the oil generation window with reflectances ranging between 0.6–0.85 per cent Rmax (Holdgate & McNicol, 1992).

5 Geohistory

Subsidence at the Rosedale 1 site was generally uniform at 106 m/million years until 101 Ma when a cessation of subsidence occurred. A dramatic reversal in subsidence then occurred from 90 to 87 Ma. After that, subsidence continued at a rate of about 25 m/million years until 45 Ma. From then on, subsidence continued at a much slower rate of about 4 m/million years, until the present (Fig. 36b).

Table 32 Rosedale 1, Rock-Eval pyrolysis

Depth (m KB)	Spore-Pollen Zone	T max oC	S1 kg/tne	S2 kg/tne	S3 kg/tne	Generative Potential (S1 + S2)	PI	S2/S3	PC	TOC %	HI	OI
438	*P. tuberculatus*	420	4.51	41.13	10.63	45.64	0.10	3.85	3.79	19.91	207	54
1478	*P. notensis*	456	0.42	2.28	0.33	2.70	0.16	6.91	0.22	2.74	83	12

Table 33 Rosedale 1 Maceral, vitrinite reflectance, lithologic and richness (TOC) data

Depth (m KB)	438	1478
Spore-Pollen Zone	*P. tuberculatus*	*P. notensis*
Vitrinite Reflectance		
Mean Ro %	0.31	1.04
Min to Max %	0.22-0.44	0.85-1.28
Sample No. Determination	26	30
Maceral Proportion		
Vitrinite % (V)	89.96	79.21
Inertinite % (I)	0.30	19.80
Liptinite % (L)	9.75	0.99
Organic Matter		
Relative Maceral Abundance	V>L>I	V>I>L
DOM %	--	Ab
Liptinite/Exinite Macerals		
Liptodetrinite		Ra; O-dO
Sporinite	Cm; Y-O	
Cutinite		
Bituminite		
Resinite		
Phytoplankton		
Lamalginite		
Liptinite (mostly oxidised)		Ra
TOC%	19.91	2.74
Lithology	Coal and siltstone	Siltstone, sandstone and shaly coal

Vr = very rare Ra = rare Sp = sporadic Cm = Common Ab = Abundant
mY = mid yellow dO = dark orange B = black iO = intense orange

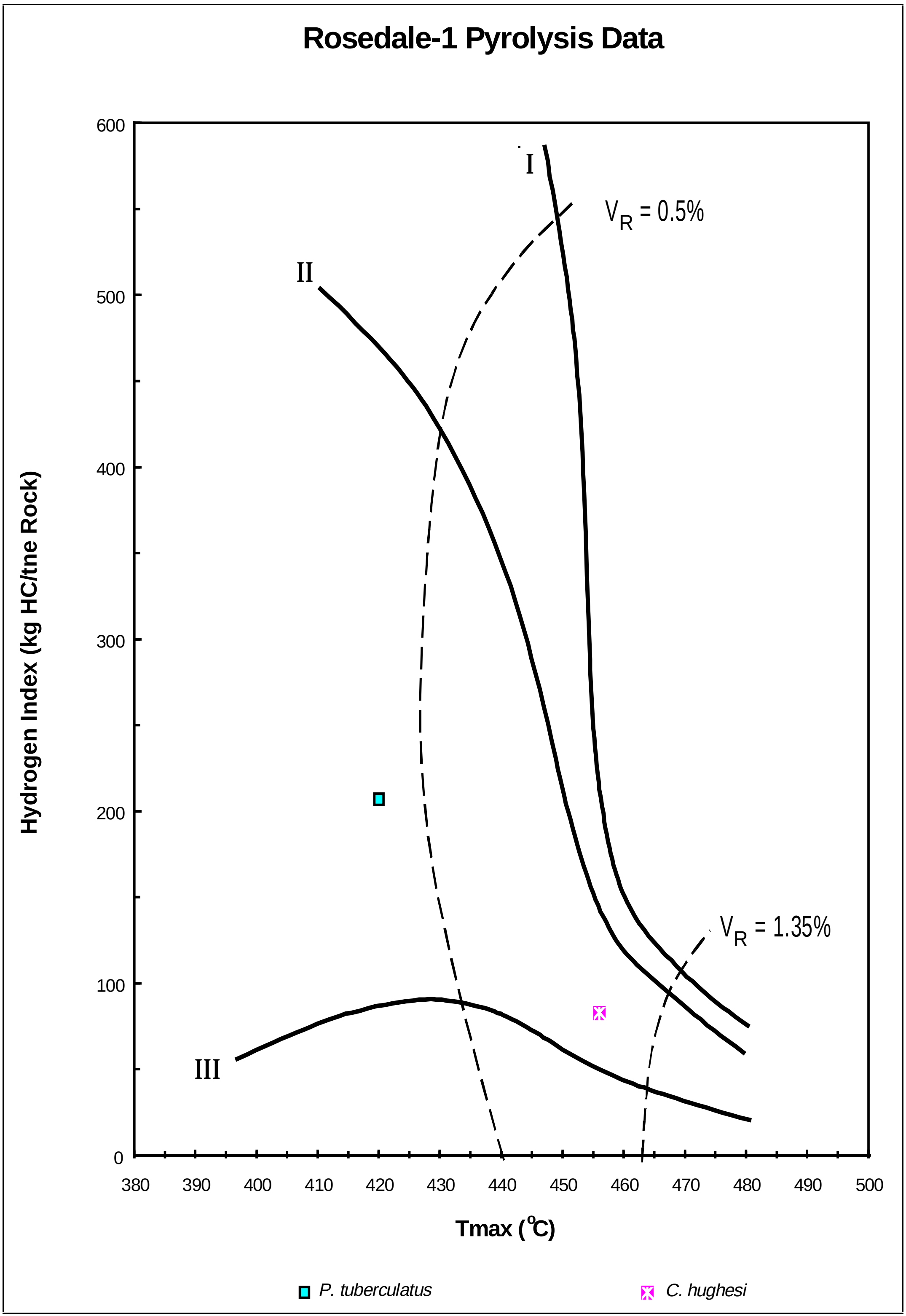


Figure 34
Rosedale 1: HI versus Tmax ºC plot.

Rosedale 1

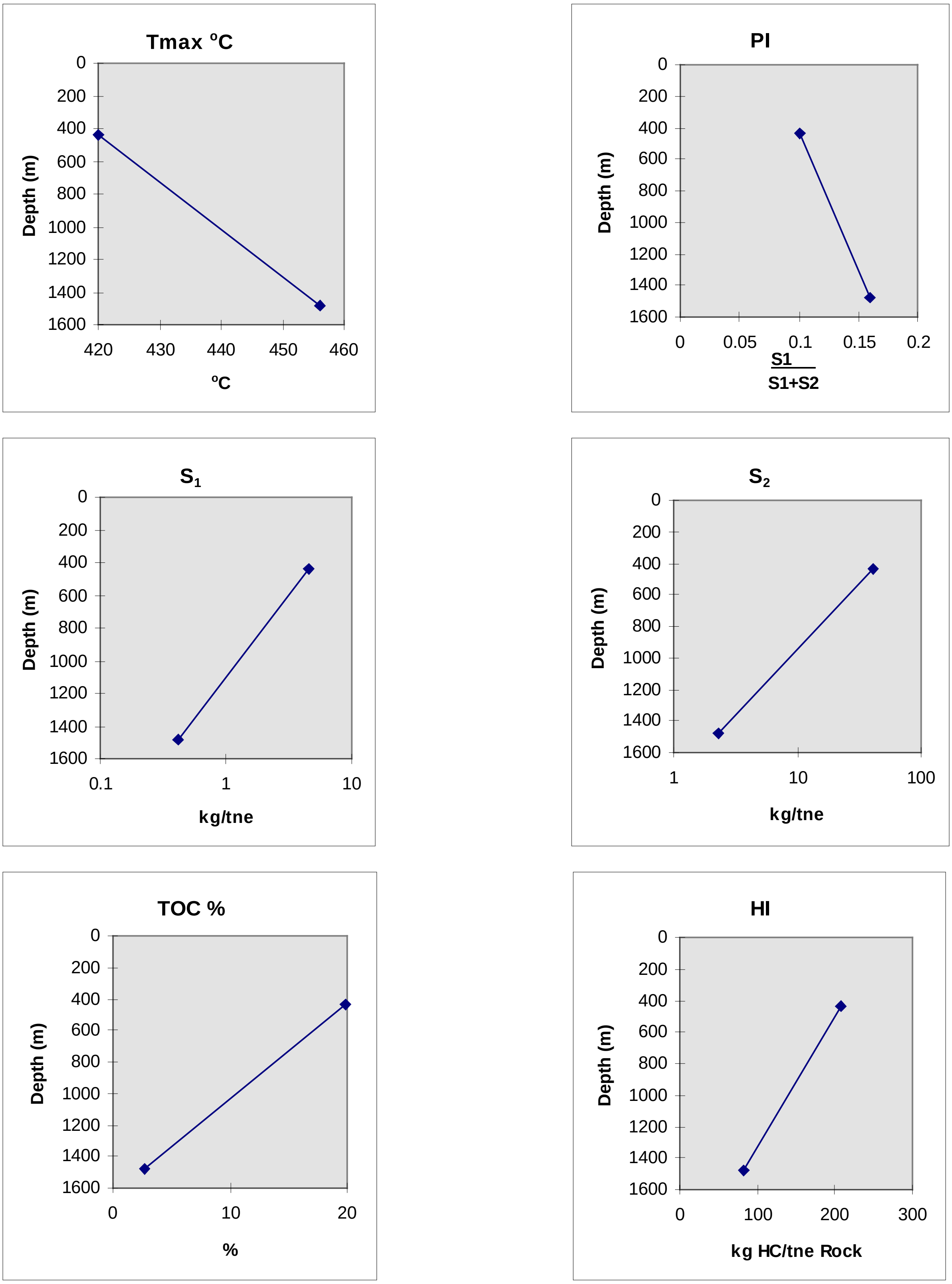


Figure 35
Rosedale 1: (a) Tmax °C; (b) S1; (c) S2; (d) PI; (e) TOC %; (f) HI.

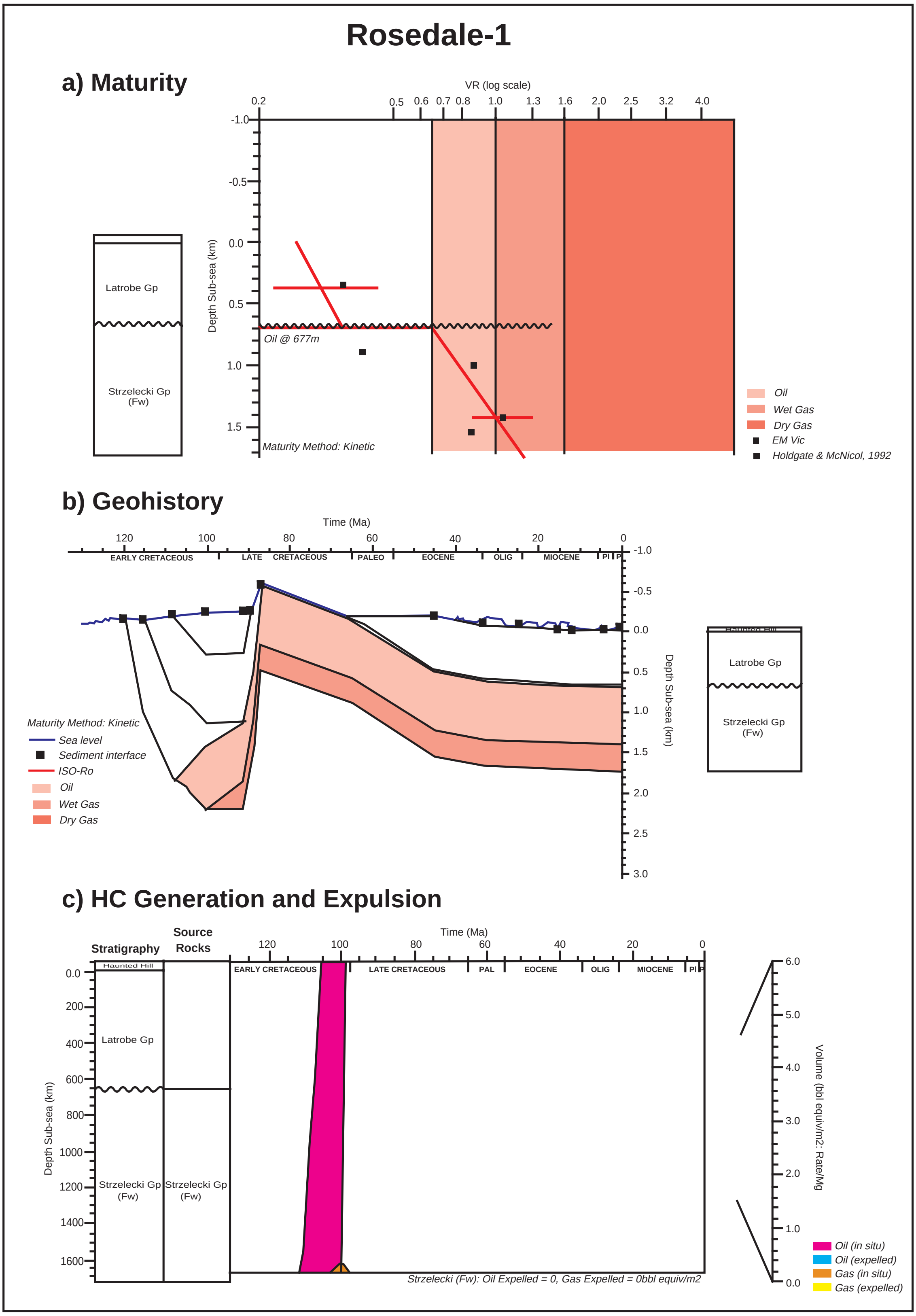


Figure 36

Rosedale 1: (a) Maturity plot; (b) Geohistory; (c) Hydrocarbon expulsion.

Wellington Park 1

1 Vitrinite reflectance

The oil window lies between 2164 and 2954 m at this well (Fig. 37a).

2 Geohistory

Subsidence at the Wellington Park 1 site was rapid at 110 m/million years until 94 Ma when a dramatic reversal in subsidence occurred until 90 Ma. After that, subsidence resumed at a much slower rate of about 15 m/million years thereafter, to the present (Fig. 37b).

3 Hydrocarbon expulsion

Minor oil expulsion commenced at about 100 Ma, peaking around 95 Ma. Rates of early stage expulsion from the Strzelecki Group was calculated to around 58 bbl/m^2 of oil; the amount of gas expelled was around 25 bbl equiv/m^2 of source rock (Fig. 37c).

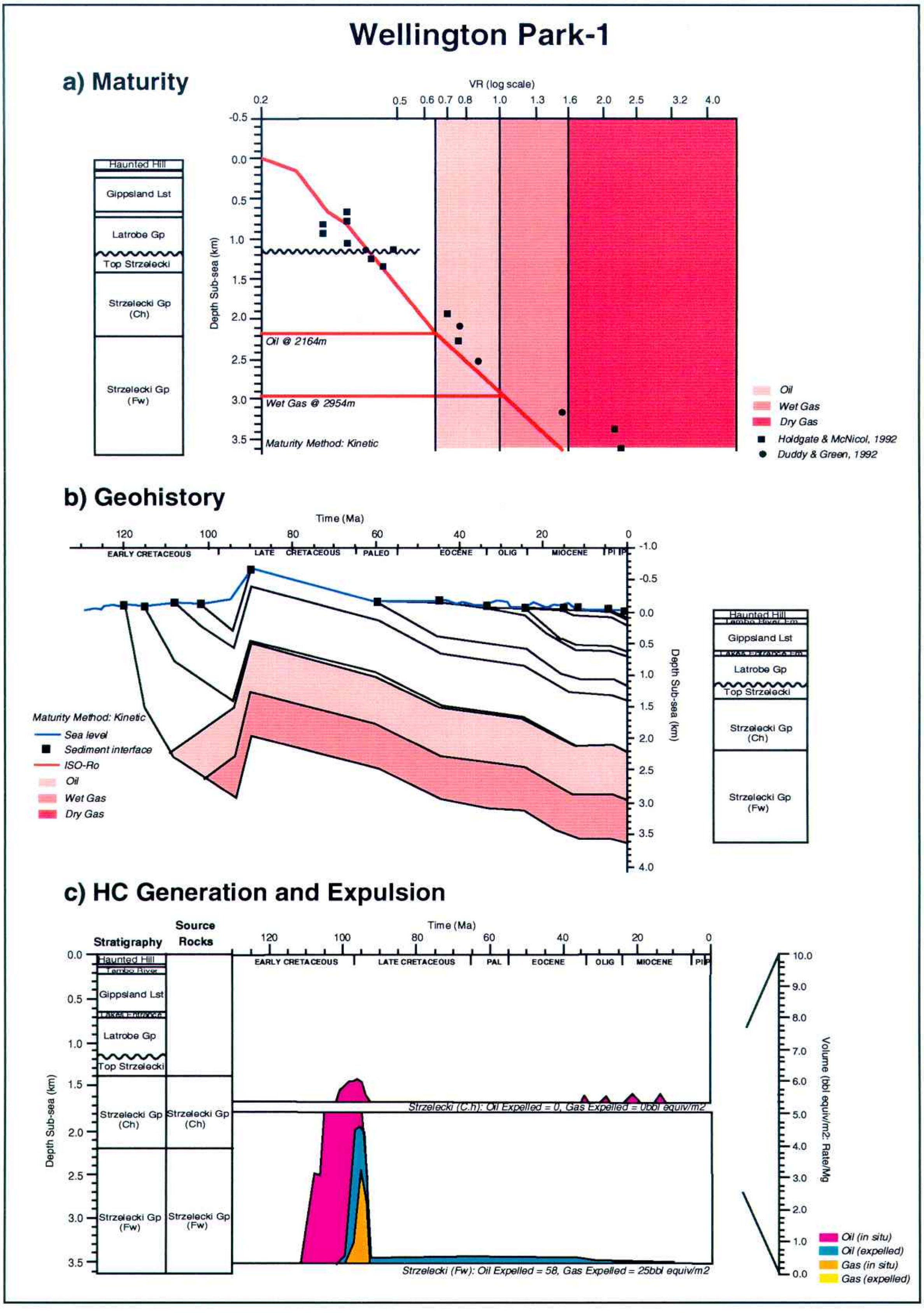


Figure 37
Wellington Park 1: (a) Maturity plot; (b) Geohistory; (c) Hydrocarbon expulsion.

Woodside 1

1 Introduction

Four samples from Woodside 1 were collected (678, 1234, 1636 & 1758 m) and analysed.

2 Source rock richness

The total organic carbon (TOC) values for the four samples analysed are in the range of 0.21 to 0.74%, which indicates that they have poor to fair source potential (Table 34). The macerals are dominated by inertinite with some vitrinite (Table 35).

3 Rock-Eval Pyrolysis

Rock-Eval pyrolysis was performed on the four samples. In the samples, the S1 values range from 0.04 to 0.10 kg/tne and S2 values vary between 0.07 to 0.58 kg/tne. These values suggest low levels of free hydrocarbons. Hydrocarbon index (HI) values are also low (23-78). Immaturity is indicated by the Tmax values of 414°C, with the value 433°C being marginally mature (Figs 38 & 39).

4 Vitrinite reflectance

Vitrinite reflectance measurements range from immaturity to marginal maturity, with the samples ranging from 0.33 to 0.67%. The oil window is from 1764 to 2590 m (Fig. 40a).

5 Geohistory

Subsidence at the Woodside 1 site was generally uniform at 95 m/million years until 101 Ma when a slow down of subsidence occurred. A dramatic reversal in subsidence the occurred from 92 to 88 Ma. After that, subsidence continued at a much slower rate of about 17 m/million years thereafter, until the present (Fig. 40b).

6 Hydrocarbon expulsion

Minor oil and gas expulsion commenced at about 106 Ma, peaking around 102 Ma. Rates of early stage expulsion from the Strzelecki Group was calculated to be around 300 bbl/m^2 of oil; the amount of gas expelled was around 239 bbl equiv/m^2 of source rock (Fig. 40c).

Table 34 Woodside 1, Rock-Eval pyrolysis

Depth (m KB)	Spore-Pollen Zone	T max oC	S1 kg/tne	S2 kg/tne	S3 kg/tne	Generative Potential (S1 + S2)	PI	S2/S3	PC	TOC %	HI	OI
678	*T. bellus*	414	0.10	0.33	1.35	0.43	0.23	0.24	0.04	0.51	65	265
1234	*C. striatus*	433	0.08	0.58	0.68	0.66	0.12	0.85	0.05	0.74	78	92
1636.	*C. striatus*		0.04	0.09	0.13	0.13	0.31	0.69	0.01	0.39	23	33
1758	*C. striatus*		0.04	0.07	0.15	0.11	0.36	0.47	0.01	0.21	33	71

Table 35 Woodside 1 Maceral, vitrinite reflectance, lithologic and richness (TOC) data

Depth (m KB)	678	1234	1636	1758
Spore-Pollen Zone	*T. bellus*	*C. striatus*	*C. striatus*	*C. striatus*
Vitrinite Reflectance				
Mean Ro %	0.33	0.46	0.67	0.54
Min to Max %	0.20-0.53	0.30-0.62	0.48-0.86	0.46-0.67
Sample No. Determination	25	25	11	21
Maceral Proportion				
Vitrinite % (V)	100.0	19.35		
Inertinite % (I)		64.52	100.0	100.0
Liptinite % (L)		16.13		
Organic Matter				
Relative Maceral Abundance	V	I>V>L	I	I
DOM %	Sp	Ab	Ab	Sp
Liptinite/Exinite Macerals				
Liptodetrinite	Ra; Y-O		Ra; O-dO	Ra; O
Sporinite		Sp; yO-O		
Cutinite		Sp; O-dO	Ra; O-dO	
Bituminite				
Resinite		Sp; Y-O		
Phytoplankton				
Lamalginite	Ra; Y	Ra; Y		
Liptinite (mostly oxidised)	Ra	Cm	Cm	Cm
TOC%	0.51	0.74	0.39	0.21
Lithology	Siltstone	Argillaceous siltstone, sandstone and claystone	Mudstone	Calcareous claystone, siltstone

Vr = very rare, mY = mid yellow, Ra = rare, dO = dark orange, Sp = sporadic, B = black, Cm = Common, iO = intense orange, Ab = Abundant

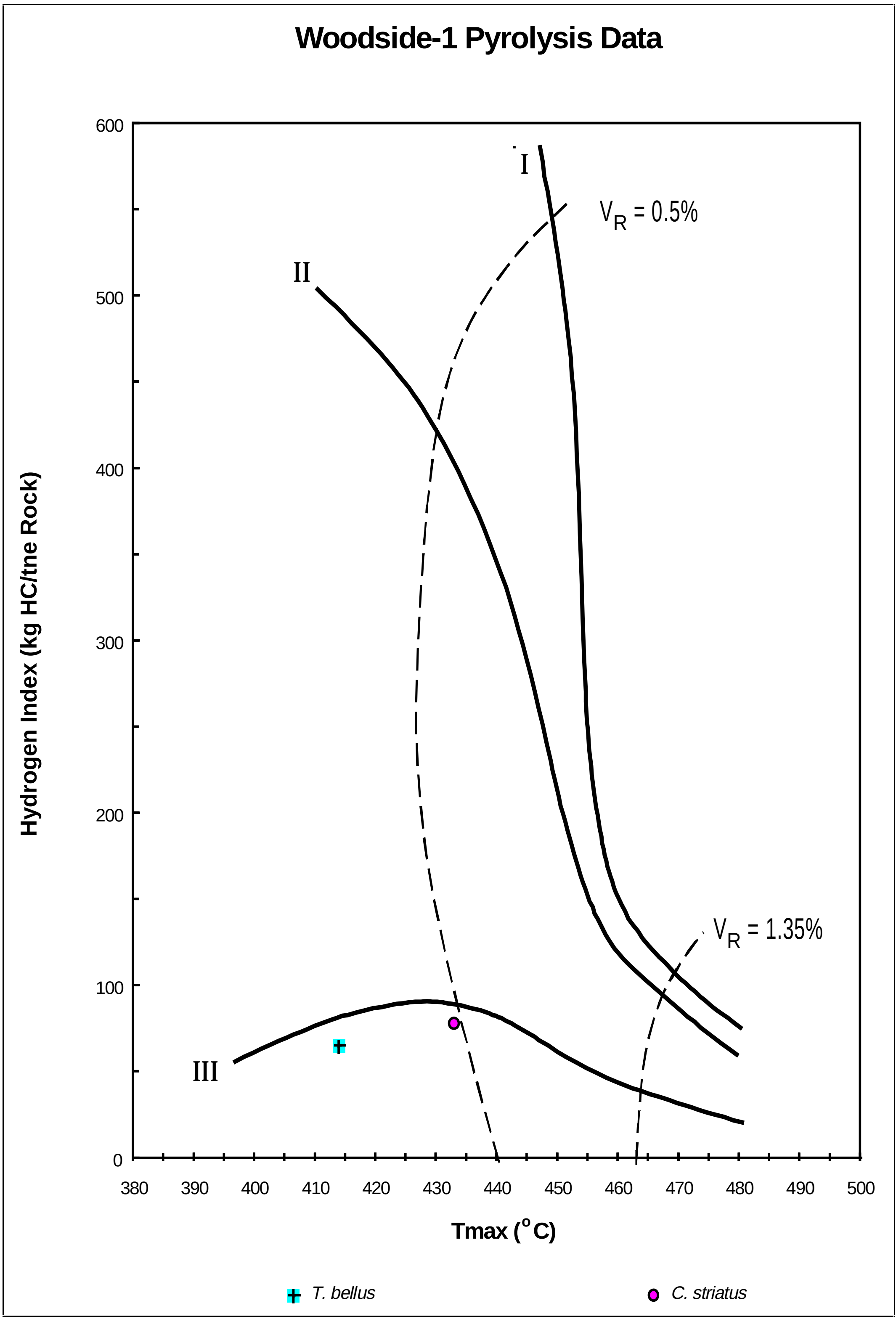


Figure 38
Woodside 1: HI versus Tmax ºC plot.

Woodside 1

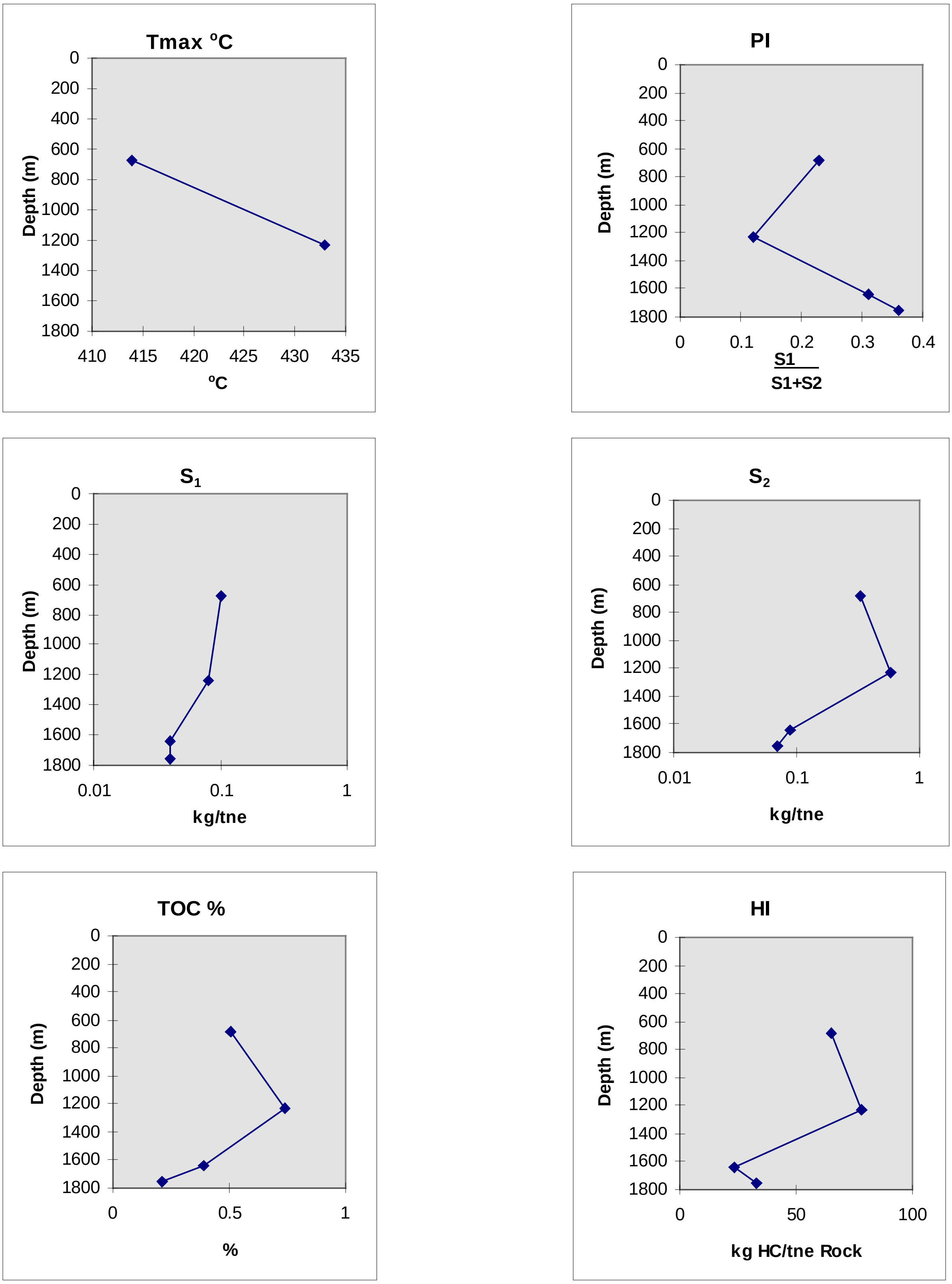


Figure 39
Woodside 1: (a) Tmax °C; (b) S1; (c) S2; (d) PI; (e) TOC %; (f) HI.

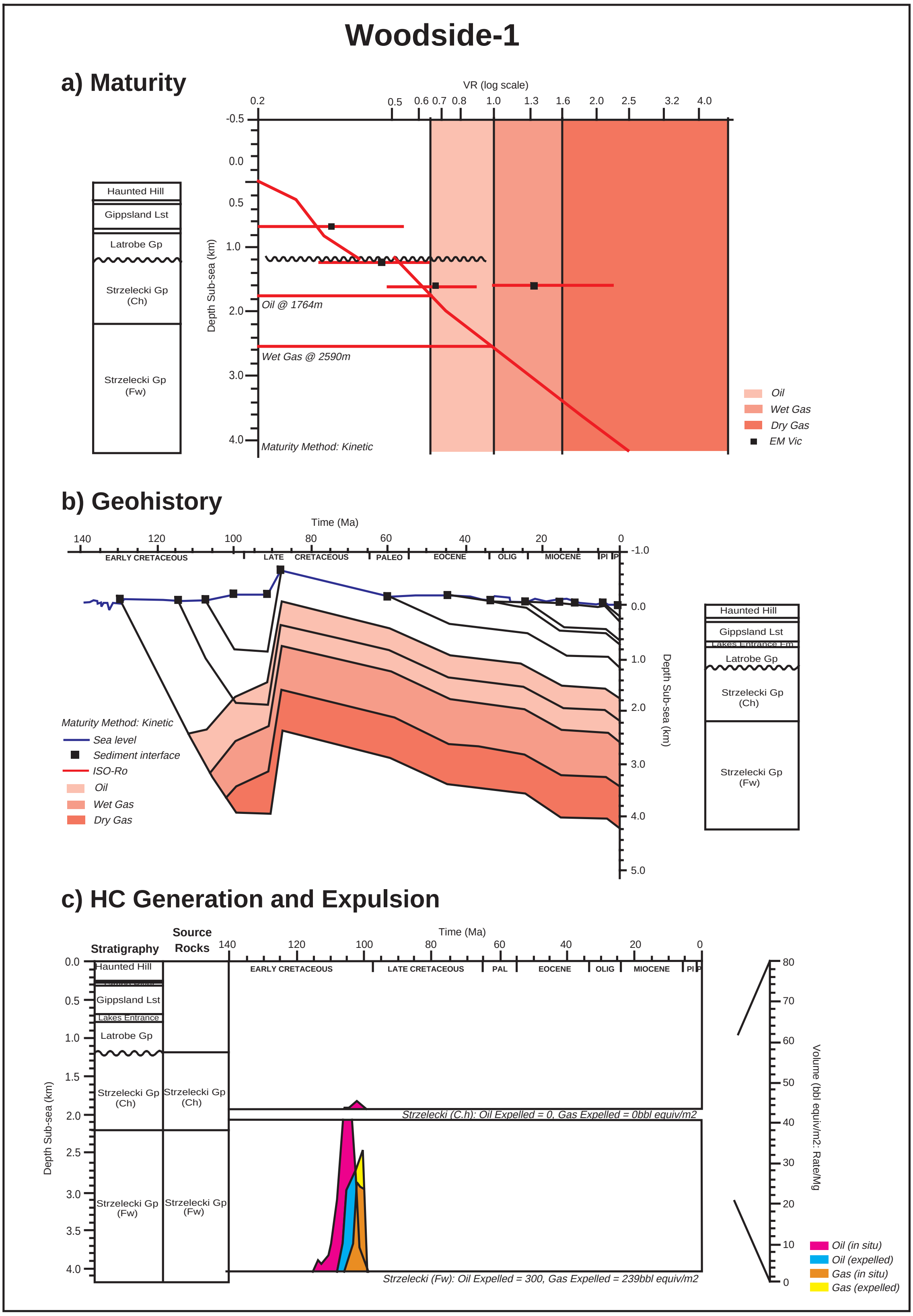


Figure 40
Woodside 1: (a) Maturity plot; (b) Geohistory; (c) Hydrocarbon expulsion.

Victorian Initiative for Minerals and Petroleum (VIMP) report series

1 BUCKLEY, R.W., BUSH, M.D., O'SHEA, P.J., WHITEHEAD, M. & VANDENBERG, A.H.M., 1994. The geology and prospectivity of the Orbost Survey area.

2 VANDENBERG, A.H.M., WILLMAN, C., HENDRICKX, M., BUSH, M.D. & SANDS, B.C., 1995. The geology and prospectivity of the 1993 Mount Wellington Airborne survey area.

3 HOLDGATE, G., 1995. The exploration potential of the Permian Numurkah Trough and Ovens Graben, Victoria.

4 BUSH, M.D., CAYLEY, R.A., ROONEY, R., SLATER, K. & WHITEHEAD M.L., 1995. The geology and prospectivity of the southern margin of the Murray Basin.

5 ROONEY, R., 1995. Mineral exploration history of the North West VIMP area.

6 WILLOCKS, A.J., 1995. An appraisal of the new airborne surveys over the North West VIMP area.

7 WHITEHEAD, M.L., 1995. Geological interpretation of geophysical data over the Dunolly 1:100 000 sheet.

8 VANDENBERG, A.H.M., CALUZZI, J., WILLOCKS, A.J. & O'SHEA, P.J., 1995. The geology and prospectivity of the Mallacoota 1:250 000 sheet, Eastern Highlands VIMP area.

9 SANDS, B.C., 1995. A geological interpretation of the geophysical data from the Orbost 1994 airborne survey.

10 OPPY, I.D., CAYLEY, R.A. & CALUZZI, J., 1995. The geology and prospectivity of the Tallangatta 1:250 000 sheet.

11 CALUZZI, J., 1995. Mineral exploration history of the Tallangatta 1:250 000 sheet.

12 SIMONS, B.A., 1995. An appraisal of new airborne geophysical data over the Tallangatta 1:250 000 map area, Victoria.

13 BUSH, M.D., CAYLEY, R.A. & ROONEY, S., 1995. The geology and prospectivity of the Glenelg region, North West VIMP area.

14 SLATER, K.R., 1995. An appraisal of new airborne geophysical data over the Glenelg region, North West VIMP area, Victoria.

15 RYAN, S.M., KNIGHT, L.A. & PARKER, G.J., 1995. The stratigraphy and structure of the Tyrendarra Embayment, Otway Basin, Victoria.

16 KNIGHT, L.A., McDONALD, P.A., FRANKEL, E. & MOORE, D.H., 1995. A preliminary appraisal of the pre-Tertiary infrabasins beneath the Murray Basin, Northwestern Victoria.

17 PERINCEK, D., SIMONS, B.A., PETTIFER, G.R. & GUNATILLAKE, K., 1995. Seismic interpretation of the onshore Western Otway Basin, Victoria.

18 LAVIN, C.J. & NAIM, H.M., 1995. The structure, stratigraphy and petroleum potential of the Portland Trough, Otway Basin, Victoria.

19 SIMPSON, C.J., SIMS, J.P. & ORANSKAIA, A., 1995. The geology and prospectivity of the Mt Elizabeth area, Eastern Highlands VIMP area.

20 ORANSKAIA, A., 1995. A geological interpretation of geophysical data over the Mallacoota 1:250 000 sheet, Eastern Highlands VIMP area.
NOT RELEASED

21 SARMA, S., 1995. Seismic interpretation of the offshore Otway Basin, Victoria.

22 MEHIN, K. & LINK, A.G., 1995. Early Cretaceous source rocks of the Victorian onshore Otway Basin.

23 PARKER, G.J., 1995. Early Cretaceous stratigraphy along the northern margin of the Otway Basin, Victoria.

24 MOORE, D.H., 1996. A geological interpretation of the geophysical data of the Horsham 1:250 000 map sheet area.

25 VANDENBERG, A.H.M., HENDRICKX, M.A., WILLMAN, C.E., MAGART, A.P.M., ORANSKAIA, A.N., ROONEY, S. & WHITE, A.J.R., 1996. The geology and prospectivity of the Orbost 1:100 000 map area, eastern Victoria.

26 HENDRICKX, M.A., WILLMAN, C.E., MAGART, A.P.M., ROONEY, S., VANDENBERG, A.H.M., ORANSKAIA, A. and WHITE, A.J.R. The geology and prospectivity of the Murrungowar 1:100 000 map area, eastern Victoria.

27 BOYLE, R.J., 1996. Mineral exploration history of the Omeo 1:100 000 map area.

28 HAYDON, S.J., 1996. An appraisal of airborne geophysical data from the 1995 Omeo survey, Victoria.

29 MAHER, S., 1996. Mineral resources of the Dunolly 1:100 000 map area.

30 CHIUPKA, J.W., 1996. Hydrocarbon Play Fairways of the Onshore Gippsland Basin, Victoria.

31 MEHIN, K. & LINK, A.G., 1996. Early Cretaceous source rock evaluation for oil and gas exploration, Victorian Otway Basin.

32 SLATER, K.R., 1996. An appraisal of new airborne geophysical data over the Dargo region, Victoria.

33 McDONALD, P.A., 1996. An appraisal of new airborne geophysical data over the Corryong region, northeastern Victoria.

34 TWYFORD, R., 1996. An appraisal of airborne geophysical data from the Murrindal survey, Victoria.

35 HUTCHINSON, D.F., 1996. Mineral exploration history of the Dunolly 1:100 000 map area.

36 BROOKES, D.J. & BOYLE, R.J., 1996. Mineral exploration history of the Bairnsdale 1:250 000 map area.

37 MAHER, S., HENDRICKX, M.A., BOYLE, R.J. & BROOKES, D.J., 1996. Geology and prospectivity of the Bairnsdale 1:250 000 map sheet area.

38 McDONALD, P.A. & WHITEHEAD M.L., 1996. Geological interpretation of geophysical data over the Ararat 1:100 000 map sheet.

39 MOORE D.H., 1996. A geological interpretation of the geophysical data of the Ouyen 1:250 000 map sheet area.

40 BROOKES, D.J., 1996. Mineral exploration history, Ararat and Grampians 1:100 000 map areas.

41 LAVIN, C.J., & MUSCATELLO, T., 1997. The petroleum prospectivity of the Casterton Petroleum System in the Victorian Onshore Otway Basin.

42 CHIUPKA, J.W., MEGALLAA, M., JONASSON, K.E. & FRANKEL E., 1997. Hydrocarbon plays and play fairways of four vacant offshore Gippsland Basin areas, 1997 acreage release.

43 MEHIN, K. & LINK, A.G., 1997. Late Cretaceous source rocks offshore Otway Basin, Victoria and South Australia.

44 WILLOCKS, A.J., 1997. An appraisal of airborne geophysical data from the Castlemaine-Woodend survey, Victoria.

45 HUTCHINSON, D.F., 1997. Mineral exploration history of the Heathcote and Nagambie 1:100 000 map areas.

46 MAHER, S., VANDENBERG, A.H.M., McDONALD, P.A. & SAPURMAS, P., 1997. The Geology and prospectivity of the Wangaratta 1:250 000 map sheet area.

47 ORANSKAIA, A.N., 1997. Geological interpretation of geophysical features Bendoc 1:100 000 sheet.

48 ORANSKAIA, A.N., 1997. Geological interpretation of geophysical features Cann, Mallacoota and Victorian part of Eden 1:100 000 sheets.

49 WILKIE, J.R. & BROOKES, D.J., 1997. Mineral exploration history of the Wangaratta 1:250 000 map area.

50 McDONALD, P.A., 1997. An appraisal of airborne geophysical data from the Yea survey, Victoria.

51 EDWARDS, J.E., WILLMAN, C.E., McHAFFIE, I.W., OLSHINA, A. & WILLOCKS, A.J., 1997. The geology and prospectivity of the Castlemaine, Woodend, Yea and part of Bacchus Marsh 1:100 000 map sheets.

52 MAHER, S., MOORE, D.H., CRAWFORD, A.J., TWYFORD, R. & FANNING, F.M., 1997. Test drilling on the southern margin of the Murray Basin.

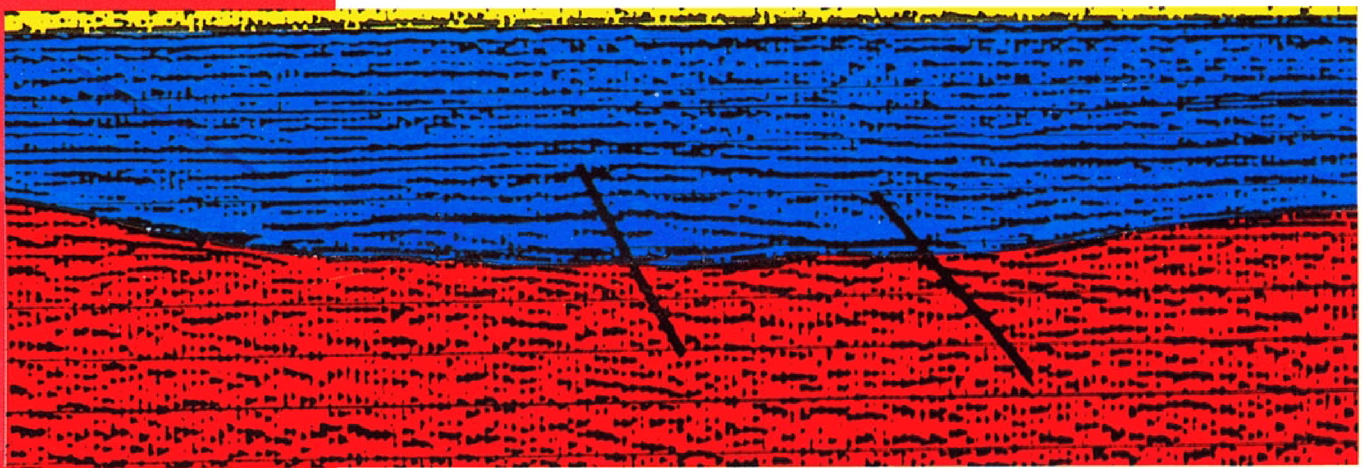
53 LAVIN, C.J. & MUSCATELLO, T. 1998. The Casterton Group - Otway Basin Victoria.

54 MEHIN, K. & BOCK, M.P., 1998. Cretaceous source rocks of the onshore Gippsland Basin, Victoria.

55 GEARY, G. & REID, I., 1998. Geology and prospectivity of the offshore eastern Otway Basin, Victoria, for the 1998 Acreage Release.

56 MEGALLAA, M., BERNECKER, T., & FRANKEL, E., 1998. Hydrocarbon prospectivity of the Northern Terrace, offshore Gippsland basin, for the 1998 Acreage Release.

57 LAVIN, C., 1998. Geology and prospectivity of the western Victorian Voluta Trough - Otway Basin, for the 1998 Acreage Release.



MINERALS AND PETROLEUM VICTORIA
P.O. BOX 500
EAST MELBOURNE
VIC. 3002
250 VICTORIA PARADE
EAST MELBOURNE
VIC. 3002
PHONE: 03 9412 4011
FAX: 03 9412 5156

Victoria ON THE MOVE